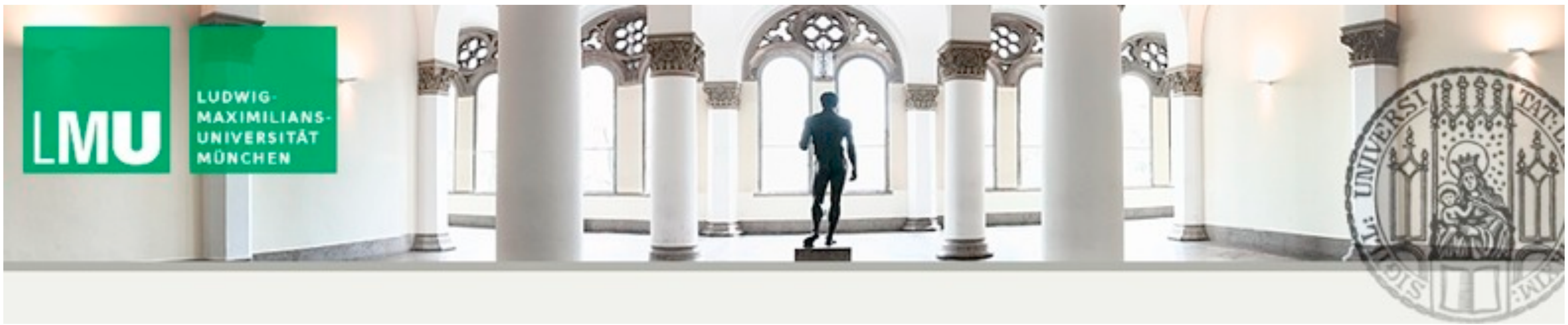
F - Theory and T - fects

DIETER LÜST (LMU-München, MPI)



F-Theory @ 20, Burke Institute, Caltech, 23th. February 2016

F - Theory and T - fects

DIETER LÜST (LMU-München, MPI)

Work in collaboration with
Stefano Massai, Valenti Vall Camell, arXiv:1508.01193

Anamaria Font, Inaki Garcia-Etxebarria, Stefano Massai, Christoph Mayrhofer, arXiv:16mm.xxxxx

F-Theory @ 20, Burke Institute, Caltech, 23th. February 2016

Outline:

I) Introduction: Non-geometric heterotic/F-theory duality

II) (Heterotic) singularities and T - fects

III) Summary

I) (Non)-geometric heterotic/F-theory duality

I) (Non)-geometric heterotic/F-theory duality

F-theory: (C. Vafa (1996); D. Morrison, C. Vafa (1996))

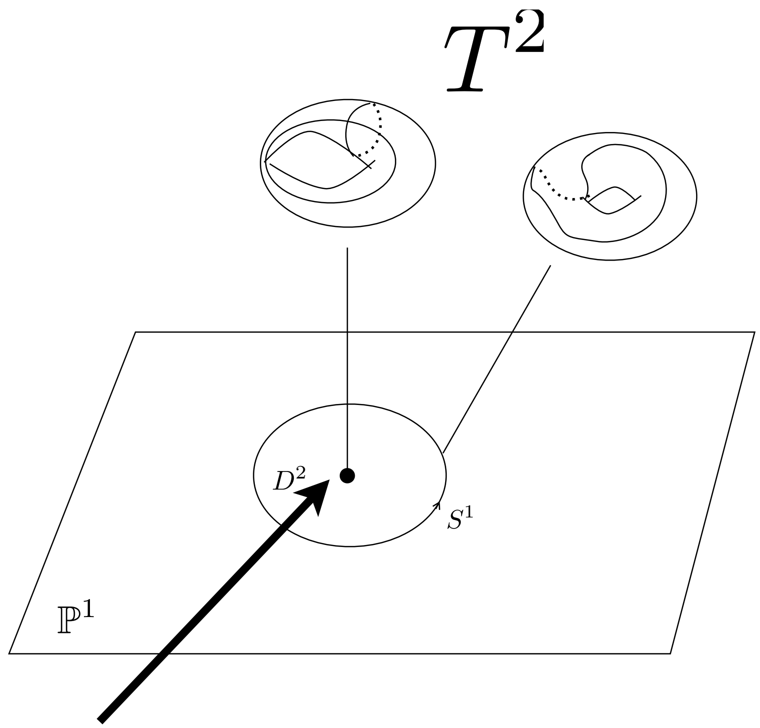
- IIB coupling constant that varies over the internal space.
- Geometrical higher dimensional description
  $\Rightarrow$ fibration of the IIB moduli space.
- Degenerations of the fibration $\leftrightarrow$ 7-branes

  $\Rightarrow$ massless gauge and matter fields

F-theory:

Degeneration of elliptic fibration:

$\mathbb{R}^{1,7} \otimes$



Locus of 7-brane

I) (Non)-geometric heterotic/F-theory duality

F-theory: (C. Vafa (1996); D. Morrison, C. Vafa (1996))

- IIB coupling constant that varies over the internal space.
- Geometrical higher dimensional description
  $\Rightarrow$ fibration of the IIB moduli space.
- Degenerations of the fibration $\leftrightarrow$ 7-branes

$\Rightarrow$ massless gauge and matter fields

I) (Non)-geometric heterotic/F-theory duality

F-theory: (C. Vafa (1996); D. Morrison, C. Vafa (1996))

- IIB coupling constant that varies over the internal space.
- Geometrical higher dimensional description
  $\Rightarrow$ fibration of the IIB moduli space.
- Degenerations of the fibration $\leftrightarrow$ 7-branes

  $\Rightarrow$ massless gauge and matter fields

8D K3: ADE classification of gauge symmetries

I) (Non)-geometric heterotic/F-theory duality

F-theory: (C. Vafa (1996); D. Morrison, C. Vafa (1996))

- IIB coupling constant that varies over the internal space.
- Geometrical higher dimensional description
  $\Rightarrow$ fibration of the IIB moduli space.
- Degenerations of the fibration $\leftrightarrow$ 7-branes

$\Rightarrow$ massless gauge and matter fields

8D K3: ADE classification of gauge symmetries

6D CY3: richer degeneration structure

$\Rightarrow$ local degenerations on the base (D3 on $\mathbb{P}^1$):

(0,1) CFT's with $\langle T \rangle = 0$

(J. Heckman, D. Morrison, C. Vafa (2013); J. Heckman, D. Morrison, T. Rudelius, C. Vafa (2015))

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

- Fibrations of heterotic moduli spaces
  $\Rightarrow$ fibration of a genus 2 surface.

