Vacua, Symmetries, and Higgsing of Chern–Simons Matter Theories

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Based on ArXiv:2503.02744 and ArXiv:2509.11733
with Marcus Sperling and Sinan Moura Soysüren

DESY – Synergies towards the future Standtard Model
23rd September 2025

The problem and the solution

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For 3d $\mathcal{N} = 4$ Chern–Simons Matter theories, describe:

- Global symmetries;
- Vacua;
- Higgsing.

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Solution

Magnetic quivers: pair of 3d $\mathcal{N} = 4$ standard (non-CS) theories.

3d $\mathcal{N} = 4$ gauge theories in Type IIB

Worldvolume theory in [Hanany-Witten '96]

brane	0	1	2	3	4	5	6	7	8	9
D3 —	×	×	×	×						
NS5 |	×	×	×		×	×	×			
D5 ⊗	×	×	×					×	×	×

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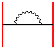
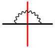
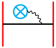
Write the QFT using **quivers**.

Brane configuration	**Supermultiplet**	**Quiver**
	$\mathcal{N} = 4$ vector	 $\mathrm{U}(N)$
	$\mathcal{N} = 4$ bifund. hyper	
	$\mathcal{N} = 4$ fund. hyper	 1

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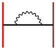
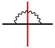
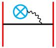
	$\mathcal{N} = 4$ vector	 U(N)
	$\mathcal{N} = 4$ bifund. hyper	
	$\mathcal{N} = 4$ fund. hyper	 1

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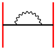
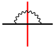
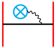
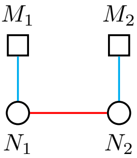
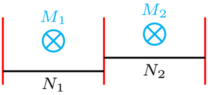
	$\mathcal{N} = 4$ vector	 $\mathrm{U}(N)$
	$\mathcal{N} = 4$ bifund. hyper	
	$\mathcal{N} = 4$ fund. hyper	 1





3d $\mathcal{N} = 4$ Chern–Simons Matter theories in Type IIB

Consider the bound-state [Kitao-Ohta-Ohta '98, Bergman-Hanany-Karch-Kol '99]

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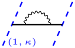
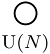
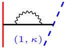
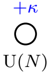
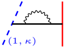
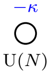
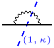
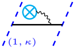
	$\mathcal{N}=4$ twisted vector	
	$\mathcal{N}=2$ vector w/ CS $+\kappa$	
	$\mathcal{N}=2$ vector w/ CS $-\kappa$	
	$\mathcal{N}=4$ bifund. twisted hyper	
	$\mathcal{N}=4$ fund. twisted hyper	

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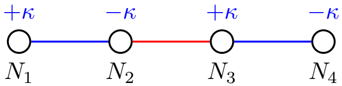

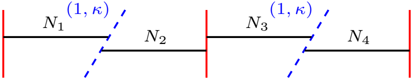

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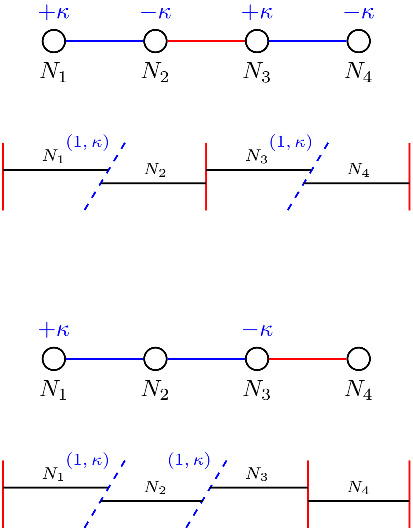

The moduli space of 3d $\mathcal{N} = 4$ theories

- Moduli space of vacua = space of gauge invariant operators VEVs.

[1] For each $\mathrm{U}(1) \in$ gauge group we can dualize the associate field strength F with a scalar γ:

$$\epsilon_{\mu\nu\rho} F^{\nu\rho} = \partial_\mu \gamma \,.$$

Then $\gamma \to \gamma +$ const is a symmetry, called **topological**. Its charged objects are **monopoles**, which can be built exponentiating a combination of γ and the scalar σ in the vector multiplet.

[Hanany-Witten '96, Gaiotto-Witten '08]

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- Moving D3 segments = operator VEV $\Rightarrow$ Higgsing along $\mathcal{C}$ and $\mathcal{H}$.

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- The equality is at the level of the **Hilbert series**, which lists the gauge invariant operators on a chosen branch of the moduli space.

