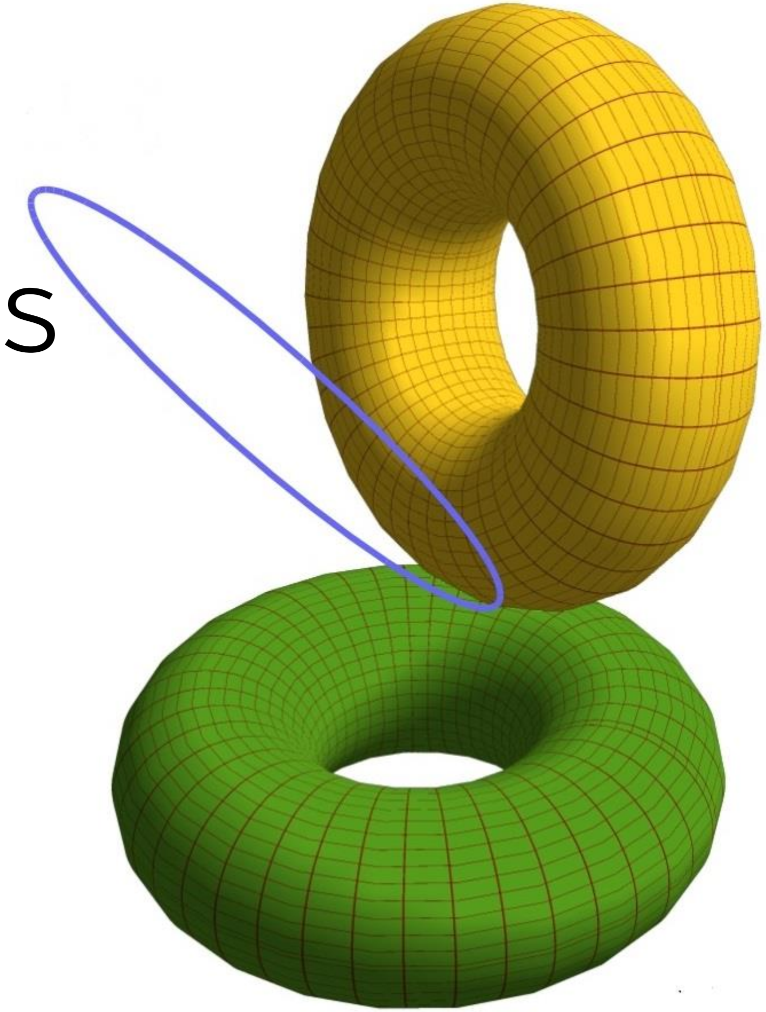
Strings, D-branes, and supergravities from M2-branes with discrete spectra



Camilo las Heras Guverneur.

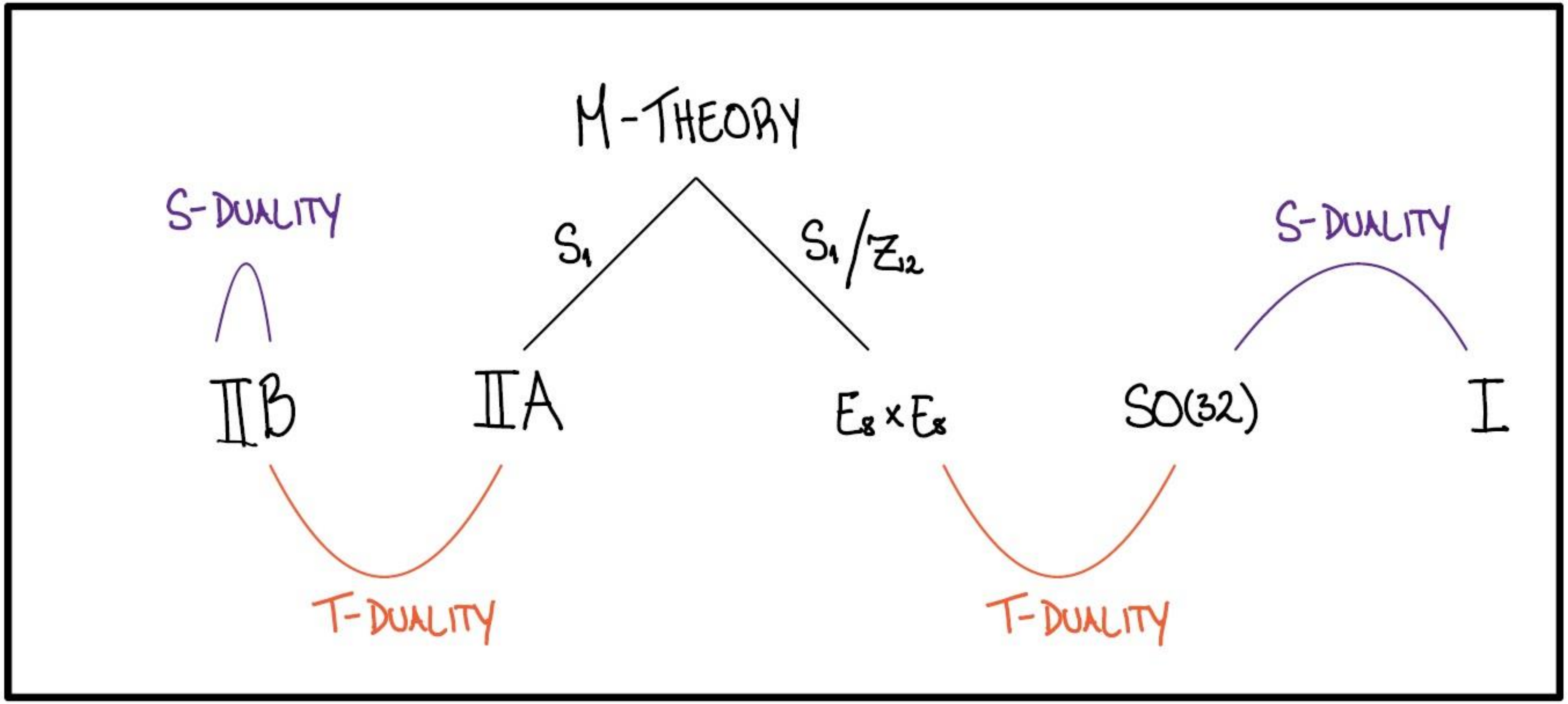
Instituto de Física Teórica UAM/CSIC

STRING PHENOMENOLOGY 2023

IBS, DAEJEON

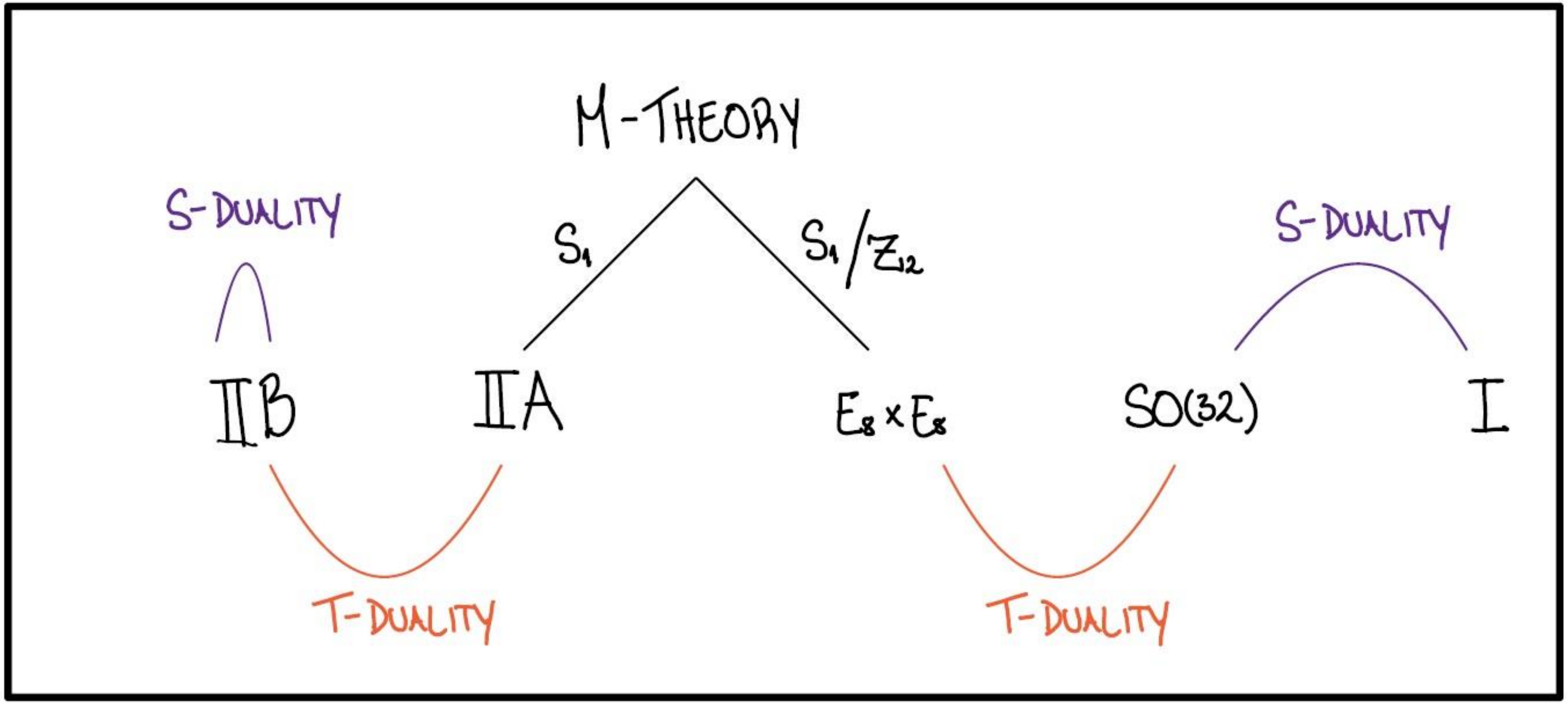
In collaboration with M.P Garcia del Moral y A. Restuccia