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

- Fibrations of heterotic moduli spaces
  $\Rightarrow$ fibration of a genus 2 surface.

- Degenerations correspond in general to exotic, non-geometric 5-branes.

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

- Fibrations of heterotic moduli spaces
  $\Rightarrow$ fibration of a genus 2 surface.

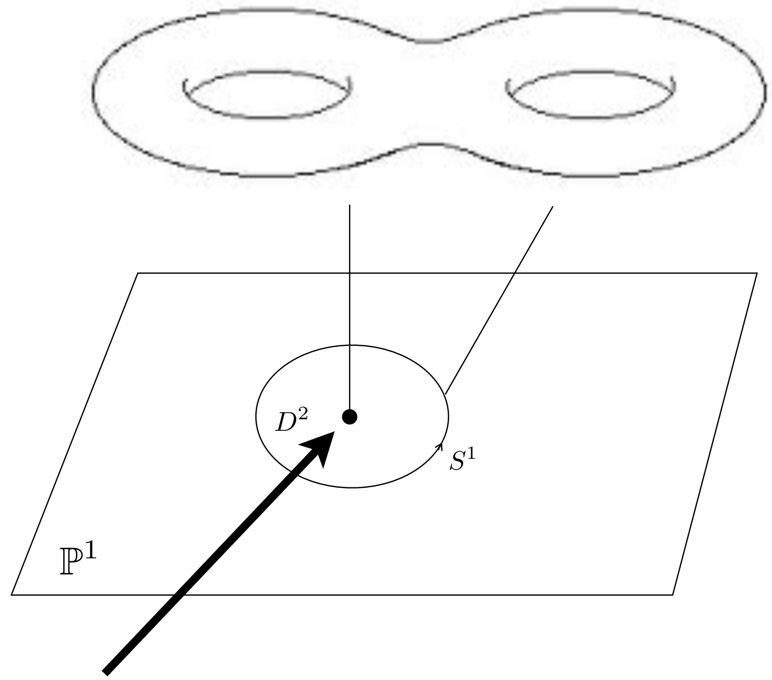
- Degenerations correspond in general to exotic, non-geometric 5-branes.

- 6 D (0,1) CFT's living on the word volume of the non-geometric 5-branes.

Heterotic:

Degeneration of genus two fibration:

$\mathbb{R}^{1,5} \otimes$



Locus of (1+5)-dimensional (non)-geometric brane.

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

- Fibrations of heterotic moduli spaces
  $\Rightarrow$ fibration of a genus 2 surface.

- Degenerations correspond in general to exotic, non-geometric 5-branes.

- 6 D (0,1) CFT's living on the word volume of the non-geometric 5-branes.

Dual heterotic description:

Carry over the F-theory idea to the heterotic case:

- Fibrations of heterotic moduli spaces
  $\Rightarrow$ fibration of a genus 2 surface.

- Degenerations correspond in general to exotic, non-geometric 5-branes.

- 6 D (0,1) CFT's living on the word volume of the non-geometric 5-branes.

Map this picture back to F-theory, where the singularities can be resolved into a smooth CY.

8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

$$y^2 = x^3 + (a\,u^4v^4 + c\,u^3v^5)\,x\,w^4 + (b\,u^6v^6 + u^5v^7 + u^7v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \qquad \Longrightarrow \qquad \text{gauge groups } E_8, E_7$$

8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

$$y^2 = x^3 + (a\,u^4 v^4 + c\,u^3 v^5)\,x\,w^4 + (b\,u^6 v^6 + u^5 v^7 + u^7 v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \qquad \Longrightarrow \qquad \text{gauge groups } \; E_8, E_7$$

8D heterotic:

Two-torus with moduli (ρ, τ, β) .

8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

$$y^2 = x^3 + (a\,u^4 v^4 + c\,u^3 v^5)\,x\,w^4 + (b\,u^6 v^6 + u^5 v^7 + u^7 v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \qquad \Longrightarrow \qquad \text{gauge groups } \; E_8, E_7$$

8D heterotic:

Two-torus with moduli (ρ, τ, β) .

Kähler

8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

$$y^2 = x^3 + (a\,u^4 v^4 + c\,u^3 v^5)\,x\,w^4 + (b\,u^6 v^6 + u^5 v^7 + u^7 v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \quad \Longrightarrow \quad \text{gauge groups } E_8, E_7$$

8D heterotic:

Two-torus with moduli (ρ, τ, β).

Kähler

compl. str.

8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

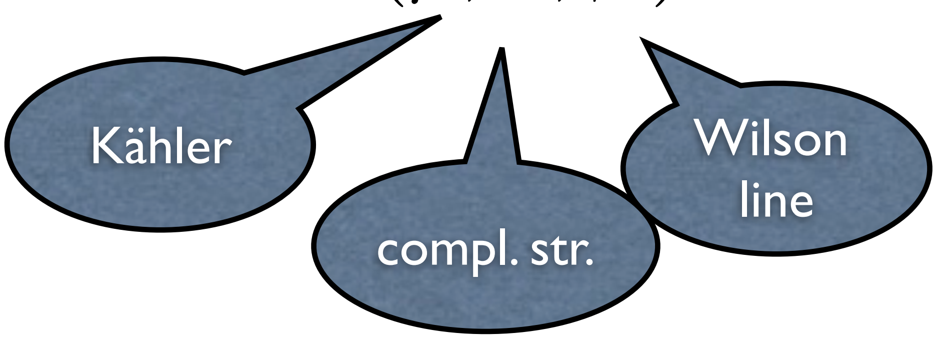
$$y^2 = x^3 + (a\,u^4 v^4 + c\,u^3 v^5)\,x\,w^4 + (b\,u^6 v^6 + u^5 v^7 + u^7 v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \qquad \Longrightarrow \qquad \text{gauge groups } \; E_8, E_7$$

8D heterotic:

Two-torus with moduli (ρ, τ, β) .



