Tao Probing the End of the World 2

Futoshi Yagi (KIAS)

Based on the collaboration with

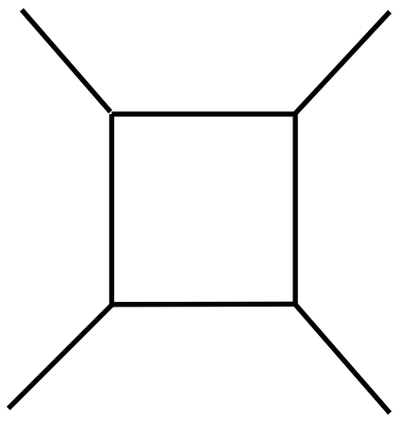
Hirotaka Hayashi, Sung-Soo Kim, Kimyeong Lee, Masato Taki

arXiv:1504.03672, 1509.03300, 1505.04439

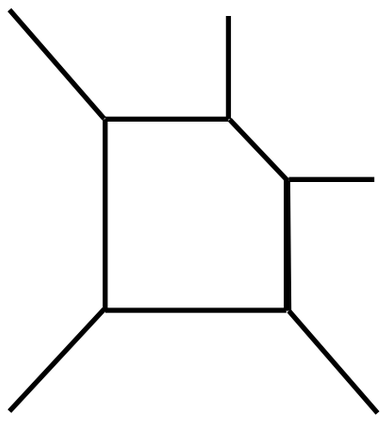
§1 Review of the previous talk + α

$5d\ \mathcal{N}=1\ SU(2)\ N_f$ flavor, $\quad 0 \leq N_f \leq 7$

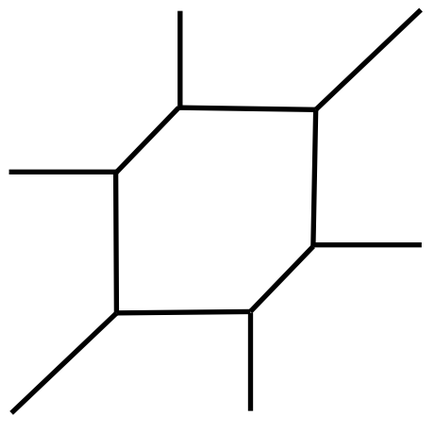
'96 Seiberg



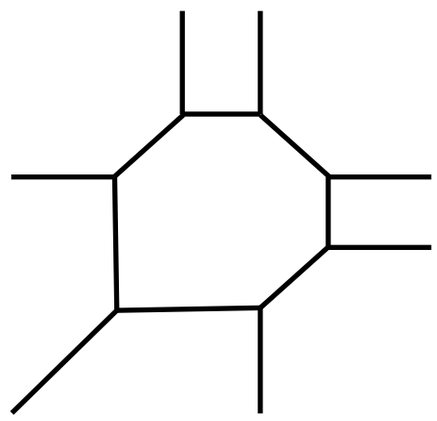
$N_f = 0$



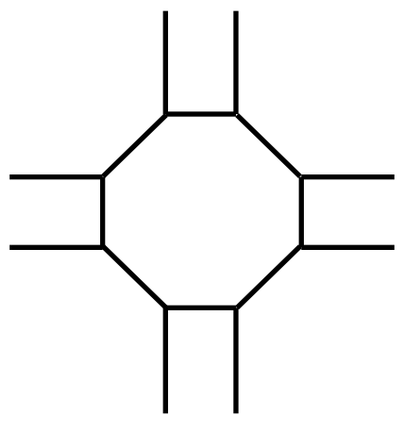