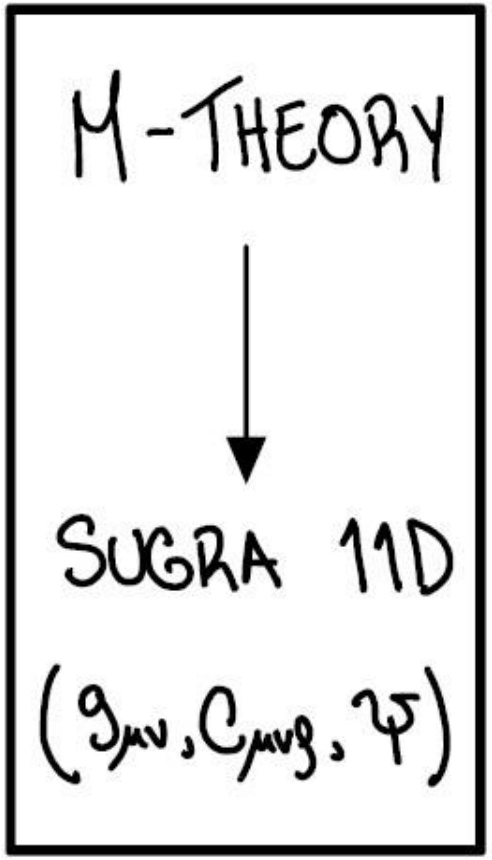
Motivation



(Font, Ibañez, Lust, Quevedo '90) (Rabinovici '94)
(Witten '95) (Horava, Witten '95) (Hull, Townsend '95)

Motivation





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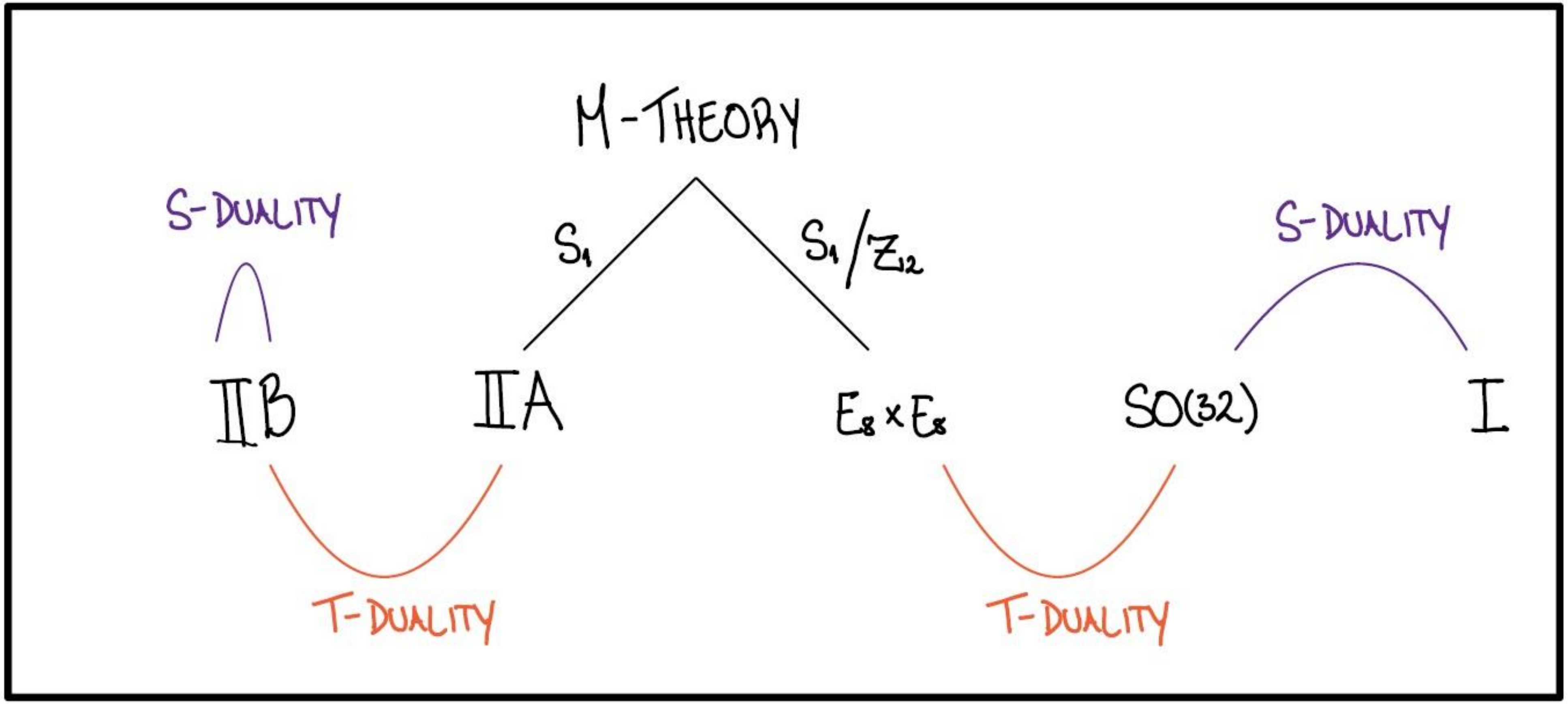

