Reflections on F-theory and the Swampland Cobordism Conjecture

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Based On:

Hopefully Soon:

hep-th/????.????? w/ Debray, Dierigl, Montero

hep-th/????.????? w/ Debray, Dierigl, Montero

hep-th/????.????? w/ Dierigl, Montero, Torres

Earlier Work:

hep-th/2107.14227 w/ Debray, Dierigl, Montero

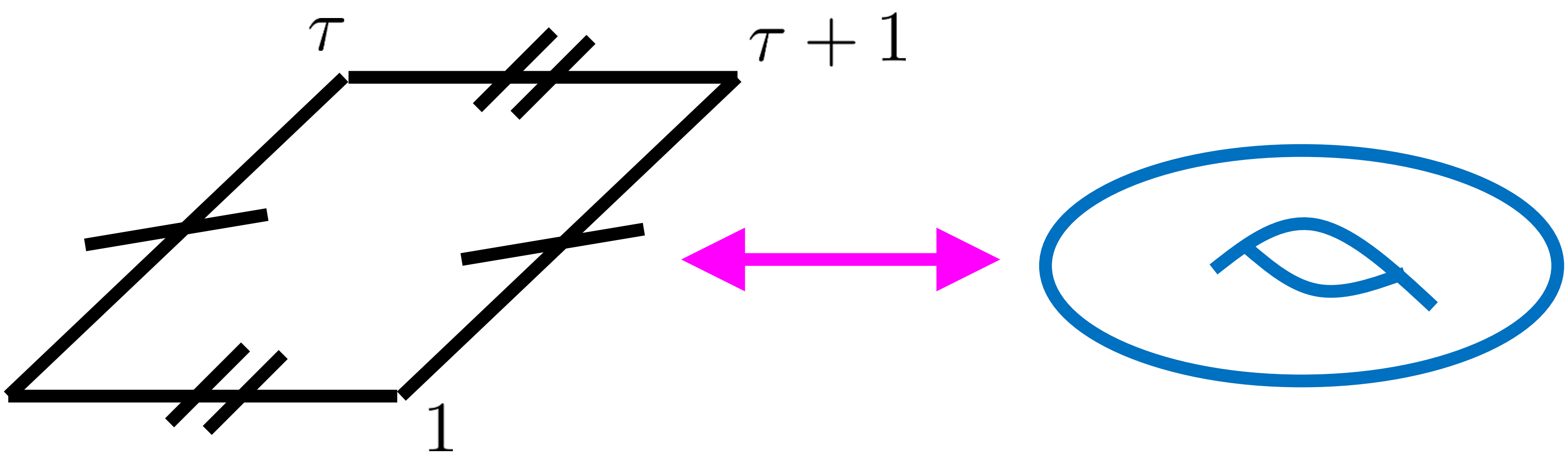
hep-th/2012.00013 w/ Dierigl

F-Theory

¿What is F-Theory?

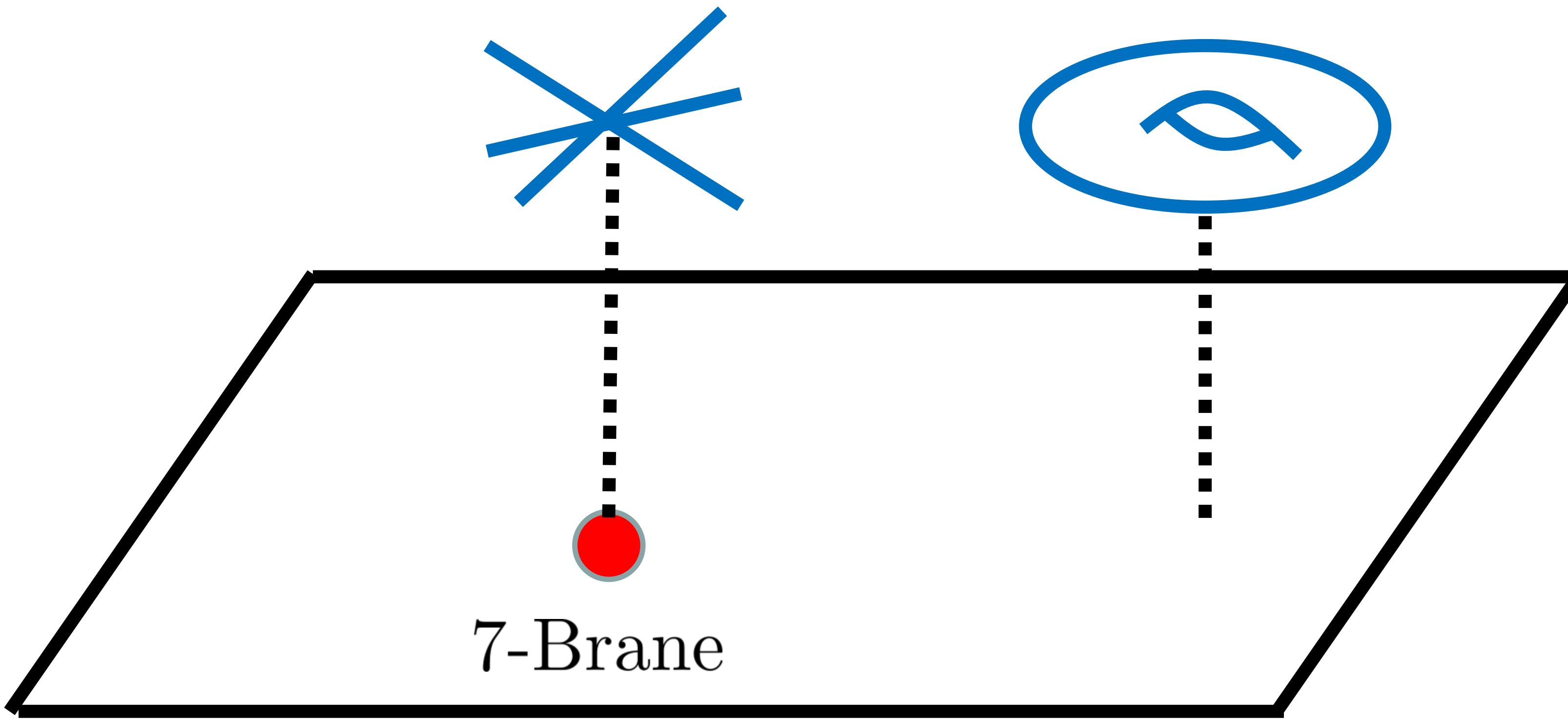
IIB Duality Implemented *Geometrically*

$\tau = C_0 + ie^{-\Phi}$



¿What is F-Theory?

IIB Duality Implemented *Geometrically*



F-Theory and String Feno

GUT Models: Flavor, Extra Sectors, Cosmology,...

JJH, Vafa + many

Example Feno: W-Mass Anomaly via probe D3

JJH '22 (see also Basiouris Leontaris '22)

Recently: Much Progress in Global Models

Cvetic et al.; Taylor et al.

Ingredients (Usually SUSY)

All these constructions involve $\cap$ 7-Branes, D3-Branes, Fluxes,... (Typically SUSY)

¿Are There Other Objects in F-Theory?

¿Non-SUSY Tools?

Non-SUSY Tools

- No superpartners have been seen (yet)

"...before the rooster crows, you will deny me three times..."

- SUSY breaking ingredients?

- How to Robustly Identify?

