6d N=(1,0) theories on T^2 and Class S theories

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Based on arXiv:1503.06217 and 1508.00915
with K. Ohmori, Y. Tachikawa and K. Yonekura

6d SCFTs

・We have non-trivial superconformal field theories in six-dimensional spacetime

・N=(2,0) (16 Q's) vs N=(1,0) (8 Q's)

6d N=(2,0) theory:
ADE classification

[Witten '95][Strominger '96]

IIB on C^2/Γ_G

M5 branes

6d N=(1,0) theories:
F-theory classification

[Heckman, Morrison, Vafa '13]
[del Zotto, Heckman, Tomasiello, Vafa '14]
[Heckman, Morrison, Rudelius, Vafa '15]

F on elliptic CY3

M5 branes + α

Many examples

4d N=2 SCFTs from 6d

- 6d N=(2,0) theory on punctured Riemann surfaces: many new “non-Lagrangian” 4d N=2 SCFTs

Class S theories

[Gaitto ’09][Gaiotto, Moore, Neitzke ’09]

- 6d N=(1,0) theories on T^2

$\rightarrow$ many 4d N=2 theories

Q. Can we identify the resulting 4d N=2 theories?

We only consider the compactification at the most singular point of the Coulomb branch/the parameter space. In particular, no Wilson lines for flavor symmetry

Plan

1. Introduction
2. Example; 6d (SU(k), SU(k)) conformal matter
3. Generalizations

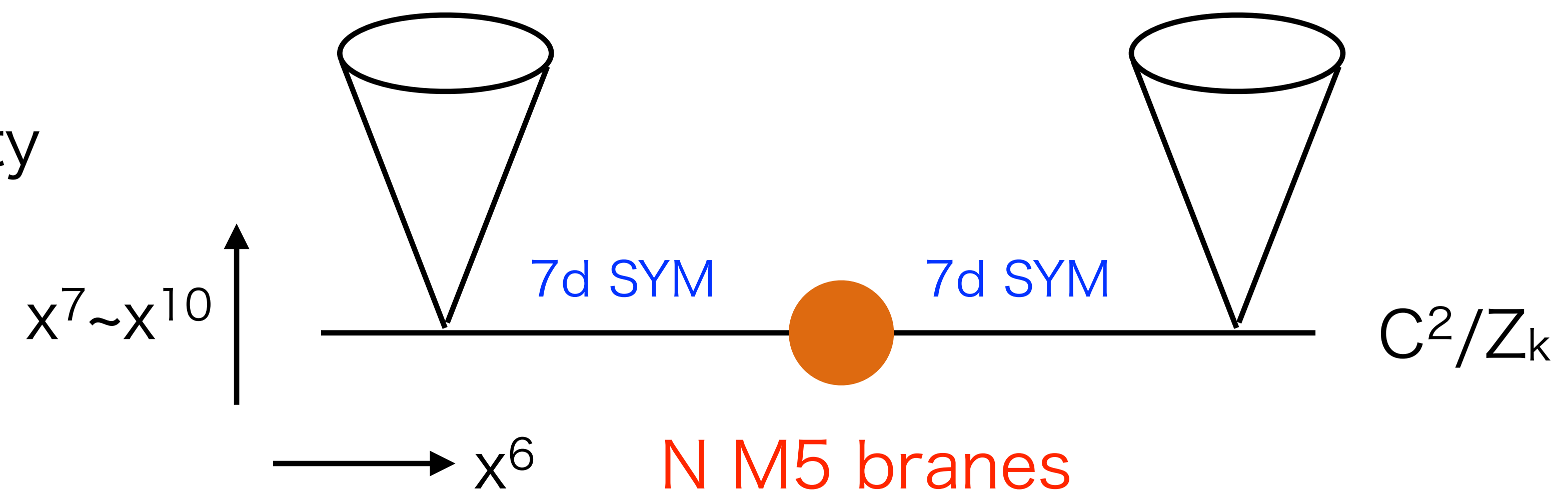
Example

6d (SU(k),SU(k)) conformal matter

6d (SU(k),SU(k)) conformal matters

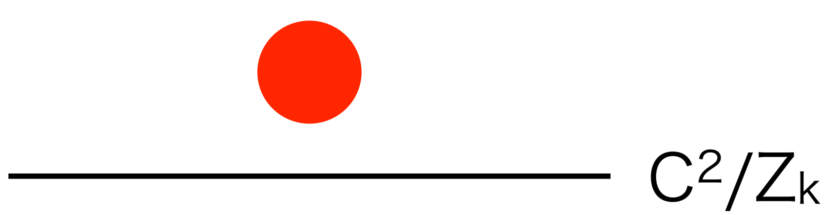
[del Zotto, Heckman, Tomasiello, Vafa '14]