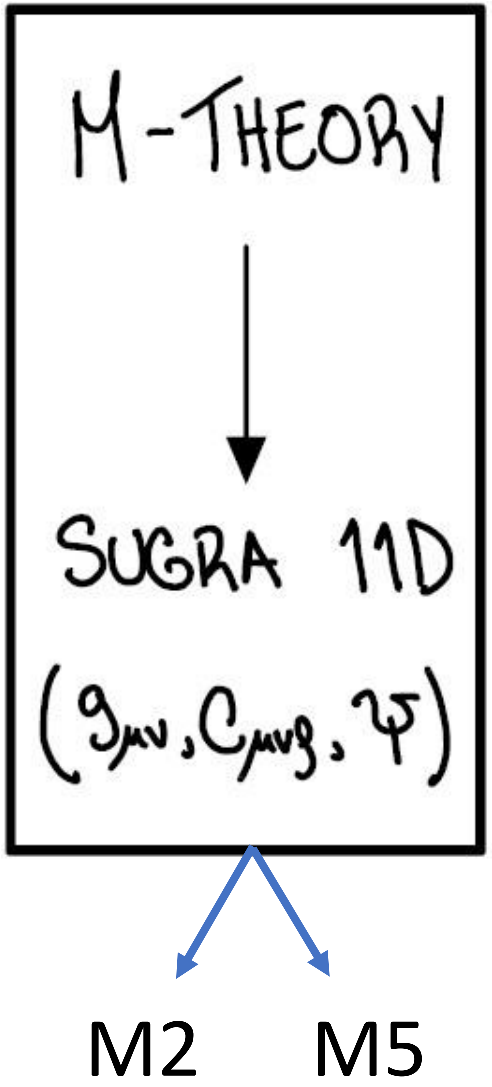

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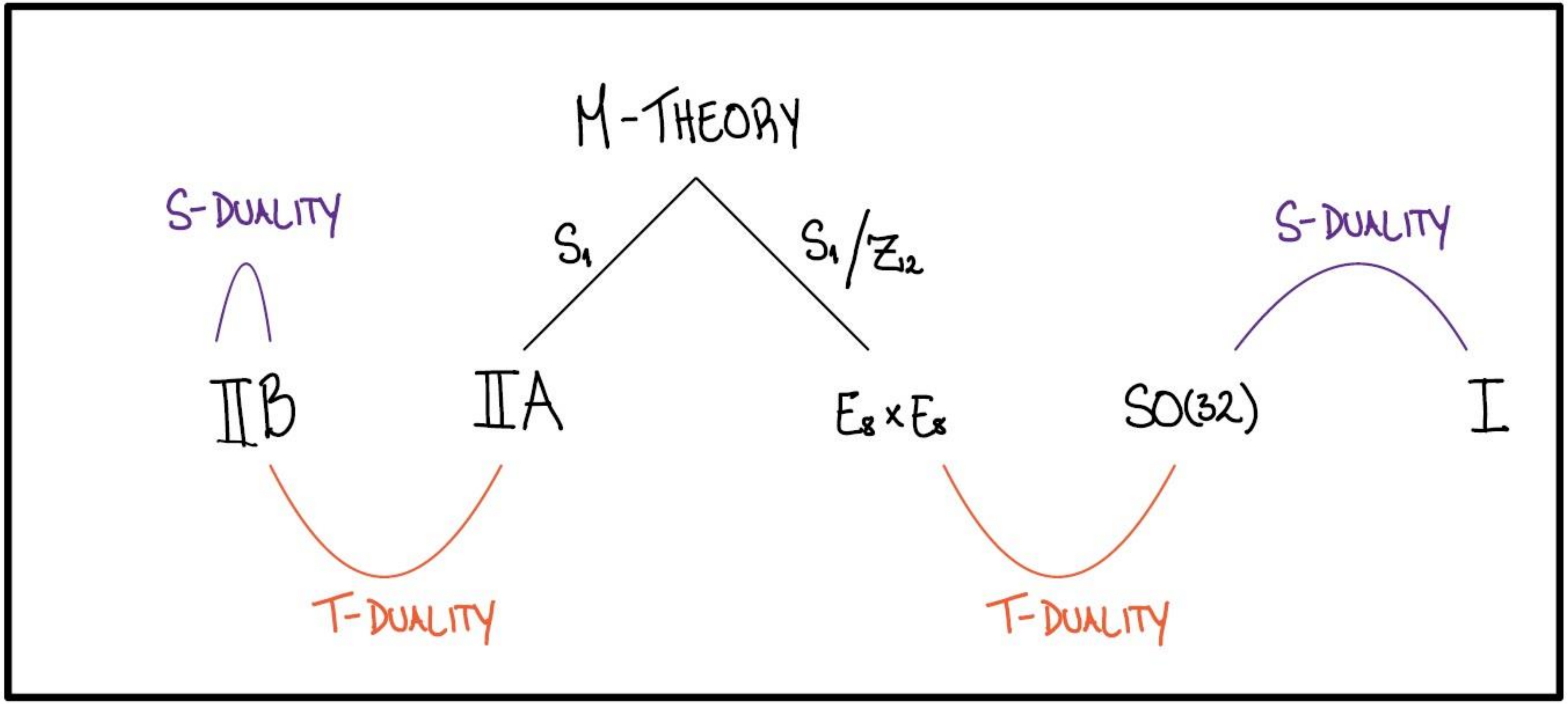

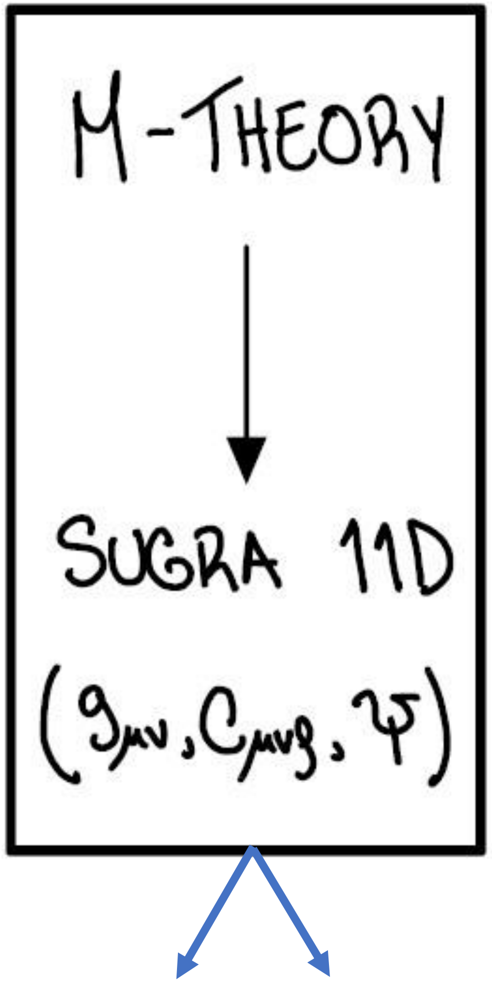

M2 M5

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Motivation

M-theory

M2-branes

(Bergshoeff, Sezgin, Townsend '87, '88) , (De Wit, Hoppe, Nicolai '88)

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- SU(N) regularized model with continuous spectra (De Wit, Luscher, Nicolai '88)

String configurations = instabilities

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(Bergshoeff, Sezgin, Townsend '87, '88) , (De Wit, Hoppe, Nicolai '88)

- SU(N) regularized model with continuous spectra (De Wit, Luscher, Nicolai '88)

  String configurations = instabilities

- Membranes with "winding" on a torus have the same spectral behavior
  (De Wit, Peeters, Plefka '97, '98)

Motivation

M-theory

M2-brane with central charges.

- SU(N) regularized model with **discrete supersymmetric spectra.**

String configurations are not instabilities.

(Martín, Restuccia, Torrealba ‘98) (Boulton, García del Moral, Restuccia ‘03)

Motivation

M-theory

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(Martín, Restuccia, Torrealba '98) (Boulton, García del Moral, Restuccia '03)

- It has been formulated in: $\mathbb{R}^{1,8} \times T^2$, $\mathbb{R}^{1,3} \times T^6 \times S^1$ and $\mathbb{R}^{1,3} \times G_2$

(García del Moral, Peña, Restuccia '08) (Bilhal, García del Moral, Restuccia '09)

Motivation

M-theory

M2-brane on a pp-wave background

M2-brane with $C_{\pm}$ fluxes (I and II).

Massive M2-brane

- SU(N) regularized model with **discrete supersymmetric spectra**.

Motivation

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(Boulton, García del Moral, Restuccia '12)

(García del Moral, León, Restuccia '22)

(García del Moral, CLH, León, Peña, Restuccia '19)
(García del Moral, CLH '22)

Motivation

M-theory

- M2-brane with central charges.
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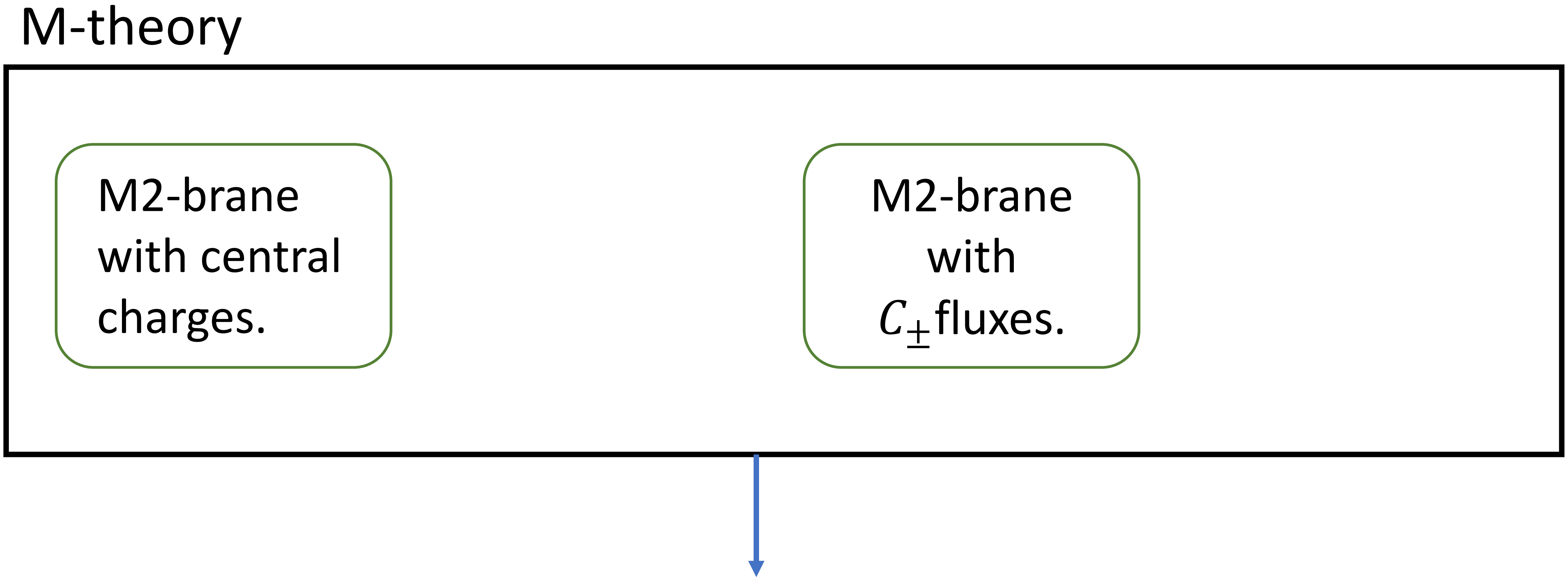
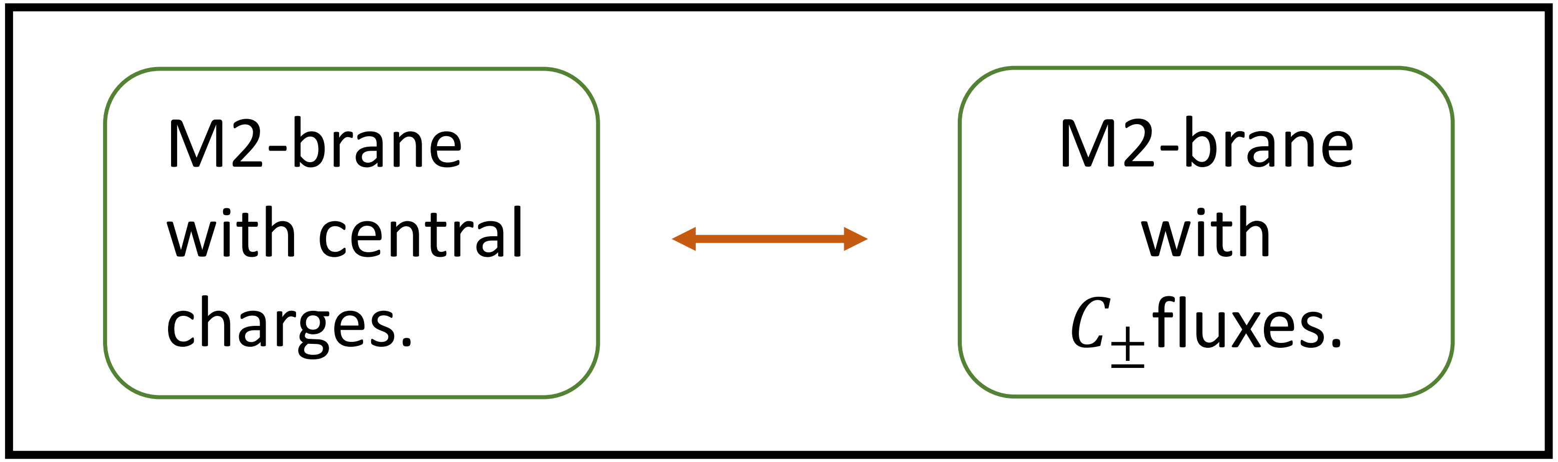


