Generalized Symmetries and Frozen Singularities

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Based on
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- To get started: more SUSY, less "compact" dimensions.

Plan of the talk

1. Frozen singularities in 8d F-theory (= O7+) via junctions
2. Frozen singularities in 7d M-theory via junctions
3. Frozen singularities in 6d IIA and topological operators

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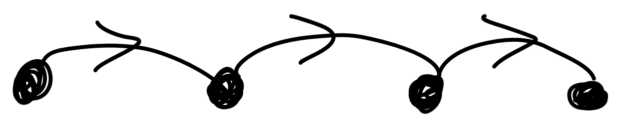
- Locally: string junctions encode gauge dynamics and center symmetries, well-known for [p,q]-7-branes, agrees with geometry under M-/F-duality [Cvetič/Dierigl/LL/Zhang ’21, Hüber/Morrison/Schäfer-Nameki/Wang ’22]



vs

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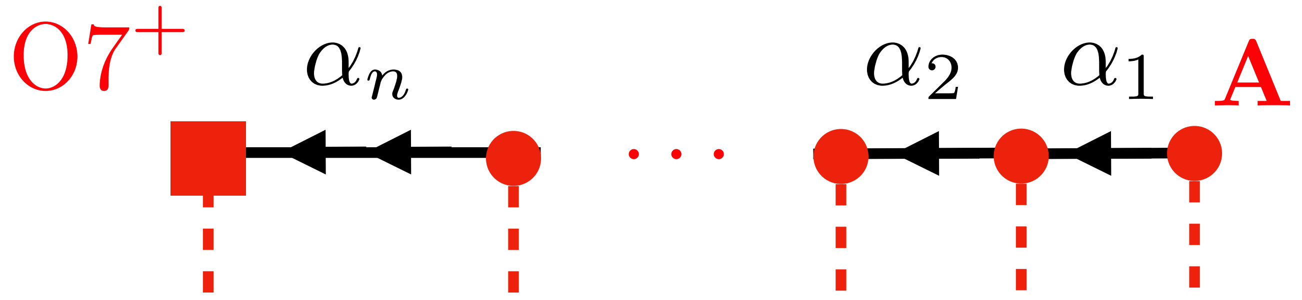

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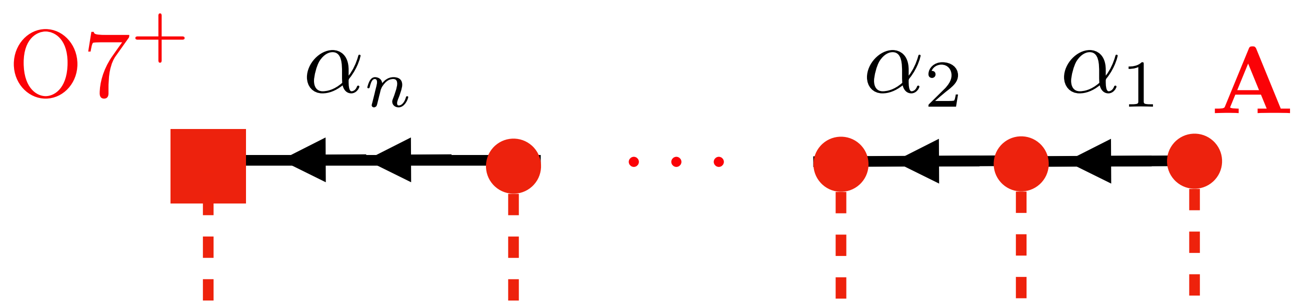

- From extended junctions (with asymptotic (p,q)-charge), also obtain $\mathbb{Z}_2$ 1-form and 5-form symmetries.