$N_f = 1$



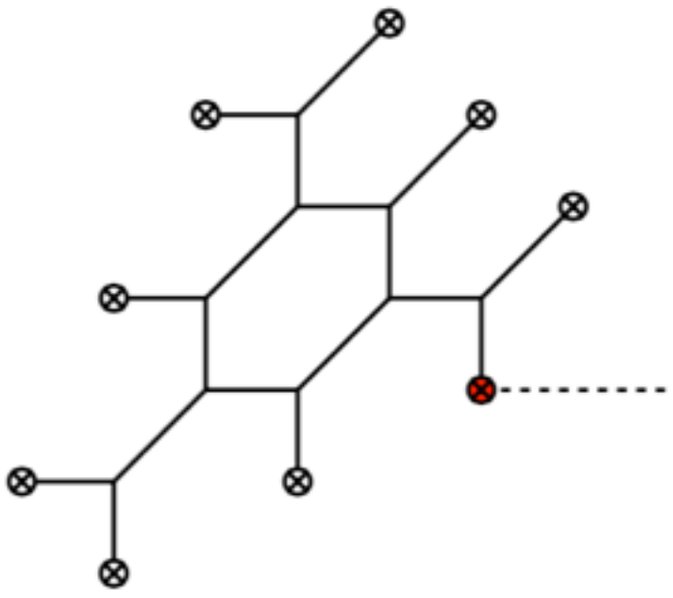
$N_f = 2$



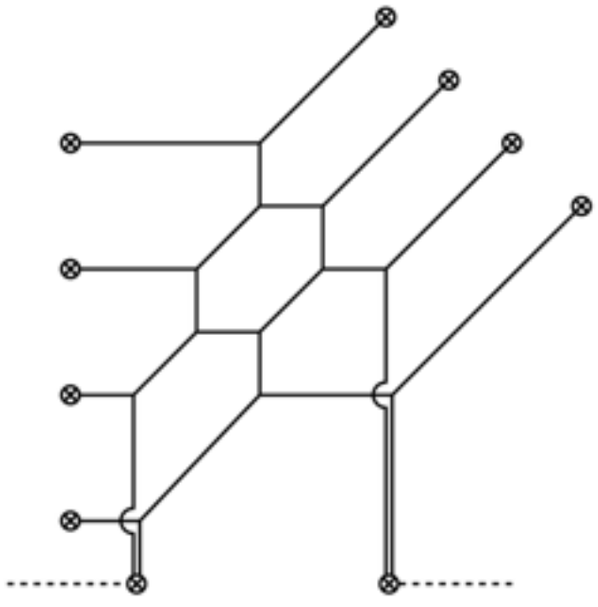
$N_f = 3$



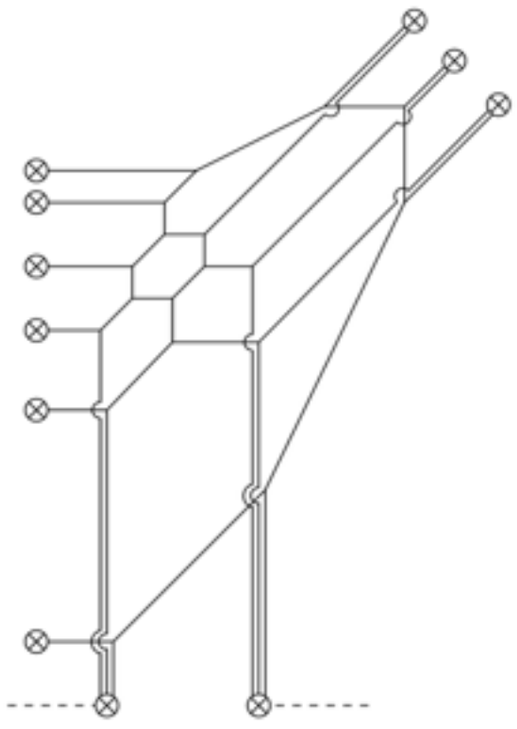
$N_f = 4$



$N_f = 5$



$N_f = 6$



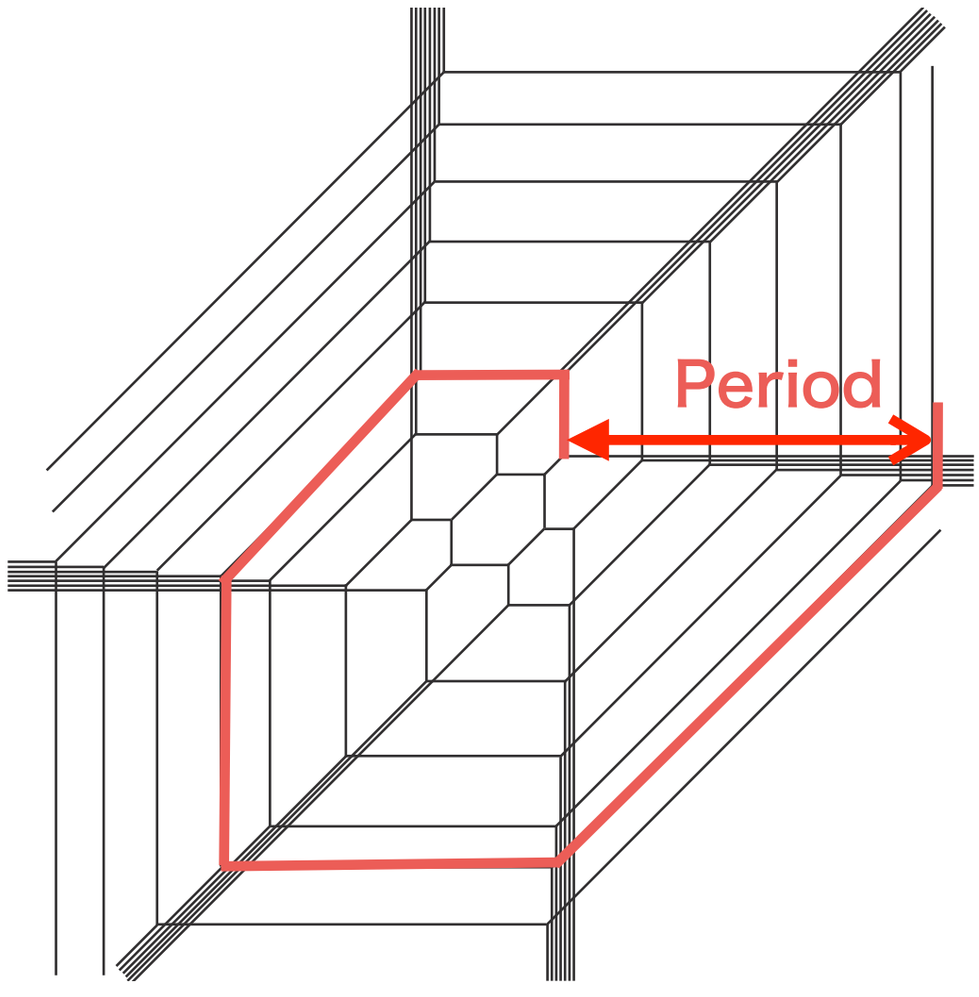
$N_f = 7$

09' Benini Benvenuti Tachikawa

$$5d\ \mathcal{N}=1\ SU(2)\ N_f=8\ \text{flavor}$$

“Tao diagram”

Infinite spiral rotation, Periodic structure



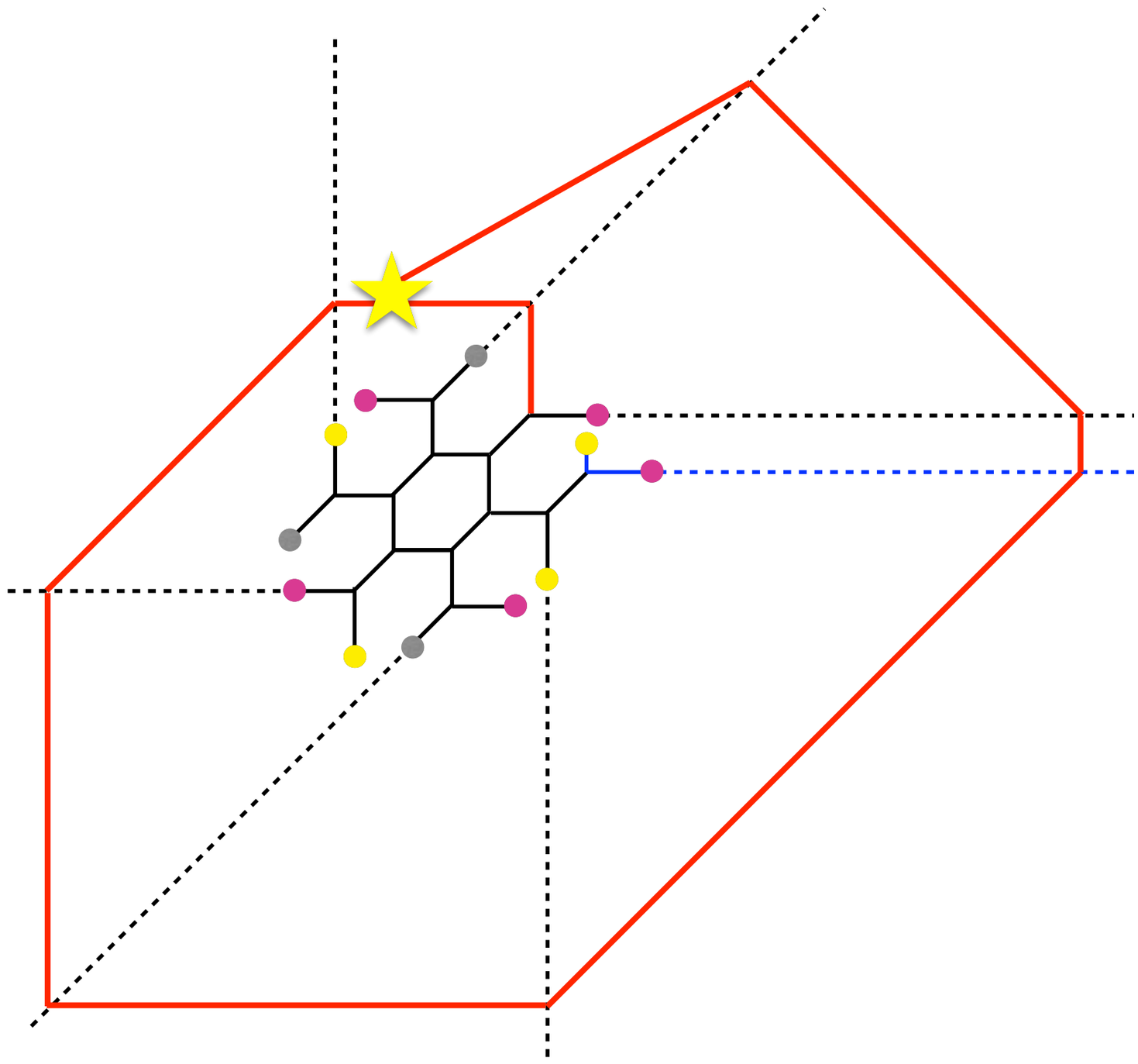
$$\text{“period”} \propto \frac{1}{R} \propto \frac{1}{g^2}$$