GOAL: Non perturbative string theory (and supergravity)

M2-branes with discrete spectra



Canonical transformation in the phase space

(García del Moral, CLH, León, Peña, Restuccia ‘19)

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Same Hamiltonian, same spectra. Dual sectors!

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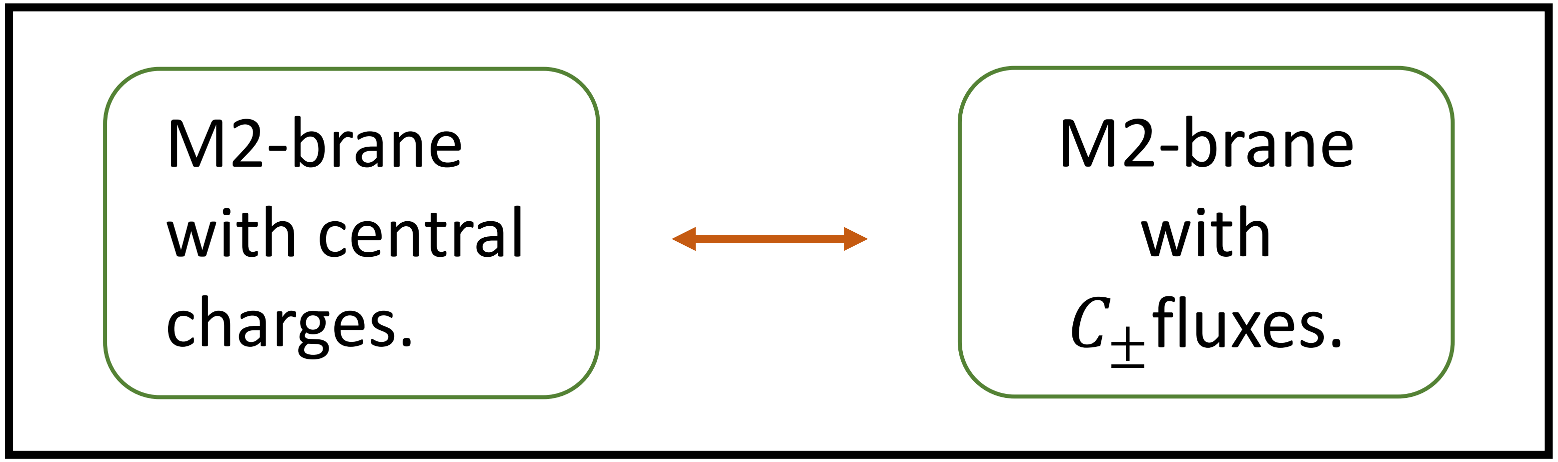

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The worldvolume ($\Sigma_g \times \mathbb{R}$) theory of these sectors is characterized by:

- Embedding of the M2-brane (with $g = 1$) on $\mathbb{R}^{1,8} \times T^2$
- Nontrivial flux condition on the (spatial) worldvolume.

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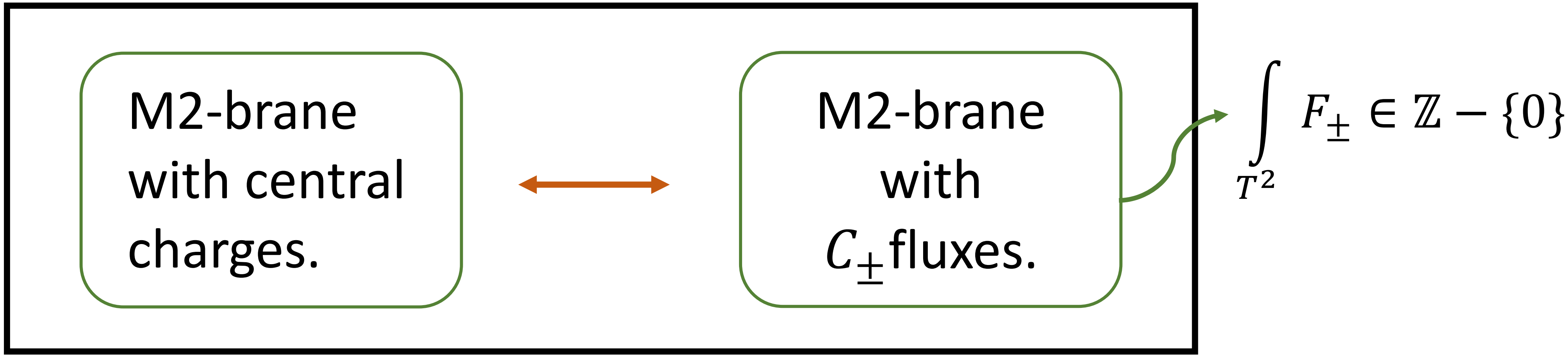
M2-branes with discrete spectra



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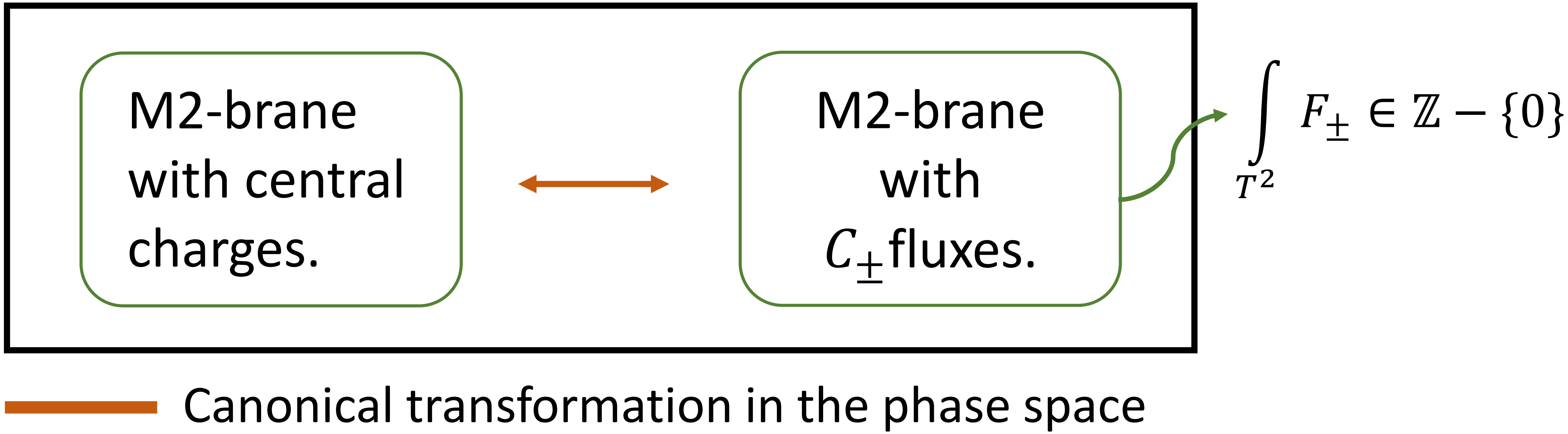

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M2-branes with discrete spectra

M2-brane with central charges. ⟷ M2-brane with $C_\pm$ fluxes.