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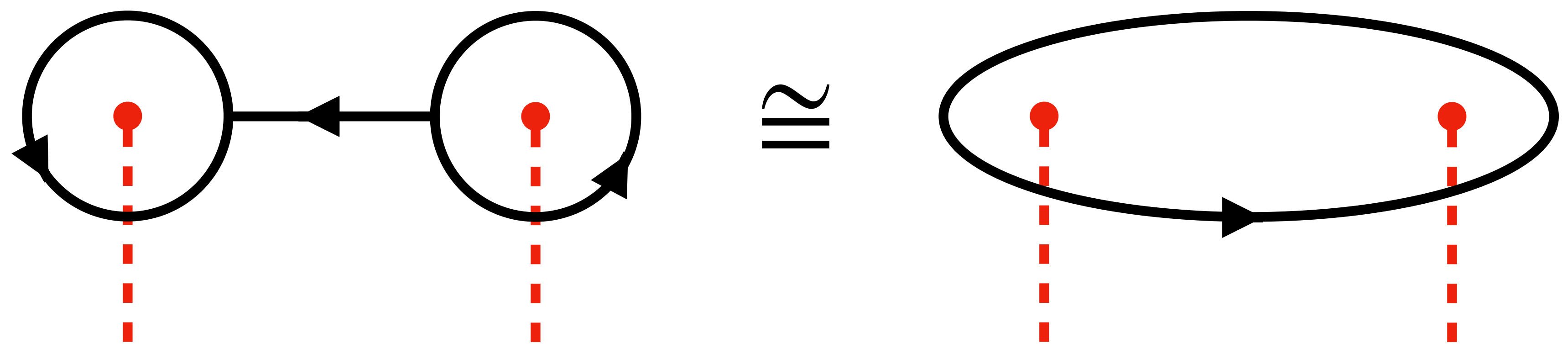

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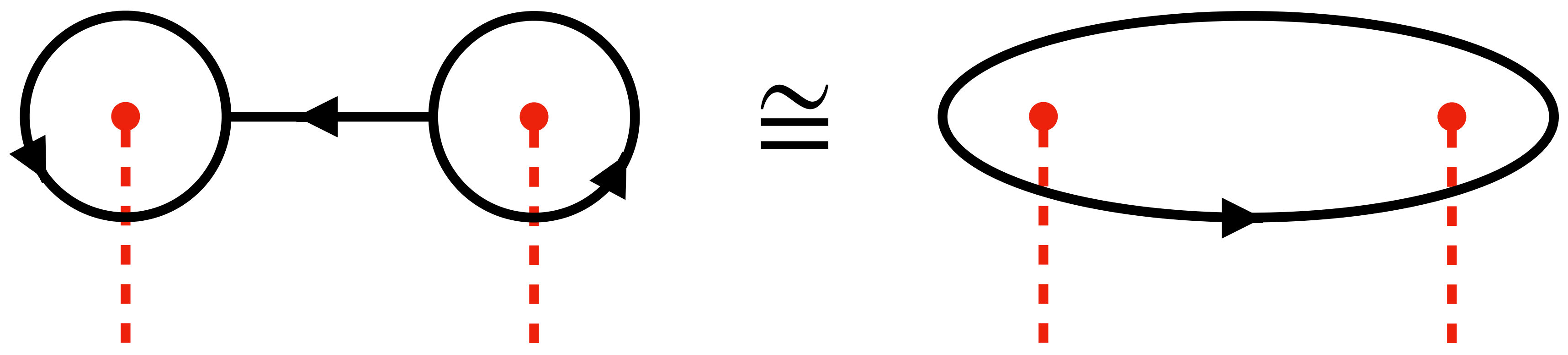

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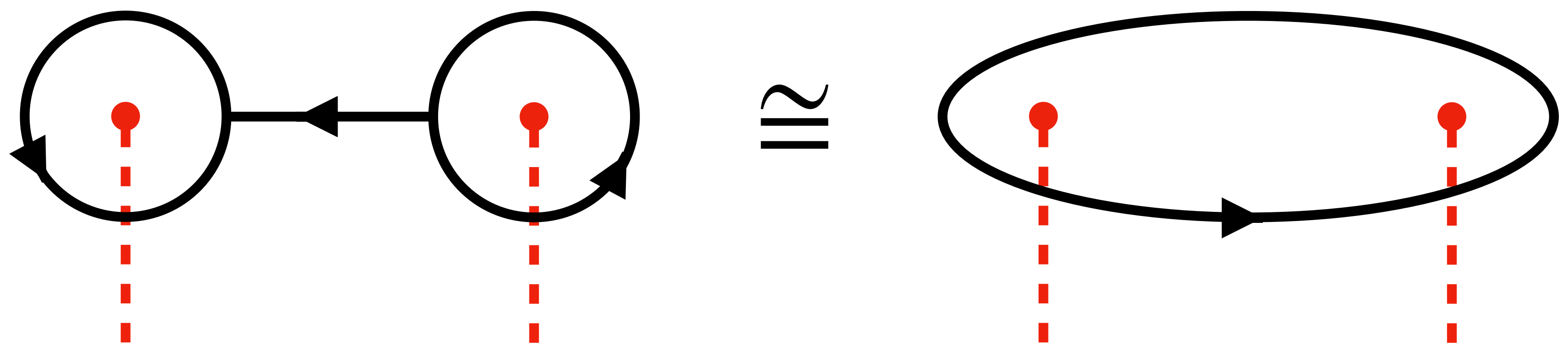