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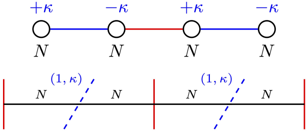

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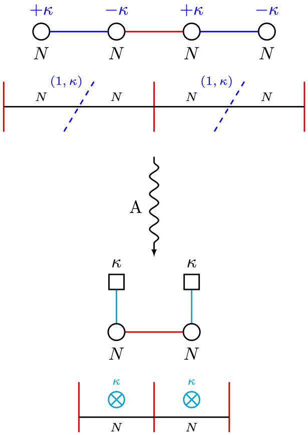

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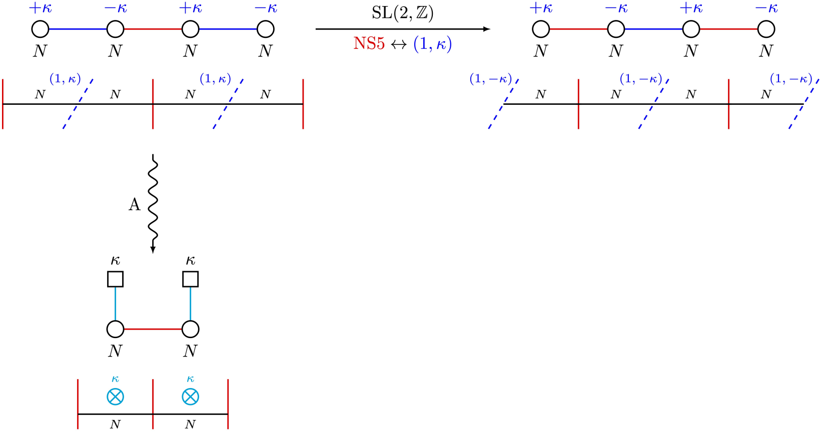

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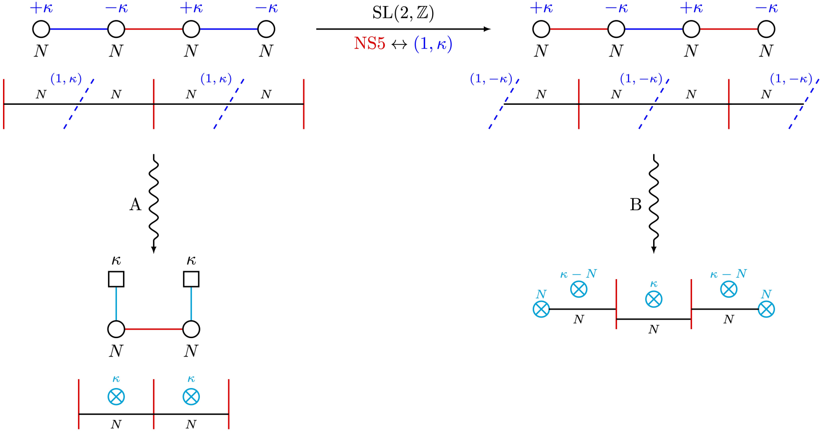

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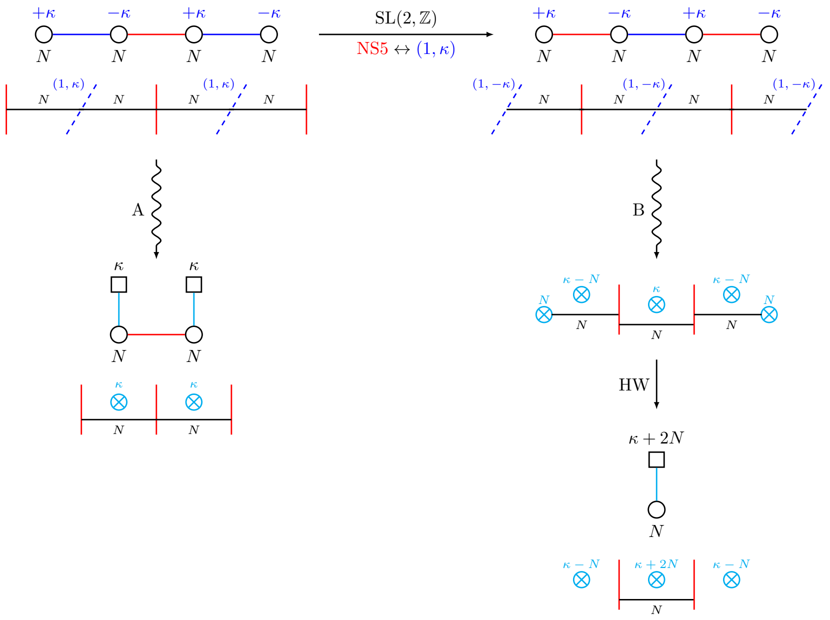

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- Future directions:
  - inclusion of other kinds of orientifolds;
  - higher form symmetries interplay.

Thank you for your attention!