- Worldvolume theory of N M5 branes probing C^2/Z_k singularity
- 6d (1,0) SCFT with $SU(k)\times SU(k)$ global symmetry



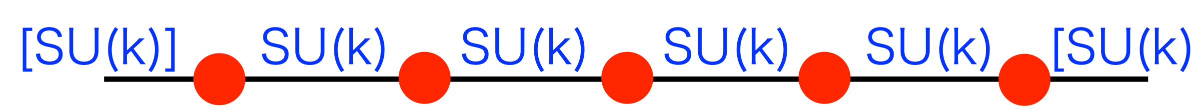
<u>Higgs branch deformation</u>

N M5 branes



SU(N)-type (2,0) theory

<u>Tensor branch deformation</u>



linear quiver gauge theory with SU(k) gauge groups

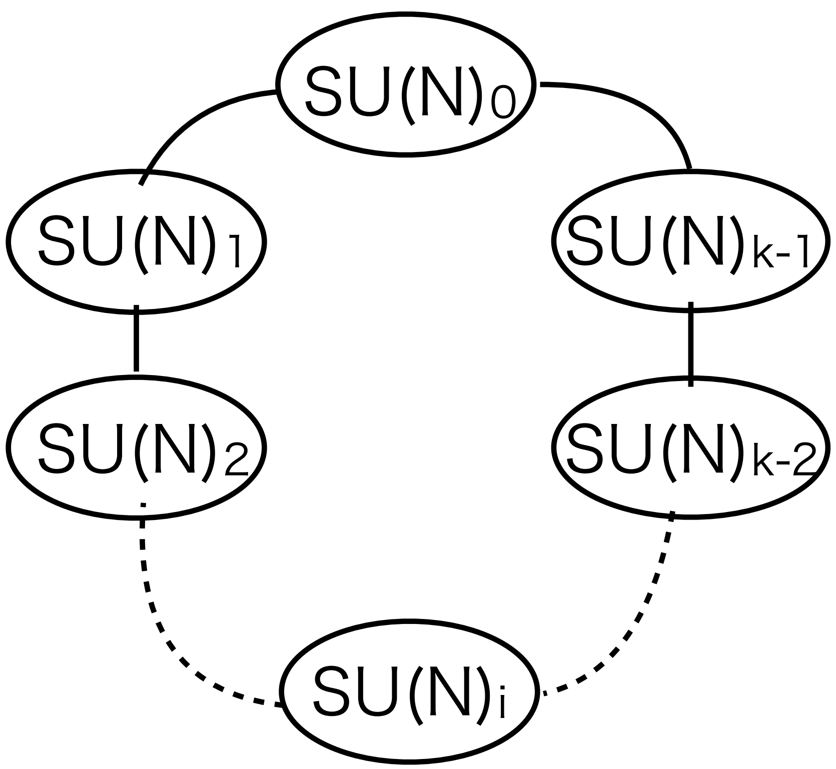
We denote this theory as $T_{6d}(k,N)$

From 6d to 5d

$T_{6d}(k,N)$ on S^1 with generic Wilson lines for $SU(k)_{diag}$

⇨ Type IIA N D4 branes probing C^2/Z_k singularity with generic B-flux through the singularity

5d necklace (=A-type affine Dynkin) quiver gauge theory



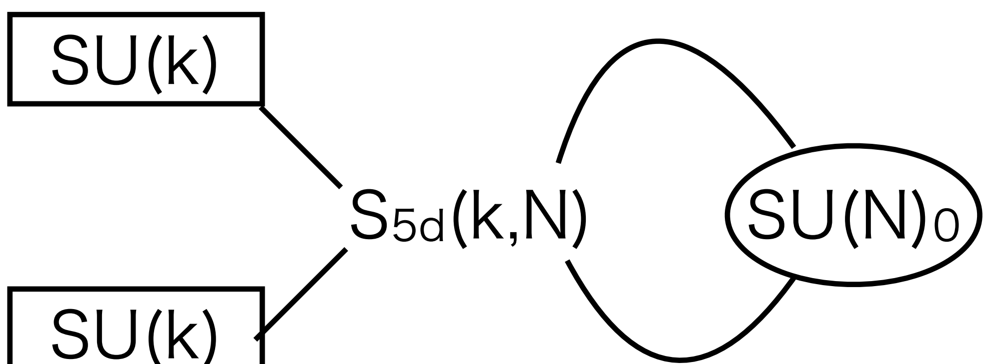
[Douglas, Moore '96]