6d KK mode

||

5d Instanton

5d $\mathcal{N}=1$, $SU(2)$, $N_f=9$ flavor



We cannot move all the 7-branes to infinity

→ **No consistent 5-brane web diagram**

Observation

For $5d$ $\mathcal{N}=1$ $SU(2)$, N_f flavor

$0 \leq N_f \leq 7$ 5D UV fixed point → Finite diagram

$N_f = 8$ **6D UV fixed point** → **“Tao diagram”**

$N_f \geq 9$ No UV fixed point → No diagram

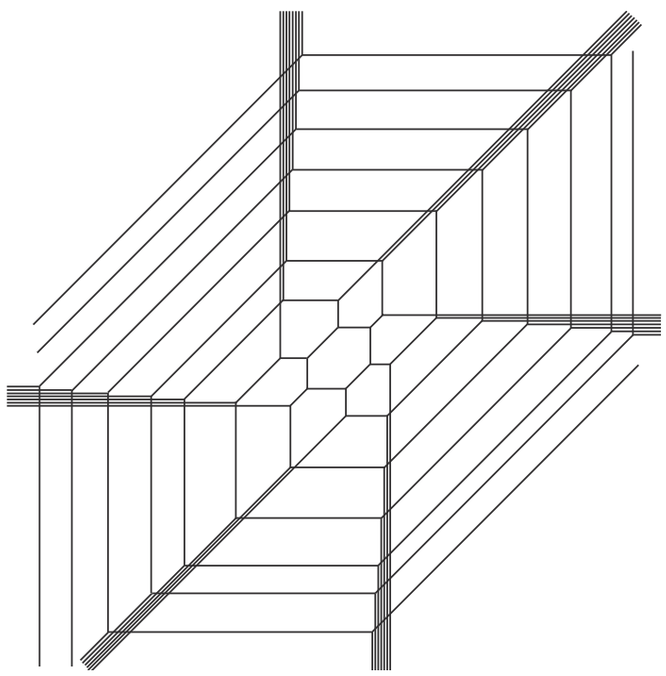
Conjecture

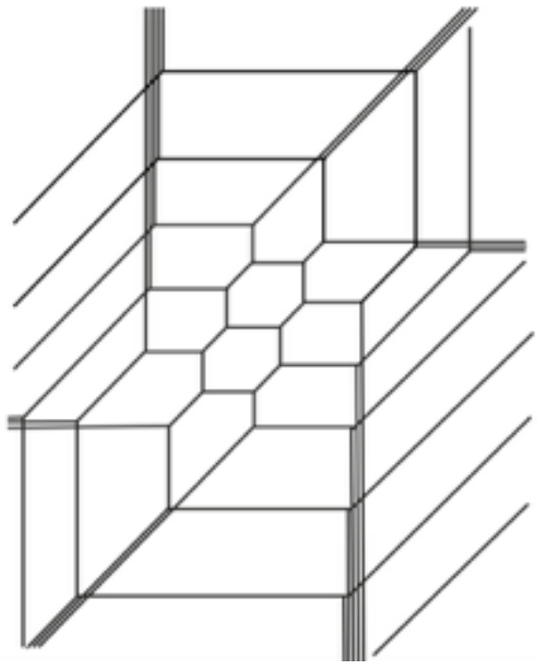
Finite diagram: → 5D UV fixed point

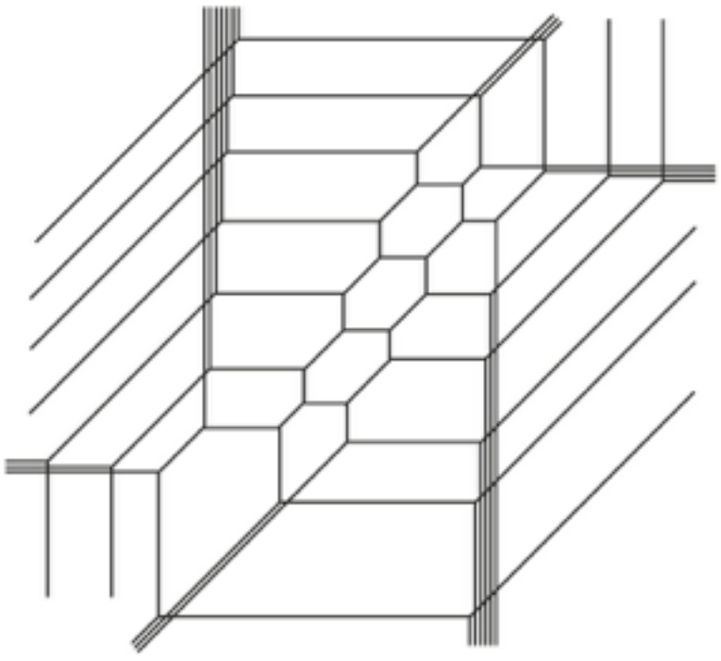
“Tao diagram”: → 6D UV fixed point

No diagram: → No UV fixed point

Tao diagrams for “class $\mathcal{T}$”