Swampland Cobordism Conjecture

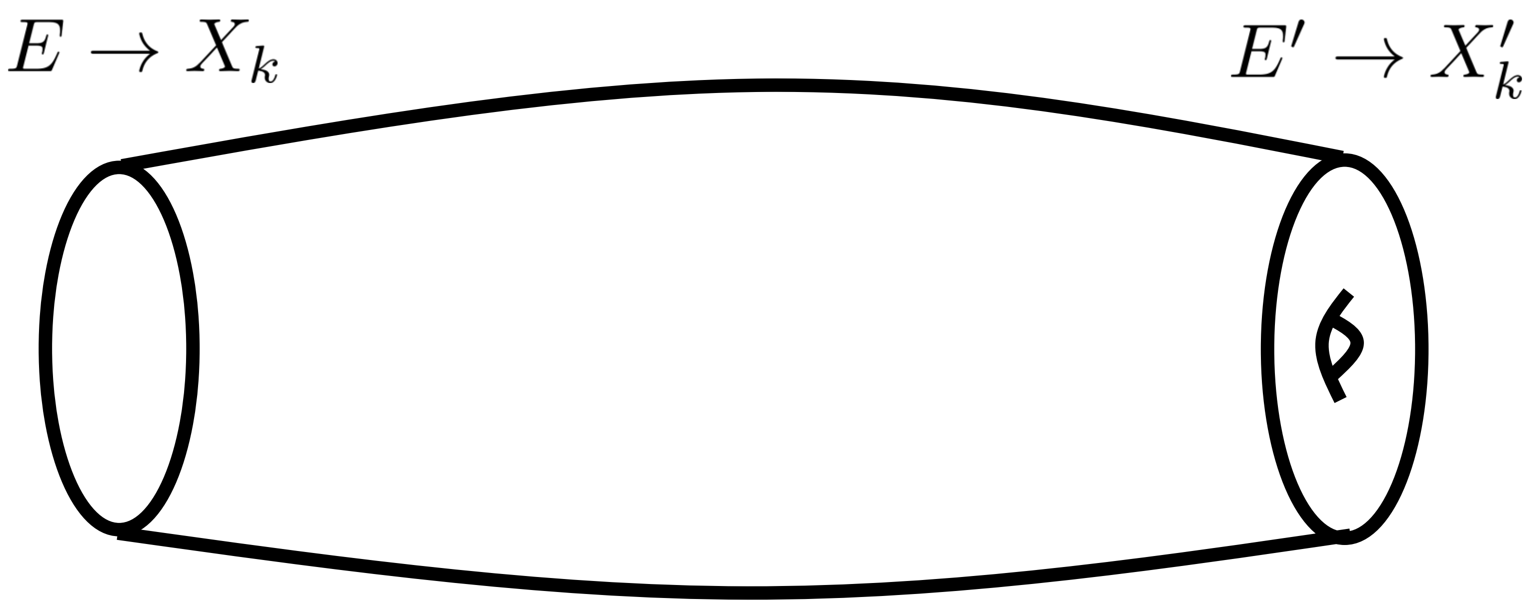
McNamara Vafa '19

See also talk by Blumenhagen

Cobordisms

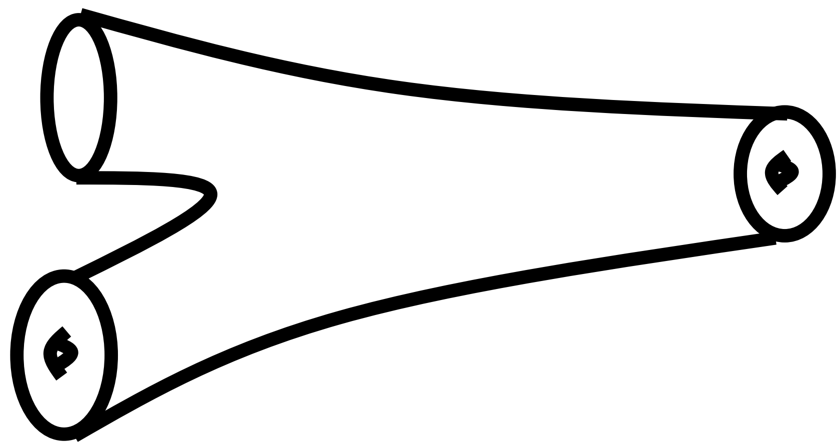
Specify bundle over k-manifold: can we interpolate?

Equivalence Relation:



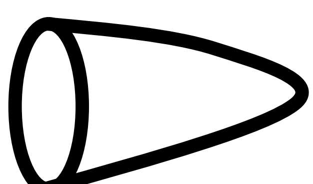
Cobordism Group: $\Omega_k^{\mathcal{G}}$

Addition:



Subtraction: Addition w/ Orientation Reversal

Identity:

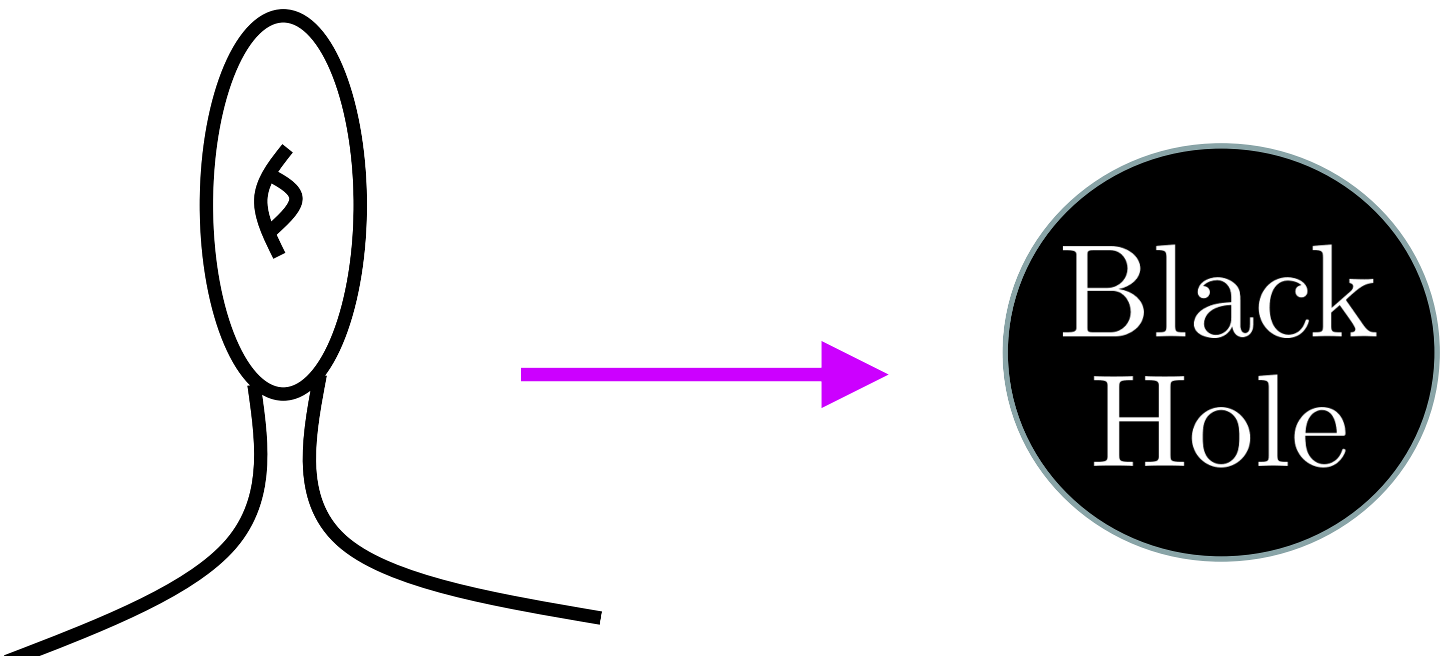


McNamara Vafa '19

No Global Symmetries

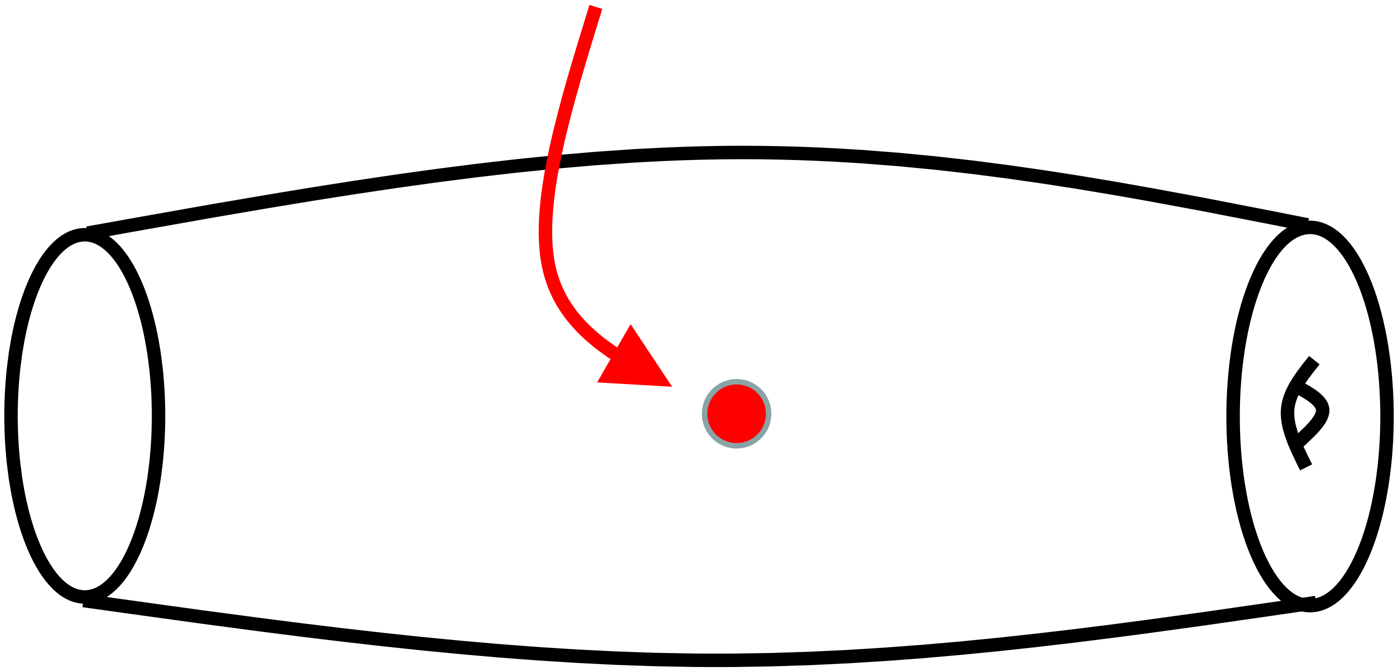
Send Topological Defect Into Black Hole...

$$\Rightarrow \Omega_k^{\mathrm{QG}} = 0$$



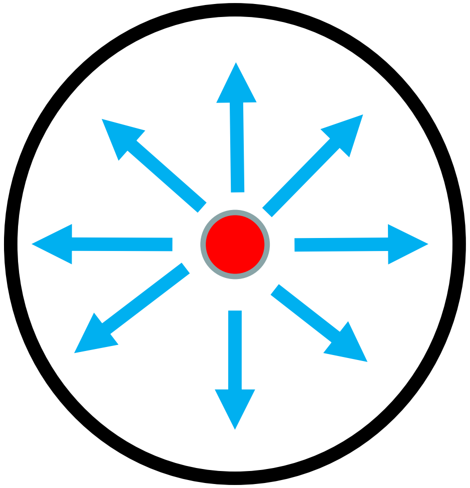
What If $\Omega_k^{\mathcal{G}} \neq 0$?

Prediction: A New Object, which trivializes Ω_k^{QG}!

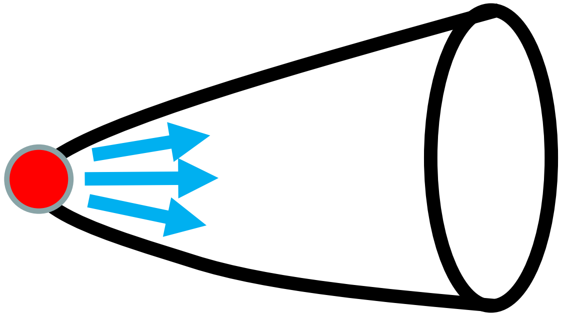


Defect View

"Flux" from Defect Measured by Bounding Space:



"Bird's Eye View"



"In Profile"

Dualities and Bordisms

Compute $\Omega_k^{\text{IIB Dualities}}$ to predict new objects

Duality Group

IIB Duality Group

IIB SUGRA has $SL(2,\mathbb{R})$

"Broken to $SL(2,\mathbb{Z})$ by branes / flux quantiz^n, etc."

Including Fermions: $Mp(2,\mathbb{Z}) \to SL(2,\mathbb{Z})$
(dilatini + gravitini)

Pantev Sharpe '16

Including Reflections: Pin^+ Cover of $GL(2,\mathbb{Z}) \equiv GL^+(2,\mathbb{Z})$

Tachikawa Yonekura '18

IIB Duality Group

IIB SUGRA has $SL(2,\mathbb{R})$

"Broken to $SL(2,\mathbb{Z})$ by branes / flux quantiz^n, etc."

