Geometry of orientifold vacua with broken supersymmetry

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Based on 2105.06913, TC, E. Dudas and H. Partouche

Introduction: Known mechanisms

- Scherk-Schwarz mechanism [Scherk, Schwarz, '79] [Rhom, '84] [Ferrara, Kounnas, Porrati, Zwirner, '89] [Kounnas, Rostand, '90]

Spacetime $\mathbb{R}^{1,3} \times S^1(R) \longrightarrow \phi(x, y + 2\pi R) \equiv \phi(x, y)$

Symmetry $T = e^{i\pi Q} \longrightarrow \phi(x, y + 2\pi R) \equiv e^{i\pi Q}\phi(x, y)$

$$\phi(x, y) = \sum_{m\in\mathbb{Z}} \phi_m(x) e^{\frac{i\left(m+\frac{Q}{2}\right)y}{R}} \longrightarrow M_{\phi_m(x)} = \frac{\left|m + \frac{Q}{2}\right|}{R}$$

Q = fermion number $F \Longrightarrow$ SUSY breaking

In string theory: Orbifold $(-1)^F \delta_p$, $\delta_p : y \to y + \pi R$

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Models with SUSY closed sector

Breaking only visible in the Möbius amplitude

Non-mutually BPS D-branes and O-planes

Orientifold plane type	Tension T	Charge q
O_--plane	< 0	< 0
O_+-plane	> 0	> 0
$\overline{O}_-$-plane	< 0	> 0
$\overline{O}_+$-plane	> 0	< 0

Global tension not zero $\Longrightarrow$ NS-NS tadpoles!

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A new realization

Start from a SUSY model with O_- and O_+-planes

Replace an O_- - O_+ pair by an $\overline{\mathrm{O}}_-$ - $\overline{\mathrm{O}}_+$ pair

Unchanged charge and tension $\Longrightarrow$ No R-R or NS-NS tadpoles

Link between geometry and amplitudes

$$\text{Amplitudes } \mathcal{K}, \mathcal{A}, \mathcal{M} \xrightarrow{\text{S transformation}} \text{Closed-string channel } \tilde{\mathcal{K}}, \tilde{\mathcal{A}}, \tilde{\mathcal{M}}$$

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Closed-string states propagation between D-branes and/or O-planes

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SO(32) type IIB orientifold theory

In 8d, $\mathbb{R}^{1,7} \times S^1(R_8) \times S^1(R_9)$

D9-branes and O9$_-$-plane $\xrightarrow{\text{T-duality}}$ D7-branes and 4 O7$_-$-planes

$(X^8, X^9) \xrightarrow{\Omega'} (-X^8, -X^9)$

Periodicity:

$g_8: \; X^8 \longrightarrow X^8 + 2\pi R_8$

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Tension = charge = 32

$\Longrightarrow N = 32$ D7-branes

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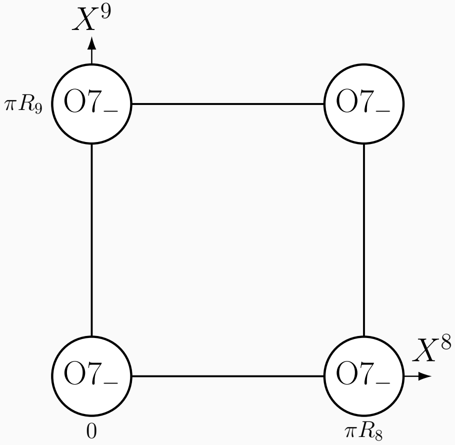

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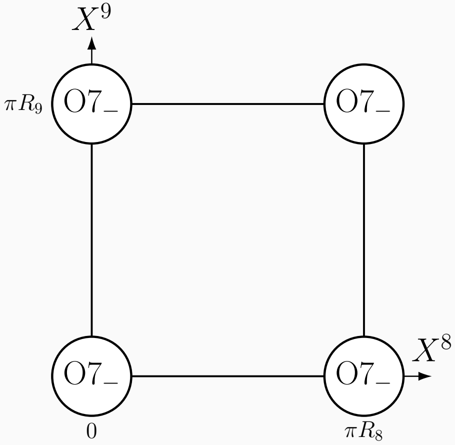