Plan of this talk

§1 Overview of the previous talk + Conjecture

§2 Evidence for the conjecture

§3 Generalization

§4 Conclusion

§2 Evidence for the conjecture

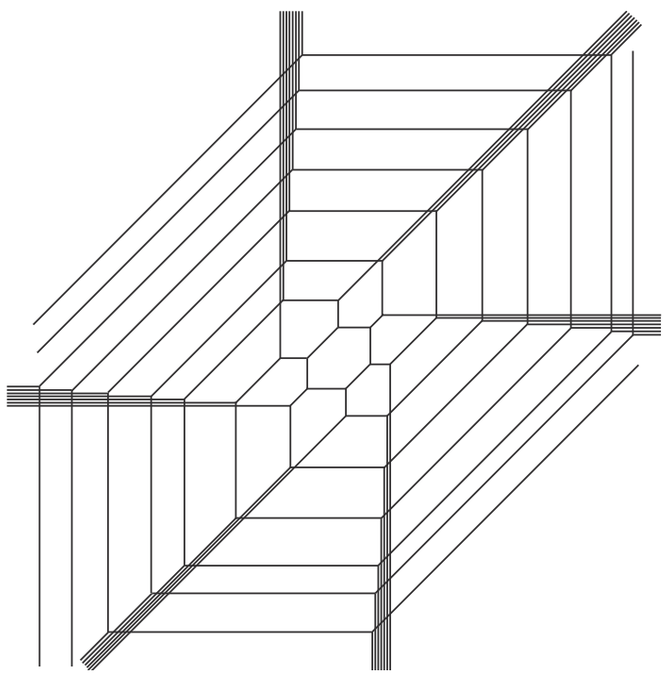
Conjecture

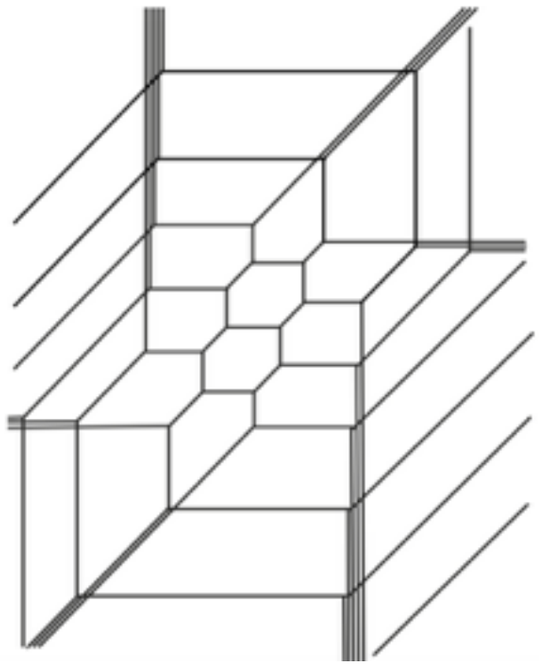
Finite diagram: → 5D UV fixed point

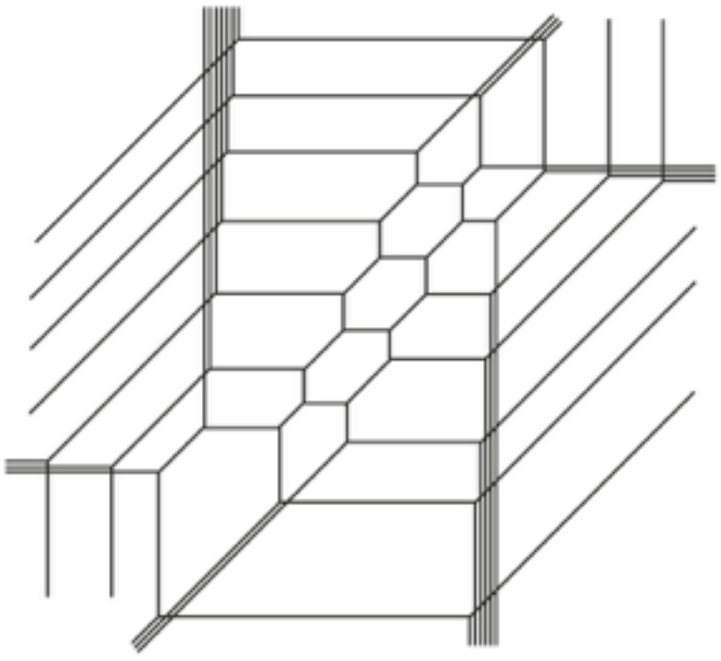
“Tao diagram”: → 6D UV fixed point

No diagram: → No UV fixed point

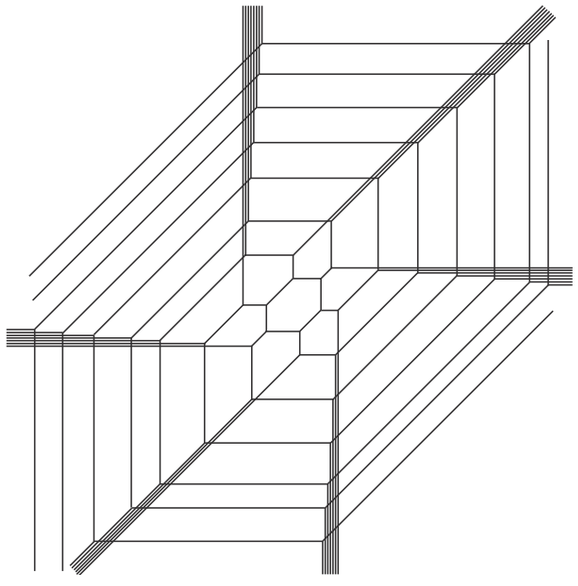
Tao diagrams for “class $\mathcal{T}$”



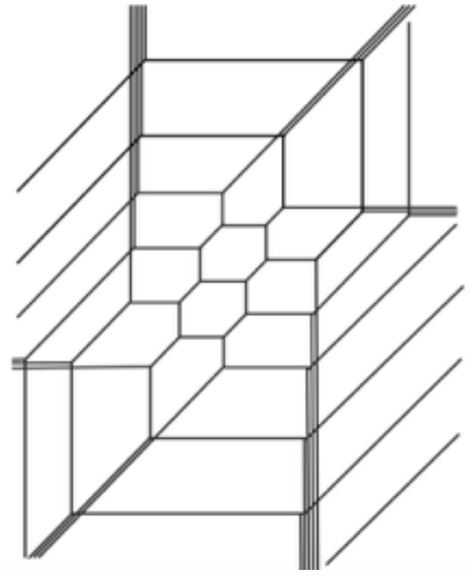




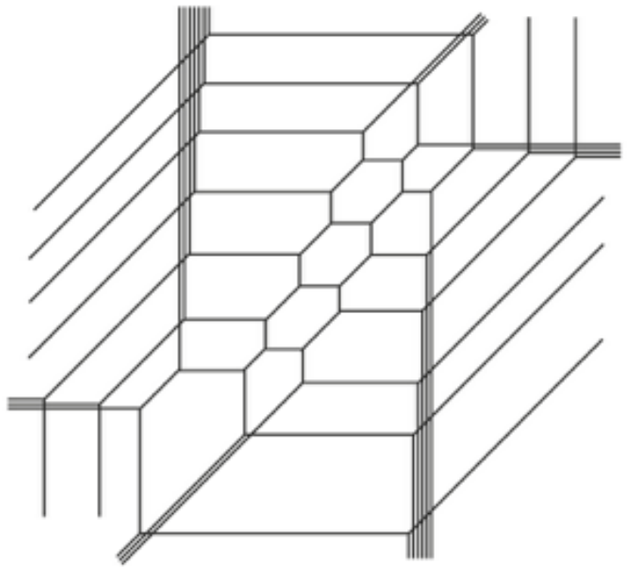
$$5\text{d } \mathcal{N}=1,\ SU(N),\ N_f = 2N+4$$



$N=2$



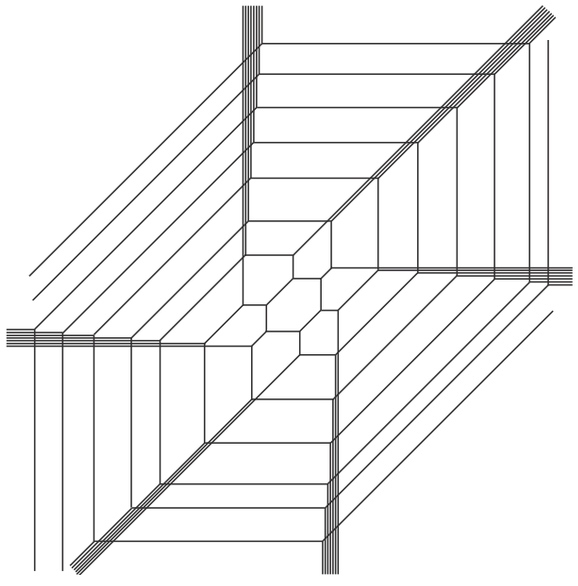
$N=3$



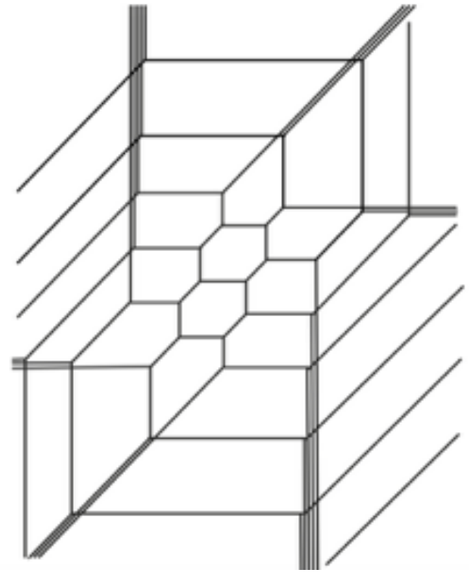
$N=4$

...

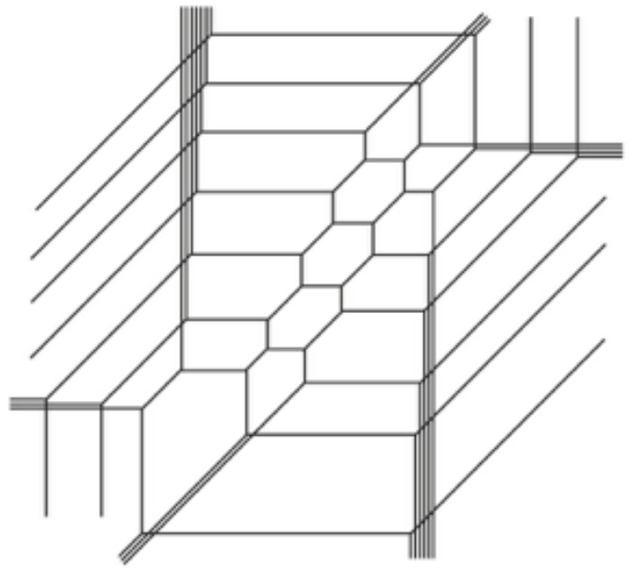
$$5\text{d } \mathcal{N}=1,\ SU(N),\ N_f = 2N+4$$