8D F-theory:

K3 described as Weierstrass model with moduli (a,b,c):

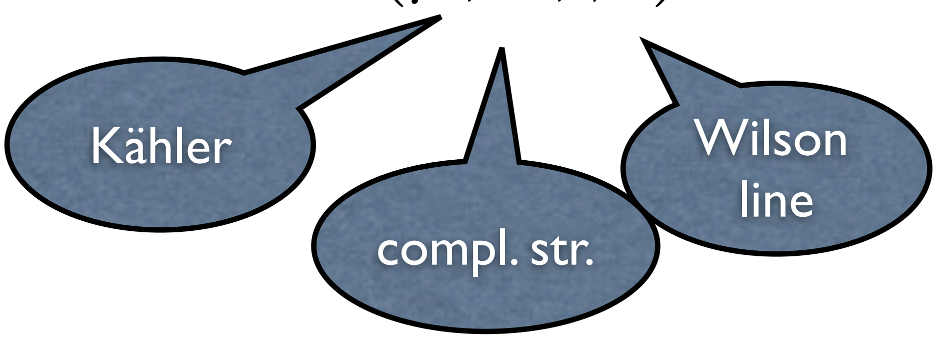
$$y^2 = x^3 + (a\,u^4 v^4 + c\,u^3 v^5)\,x\,w^4 + (b\,u^6 v^6 + u^5 v^7 + u^7 v^5)\,w^6 = 0$$

u,v: homogenous coordinates on $\mathbb{P}^1$ base.

$$u, v = 0 \qquad \Longrightarrow \qquad \text{gauge groups } \; E_8, E_7$$

8D heterotic:

Two-torus with moduli (ρ, τ, β) .



$\Rightarrow$ Moduli space of genus two Riemann surface Σ_2

Heterotic/F-theory map:

vanishing Wilson line: $c = 0 \quad \Leftrightarrow \quad \beta = 0$

$$\begin{aligned} j(\tau)j(\rho) &= -1728^2\,\tfrac{a^3}{27}\,, \\ (j(\tau)-1728)(j(\rho)-1728) &= 1728^2\,\tfrac{b^2}{4} \end{aligned}$$

(G. Lopes Cardoso, G. Curio, D.L., T. Mohaupt (1996))

Heterotic/F-theory map:

vanishing Wilson line: $c = 0 \quad \Leftrightarrow \quad \beta = 0$

$$j(\tau)j(\rho) = -1728^2 \frac{a^3}{27} ,$$
$$(j(\tau) - 1728)(j(\rho) - 1728) = 1728^2 \frac{b^2}{4}$$

(G. Lopes Cardoso, G. Curio, D.L., T. Mohaupt (1996))

non-vanishing Wilson line: $c \neq 0 \quad \Leftrightarrow \quad \beta \neq 0$

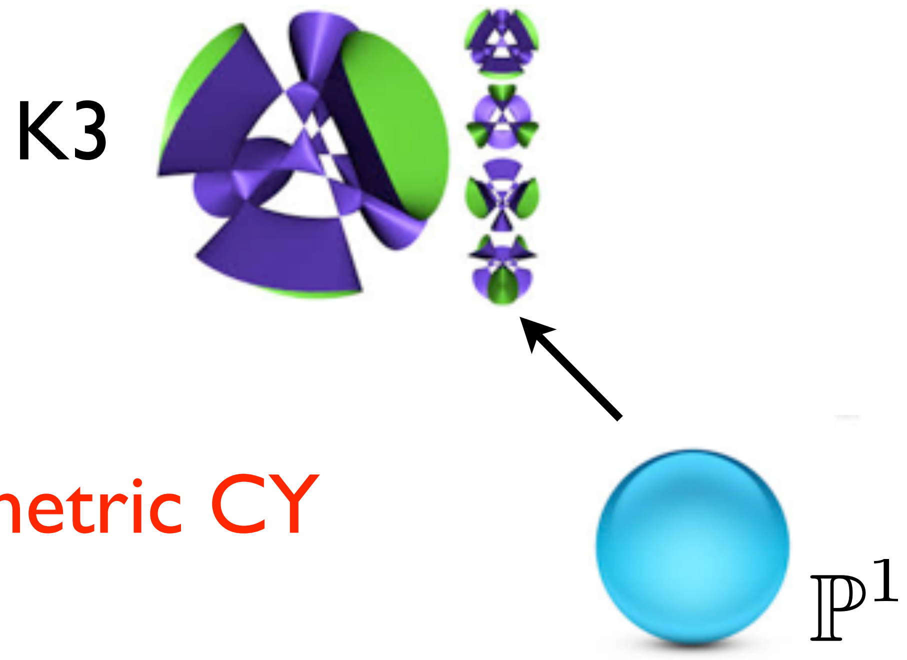
$\Rightarrow$ map in terms of genus-two Siegel modular forms.

(A. Clingher, C.F. Doran (2010); A. Malmendier, D. Morrison (2014); J. Gu, H. Jockers (2015))

6D constructions: fibre this picture over $\mathbb{P}^1$:

6D constructions: fibre this picture over $\mathbb{P}^1$:

F-theory:



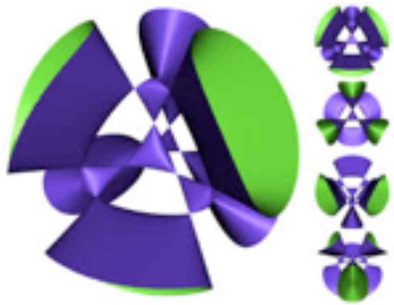
6D geometric CY

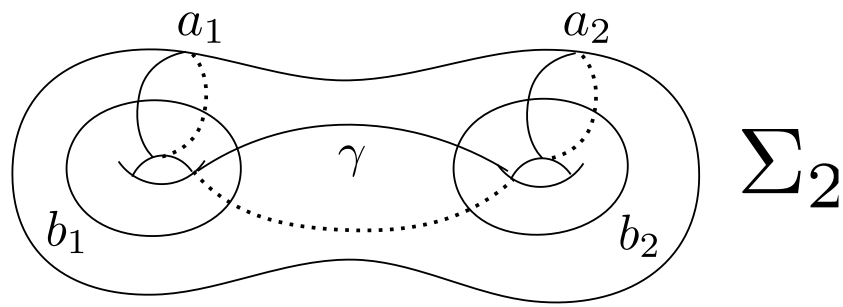
6D constructions: fibre this picture over $\mathbb{P}^1$:

F-theory:

Heterotic:

K3





6D geometric CY

$\mathbb{P}^1$

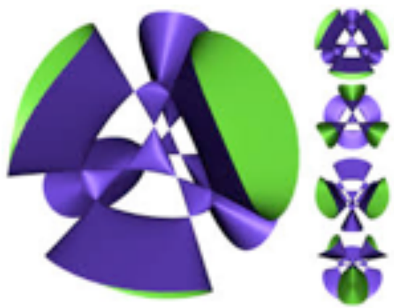
4D non-geometric background (as generalization of K3)