$$\sum_{i=0}^{k-1} \frac{8\pi^2}{g_i^2} = \frac{1}{R}$$

$$\frac{8\pi^2}{g_i^2} \to 0 \ (m_{SU(k)} \to 0) \text{ for } i = 1, \cdots k-1$$

$$m_{SU(k)} = \text{diag}(\cdots, m_{SU(k),i}, \cdots)$$

Turning off Wilson lines



$$\frac{8\pi^2}{g_0^2} = \frac{1}{R}$$

※SU(N)$_0$ at affine node: weakly coupled

※SU(N)$_i$ (i=1,,,,k-1) at finite node: strongly coupled

5d SCFT S$_{5d}$(k,N)

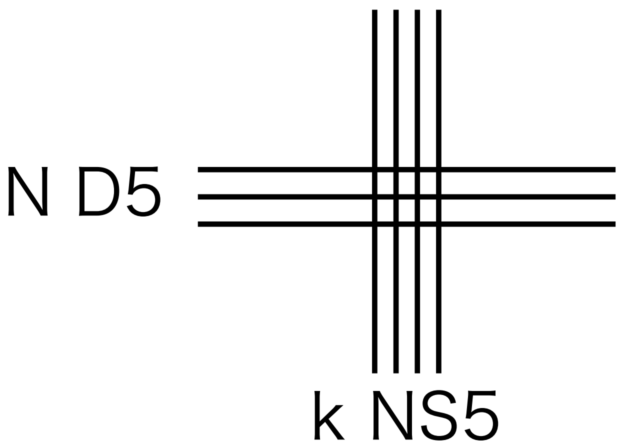
- UV fixed point of linear quiver gauge theory

$$[\mathrm{SU}(N)_L] - \mathrm{SU}(N)_1 - \cdots - \mathrm{SU}(N)_{k-1} - [\mathrm{SU}(N)_R]$$

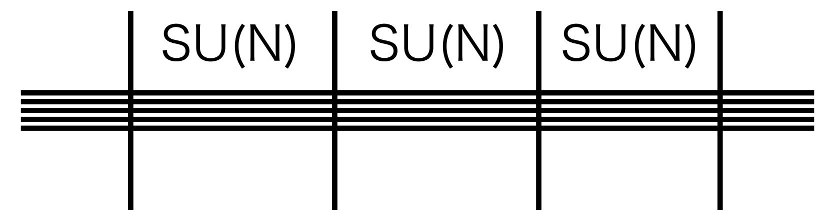
- Global symmetry enhancement

$$\mathrm{SU}(N)_L \times \mathrm{SU}(N)_R \longrightarrow$$
$$\mathrm{SU}(N)_L \times \mathrm{SU}(N)_R \times \mathrm{SU}(k)_L \times \mathrm{SU}(k)_R$$

IIB brane web for $S_{5d}(k,N)$



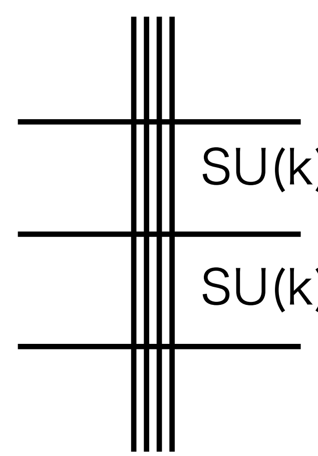
Mass deform by
$SU(k)_{diag} \subset SU(k)_L \times SU(k)_R$



$$[\mathrm{SU}(N)_L] - \mathrm{SU}(N)_1 - \cdots - \mathrm{SU}(N)_{k-1} - [\mathrm{SU}(N)_R]$$