$N=2$

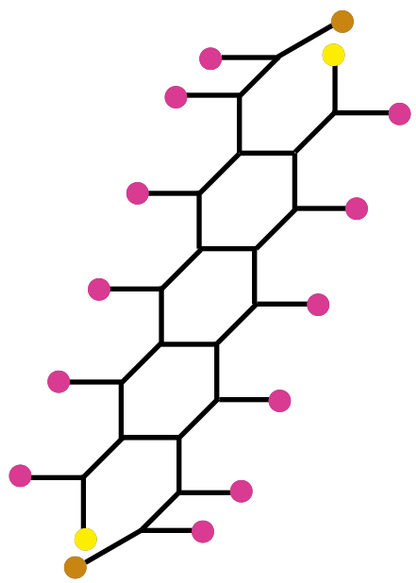


$N=3$

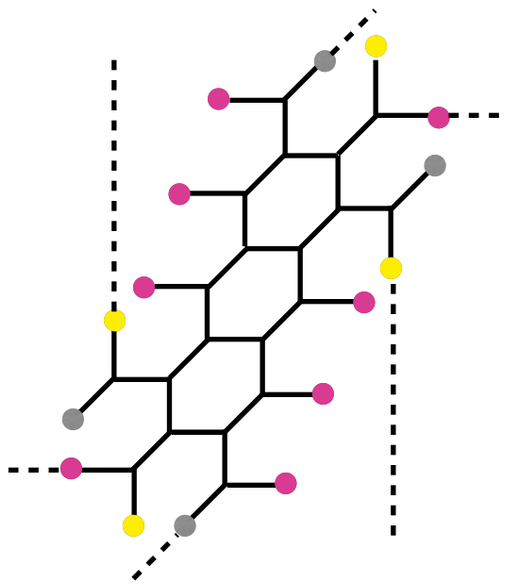


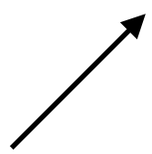
$N=4$

...



$SU(4), N_f = 12$





Conjecture

For 5d $\mathcal{N}=1$ $SU(N)$, N_f flavor, Chern-Simons level κ

6d fixed point for $N_f = 2N+4$, $\kappa = 0$

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For 5d $\mathcal{N}=1$ $SU(N)$, N_f flavor, Chern-Simons level κ

6d fixed point for $N_f = 2N+4$, $\kappa = 0$

5d fixed point for $N_f < 2N+4$, $\kappa \leq 2N+4-N_f$ Bergman, Zafrir '14

Via "Mass deformation"

No fixed point for others

Conjecture

For 5d $\mathcal{N}=1$ $SU(N)$, N_f flavor, Chern-Simons level κ

6d fixed point for $N_f = 2N+4$, $\kappa = 0$

M5-brane probing D_{N+2} singularity

"(D_{N+2}, D_{N+2}) conformal matter"

Del Zotto - Heckman - Tomasiello - Vafa '14

5d fixed point for $N_f < 2N+4$, $\kappa \leq 2N+4-N_f$ Bergman, Zafrir '14

Via "Mass deformation"

No fixed point for others

Comments on the previously known classification

5d SU(N>3) theories [Intriligator-Morrison-Seiberg '97]

"All" UV complete theories were claimed to be classified.

Comments on
the previously known classification

5d SU(N>3) theories [Intriligator-Morrison-Seiberg '97]

$$N_f = \underbrace{0, 1, \cdots, 2N}, \underbrace{2N+1, 2N+2, 2N+3, 2N+4}$$

5d SCFT

"dead" (Landau pole)

Comments on
the previously known classification

5d SU(N>3) theories [Intriligator-Morrison-Seiberg '97]

$$N_f = \underbrace{0, 1, \cdots, 2N}, \underbrace{2N+1, 2N+2, 2N+3}, \underbrace{2N+4}$$

[Bergman, Zafrir '14]

Previously known 5d SCFT

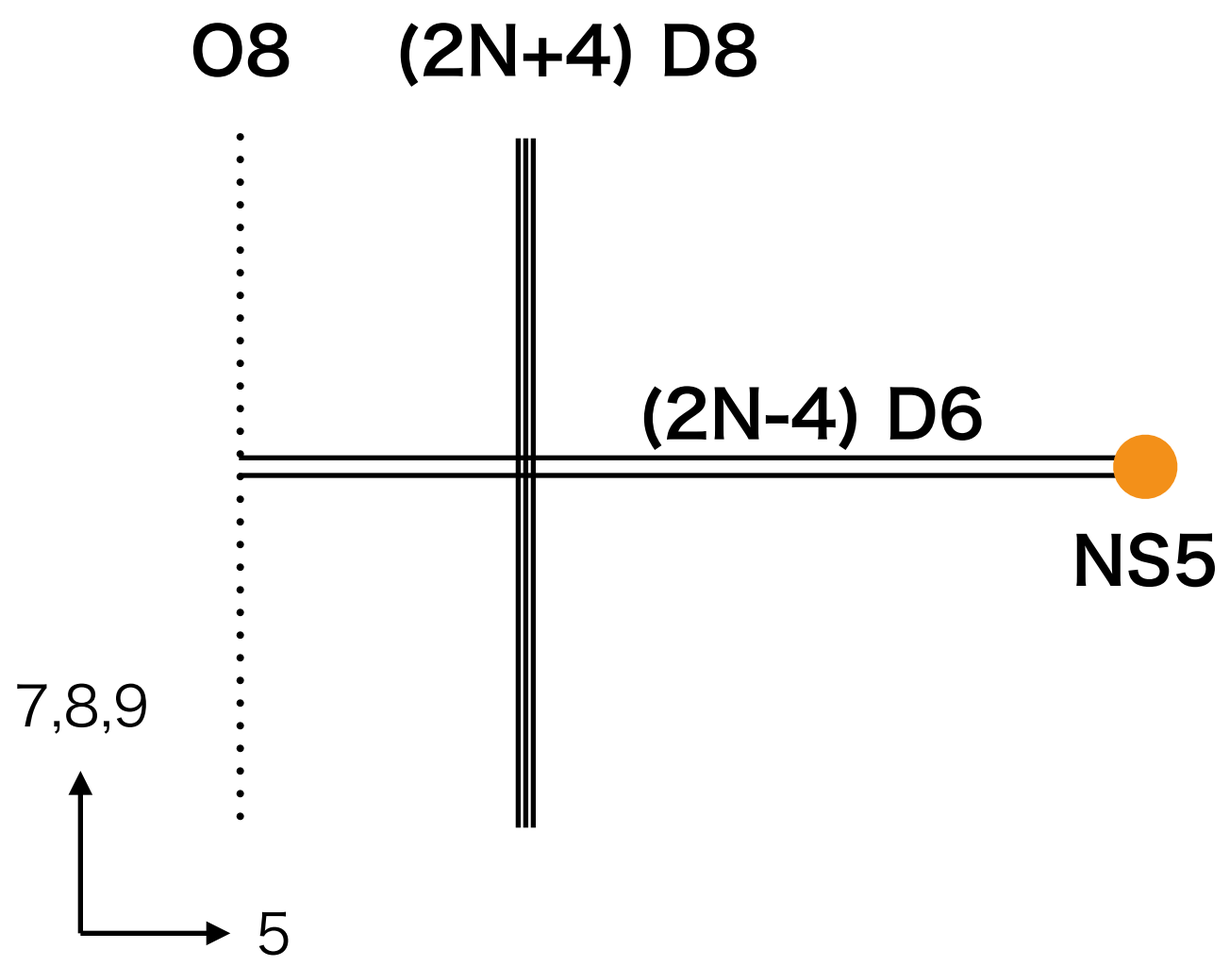
This talk

Overlooked for 20 years

M5-brane probing D_{N+2} singularity

Tensor branch
(≒ Coulomb branch)

$$6\mathrm{d}\ \mathcal{N}=(1,0)\ Sp(N-2)\ \text{gauge theory}$$
$$N_f = 2N+4,\ \text{w/tensor multiplet}$$