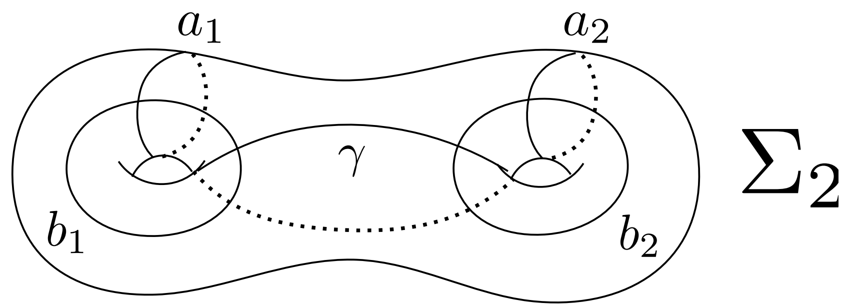
6D constructions: fibre this picture over $\mathbb{P}^1$:

F-theory:

Heterotic:

K3





6D geometric CY

$\mathbb{P}^1$

4D non-geometric background (as generalization of K3)

Local degenerations of genus two fibration over $\mathbb{P}^1$:
co-dimension two defects $\Rightarrow$ (1+5)-dim. T-fects

(0,1) CFT's: low energy degrees of freedom localized at (non)-geometric degenerations.

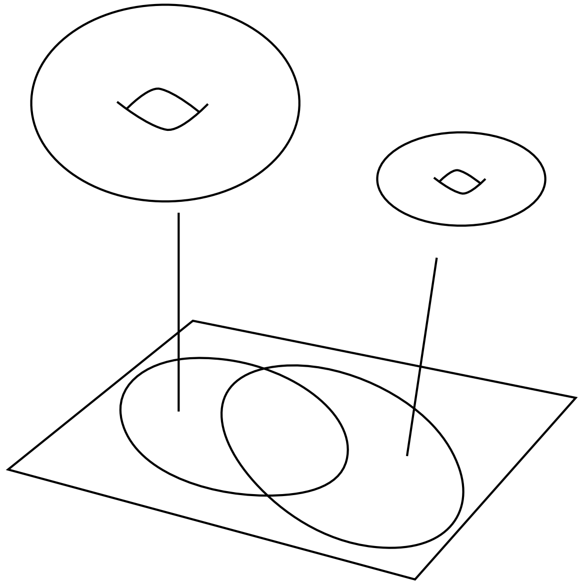
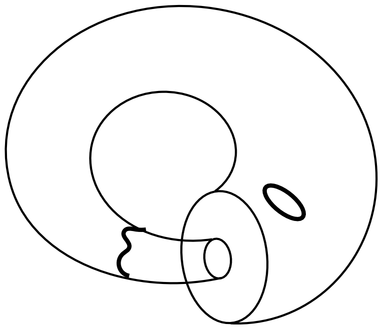
II) (Heterotic) singularities and T-fects

II) (Heterotic) singularities and T-fects

T-fects: defects related to monodromies of T-duality.

$\Rightarrow$ in general non-geometric monodromies.

$\Rightarrow$ non-geometric branes

$\mathbb{R}^{1,5} \otimes$  $\longrightarrow$ 

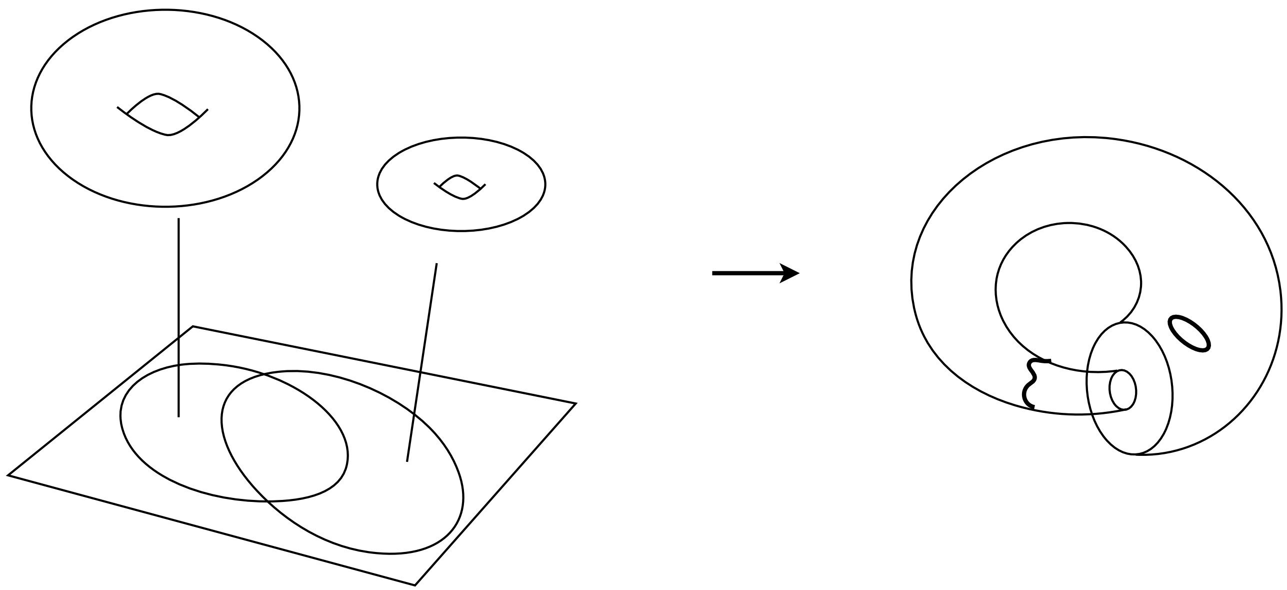
II) (Heterotic) singularities and T-fects

T-fects: defects related to monodromies of T-duality.

$\Rightarrow$ in general non-geometric monodromies.