5d UV SCFT $S_{5d}(k,N)$

Mass deform by
$SU(N)_{diag} \subset SU(N)_L \times SU(N)_R$



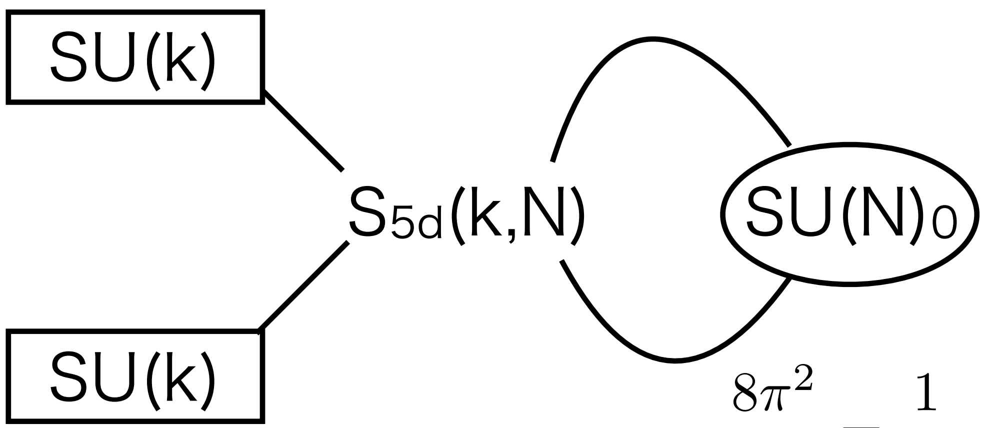
$$[\mathrm{SU}(k)_L] - \mathrm{SU}(k)_1 - \cdots - \mathrm{SU}(k)_{N-1} - [\mathrm{SU}(k)_R]$$

"Novel 5d duality"

[Katz, Mayr, Vafa '96]
[del Zotto, Heckman, Tomasiello, Vafa '14]

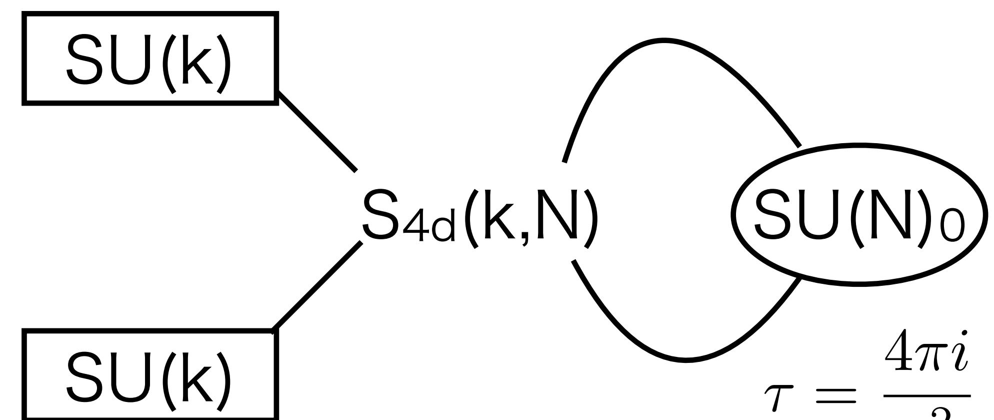
From 5d to 4d

$T_{6d}(k,N)$ on S^1 with radius R



$$\frac{8\pi^2}{g_0^2} = \frac{1}{R}$$

$T_{6d}(k,N)$ on T^2 with cpx str τ



$$\tau = \frac{4\pi i}{g^2} + \frac{\theta}{2\pi}$$

$S_{4d}(k,N) = S_{5d}(k,N)$ on S^1

To study $S_{4d}(k,N)$, mass deform $S_{5d}(k,N)$ in two ways

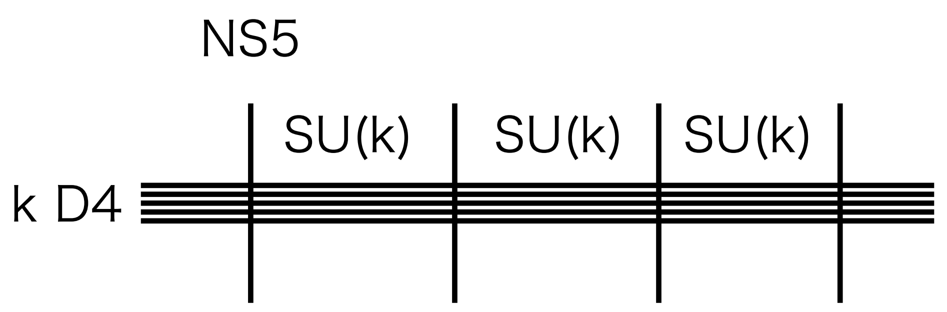
$S_{5d}(k,N)$ → 5d SU(N) linear quiver → 4d SU(N) linear quiver

$S_{5d}(k,N)$ → 5d SU(k) linear quiver → 4d SU(k) linear quiver

class S theory !