$\int_{T^2} F_\pm \in \mathbb{Z} - \{0\}$

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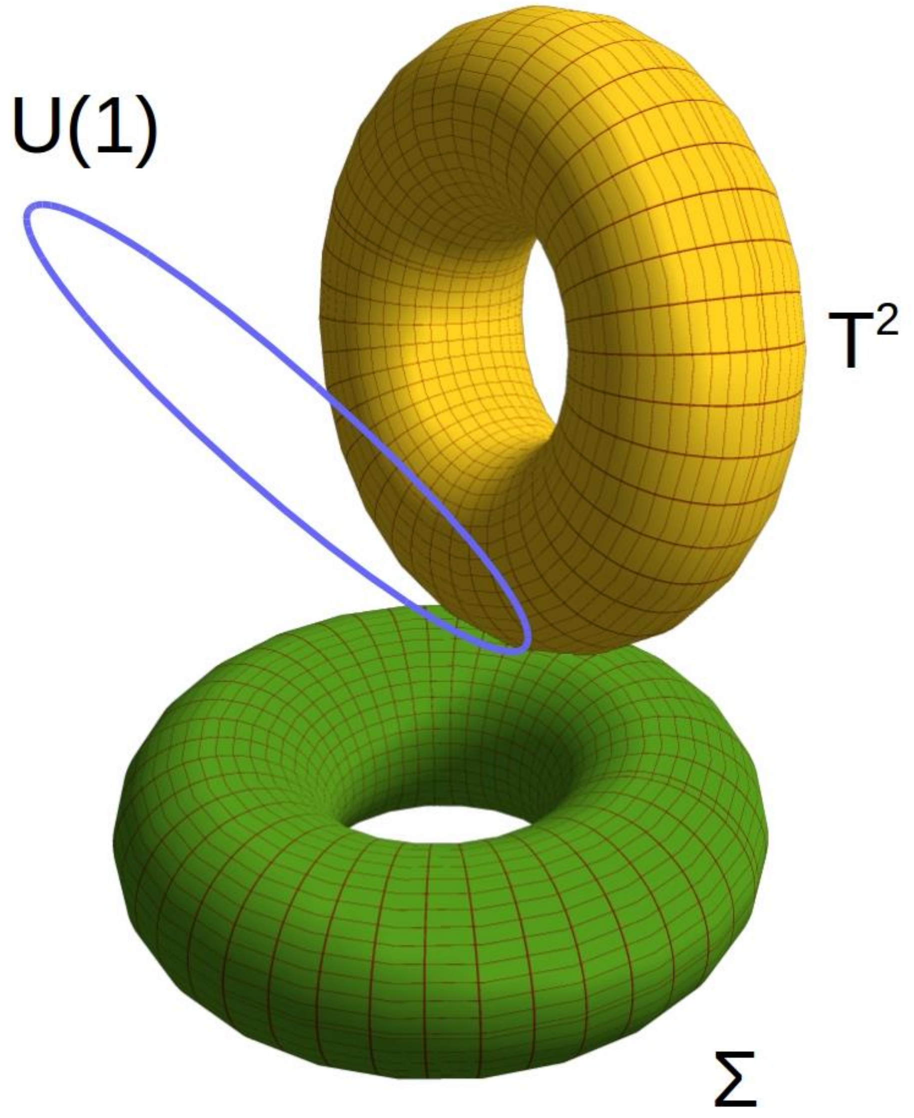
- Nontrivial flux condition on the (spatial) worldvolume. It implies $\det(\mathbb{W}) \in \mathbb{Z} - \{0\}$
- <u>Nontrivial</u> gauge symmetries: symplectic and 3 U(1) (on the same bundle).

(García del Moral, CLH, León, Peña, Restuccia '19, '20)

M2-branes with discrete spectra

- Twisted torus bundle with $\mathcal{M}_g \subseteq SL(2,\mathbb{Z})$.



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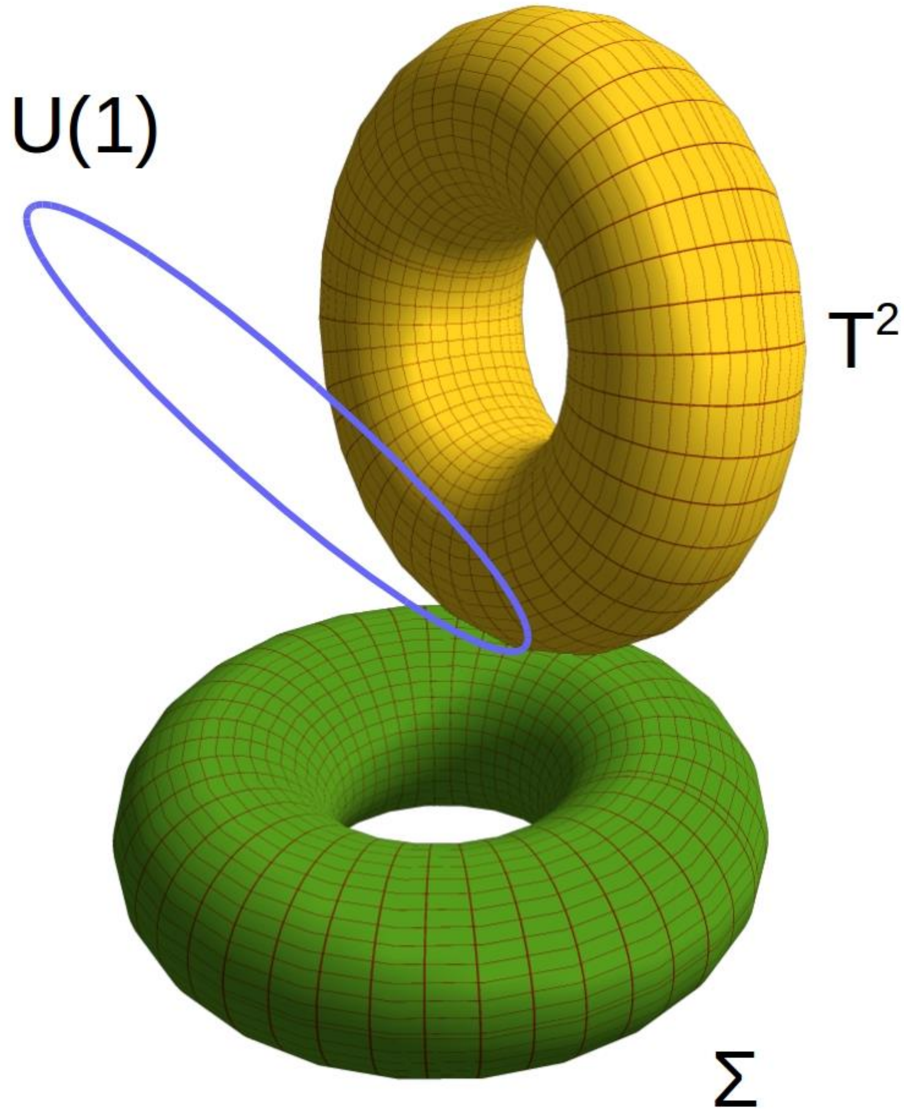
$$C_F = \{Q + (\mathcal{M}_g - \mathbb{I})\hat{Q}\}$$



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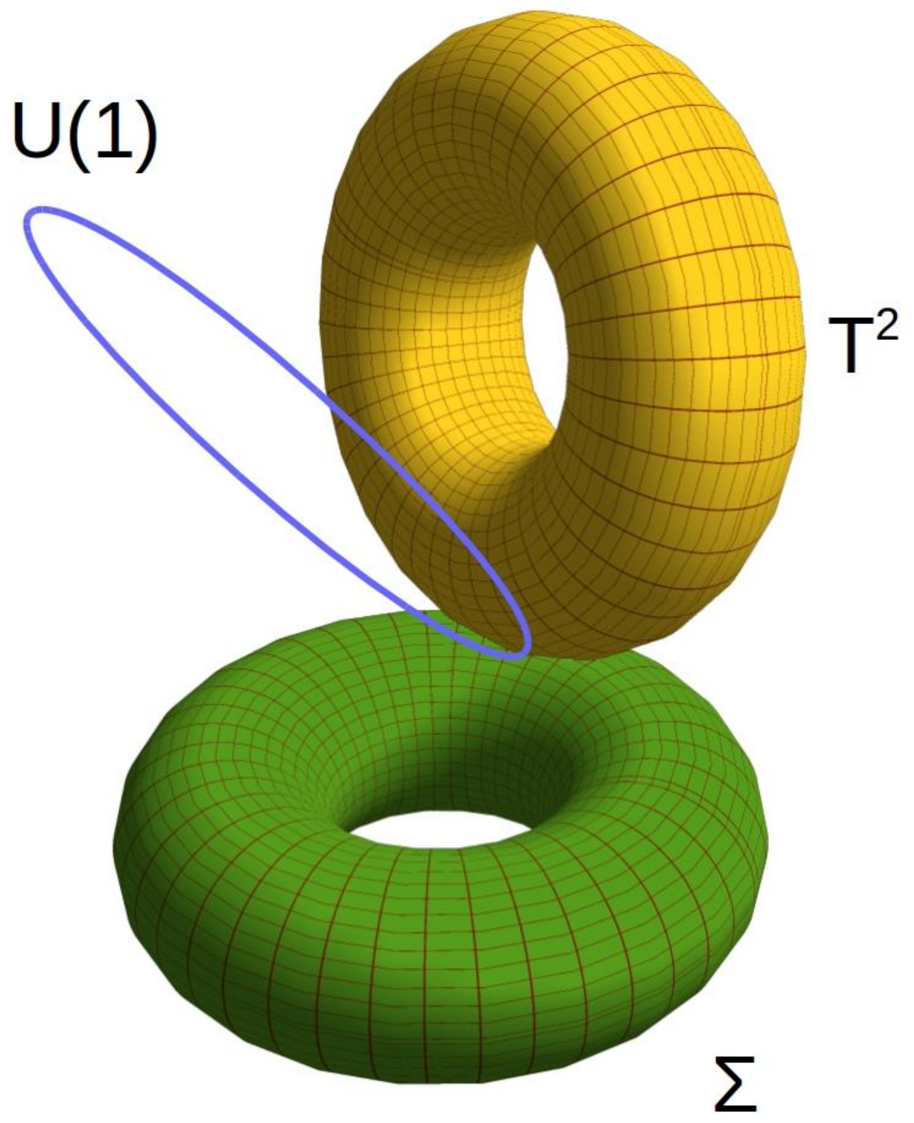
$$\binom{p}{q} \in H_1(T^2)$$