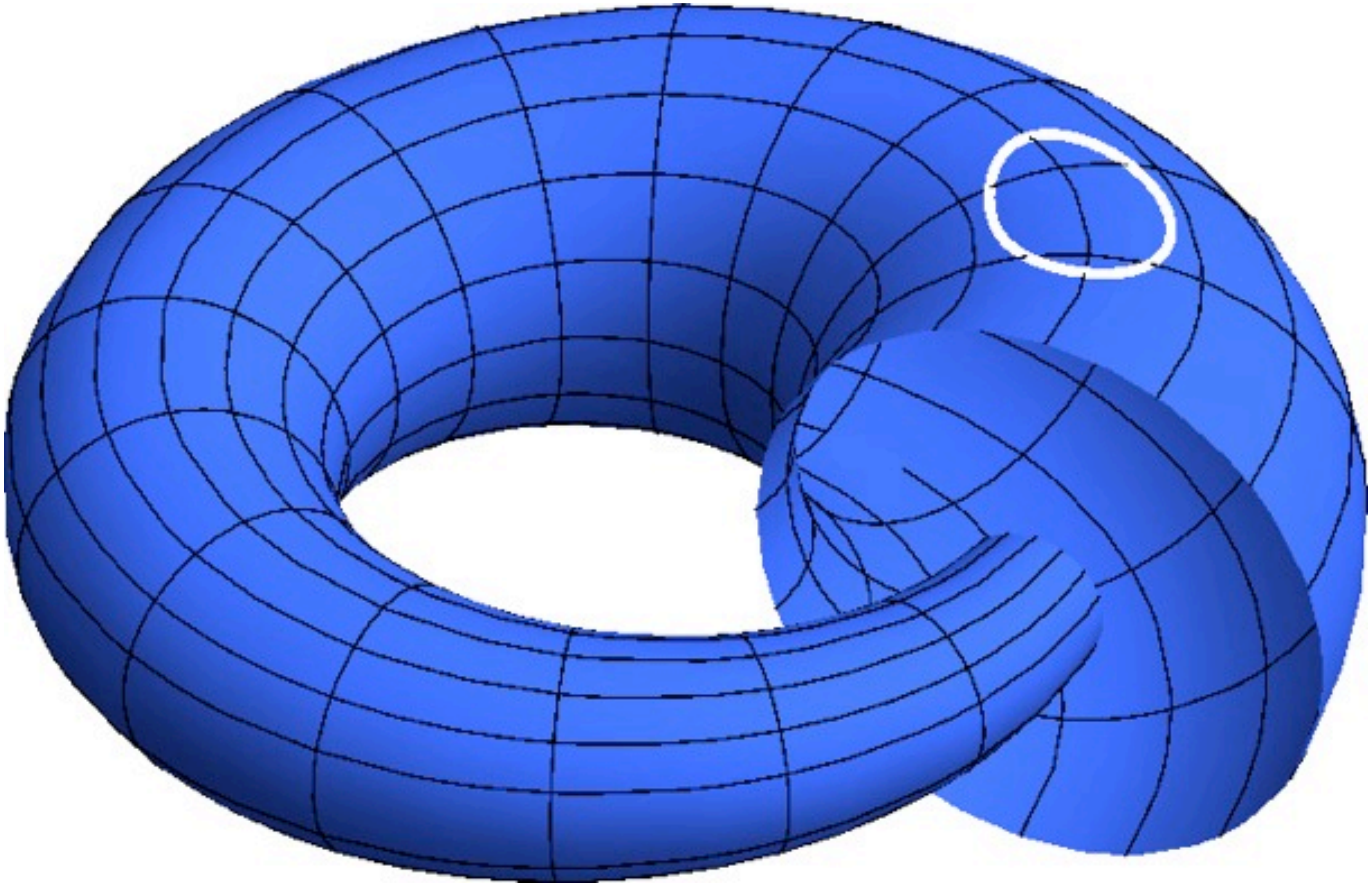
$\Rightarrow$ non-geometric branes

$\mathbb{R}^{1,5} \otimes$

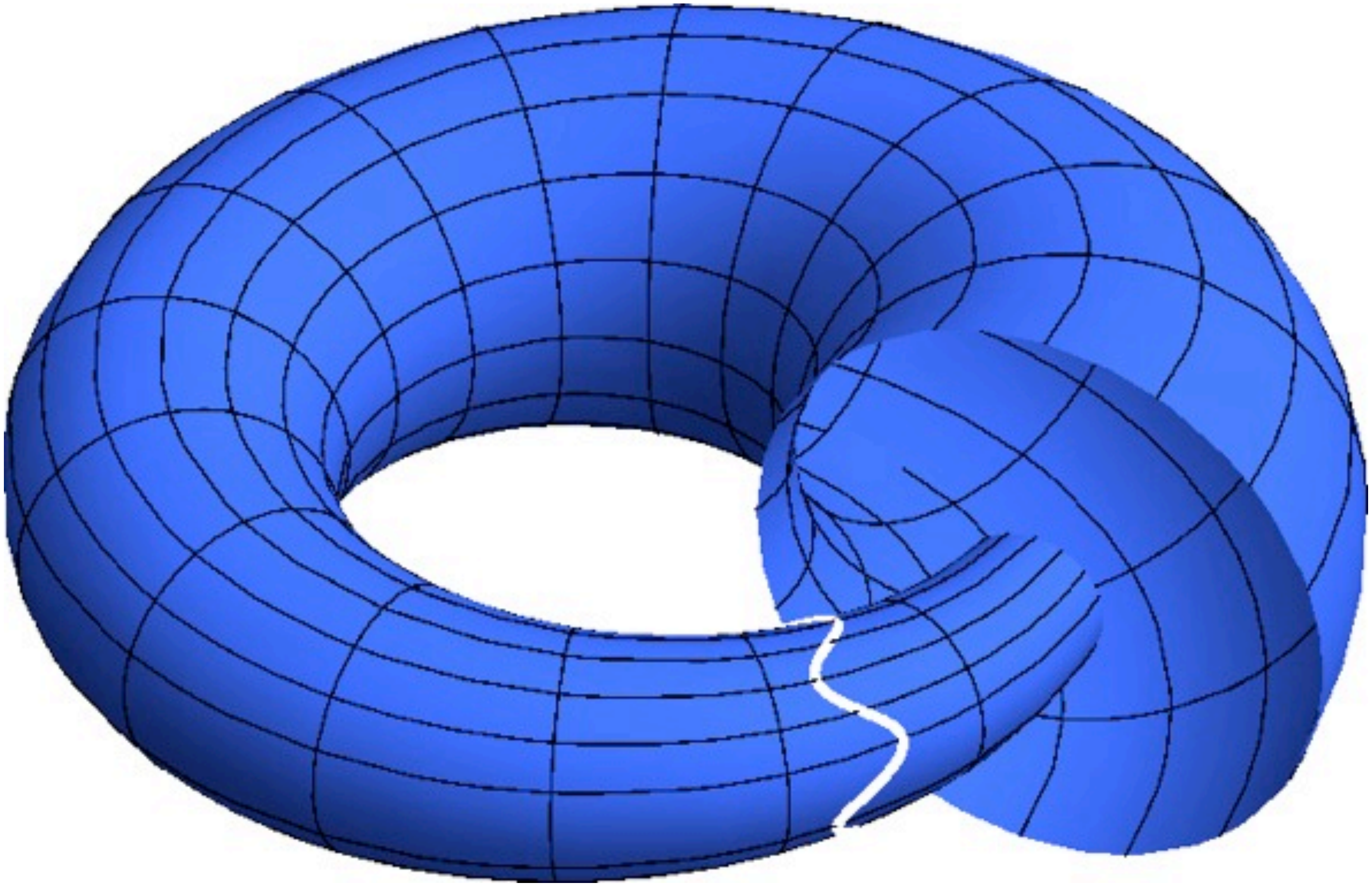


Closely related to T-folds: corresponding flux picture with H,f,Q - flux on 3-torus:

$\Rightarrow$ Torus fibration over S^1 .