Including Fermions: $Mp(2,\mathbb{Z}) \to SL(2,\mathbb{Z})$
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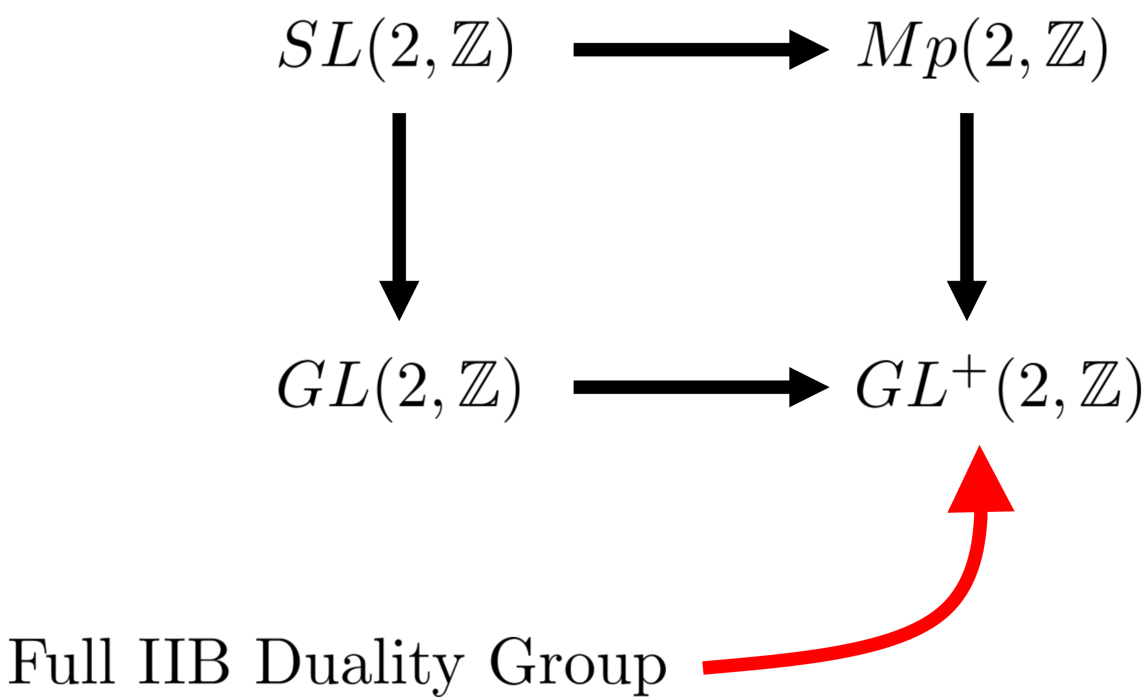
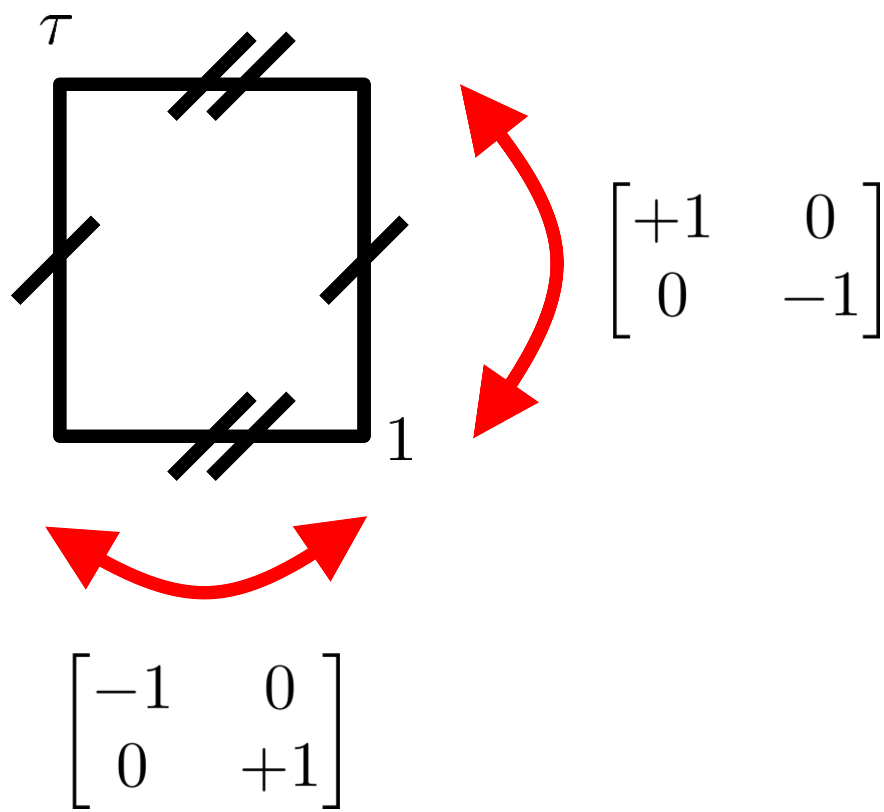
IIB Duality Group



Reflections and $GL(2,\mathbb{Z})$

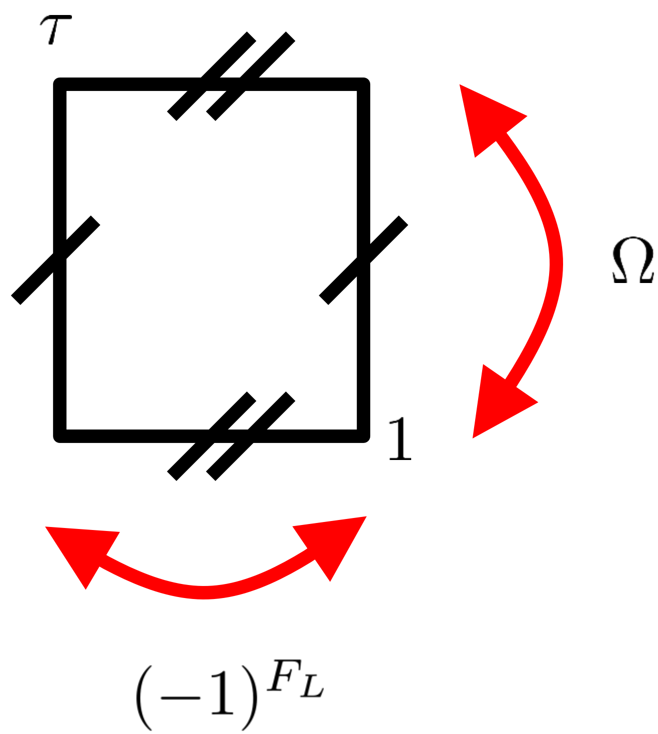
$\tau = C_0 + ie^{-\Phi}$: $\tau \mapsto -\overline{\tau}$

Torus:



Reflections and $GL(2,\mathbb{Z})$

Torus:



Bordism Duality Groups

Setup

Take IIB SUGRA (10D Spacetime) + "$\mathcal{G}$-Duality Bundle"

Demand $\frac{Spin\times\mathcal{G}}{\mathbb{Z}_2}$ Structure Group

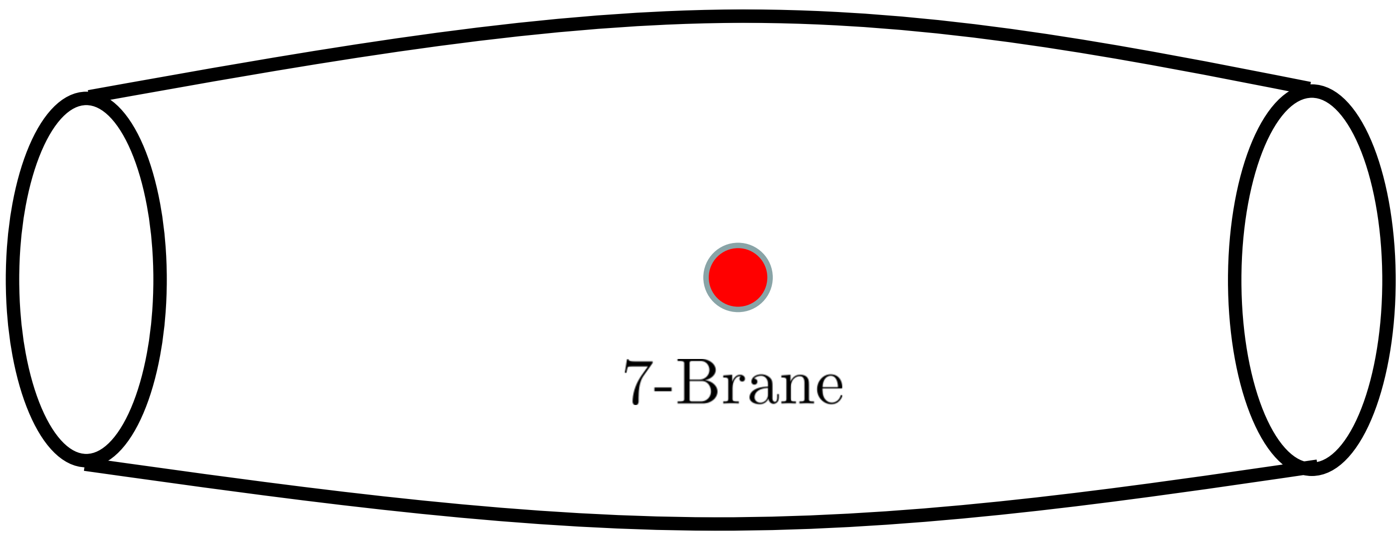
$\Omega_k^{SL(2,\mathbb{Z})}$ (Basic Duality Group)