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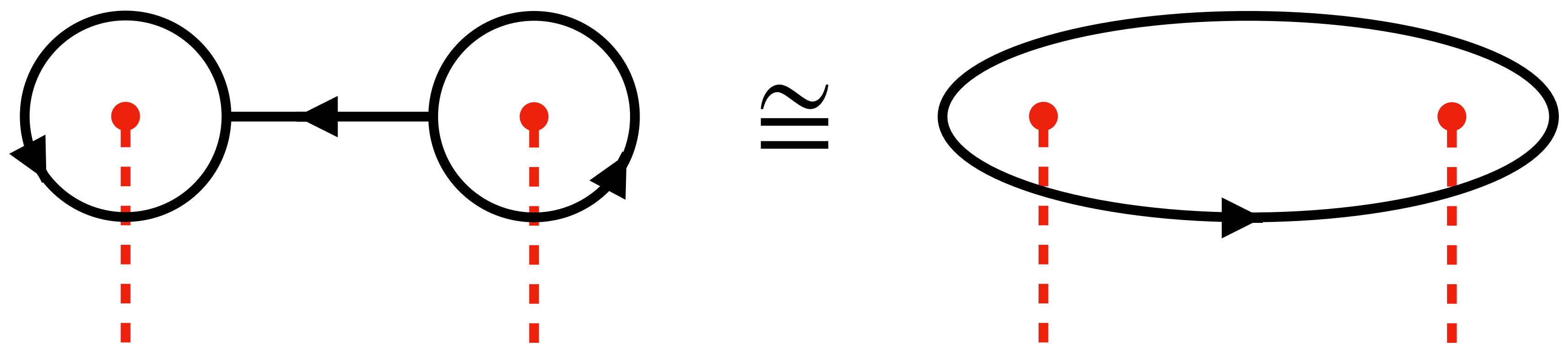

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- Classifies 9d $\mathcal{N} = 1$ gauge groups; also includes new moduli branch.

Frozen singularities in 7d M-theory

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- M-theory on $\mathbb{C}^2/\Gamma_{\mathfrak{g}_{\mathrm{ADE}}}$ engineer 7d $\mathfrak{g}_{\mathrm{ADE}}$ SYM. Generalized symmetries from $H_2^{\mathrm{rel}}(\mathbb{C}^2/\Gamma) \cong H_1(S^3/\Gamma)$ [Morrison/Schäfer-Nameki/Willett, Albertini/del Zotto/Garcia-Etxebarria/Hosseini '20].

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- If $\int_{S^3/\Gamma} C_3 = \frac{n}{d} \equiv r \neq 0 \mod \mathbb{Z}$, instead have “frozen” $\mathfrak{h}_r$: [de Boer et al, Atiyah/Witten ’01]

$\mathfrak{g}$	$\mathfrak{so}_{2k+8}$	$\mathfrak{e}_6$		$\mathfrak{e}_7$			$\mathfrak{e}_8$				
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- Global: M-theory on "frozen K3" dual to heterotic on T^3 with "triples", resulting 7d landscape from lattice techniques [(Font/)Fraiman/(Graña/Núñez/)Parra De Freitas '21(x3), '22].

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- Local: Microscopic description? "Geometric" origin of generalized symmetries?

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- (Subgroup of) $\mathbb{Z}_d$ acts as outer automorphism on $\mathfrak{g}(Y^d) \Rightarrow \mathfrak{h}_r$.