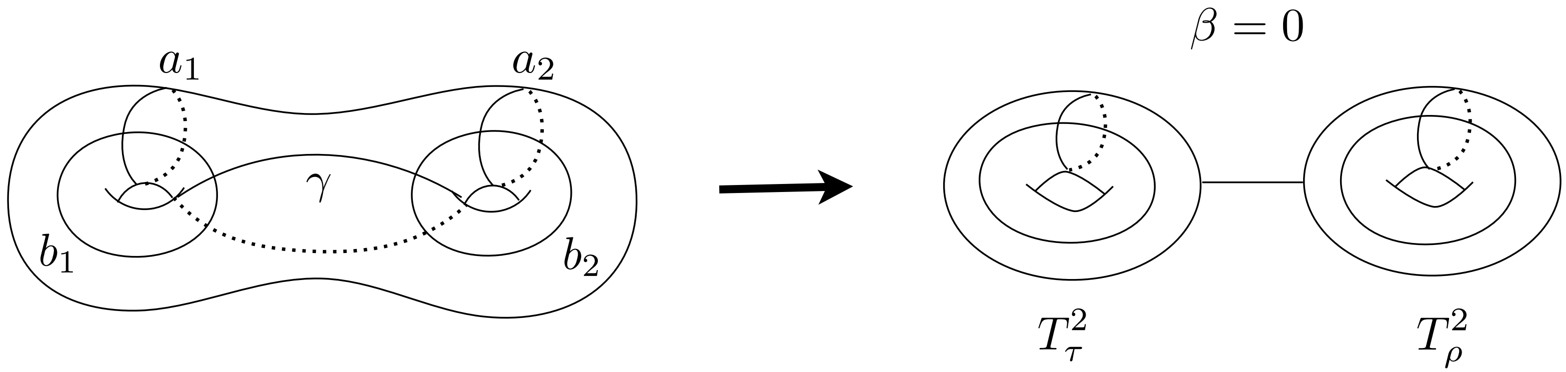
Non geometric torus, metric is patched together by a T-duality transformation.



Non geometric torus, metric is patched together by a T-duality transformation.

T-fects $\Rightarrow$ genus two surface with Wilson line:

Σ_2



ρ, τ, β live on Narain coset $\mathcal{D}_{2,3} = \dfrac{O(2,3,\mathbb{R})}{O(2,\mathbb{R}) \times O(3,\mathbb{R})}$

$$\mathcal{D}_{2,3} \cong \mathbb{H}_2 = \left\{ \Omega = \begin{pmatrix} \tau & \beta \\ \beta & \rho \end{pmatrix} \middle| \ \tau, \rho, \beta \in \mathbb{C}, \ \det(\Omega) > 0, \ \Im(\rho) > 0 \right\} .$$

Monodromy group: Dehn twists along the five cycles.

$$M(\Omega) = (A\Omega + B)(C\Omega + D)^{-1} , \quad M = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \in Sp(4, \mathbb{Z})$$

The corresponding singularities generalize the Kodaira singularites of the elliptic curve.

(K. Kodaira (1963); A. Ogg (1996); Y. Namikawa, K. Ueno (1973))

$\beta = 0$: Monodromies in τ and in ρ :

$\Rightarrow$ two colliding Kodaira singularities: $[K_\tau - K_\rho]$

$$\tau \quad \rightarrow M_\tau[\tau] \equiv \tfrac{a\tau+b}{c\tau+d}\,, \qquad M_\tau = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \in SL(2,\mathbb{Z})_\tau\,,$$

$$\rho \quad \rightarrow M_\rho[\rho] \equiv \tfrac{\tilde{a}\rho+\tilde{b}}{\tilde{c}\rho+\tilde{d}}\,, \qquad M_\rho = \begin{pmatrix} \tilde{a} & \tilde{b} \\ \tilde{c} & \tilde{d} \end{pmatrix} \in SL(2,\mathbb{Z})_\rho$$

Two Dehn twists (two for each group):

$$U = \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix}\,, \qquad V = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$$

3 classes of transformations:

elliptic $\quad tr(M)| < 2$

parabolic $\quad tr(M)| = 2$

hyperbolic $\quad tr(M)| > 2$

T-fects: are given by the singularities of the fibration of Σ_2 over $\mathbb{C}$.

The functions $\tau(z), \rho(z) \quad (z \in \mathbb{C})$ are specified by the monodromy transformations:

Class	K-Type	Monodromy	Local model
Parabolic	I_n	$V^n = \begin{pmatrix} 1 & n \\ 0 & 1 \end{pmatrix}$	$\frac{n}{2\pi i} \log z\,, \quad n > 0$
Elliptic order 6	II	$UV = \begin{pmatrix} 1 & 1 \\ -1 & 0 \end{pmatrix}$	$\frac{\eta - \eta^2 z^{1/3}}{1 - z^{1/3}}\,, \quad \eta = e^{2\pi i/3}$
Elliptic order 4	III	$UVU = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$	$\frac{i + i\sqrt{z}}{1 - \sqrt{z}}$
Elliptic order 3	IV	$UVUV = \begin{pmatrix} 0 & 1 \\ -1 & -1 \end{pmatrix}$	$\frac{\eta - \eta^2 z^{2/3}}{1 - z^{2/3}}$

This can be compared with the ADE Kodaira classification of degenerations of elliptic fibrations:

Order	Singularity	K-Type	Monodromy
1	-	I_0	1
n	A_{n-1}	I_n	V^n
2	cusp	II	UV
3	A_1	III	UVU
4	A_2	IV	$(UV)^2$
6	D_4	I_0^*	$(UV)^3$
$6+n$	D_{4+n}	I_n^*	$(UV)^3V^n = -V^n$
8	E_6	IV^*	$(UV)^4 = (UV)^{-2}$
9	E_7	III^*	$(UV)^4U = (UVU)^{-1}$
10	E_8	II^*	$(UV)^5 = (UV)^{-1}$

Examples: τ - fects: geometric defects:

Examples: τ - fects: geometric defects:

I_n : parabolic τ - fect: $M_\tau = V \, , \quad \tau \to \tau + 1$

$$\tau(z) = \frac{i}{2\pi} \log\left(\frac{\mu}{z}\right)$$

$$z \in \mathbb{P}^1$$

KK-monopole,
TAUB NUT space,
located at point in $\mathbb{P}^1$.