$\Omega_k^{Mp(2,\mathbb{Z})}$ (+ Fermions)

$\Omega_k^{GL^+(2,\mathbb{Z})}$ (+ Fermions + Reflections)

Illustrative Example: $\Omega_1^{\mathcal{G}}$

Dierigl JJH '20; Debray Dierigl JJH Montero '22



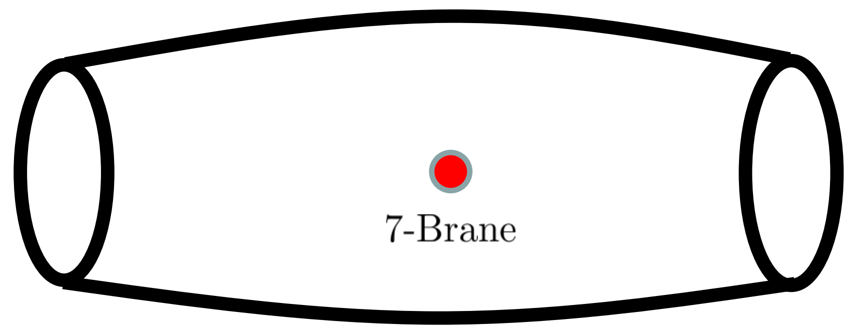
Illustrative Example: $\Omega_1^{\mathcal{G}}$

Dierigl JJH '20; Debray Dierigl JJH Montero '22

$$\Omega_1^{SL(2,\mathbb{Z})} = \mathbb{Z}_2 \times \mathbb{Z}_{12}$$

$$\Omega_1^{Mp(2,\mathbb{Z})} = \mathbb{Z}_3 \times \mathbb{Z}_8$$

$$\Omega_1^{GL^+(2,\mathbb{Z})} = \mathbb{Z}_2 \times \mathbb{Z}_2$$



$$\Omega_1^{Mp(2,\mathbb{Z})}$$

$\mathbb{Z}_3$ Factor of $\Omega_1^{Mp(2,\mathbb{Z})}$

$\Omega_1^{Mp(2,\mathbb{Z})} = \mathbb{Z}_3 \times \mathbb{Z}_8$

F-theory Picture: $\partial(T^2 \times \mathbb{C})/\mathbb{Z}_3$

Duality Bundle: $\mathbb{E} \to S^1/\mathbb{Z}_3$

These are 7-branes with $\tau = \exp(2\pi i/3)$

Example: E_6 gauge group: $y^2 = x^3 + z^4$ "Type IV^*"

Example: $SU(3)$ gauge group: $y^2 = x^3 + z^2$ "Type IV"

$\mathbb{Z}_8$ Factor of $\Omega_1^{Mp(2,\mathbb{Z})}$

$\Omega_1^{Mp(2,\mathbb{Z})} = \mathbb{Z}_3 \times \mathbb{Z}_8$

F-theory Picture: $\partial(T^2 \times \mathbb{C})/\mathbb{Z}_4$

Duality Bundle: $\mathbb{E} \to S^1/\mathbb{Z}_4$

These are 7-branes with $\tau = \exp(2\pi i/4)$

Example: E_7 gauge group: $y^2 = x^3 + z^3 x$ "Type III^*"

Example: $SU(2)$ gauge group: $y^2 = x^3 + zx$ "Type III"

$$\Omega_1^{GL^+(2,\mathbb{Z})}$$

$$\Omega_1^{GL^+(2,\mathbb{Z})} = \mathbb{Z}_2 \times \mathbb{Z}_2$$

STILL have 7-branes with $\tau = \exp(2\pi i/4)$

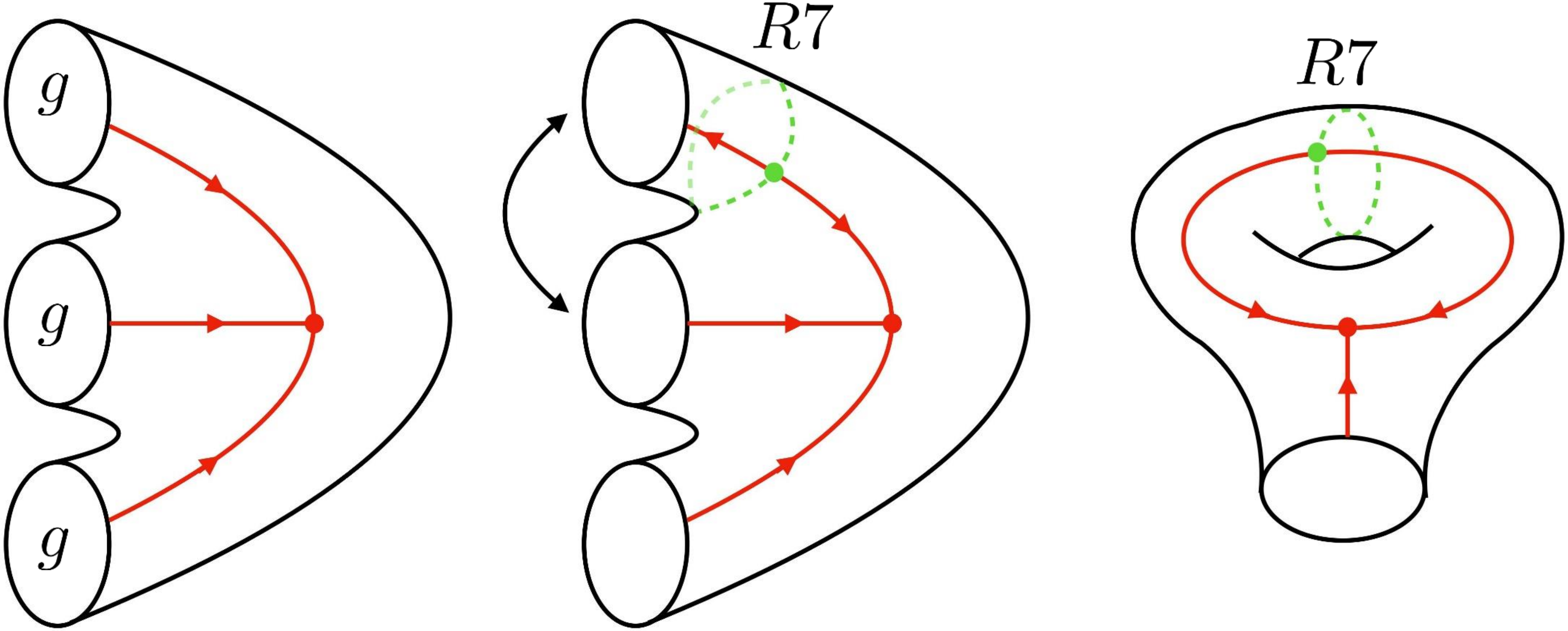
DON'T have 7-branes with $\tau = \exp(2\pi i/3)$