Tuning mass parameters (1)

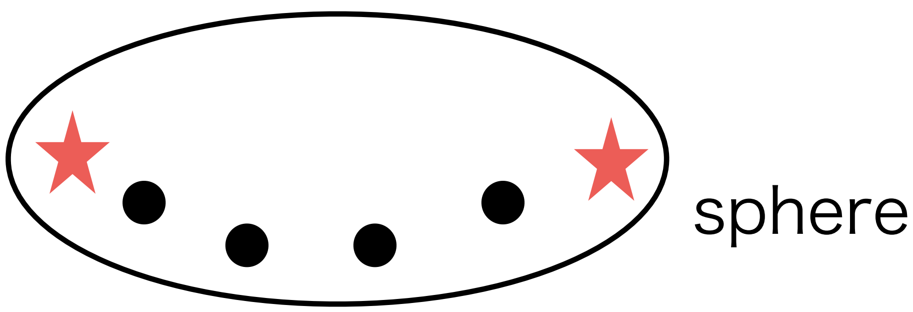
[Gaiotto '09]



4d linear quiver gauge theory

=

A_{k-1} (2,0) theory on



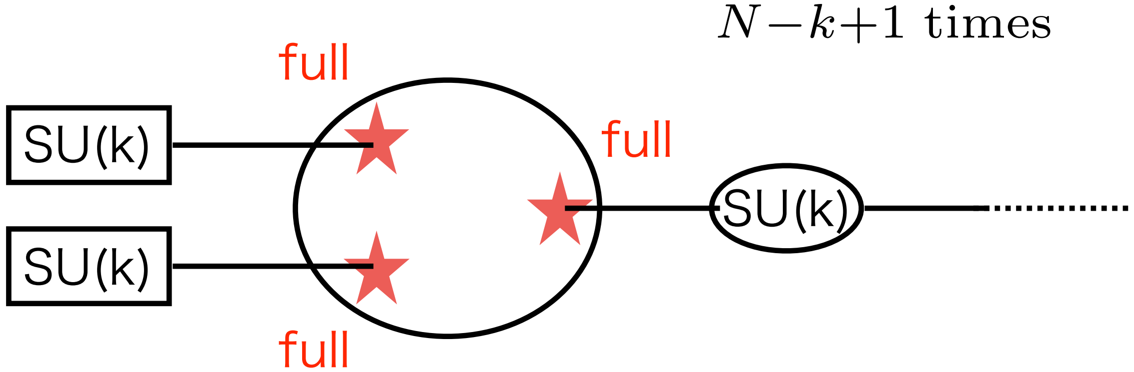
★ full puncture $[1^k]$

● simple puncture [k-1,1]

Tuning 5d mass parameters for $SU(N)_{diag}$ → Collide N simple punctures

⇒

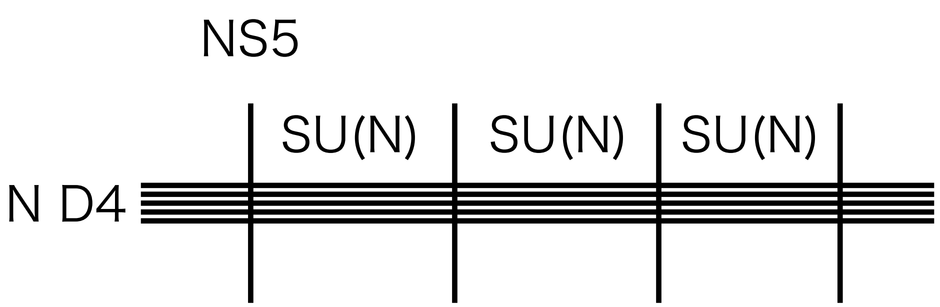
$$T_k\{[1^k],[1^k],[1^k]\} - \underbrace{SU(k) - \cdots - SU(k)}_{N-k+1 \text{ times}} - SU(k-1) - \cdots - SU(1)$$