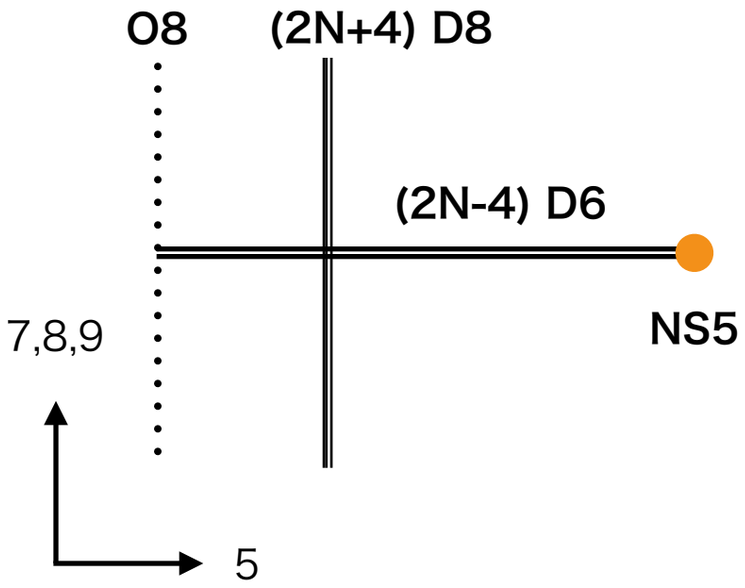


S^1

	0	1	2	3	4	5	6	7	8	9
D6-brane	×	×	×	×	×	×	×			
NS5-brane	×	×	×	×	×		×			
D8-brane	×	×	×	×	×		×	×	×	×
O8-plane	×	×	×	×	×		×	×	×	×

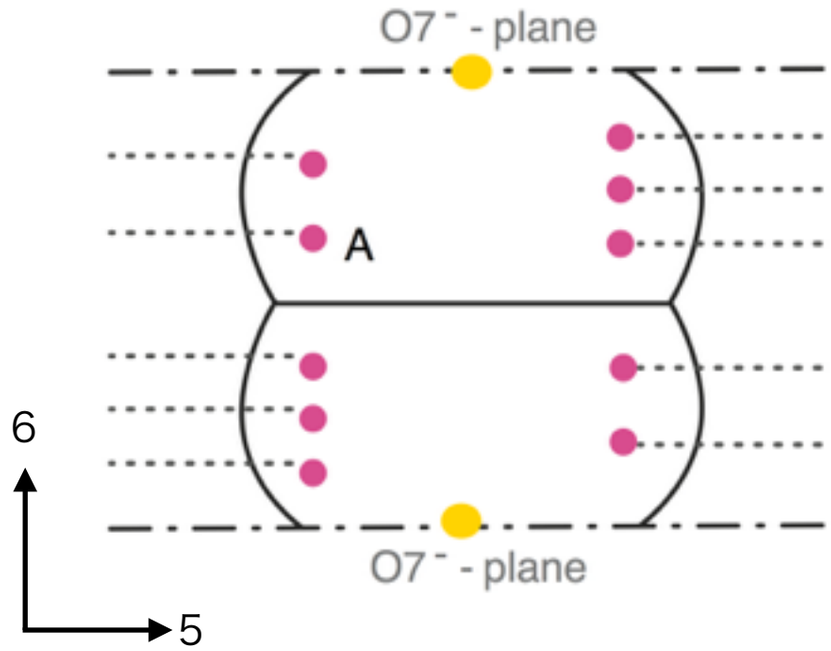
Brunner, Karch '97, Hanany, Zaffaroni '97

Diagramatic “Derivation”



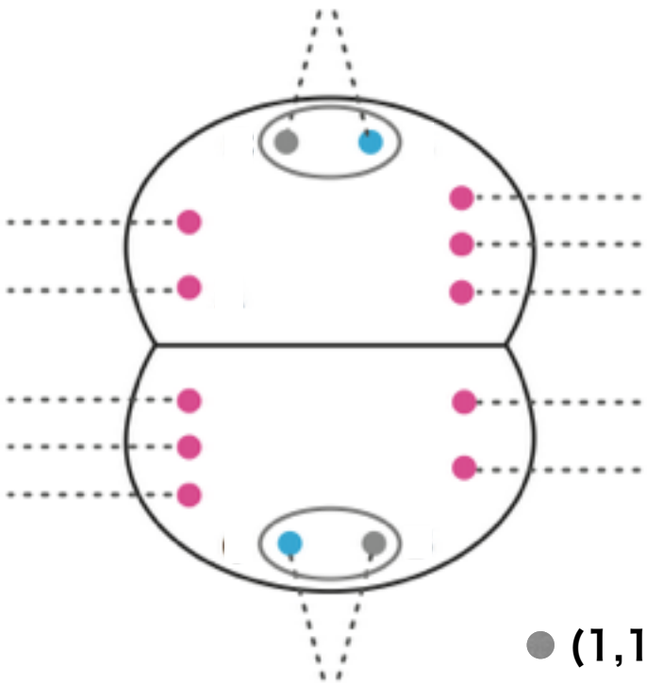
T-duality

(N=3)



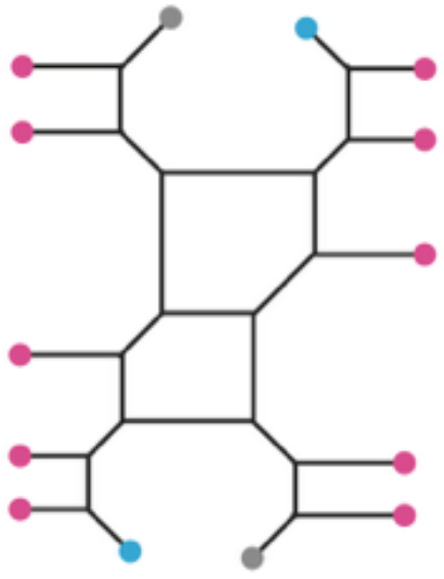
O7⁻ -plane
= (1,1) 7-brane
+ (1,-1) 7-brane