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Amplitude from geometry: $\tilde{\mathcal{K}}$

$$\underset{A}{\text{O-plane}} \text{ — } \underset{\text{NS-NS or RR}}{\text{Closed-string propagator}} \text{ — } \underset{B}{\text{O-plane}}$$

KK wave functions multiplied by phases $e^{i\vec{m}\cdot(\vec{x}_A-\vec{x}_B)}$

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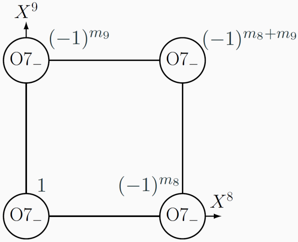

$\tilde{\mathcal{K}} \supset$

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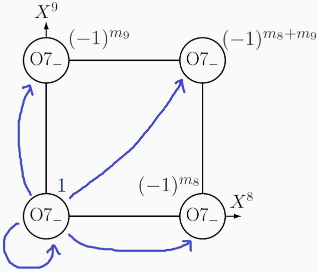

$$\tilde{\mathcal{K}} \supset 1 + (-1)^{m_8} + (-1)^{m_9} + (-1)^{m_8+m_9}$$

Amplitude from geometry: $\tilde{\mathcal{K}}$

O-plane — Closed-string propagator — O-plane
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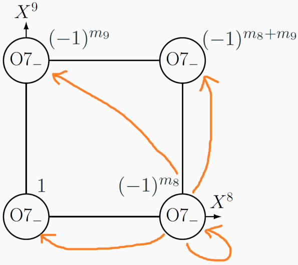

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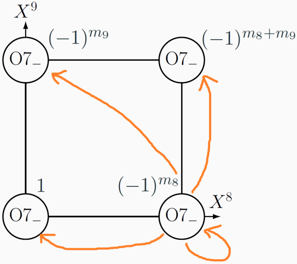

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$$\tilde{\mathcal{K}} \supset 4[1+(-1)^{m_9}][1+(-1)^{m_8}]P_{m_8}P_{m_9}\frac{V_8-S_8}{\eta^8}$$

Amplitude from geometry: $\tilde{\mathcal{A}}$ and $\tilde{\mathcal{M}}$

Annulus = D-branes/D-branes, single stack $\Longrightarrow$ no projection
multiplicity N^2

Möbius strip = D-branes/O-planes

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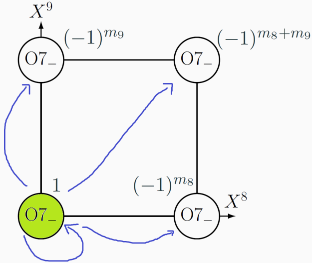

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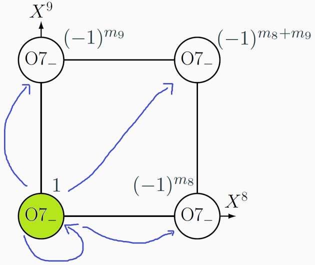

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$$\mathcal{A} + \mathcal{M}\big|_0 \supset \frac{N(N-1)}{2}\,\frac{V_8 - S_8}{\eta^8}\bigg|_0 \quad \Longrightarrow \text{SO(32) gauge group}$$

Rank 8 type IIB orientifold theory

- Keep a quantized B_{ab} compatible with Ω [Bianchi, Pradisi, Sagnotti, '92] [Bianchi, '98]

Tension = charge = 16

$\Longrightarrow N = 16$ D7-branes

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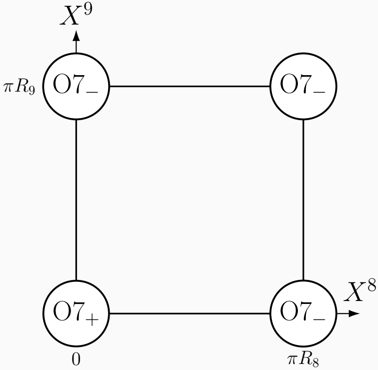