A NEW $\mathbb{Z}_2$ Class: "Reflection 7-Brane"

Ω-Brane ⟷ (S-Dual) ⟷ F_L-Brane

$$\Omega_1^{Mp(2,\mathbb{Z})} \quad \textbf{vs} \quad \Omega_1^{GL^+(2,\mathbb{Z})}$$

Eating $\mathbb{Z}_3$ with an R7 ($g^3 = 1$ in $\mathbb{Z}_3$)



R7-Branes

$GL(2,\mathbb{Z})$ Monodromy

S-Dual

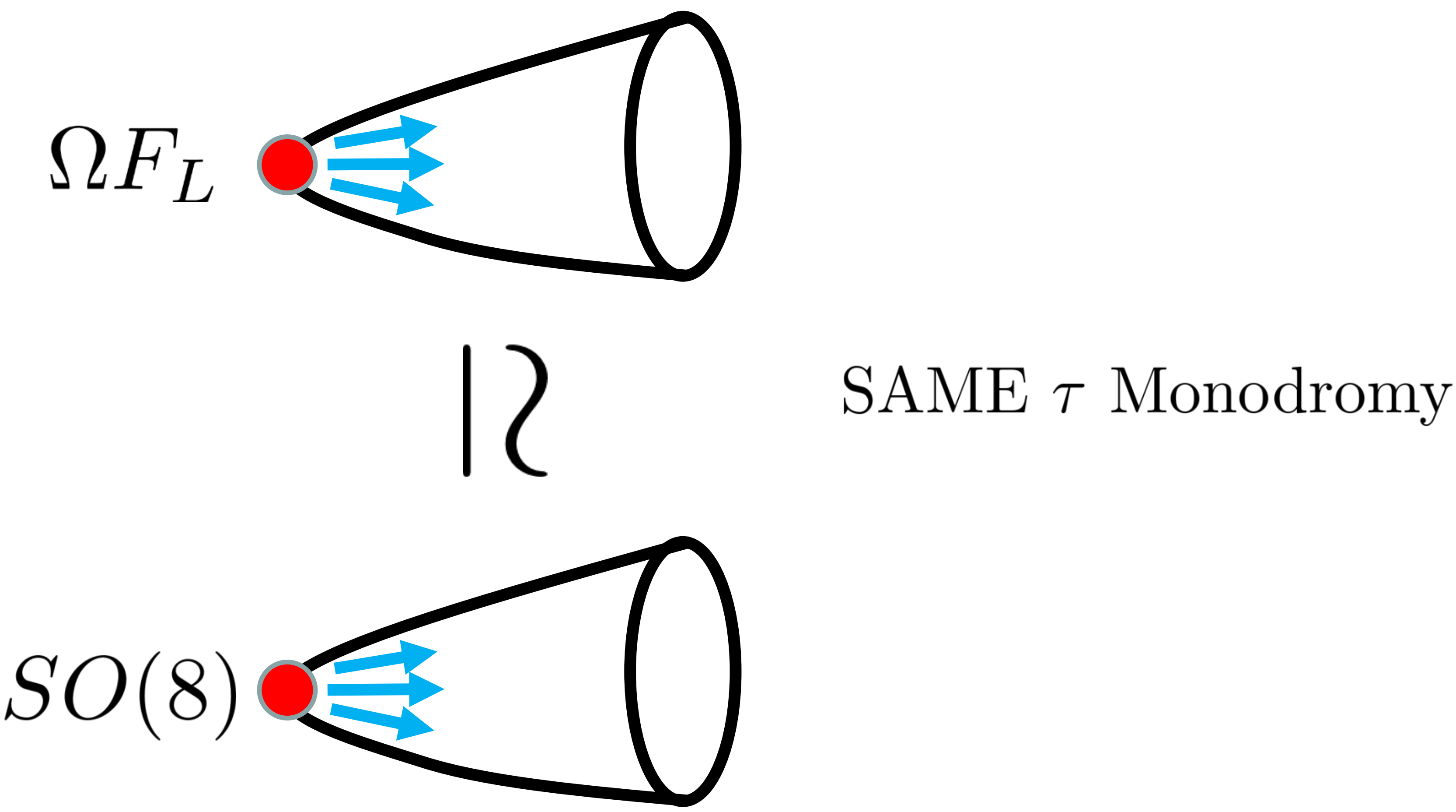
$$M_{\Omega} = \begin{bmatrix} +1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$M_{F_L} = \begin{bmatrix} -1 & 0 \\ 0 & +1 \end{bmatrix}$$

$$M_{SO(8)} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$

$SO(8)$ 7-Brane: $y^2 = x^3 + \alpha z^2 x + z^3$

ΩF_L Bound State



~~SUSY~~

Ω and F_L Break SUSY (no Q's preserved)

But $SO(8)$ 7-Brane (4 D7's and an O7$^-$)
Is Supersymmetric

$$\Omega + F_L \to SO(8) + \text{radiation}$$

Processes

$$\Omega + \Omega \to \text{radiation}$$

$$F_L + F_L \to \text{radiation}$$

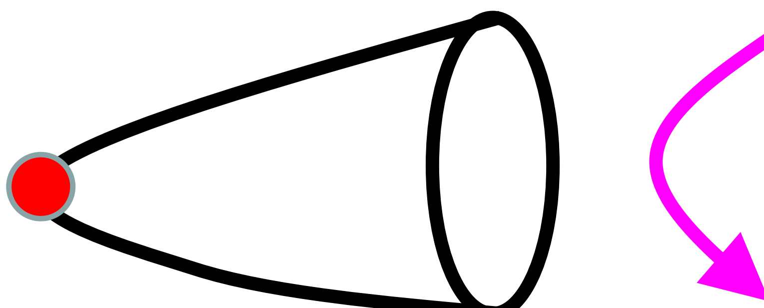
$$\Omega + F_L \to SO(8) + \text{radiation}$$

¿Stability?

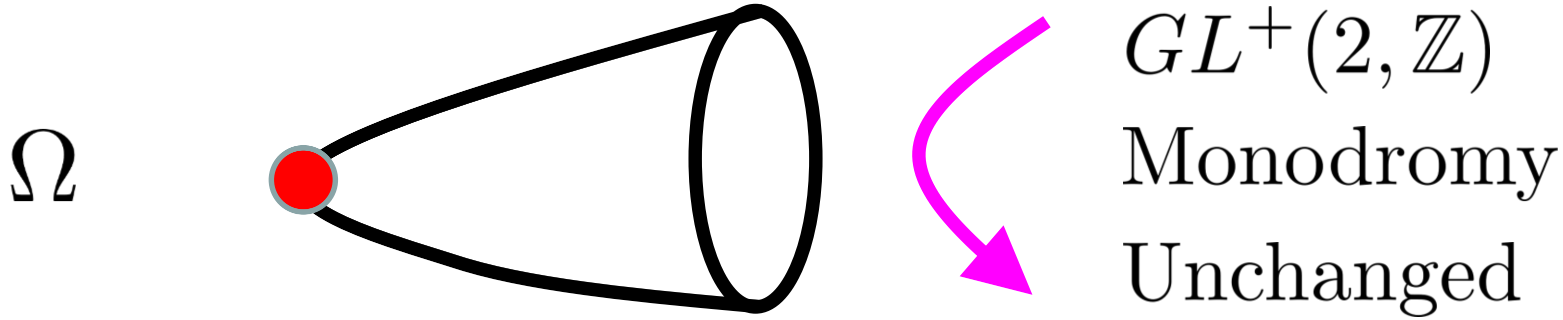
Not Required by Cobordism Conjecture...