Sen ‘96



(1,1) 7-brane
(1,-1) 7-brane

$$5\mathrm{d}\ SU(N)\ N_f = 2N + 4$$



Hanany-Witten
transition

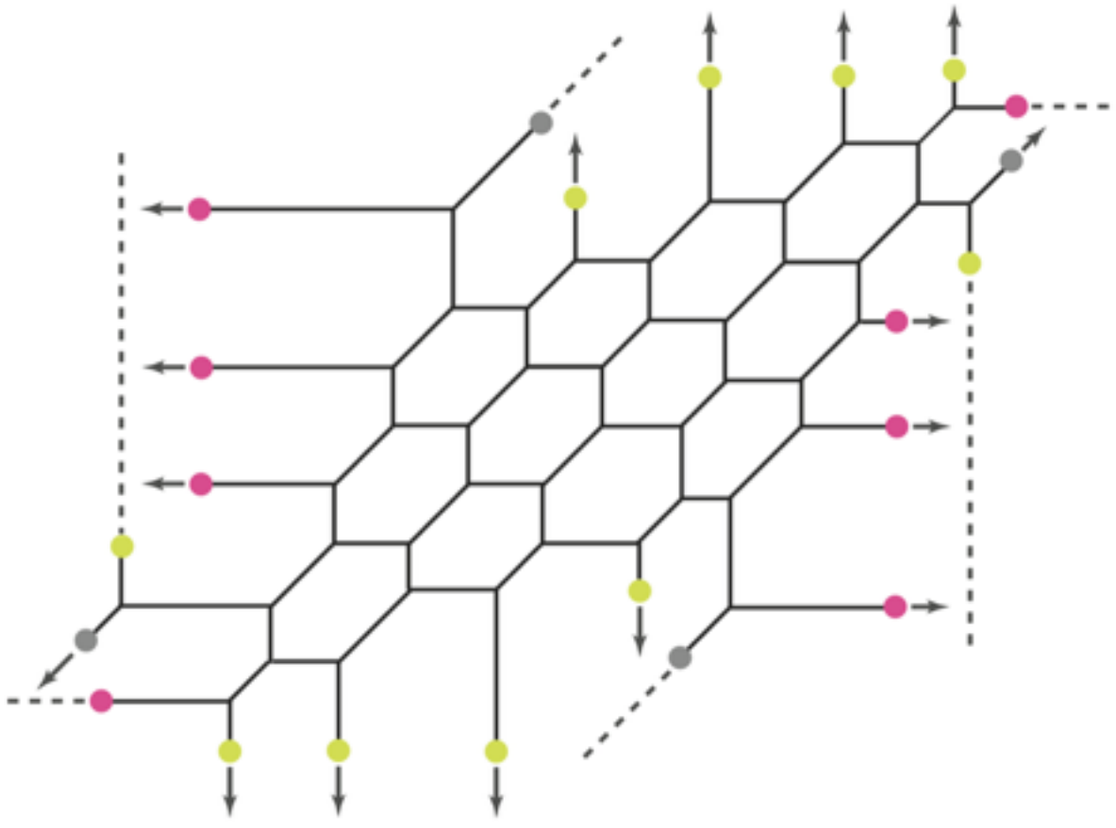
Tao Probing the End of the World 2

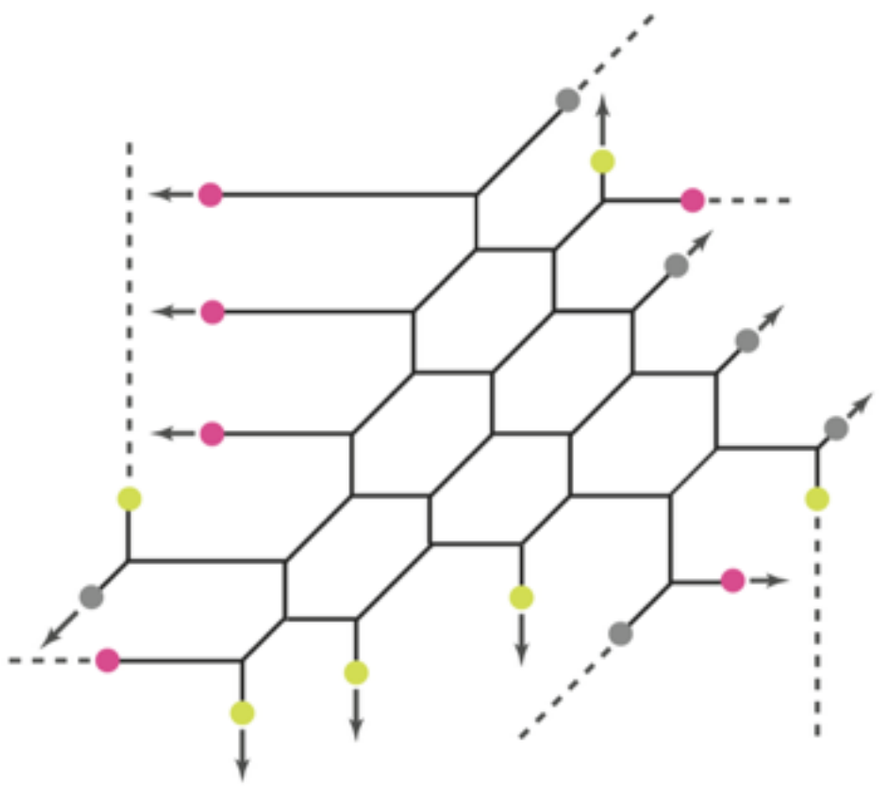
~~Tao Probing the End of the World 2~~

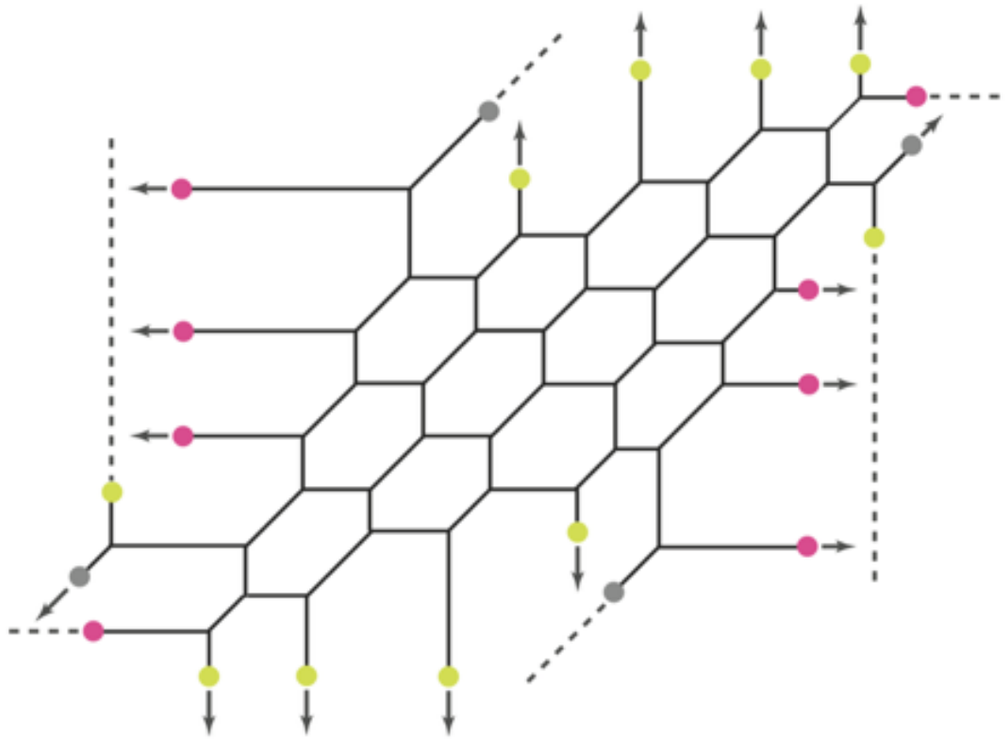
Tao probing the D-type singularity

§3 Generalization

What about still other types of Tao diagrams?







$$k$$

$$5\text{d } [N+2] - SU(N) - \cdots - SU(N) - [N+2]$$

'15 Yonekura

$$k = 2n+1$$

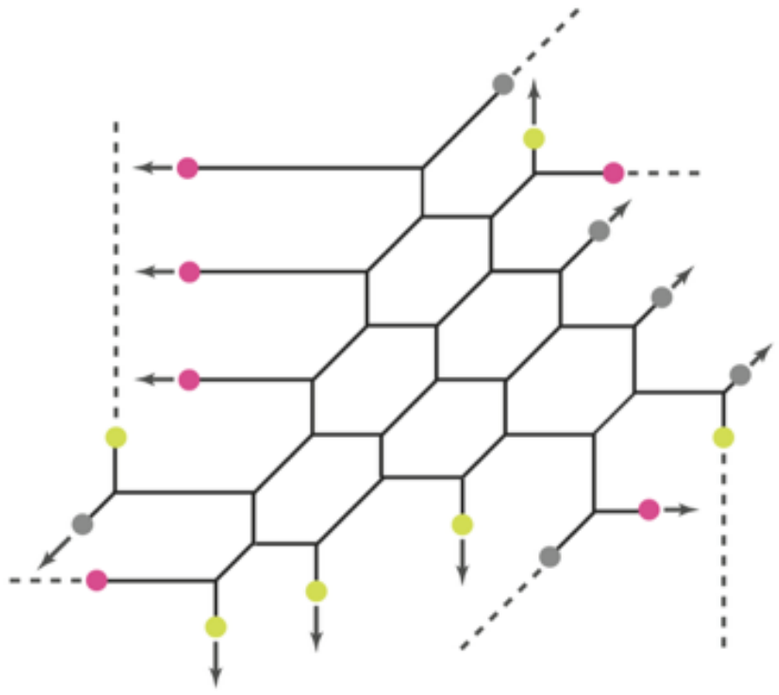
$$6\text{d } Sp(N') - SU(2N'+8) - SU(2N'+16) - \cdots - SU(2N'+8(n-1)) - [2N'+8n]$$

$$N' = N - 2n$$

$$k = 2n$$

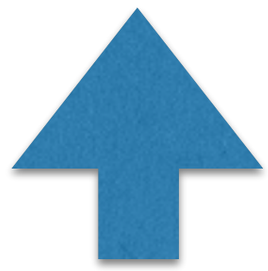
$$6\text{d } [A] - SU(N') - SU(2N'+8) - SU(2N'+16) - \cdots - SU(2N'+8(n-1)) - [2N'+8n]$$

$$N' = N - 2n - 1$$



$$5\mathrm{d}\ [N+3]-SU(N)-SU(N-1)-SU(N-2)-\cdots-SU(3)-SU(2)-[3]$$

(“Tao-nization” of 5d T_N)