※ full puncture→ SU(k) flavor symmetry

Tuning mass parameters (2)

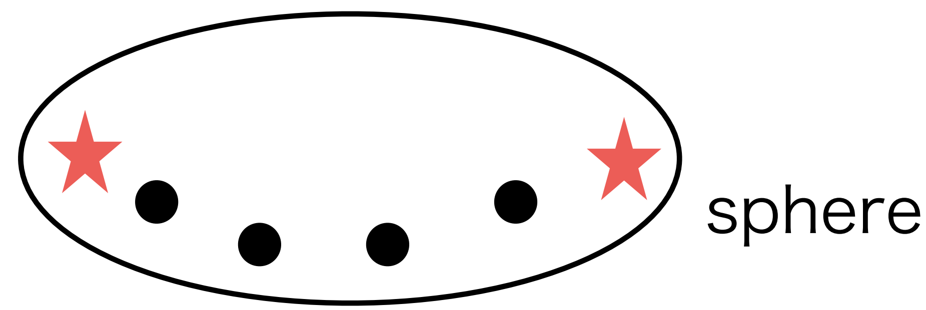
[Gaiotto '09]



4d linear quiver gauge theory

=

A_{N-1} (2,0) theory on



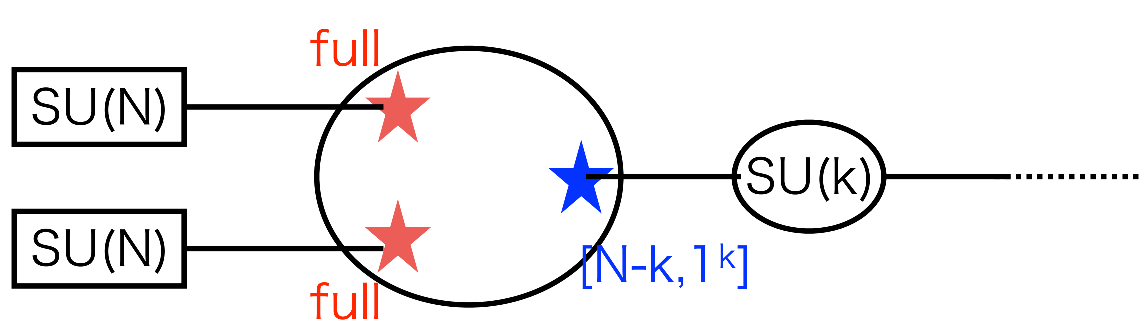
★ full puncture $[1^N]$

● simple puncture [N-1,1]

Tuning 5d mass parameters for $SU(k)_{diag}$ → Collide k simple punctures

$$T_N\{[1^N],[1^N],[N-k,1^k]\}-\mathrm{SU}(k)-\mathrm{SU}(k-1)-\cdots-\mathrm{SU}(1)$$