Examples: τ - fects: geometric defects:

I_n : parabolic τ - fect: $M_\tau = V\,, \quad \tau \to \tau + 1$

$$\tau(z) = \frac{i}{2\pi} \log\left(\frac{\mu}{z}\right)$$

KK-monopole,
TAUB NUT space,
located at point in $\mathbb{P}^1$.

$$z \in \mathbb{P}^1$$

III : elliptic τ - fect: $M_\tau = UVU\,, \quad \tau \to -1/\tau$

$$\tau(z) = \frac{i - ie^{2iC}\sqrt{z}}{1 - ie^{2iC}\sqrt{z}}$$

The corresponding metric can be explicitly constructed.

ρ - fects: (non)-geometric defects:

I_n : parabolic ρ - fect: $M_\rho = V \, , \quad \rho \rightarrow \rho + 1$

$$\rho(z) = \frac{i}{2\pi} \log\left(\frac{\mu}{z}\right)$$

NS 5 -brane,
located at point in $\mathbb{P}^1$.

ρ - fects: (non)-geometric defects:

I_n : parabolic ρ - fect: $M_\rho = V\ , \quad \rho \to \rho + 1$

$$\rho(z) = \frac{i}{2\pi} \log\left(\frac{\mu}{z}\right)$$

NS 5 -brane, located at point in $\mathbb{P}^1$.

Different conjugacy classes of parabolic monodromy:

$\Rightarrow$ Brane that is T-dual to NS 5-brane:

$$\tilde{V} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix}, \quad \rho \to \frac{\rho}{\rho + 1} \qquad \rho(z) = \frac{2\pi i}{\log\left(\frac{\mu}{z}\right)}$$

This is a non-geometric brane: Q-brane, 5_2^2 brane.

(E. Bergshoeff, T. Ortin, F. Riccion (2011); J. de Boer, M. Shigemori (2012); F. Hassler, D.L. (2014))

III : elliptic ρ - fect: $M_\rho = UVU \, , \quad \rho \to -1/\rho$

$$\rho(z) = \frac{i - ie^{2iC}\sqrt{z}}{1 - ie^{2iC}\sqrt{z}}$$

The entire background can be explicitly constructed.

$\Rightarrow$ New non-geometric brane.

Colliding singularities:

Simultaneous monodromies in τ and in ρ .

$[I_n - I_n]$: Double parabolic T - fects:

NS 5 + TAUB NUT

Q - brane + TAUB NUT

Colliding singularities:

Simultaneous monodromies in τ and in ρ .

$[I_n - I_n]$: Double parabolic T - fects:

NS 5 + TAUB NUT

Q - brane + TAUB NUT

$[III - III]$: double elliptic T - fect:

$$M_\tau = M_\rho = UVU = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \qquad \tau \longrightarrow -\frac{1}{\tau}\,, \quad \rho \longrightarrow -\frac{1}{\rho}$$

$\Rightarrow$ New non-geometric background that is not T-dual to any geometric background.

Colliding singularities:

Simultaneous monodromies in τ and in ρ .

$[I_n - I_n]$: Double parabolic T - fects:

NS 5 + TAUB NUT

Q - brane + TAUB NUT

$[III - III]$: double elliptic T - fect:

$$M_\tau = M_\rho = UVU = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \qquad \tau \rightarrow -\frac{1}{\tau}\,, \quad \rho \rightarrow -\frac{1}{\rho}$$

$\Rightarrow$ New non-geometric background that is not T-dual to any geometric background.

The corresponding double elliptic flux background was constructed in double field theory. (F. Hassler, D.L. (2014))

Now we can consider a few heterotic 6D models:

Geometric models:

$$[II^* - I_0] \qquad \Rightarrow \; E_8 \text{ singularity}$$

$$M_{[II^*-I_0]} = \begin{pmatrix} 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \in Sp(4,\mathbb{Z})$$

$$\tau \to -\frac{1}{1+\tau}\,, \quad \beta \to \frac{\beta}{1+\tau}\,, \quad \rho \to \rho - \frac{\beta^2}{1+\tau}$$

Corresponding heterotic genus 2 fibration:

$$y^2 = \left(t^5 + x^3\right)\left(x^2 + \alpha x + 1\right)$$

$t = z - z_0$: coord. on disk around point of degeneration.

F-theory K3 fibration:

$$y^3 = x^3 + f(u,v,t)x + g(u,v,t)$$

$$\begin{aligned}
f &= 108(\alpha-2)(\alpha+2)t^5u^3v^4\big[486t^{25}v - 972\alpha^3t^{20}v + 2916\alpha t^{20}v + 486\alpha^6t^{15}v - 2916\alpha^4t^{15}v \\
&\quad +4374\alpha^2t^{15}v + 972t^{15}v - 972\alpha^3t^{10}v + 2916\alpha t^{10}v + 2t^5u + 486t^5v - \alpha u\big]\,, \\
g &= u^5v^5\big[-314928\alpha^3t^{35}v^2 + 1259712\alpha t^{35}v^2 + 629856\alpha^6t^{30}v^2 - 4408992\alpha^4t^{30}v^2 \\
&\quad +7479540\alpha^2t^{30}v^2 + 314928t^{30}v^2 - 314928\alpha^9t^{25}v^2 + 3149280\alpha^7t^{25}v^2 - 10235160\alpha^5t^{25}v^2 \\
&\quad +9605304\alpha^3t^{25}v^2 + 4408992\alpha t^{25}v^2 + 216t^{20}uv - 78732\alpha^8t^{20}v^2 + 1417176\alpha^6t^{20}v^2 \\
&\quad -7007148\alpha^4t^{20}v^2 + 10235160\alpha^2t^{20}v^2 + 629856t^{20}v^2 - 1944\alpha^3t^{15}uv + 7452\alpha t^{15}uv \\
&\quad +157464\alpha^5t^{15}v^2 - 1417176\alpha^3t^{15}v^2 + 3149280\alpha t^{15}v^2 + 216\alpha^6t^{10}uv - 1620\alpha^4t^{10}uv \\
&\quad +6156\alpha^2t^{10}uv - 11880t^{10}uv - 78732\alpha^2t^{10}v^2 + 314928t^{10}v^2 + 216\alpha^3t^5uv - 972\alpha t^5uv + u^2\big]
\end{aligned}$$