’15 Zafrir

’15 Ohmori, Shimizu

$$\begin{aligned}
N=3n: &\quad 6\mathrm{d}\ SU(3)-SU(12)-\cdots-SU(3+9(n-1))-[3+9n]\\
N=3n+1: &\quad 6\mathrm{d}\ SU(3)-SU(12)-\cdots-SU(9n-6)-[9n+3]\\
N=3n+2: &\quad 6\mathrm{d}\ SU(0)-SU(9)-\cdots-SU(9n)-[9n+9]
\end{aligned}$$

§4 Conclusion

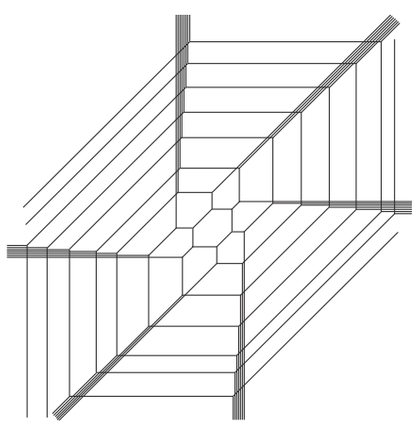
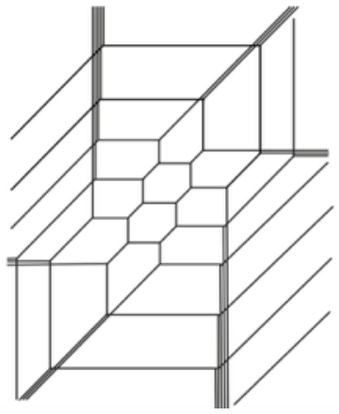
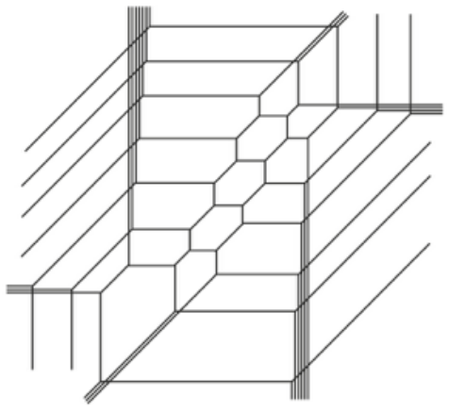
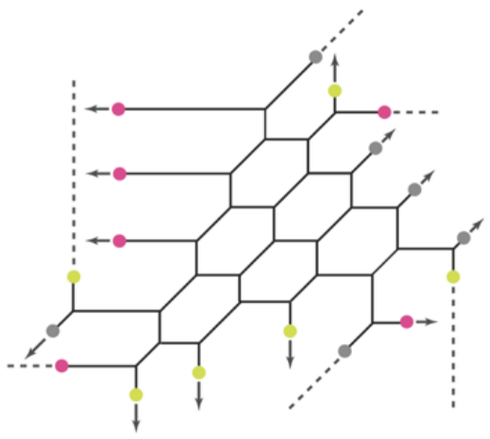
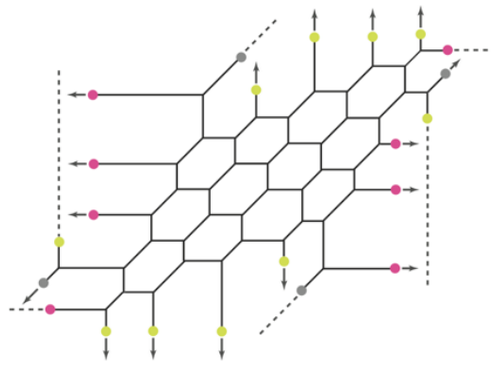
Partially checked the conjecture

Finite diagram: → 5D UV fixed point

"Tao diagram": → 6D UV fixed point

No diagram: → No UV fixed point

Tao diagrams for "class $\mathcal{T}$"

…

Classification by Intriligator - Morrison - Seiberg

$$\text{Im } \tau_{\text{eff}}(a) > 0 \quad \text{for } \forall a$$

			flavor	Chern-Simons level
$5d$	$SU(N)$	$(N > 2)$:	$N_f \leq 2N$	$\kappa \leq 2N - N_f$

No UV fixed point for product gauge group

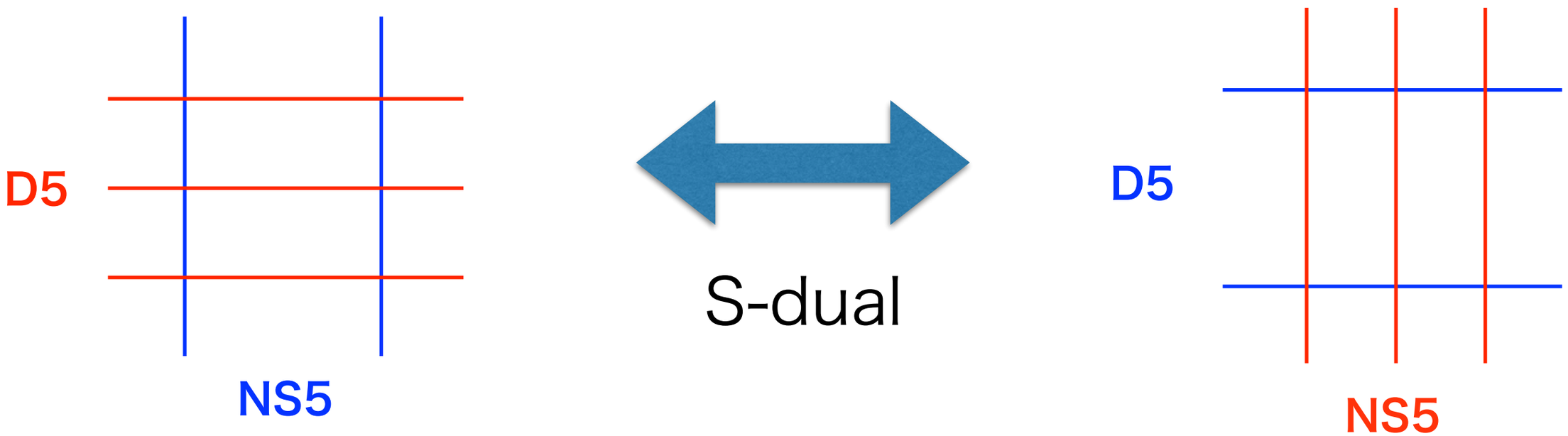
VS

Our conjecture

$5d$	$SU(N)$	:	$N_f \leq 2N + 4,$	$\kappa \leq 2N + 4 - N_f$

Some quiver gauge theories have UV fixed point

Conflict between their classification and web diagram



$SU(3) \quad N_f = 6$

$[2] - SU(2) - SU(2) - [2]$

Intriligator-Morrison-Seiberg

5d UV fixed point

No UV fixed point

?!