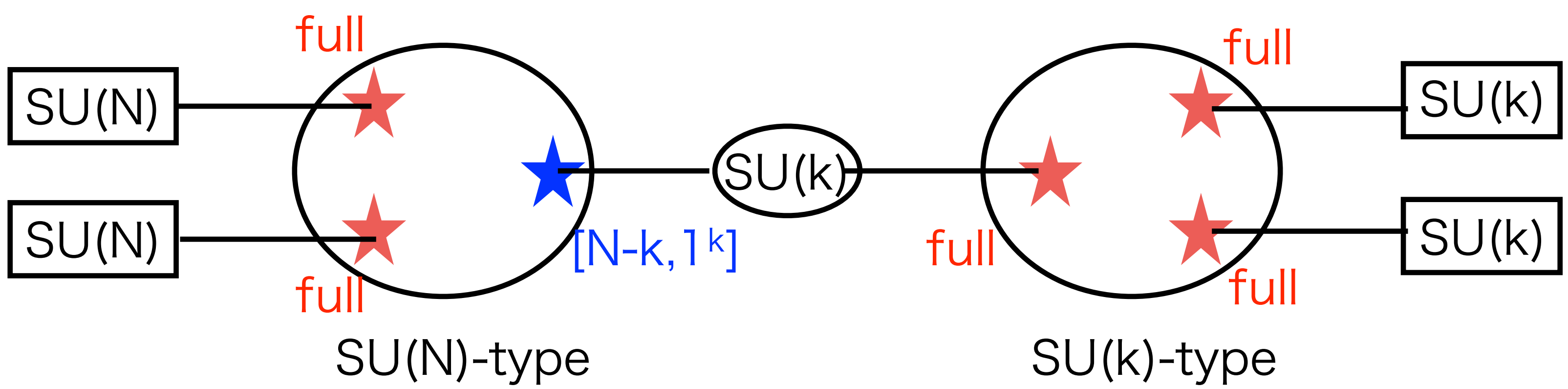
⇨



※ $[N-k,1^k]$ puncture→ SU(k) flavor symmetry

Class S description of $S_{4d}(k,N)$

$$S_{4\mathrm{d}}(k,N) = T_N\{[1^N],[1^N],[N-k,1^k]\} - \mathrm{SU}(k) - T_k\{[1^k],[1^k],[1^k]\}$$



※beta function computation

→ SU(k) is **IR free**

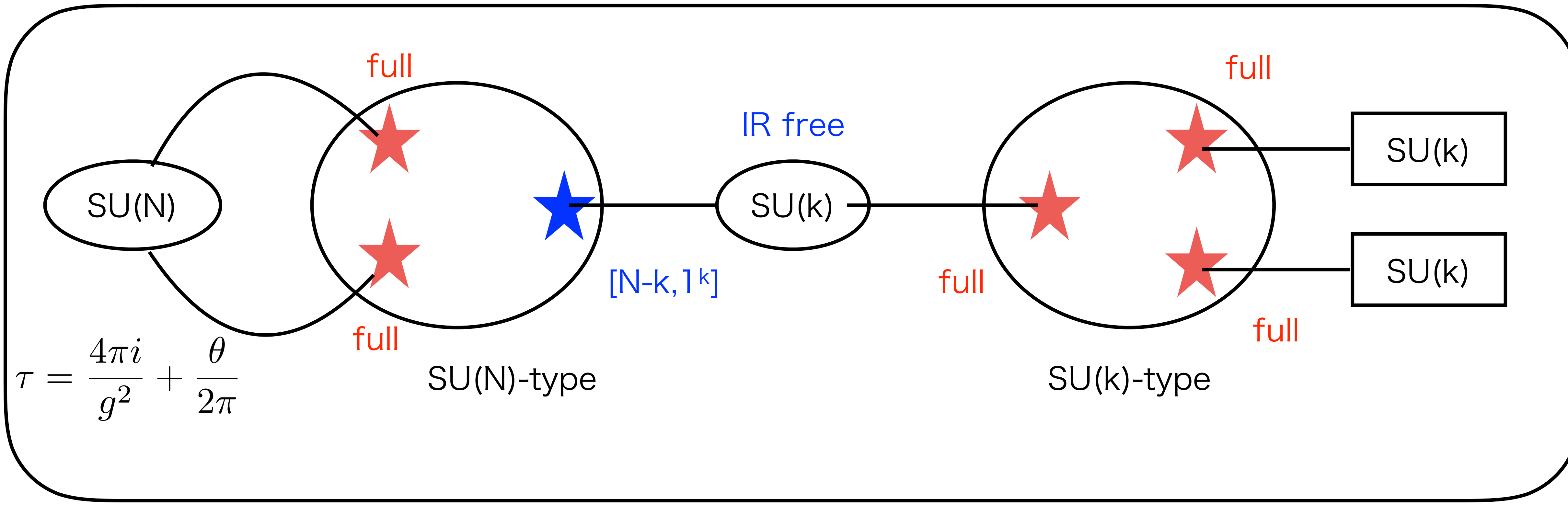
<u>Check</u>: mass deformation of class S theory

$T_M\{[1^M],[1^M],Y\}$ by $SU(M)_{diag}$

[Bergman, Zafrir '14][Hayashi, Tachikawa, Yonekura '14]

⟶ Reproduce previous generalized quivers!