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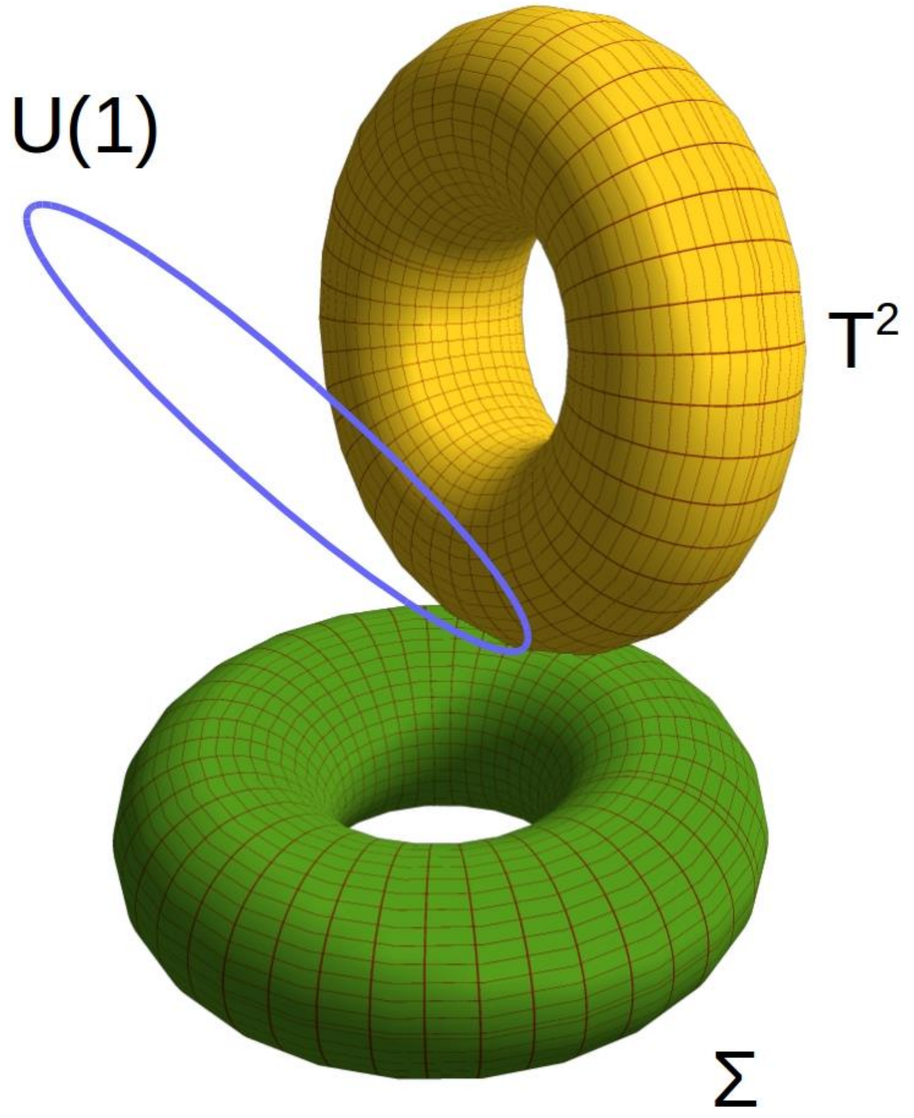
$$\begin{pmatrix} p \\ q \end{pmatrix} \in H_1(T^2) \qquad \mathcal{M}_g \in \begin{cases} parabolic\ \ if\ Trace = 2 \\ elliptic\ \ if\ \ \ Trace < 2 \\ hiperbolic\ if\ Trace > 2 \end{cases}$$



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$\hat{Q}$: arbitrary

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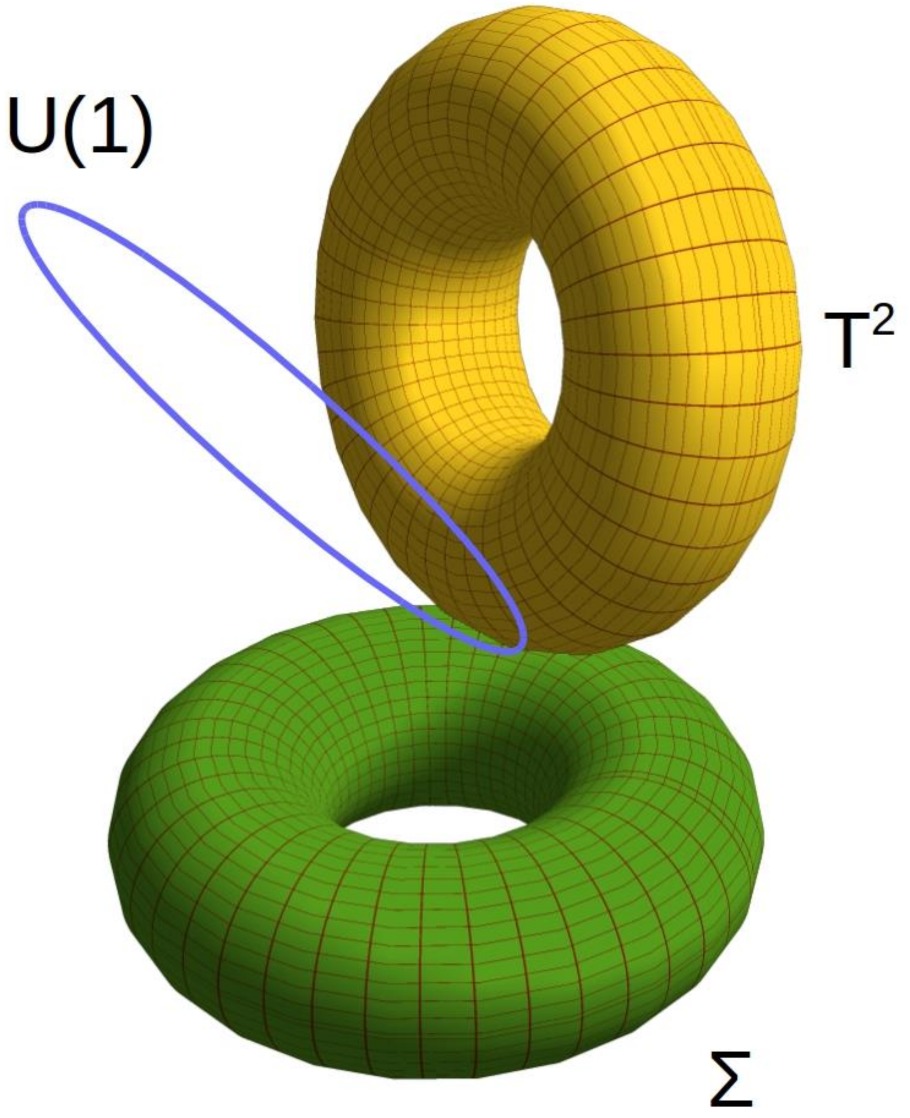

Type IIB $SL(2,\mathbb{Z})$(p,q)-strings on a circle from M2-branes with discrete spectra

Notice that

- if $\mathcal{M}_g = \mathbb{I}$, then $C_F = \{Q + \left(\mathcal{M}_g - \mathbb{I}\right)\hat{Q}\} = Q$

Type IIB $SL(2,\mathbb{Z})$(p,q)-strings on a circle from M2-branes with discrete spectra

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The mass operator of the M2-brane with C_- fluxes and trivial monodromy (string configurations) is given by

$$M^2_{C_-} = (\mathrm{Tn}A_{T^2})^2 + \left(\frac{m|q\tau - p|}{R\mathbb{I}m(\tau)}\right)^2 + T8\pi^2 R|q\tau - p|(N_T - \overline{N}_T)$$

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From where, following Schwarz, we obtain

$$M_{p,q}^2 = \left(\frac{n}{R_B}\right)^2 + (2\pi R_B \mathrm{m} T_{(p,q)})^2 + 4\pi T_{(p,q)}(N_L - \bar{N}_R)$$

(Schwarz, '95) (García del Moral, CLH, Restuccia '23)

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M2-branes with fluxes ($n = \det(\mathbb{W}) \in \mathbb{Z} - \{0\}$) ⟹

- Winding term
- KK term $(p, q \neq 0)$
- Membrane excitations

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Type IIB $Parabolic$(p,q)-strings from M2-branes with discrete spectra

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But if $\mathcal{M}_g$ corresponds to the parabolic subgroup, then $C_F = \begin{pmatrix} \mathbb{Z} \\ q \end{pmatrix}$.