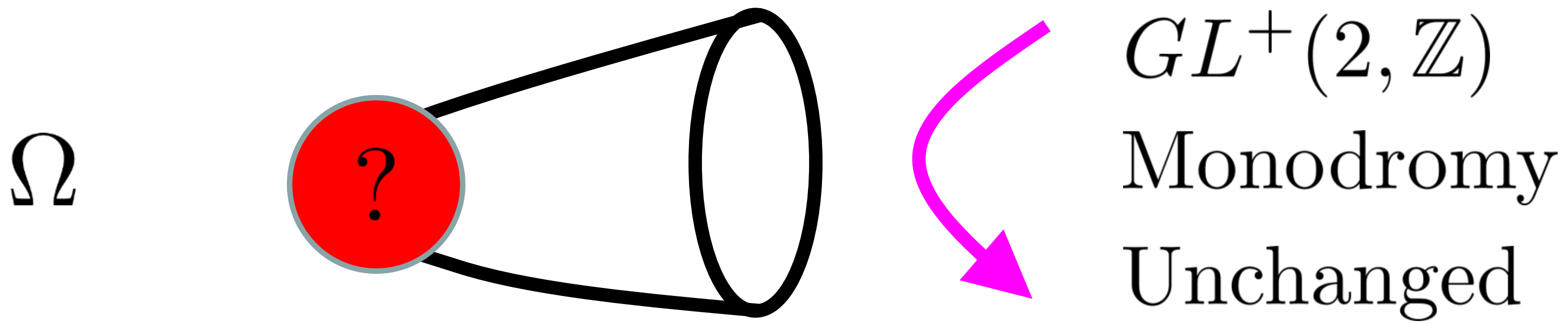
Analogous to Type I D7-Brane (Unstable)
Sen '98

Ω

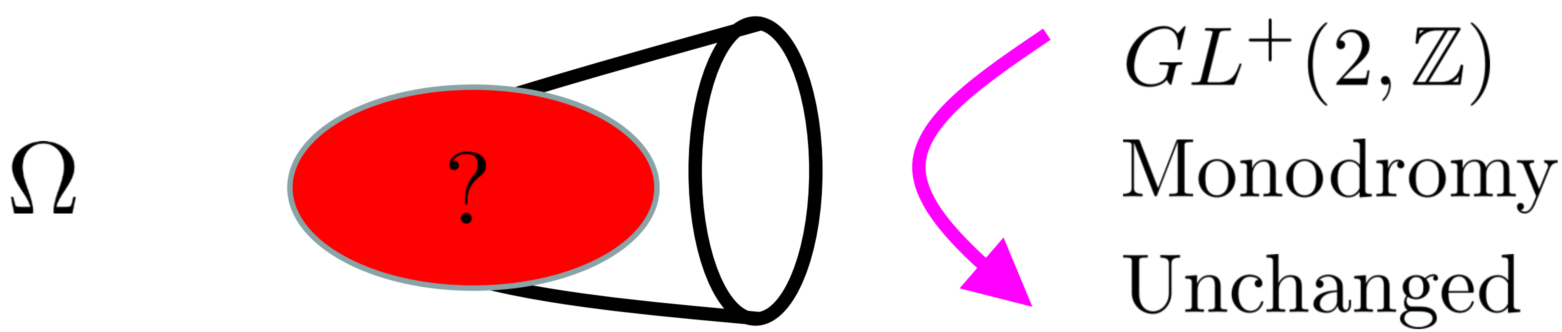


$GL^+(2,\mathbb{Z})$
Monodromy
Unchanged


Ω
$GL^+(2,\mathbb{Z})$
Monodromy
Unchanged



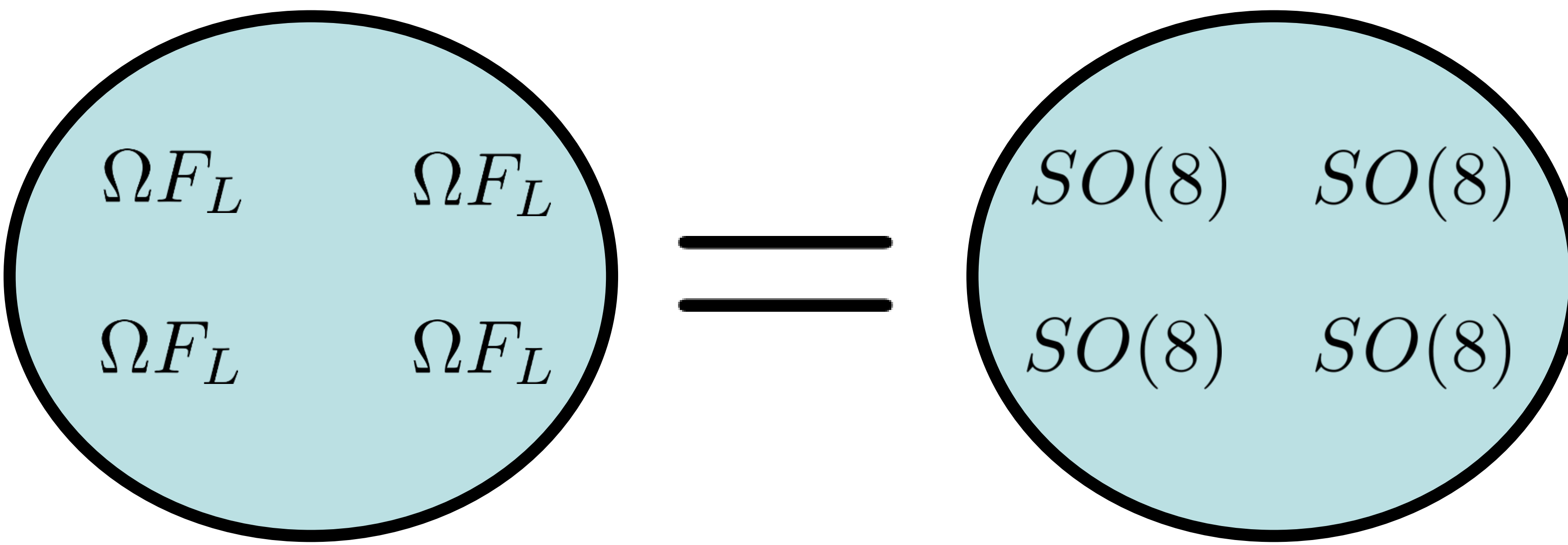
Ω
?
$GL^+(2,\mathbb{Z})$
Monodromy
Unchanged