F-theory K3 fibration:

$$y^3 = x^3 + f(u,v,t)x + g(u,v,t)$$

$$\begin{aligned} f &= 108(\alpha-2)(\alpha+2)t^5u^3v^4\big[486t^{25}v - 972\alpha^3t^{20}v + 2916\alpha t^{20}v + 486\alpha^6t^{15}v - 2916\alpha^4t^{15}v \\ &\quad +4374\alpha^2t^{15}v + 972t^{15}v - 972\alpha^3t^{10}v + 2916\alpha t^{10}v + 2t^5u + 486t^5v - \alpha u\big]\,, \\ g &= u^5v^5\big[-314928\alpha^3t^{35}v^2 + 1259712\alpha t^{35}v^2 + 629856\alpha^6t^{30}v^2 - 4408992\alpha^4t^{30}v^2 \\ &\quad +7479540\alpha^2t^{30}v^2 + 314928t^{30}v^2 - 314928\alpha^9t^{25}v^2 + 3149280\alpha^7t^{25}v^2 - 10235160\alpha^5t^{25}v^2 \\ &\quad +9605304\alpha^3t^{25}v^2 + 4408992\alpha t^{25}v^2 + 216t^{20}uv - 78732\alpha^8t^{20}v^2 + 1417176\alpha^6t^{20}v^2 \\ &\quad -7007148\alpha^4t^{20}v^2 + 10235160\alpha^2t^{20}v^2 + 629856t^{20}v^2 - 1944\alpha^3t^{15}uv + 7452\alpha t^{15}uv \\ &\quad +157464\alpha^5t^{15}v^2 - 1417176\alpha^3t^{15}v^2 + 3149280\alpha t^{15}v^2 + 216\alpha^6t^{10}uv - 1620\alpha^4t^{10}uv \\ &\quad +6156\alpha^2t^{10}uv - 11880t^{10}uv - 78732\alpha^2t^{10}v^2 + 314928t^{10}v^2 + 216\alpha^3t^5uv - 972\alpha t^5uv + u^2\big] \end{aligned}$$

Degenerations:

(i) $u = 0\,, \quad v = 0 \quad \Rightarrow \quad [II^* - III^*]$

additional E_7 gauge group.

(ii) $u = t = 0 \quad \Rightarrow$ additional singularity in base.

This singularity is worse than II^* of Kodaira.

It needs to be resolved by series of blow-ups in base.

$\Rightarrow$ Chain of intersecting Kodaira singularities

with additional matter fields.

$$[III^*] - \square - I_0 - II^* - \square$$

$$\square = \mathrm{I}_0 - \mathrm{II} - \mathrm{IV} - \mathrm{I}_0^* - \mathrm{II} - \mathrm{IV}^* - \mathrm{II} - \mathrm{I}_0^* - \mathrm{IV} - \mathrm{II}$$

The associated matter content of (0,1) CFT, being located at the intersections of the singularities, can be explicitly derived. $\Rightarrow$ Talk by Christoph Mayrhofer.

It agrees with one of the models of Heckman et. al.

(It is the CFT of 10 pointlike instantons on an E_8 singularity.) (P. Aspinwall, D. Morrison (1997))

Heterotic model with colliding Kodaira singularities:

Non-geometric double elliptic model: $[III - III]$

$$\tau \to \frac{\rho}{\beta^2 - \rho\tau}\,, \quad \beta \to -\frac{\beta}{\beta^2 - \rho\tau}\,, \quad \rho \to \frac{\tau}{\beta^2 - \rho\tau}$$

Corresponding heterotic genus 2 fibration: sextic:

$$y^2 = x(x-1)(x^2+t)\left[(x-1)^2+t\right]$$

F-theory K3 fibration:

$$\begin{aligned}
f &= -12t^2u^3v^4\big(41472t^{10}v + 186624t^9v + 334368t^8v + 300672t^7v + 139968t^6v \\
&\quad +31104t^5v + 16t^4u + 2592t^4v + 36t^3u + 57t^2u + 30tu + 9u\big)\,, \\
g &= u^5v^5\big(-3981312t^{15}v^2 - 8957952t^{14}v^2 + 11197440t^{13}v^2 + 57542400t^{12}v^2 + 78941952t^{11}v^2 \\
&\quad +54914112t^{10}v^2 - 1024t^9uv + 21959424t^9v^2 - 3456t^8uv + 5318784t^8v^2 - 288t^7uv \\
&\quad +746496t^7v^2 + 9648t^6uv + 46656t^6v^2 + 8640t^5uv + 2160t^4uv + u^2\big)
\end{aligned}$$

$u = t = 0 \quad \Rightarrow$ again additional degeneration in base.

Resolution by blow ups: chain of singularities:

$$[III^*] - I_0 - II - IV - I_0^* - IV - II$$

(It is the CFT of six pointlike instantons on an D_4 singularity.)

$\Rightarrow$ Talk by Christoph Mayrhofer.

III) Summary

III) Summary

We have provided a classification of 6D CFT's via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

III) Summary

We have provided a classification of 6D CFT's via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

Open problems:

III) Summary

We have provided a classification of 6D CFT‘s via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

Open problems:

- What is the geometric description of genus two fibrations - relation to double field theory?

III) Summary

We have provided a classification of 6D CFT's via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

Open problems:

- What is the geometric description of genus two fibrations - relation to double field theory?
- Hyperbolic monodromies in F-theory ?

III) Summary

We have provided a classification of 6D CFT's via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

Open problems:

- What is the geometric description of genus two fibrations - relation to double field theory?
- Hyperbolic monodromies in F-theory ?
- Can one also map non-geometric R - branes and R-flux to F-theory ?

III) Summary

We have provided a classification of 6D CFT's via (non)-geometric heterotic string compactifications and non-geometric branes and their F-theory dual constructions. Anomaly matching also works.

Open problems:

- What is the geometric description of genus two fibrations - relation to double field theory?
- Hyperbolic monodromies in F-theory ?
- Can one also map non-geometric R - branes and R-flux to F-theory ?
- Can one construct the 6D CFT's directly on the heterotic side? What are their possible deformations?

(0,1) CFT's do not possess marginal deformations!

(J. Louis, S. Lüst (2015); C. Cordova, T. Dumitrescu, K. Intriligator (2016))