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$$Q \xrightarrow{\Lambda} C_F = \begin{pmatrix} \mathbb{Z} \\ q \end{pmatrix} \qquad \mathbb{W} \xrightarrow{\Lambda^*} \Lambda^*\mathbb{W} \qquad \tau \longrightarrow \tau + \frac{\mathbb{Z}}{q}$$

(García del Moral, CLH, Restuccia ‘23)

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The theory is formulated on the parabolic coinvariants! (Equivalence class)

(García del Moral, CLH, Restuccia ‘23)

Type IIB $\mathcal{P}arabolic$(p,q)-strings from M2-branes with discrete spectra

Notice that

- if $\hat{Q} = Q$, then $C_F = \{Q + (\mathcal{M}_g - \mathbb{I})\hat{Q}\} = \mathcal{M}_g Q$ $\Longrightarrow$ Formulation of the local theory according to $SL(2,Z)_{T^2}$

But if $\mathcal{M}_g$ corresponds to the parabolic subgroup, then $C_F = \begin{pmatrix} \mathbb{Z} \\ q \end{pmatrix}$.

The mass operator is invariant if

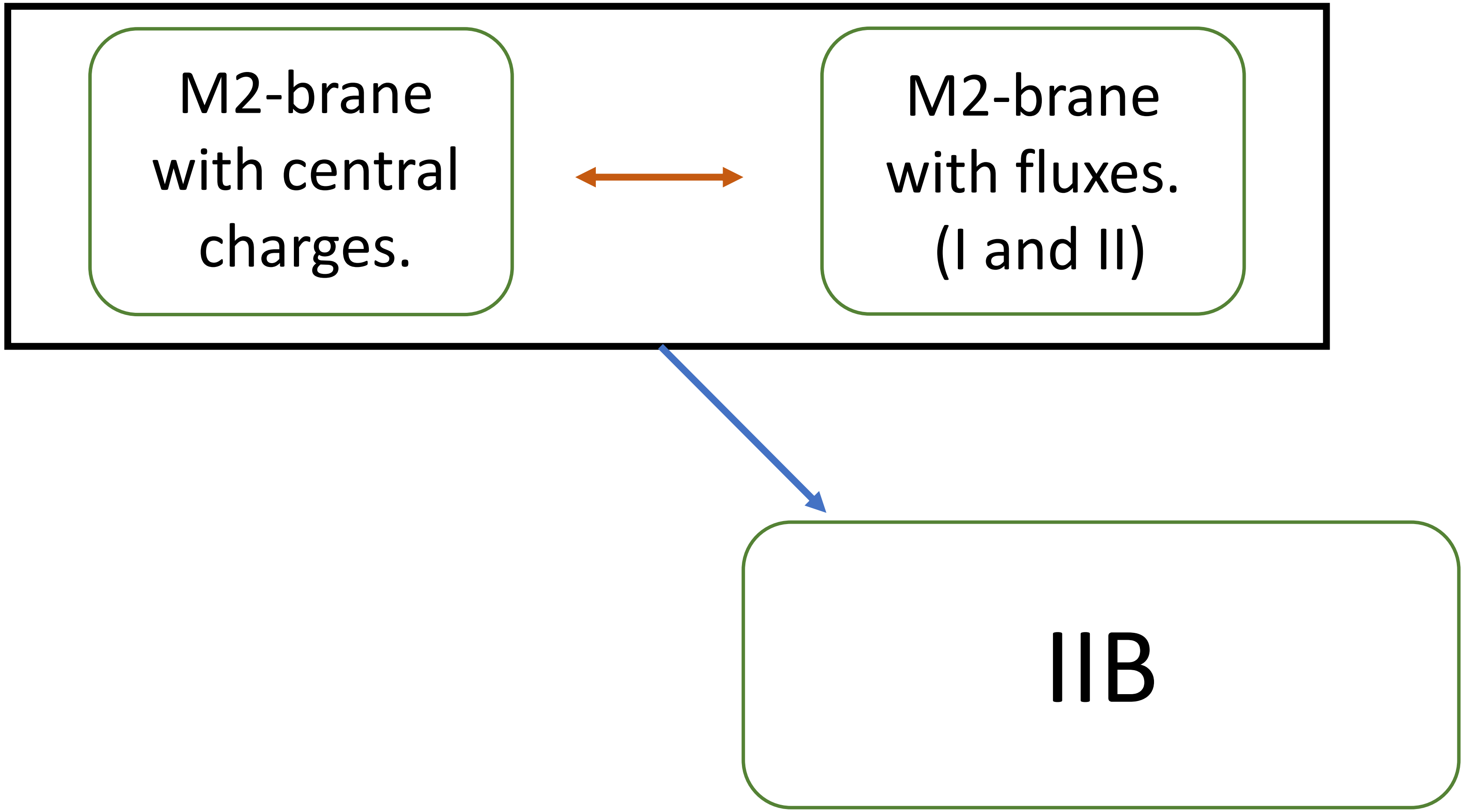
$$Q \xrightarrow{\Lambda} C_F = \begin{pmatrix} \mathbb{Z} \\ q \end{pmatrix} \qquad \mathbb{W} \xrightarrow{\Lambda^*} \Lambda^* \mathbb{W} \qquad \tau \longrightarrow \tau + \frac{\mathbb{Z}}{q} \qquad \Lambda \in SL(2,\mathbb{Q})$$

The theory is formulated on the parabolic coinvariants! (Equivalence class)

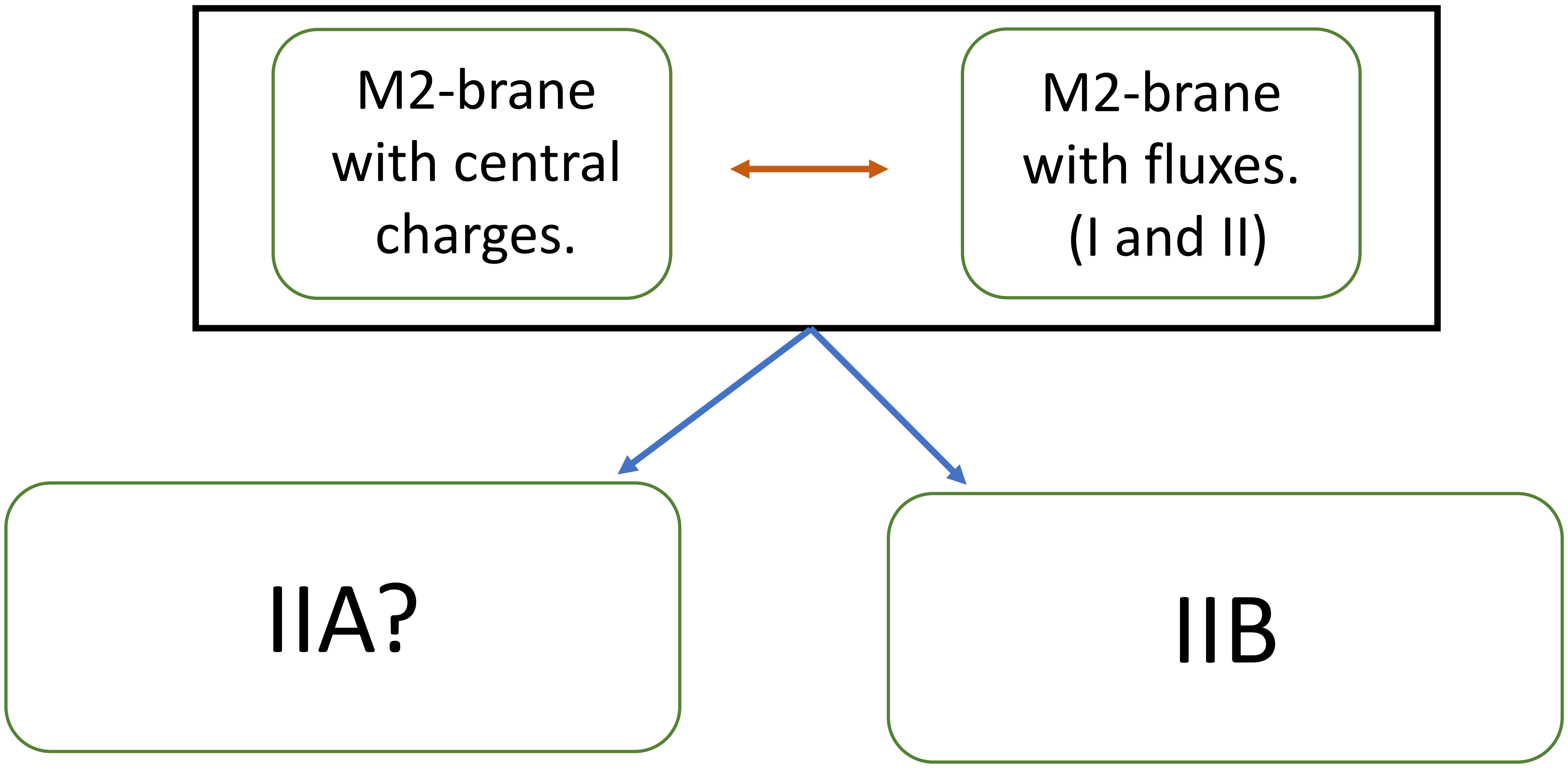
The associated (p,q)-strings on a circle, which we called parabolic (p,q)-strings or just q-strings, were conjectured by C. Hull (Hull, ‘98) as compactification of F-theory on a twisted 3-torus. Their low energy is given by type IIB parabolic gauged supergravity

(García del Moral, CLH, Restuccia ‘23)

So far…


M2-brane with central charges.
M2-brane with fluxes. (I and II)
IIB

So far…


M2-brane with central charges.
M2-brane with fluxes. (I and II)
IIA?
IIB

Type IIA D2-branes with fluxes from M2-branes with discrete spectra

There is a known relation between (standard) M2 on S^1 and (standard) D2-branes.