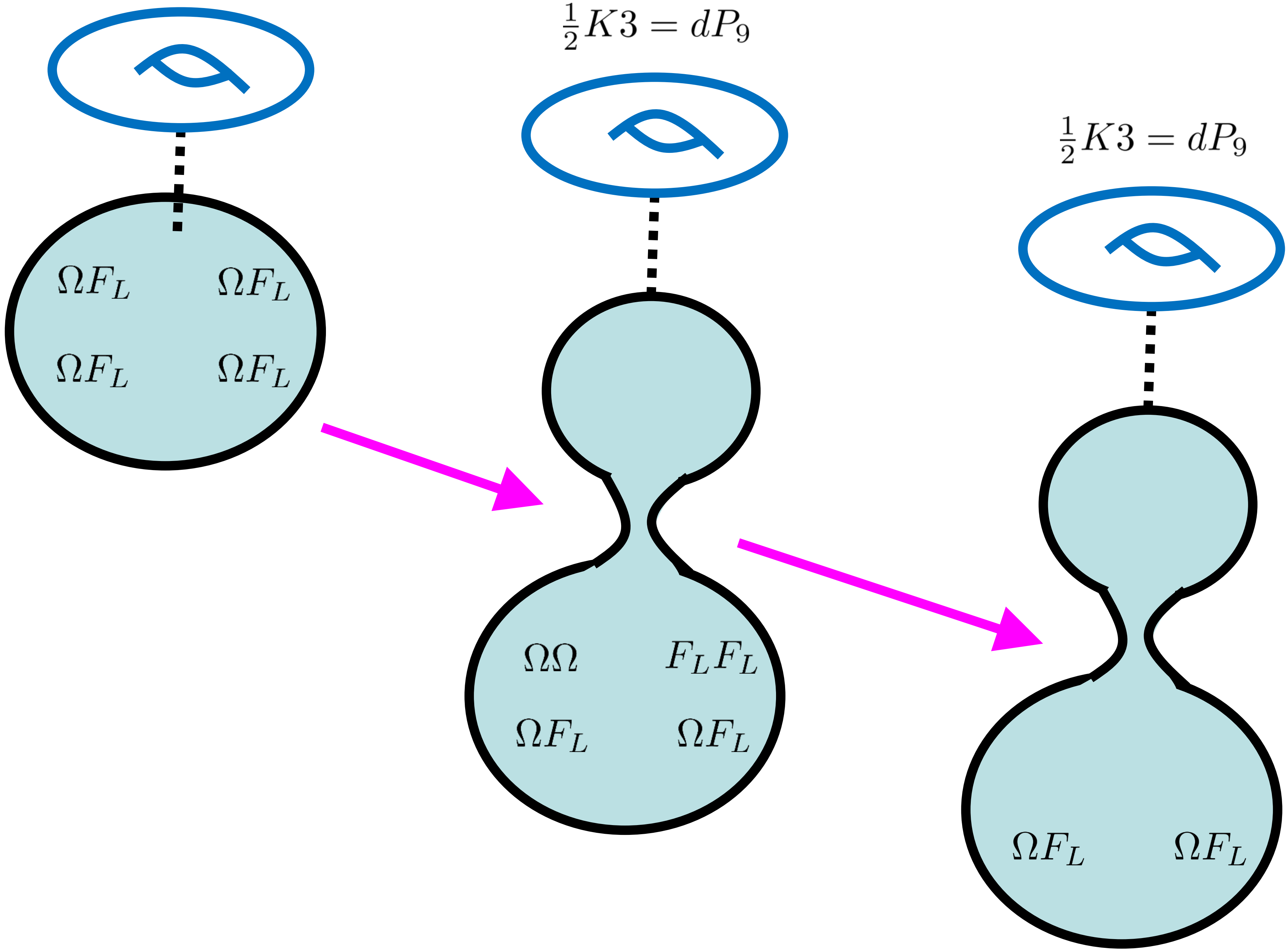

Ω
?
$GL^+(2,\mathbb{Z})$
Monodromy
Unchanged

Rearrangements

Sen Limit: F-th on K3 with $SO(8)^4$

10D Spacetime: $\mathbb{R}^{7,1} \times \mathbb{CP}^1$





$\frac{1}{2}K3 = dP_9$
$\frac{1}{2}K3 = dP_9$
ΩF_L ΩF_L
ΩF_L ΩF_L
$\Omega\Omega$ F_LF_L
ΩF_L ΩF_L
ΩF_L ΩF_L

How About $\Omega_k^{\mathcal{G}}$?

$\Omega_k^{Mp(2,\mathbb{Z})}$ and $\Omega_k^{GL^+(2,\mathbb{Z})}$

$\Omega_k^{Mp(2,\mathbb{Z})}$ for k odd all known SUSY bkgnds

$\Omega_k^{GL^+(2,\mathbb{Z})}$ for k odd: Just add R7's!

S-Folds and $\Omega_5^{Mp(2,\mathbb{Z})}$

S-Fold: Non-Perturbative Gen^n of O3-Plane

$\Omega_5^{Mp(2,\mathbb{Z})} = \mathbb{Z}_{32} \times \mathbb{Z}_2 \times \mathbb{Z}_9$

F-theory Picture:

$\mathbb{Z}_{32}$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_4$ "Standard" Spin-$\mathbb{Z}_8$-Bundle

$\mathbb{Z}_2$ via $\partial(\widetilde{\mathbb{C}}^3 \times T^2)/\mathbb{Z}_4$ Different Spin-$\mathbb{Z}_8$ Bundle!

$\mathbb{Z}_9$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_3$ "Standard" Spin-$\mathbb{Z}_6$ Bundle

4D SCFTs

Probe with N D3-Branes $\Rightarrow$ SCFTs
(natural extra sectors)

$\mathbb{Z}_{32}$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_4$ "Standard" Spin-$\mathbb{Z}_8$ Bundle

$\Rightarrow \mathcal{N} = 3$ SCFT

$\mathbb{Z}_2$ via $\partial(\widetilde{\mathbb{C}}^3 \times T^2)/\mathbb{Z}_4$ Different Spin-$\mathbb{Z}_8$ Bundle!

$\Rightarrow \mathcal{N} = 1$ SCFT

$\mathbb{Z}_9$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_3$ "Standard" Spin-$\mathbb{Z}_6$ Bundle

$\Rightarrow \mathcal{N} = 3$ SCFT

4D SCFTs

Probe with N D3-Branes $\Rightarrow$ SCFTs
(natural extra sectors)

$\mathbb{Z}_{32}$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_4$ "Standard" Spin-$\mathbb{Z}_8$ Bundle
$\Rightarrow \mathcal{N} = 3$ SCFT

$\mathbb{Z}_2$ via $\partial(\widetilde{\mathbb{C}}^3 \times T^2)/\mathbb{Z}_4$ Different Spin-$\mathbb{Z}_8$ Bundle!
$\Rightarrow \mathcal{N} = 1$ SCFT NEW SCFTs...

$\mathbb{Z}_9$ via $\partial(\mathbb{C}^3 \times T^2)/\mathbb{Z}_3$ "Standard" Spin-$\mathbb{Z}_6$ Bundle
$\Rightarrow \mathcal{N} = 3$ SCFT

Summary / Future

Summary / Future

Summary:

- $\Omega_k^{\text{Duality}}$ + Swamp $\Rightarrow$ Predict Objects
- New Non-SUSY Ingredient: R7-Brane
- New 4D $\mathcal{N} = 1$ SCFTs

Future:

- ~~SUSY~~ and R7?
- Bigger Duality Groups, e.g. $E_{7(7)}(\mathbb{Z})$?
- Model Building with R7's?