6d (SU(k),SU(k)) conformal matters on T^2



- Class S theories as building blocks
- IR free gauge group SU(k)
- SL(2,Z) action on $SU(N)_{diag}$ gauge coupling
- SU(k) × SU(k) flavor symmetry is manifest

Generalizations

Very Higgsable 6d N=(1,0) SCFT

[arXiv:1503.06217]

- Consider 6d N=(1,0) SCFT that can be completely Higgsed to **free hypermultplets**

(Precise definition needs F-theory)

Ex.1 (general rank) E-string theory

Ex.2 minimal 6d (G,G) conformal matter

= single M5 brane probing C^2/Γ_G singularity

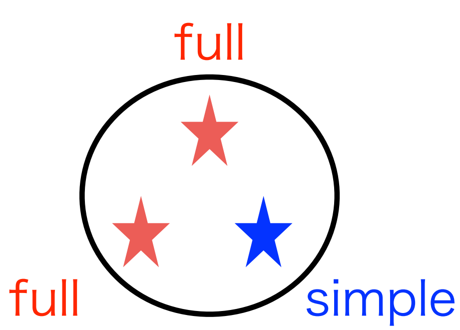
Circle/Torus compactification

S^1/T^2 compactification of very Higgsable
6d N=(1,0) SCFT

⇒ genuine 5d N=1/4d N=2 SCFT

Example: ・E-string theory
→(higher-rank) MN E_8 SCFT

・minimal 6d (G,G) conformal matter



→ G-type class S theory on a sphere
with two full and one simple punctures

6d N=(1,0) SCFT that is Higgsable to N=(2,0) theory

[arXiv:1508.00915]

- Consider 6d N=(1,0) SCFT that can be Higgsed to
  G-type 6d (2,0) theory

(Precise definition needs F-theory)

Ex.1 (non-minimal) 6d (G,G) conformal matter

= multiple M5 branes probing C^2/Γ_G singularity

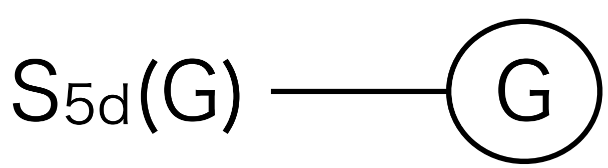
Ex.2 $\{SU(u_i)\}$ linear quiver gauge theory

[Gaiotto, Tomasiello '14]

Circle compactification

S^1 compactification of 6d N=(1,0) SCFT that is Higgsable to G-type (2,0) theory

⟹ 5d N=1 SCFT $S_{5d}\{G\}$ with global symmetry G
+ IR free G vector multiplet



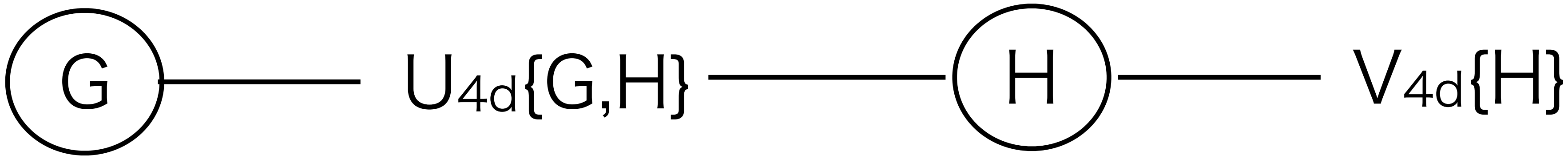
$$\frac{8\pi^2}{g^2} = \frac{1}{R}$$

Torus compactification

T^2 compactification of 6d N=(1,0) SCFT that is Higgsable to G-type (2,0) theory

⇨ 4d N=2 SCFTs $U_{4d}\{G,H\}$ and $V_{4d}\{H\}$ + G vector multiplet + H vector multiplet

Note that IR free vector H and 4d N=2 SCFT $V_{4d}\{H\}$ can be empty for some theories (For details, see our paper)



- gauge coupling of G = cpx moduli of T^2
- H vector: IR free
- We identified $U_{4d}\{G,H\}$, $V_{4d}\{H\}$ and H for (non-minimal) 6d (G,G) conformal matter and $\{SU(u_i)\}$ linear quiver gauge theory

Conclusions

・Circle/torus compactification of 6d N=(1,0) SCFT may contain IR free gauge group

・We introduced the concept of 6d N=(1,0) SCFT that is very Higgsable or Higgsable to (2,0) theory

・We identified the resulting 5d N=1/4d N=2 theories for many concrete 6d N=(1,0) SCFTs

Thank you!