(Leigh '89) (Duff '93) (Townsend '95) (Schmidhuber '96)

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$$\mathcal{H}_{10D} = \boxed{\text{LCG D2-brane on a torus}}$$

(Manvelyan, Melikyan, Mkrtchian, ‘98)

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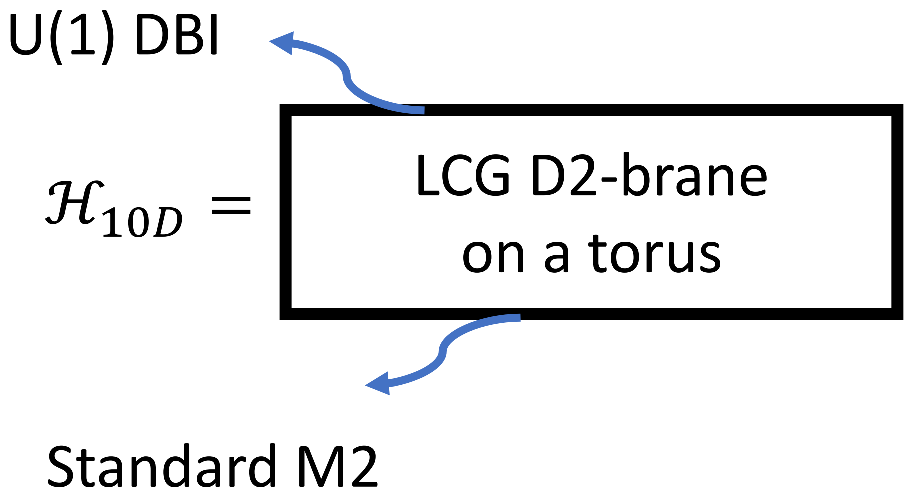

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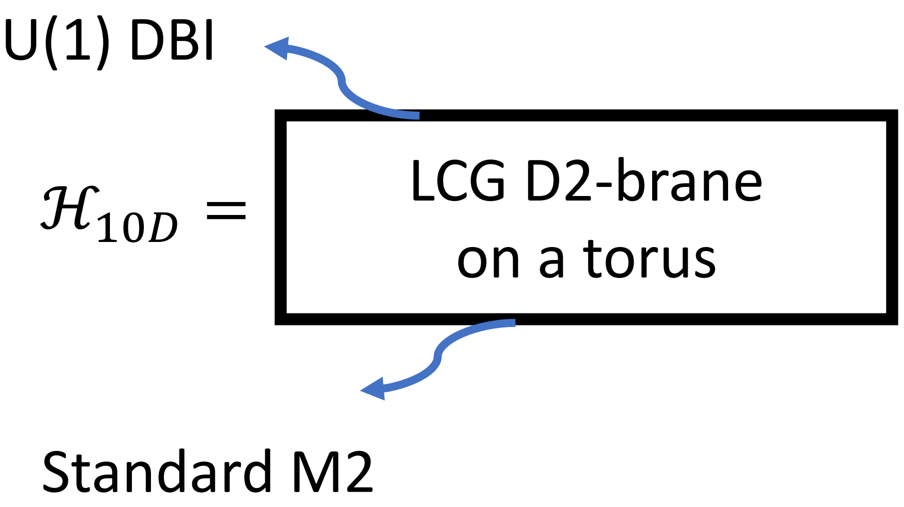

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U(1) DBI

$\mathcal{H}_{10D} =$ [LCG D2-brane on a torus] + [Nontrivial gauge symmetries] + [Nontrivial RR and NSNS fluxes (B-field terms)]

Standard M2

(Manvelyan, Melikyan, Mkrtchian, '98) (García del Moral, CLH '22)

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(Manvelyan, Melikyan, Mkrtchian, '98)

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LCG DBI

LCG DBI
$+C_{-}^{RR}$ fluxes

LCG DBI + WZ
$+ C_{+}^{RR}$ fluxes
+ B-field
quantization

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Standard D2?

(D2,D0)?

(F,Dp)?

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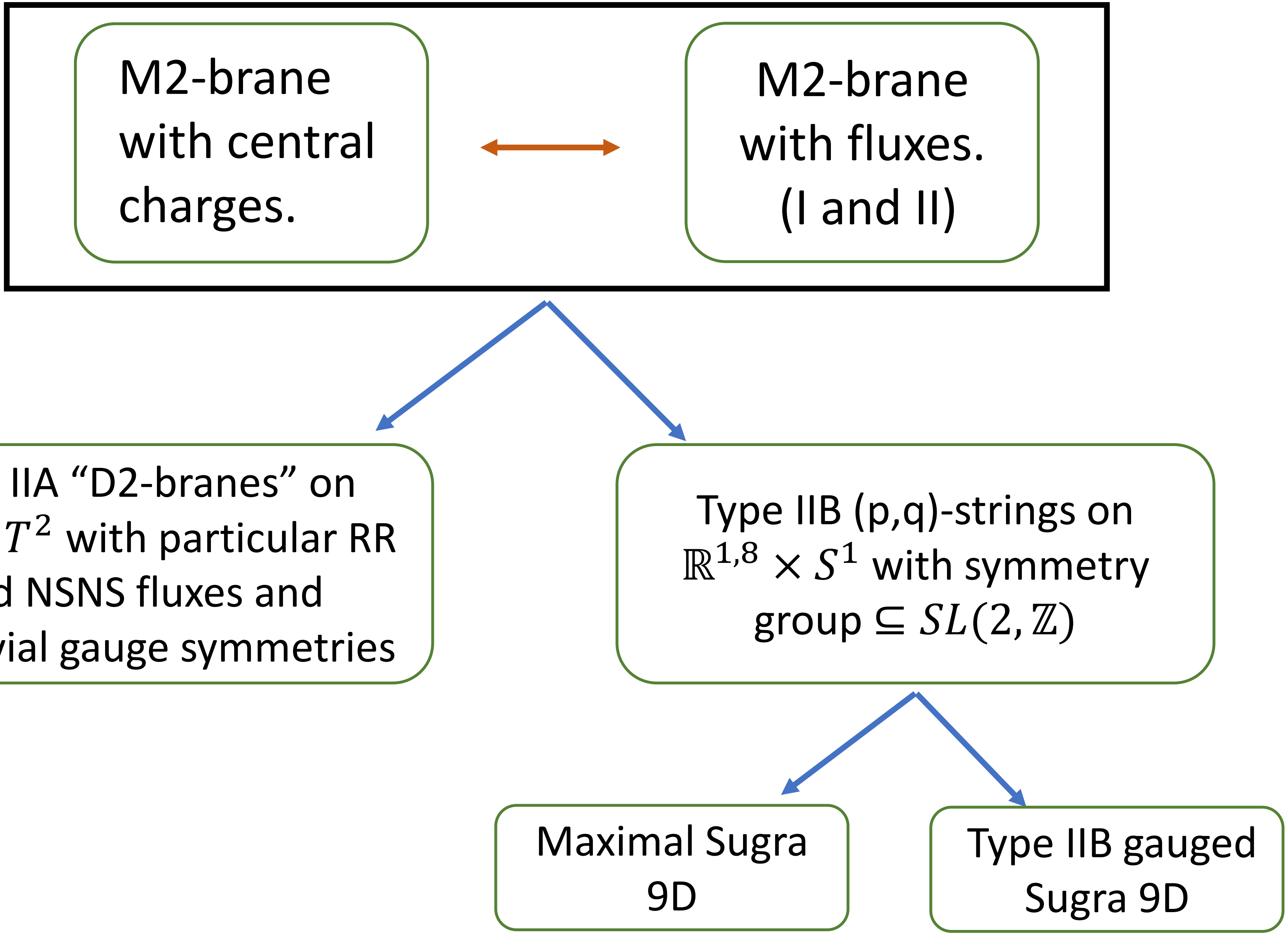
Summary


M2-brane with central charges.
M2-brane with fluxes. (I and II)
Type IIA "D2-branes" on $\mathbb{R}^{1,7} \times T^2$ with particular RR and NSNS fluxes and nontrivial gauge symmetries
Type IIB (p,q)-strings on $\mathbb{R}^{1,8} \times S^1$ with symmetry group $\subseteq SL(2,\mathbb{Z})$
Maximal Sugra 9D
Type IIB gauged Sugra 9D

Acknowledgments

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THANK YOU FOR YOUR ATTENTION

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