g	Y	$\theta_g/\frac{\pi}{6}$	alg.	$r=\frac{n}{d}$	g^d	Y^d	$\theta_{g^d}/\frac{\pi}{6}$	alg.	outer	fixed $=\mathfrak{h}_r$
$\begin{pmatrix}-1 & -k\\ 0 & -1\end{pmatrix}$	I_k^*	$6-k$	$\mathfrak{so}(2k+8)$	$\frac{1}{2}$	$\begin{pmatrix}1 & 2k\\ 0 & 1\end{pmatrix}$	I_{2k}	$12-2k$	$\mathfrak{su}(2k)$	$\mathbb{Z}_2$	$\mathfrak{sp}(2k)$
$\begin{pmatrix}-1 & -1\\ 1 & 0\end{pmatrix}$	IV^*	4	$\mathfrak{e}_6$	$\frac{1}{2}$	$\begin{pmatrix}0 & 1\\ -1 & -1\end{pmatrix}$	IV	8	$\mathfrak{su}(3)$	$*$	$\mathfrak{su}(3)$
$\begin{pmatrix}-1 & -1\\ 1 & 0\end{pmatrix}$	IV^*	4	$\mathfrak{e}_6$	$\frac{1}{3},\frac{2}{3}$	$\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$	I_0	12	$*$	$*$	$*$
$\begin{pmatrix}0 & -1\\ 1 & 0\end{pmatrix}$	III^*	3	$\mathfrak{e}_7$	$\frac{1}{2}$	$\begin{pmatrix}-1 & 0\\ 0 & -1\end{pmatrix}$	I_0^*	6	$\mathfrak{so}(8)$	$\mathbb{Z}_2$	$\mathfrak{so}(7)$
$\begin{pmatrix}0 & -1\\ 1 & 0\end{pmatrix}$	III^*	3	$\mathfrak{e}_7$	$\frac{1}{3},\frac{2}{3}$	$\begin{pmatrix}0 & 1\\ -1 & 0\end{pmatrix}$	III	9	$\mathfrak{su}(2)$	$*$	$\mathfrak{su}(2)$
$\begin{pmatrix}0 & -1\\ 1 & 0\end{pmatrix}$	III^*	3	$\mathfrak{e}_7$	$\frac{1}{4},\frac{3}{4}$	$\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$	I_0	12	$*$	$*$	$*$
$\begin{pmatrix}0 & -1\\ 1 & 1\end{pmatrix}$	II^*	2	$\mathfrak{e}_8$	$\frac{1}{2}$	$\begin{pmatrix}-1 & -1\\ 1 & 0\end{pmatrix}$	IV^*	4	$\mathfrak{e}_6$	$\mathbb{Z}_2$	$\mathfrak{f}_4$
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$\begin{pmatrix}0 & -1\\ 1 & 1\end{pmatrix}$	II^*	2	$\mathfrak{e}_8$	$\frac{1}{6},\frac{5}{6}$	$\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}$	I_0	12	$*$	$*$	$*$

[taken from Tachikawa ’15]

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- This is a subspace in root lattice of $\mathfrak{g}(Y^2) = \mathfrak{su}_4$.
- Precisely those that survive the subsequent outer-automorphism quotient $\mathfrak{su}_4 \to \mathfrak{sp}_2 = \mathfrak{h}_{1/2}$ [Bonora/Savelli '10, Grassi/Halverson/(Long/)Shaneson(/Tian) '13+'18, Heckman/Lawrie/Rochais/Zhang/Zoccarato '20].

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- Also gives a handle on center symmetries via extended junctions in Y^d that are invariant under outer automorphism.
- In particular: $(\mathfrak{e}_8, 1/4)$ with $\mathfrak{h} = \mathfrak{su}_2$ has $\mathbb{Z}_2$ even though $H_1(S^3/\Gamma_{\mathfrak{e}_8}) = 0$.

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- Vevs of these operators: $\exp(2\pi i \int_\lambda C_1)$.

Frozen compactifications = “universes” (?)

- Top. point-operators $\rightarrow$ $(d-1)$-form symmetry $\rightarrow$ “Decomposition” of theory into “universes” [Hellerman/Henriques/Pantev/Sharpe/Ando ’06, …(Sharpe et al)…, Sharpe ’22 (review); Komargodski/Ohmori/Roumpedakis/Seifnashri ’08, Meynet/Moscrop ’22, Vandermeulen ’22].

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- Normally, universes have same local dynamics. Here, universes labelled by different “frozen fluxes” → counterexample (?)

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- Top. point-operators → $(d-1)$-form symmetry → “Decomposition” of theory into “universes” [Hellerman/Henriques/Pantev/Sharpe/Ando ’06, …(Sharpe et al)…, Sharpe ’22 (review); Komargodski/Ohmori/Roumpedakis/Seifnashri ’08, Meynet/Moscrop ’22, Vandermeulen ’22].

- Separated by infinite tension domain walls = charged objects; in IIA on $\mathbb{C}^2/\Gamma$ given by D6s wrapping $\Lambda \in H_2^{\text{rel}}(\mathbb{C}^2/\Gamma)$.

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- Dual (-1)-form symmetry perspective: top. spacetime-filling operators = top. sectors given by D6s wrapping $\lambda \in H_1(S^3/\Gamma)$; can these modify local (SUSY) dynamics?

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- In 6d IIA, find “more exotic” topological symmetry generators; (perhaps) tied to “decomposition”.

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Thank you!