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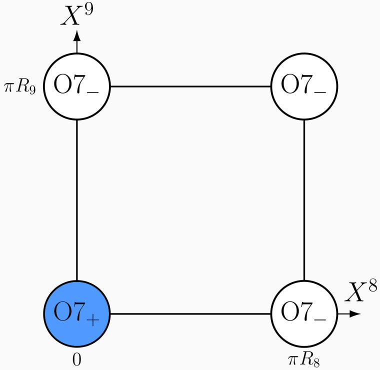

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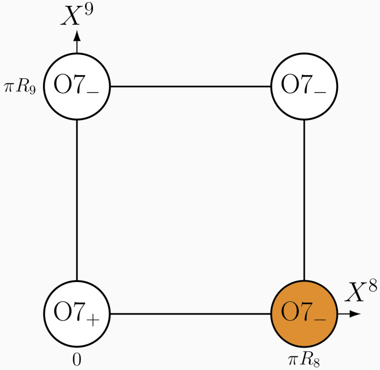

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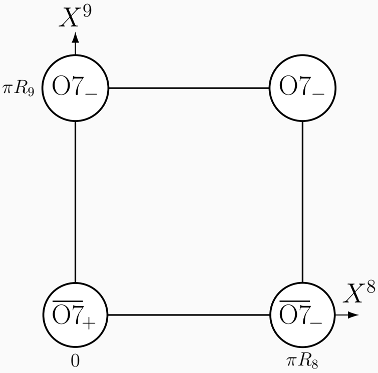

The Klein bottle remains SUSY

The annulus also

Only the Möbius sees the breaking

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Gauge group USp(16) Gauge-singlet goldstino

$\Longrightarrow$ Nonlinear realization of supersymmetry

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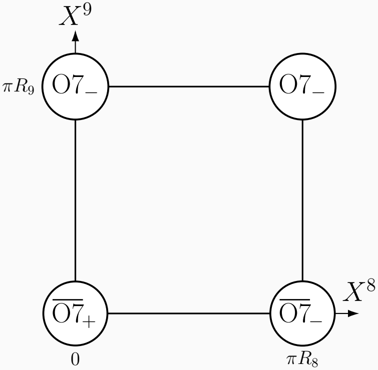

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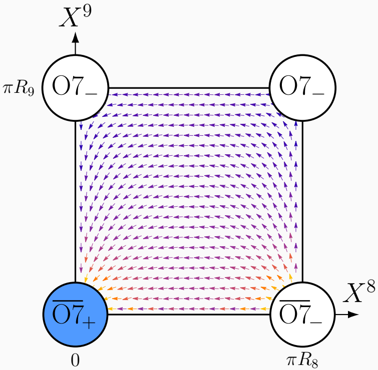

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Closed sector

SUSY Klein bottle $\Longrightarrow$ SUSY closed-string spectrum? [Angelantonj, Cardella, '04]

Torus cannot be the SUSY one:

- Consistency with geometry. Orientifold: $\Omega'' = \Omega'(-\delta_{w_9})^F$

$$\delta_w : \text{ Winding shift} \qquad \delta_p : \text{ Momentum shift}$$

- Quantized $B_{ab} \Longleftrightarrow$ Freely-acting orbifold $g = \delta_{w_8}\delta_{p_9}$

$g \longrightarrow g' = (-1)^F g \Longrightarrow$ Soft breaking Scherk-Schwarz-like

$$X^9 \longrightarrow X^9 + (-1)^F 2\pi R_9 \Longrightarrow \text{O-planes at } X_9 = 0$$
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$\overline{\text{O}}$-planes at $X_9 = \pi R_9$

Supersymmetric limits

SUSY restored in torus when $\begin{cases} R_8 \to 0 \\ R_9 \to +\infty \end{cases}$

$R_8 \to 0$: open sector also becomes SUSY

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- Share properties with BSB $\longrightarrow$ Avoid NS-NS tadpoles
- Share properties with Scherk-Schwarz $\longrightarrow$ Annulus untouched
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Thank you for your attention!

And bon appétit :)