Title: Brane webs, 5d gauge theories and 6d N=(1,0) SCFT's

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Abstract: Some 5d gauge theories have a 6d N=(1,0) SCFT as their UV completion. Given such 5d gauge theory we desire to determine its 6d UV completion. In this talk, I will present a method to do this for 5d gauge theories that can be engineered in string theory by brane webs. This can then be applied to study compactification of 6d N=(1,0) SCFT's on a torus.

Motivation

- Investigate the relation between 5d N=1 gauge theories and 6d N= (1,0) SCFT's.
- A 5d N=1 gauge theory sometimes has 6d N= (1,0) SCFT as its UV completion.
- Would like to determine the 6d N= (1,0) SCFT UV completion.
- The 5d theory can then be used to study the 6d SCFT.
- This has interesting implications on the compactification of the 6d SCFT to 4d on a torus.

Outline

1. Introduction
   - Generalities of 5d gauge theories and their description using brane webs
   - 6d N= (1,0) SCFT's and their description using brane systems
   - 5d gauge theories with a 6d SCFT UV completion
2. Determining the 6d SCFT UV completion using brane webs
3. Implication for the compactification of 6d SCFT's on a torus
4. Conclusions

1. Introduction: 5d gauge theories

- 5d gauge theories are non-renormalizable.
- Yet, in the N=1 SUSY case a UV fixed point may exist.
- 5d gauge theory generated from a 5d SCFT by a mass deformation associated with the coupling constant.
- Exhibit interesting non-perturbative properties such as enhancement of symmetry.

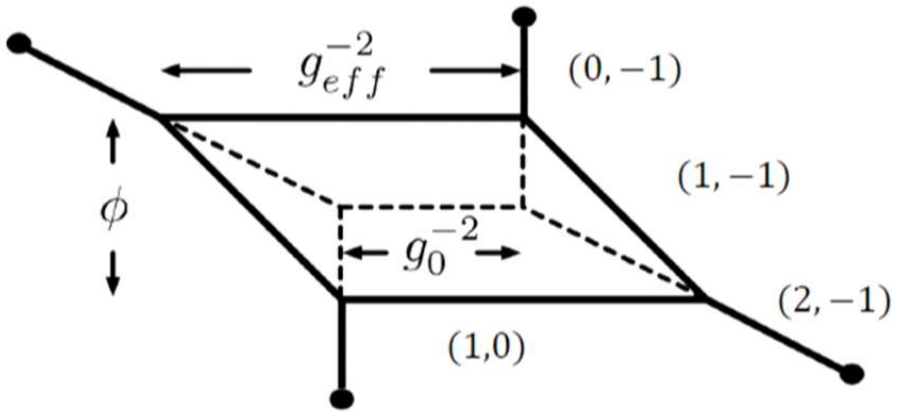
[Seiberg, 1996]

Enhancement of symmetry

- In 5d every simple non-abelian gauge group has a topologically conserved $U(1)$ current: $J \sim * Tr\ F \wedge F$.
- This current is carried by instanton particles.
- These can provide additional conserved currents leading to an enhancement of symmetry.
- A classic example is an $SU(2) + N_F F$, with N_F<8, where instantons enhance the classical $U(1) \times SO(2N_F)$ global symmetry to E_{N_F+1} [Seiberg, 1996].

5-Brane webs

- Convenient way to represent 5d gauge theories.
- Parameters represented by position of external branes.
- Moduli represented by moving internal branes.
- Fixed point realized when all the 5-branes intersect at a point.



[Aharony, Hanany, 1997]
[Aharony, Hanany, Kol, 1997]

6d N= (1,0) SCFT's

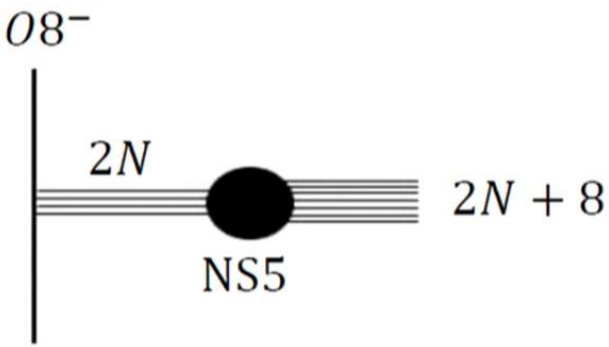
- Made from: hypermultiplets, vector multiplets and tensor multiplets.
- Tensor multiplet has a self-dual tensor and real scalar as its bosonic degrees of freedom.
- Scalar can acquire a vev leading to a moduli space called the tensor branch.

Examples of 6d N= (1,0) SCFT's

- Rank N E-string theories: made of N tensor multiplets with an E_8 global symmetry. Described in string theory by N M5-branes near an M9-plane [Ganor, Hanany, 1996].
- 6d gauge theories are non-renormalizable, but some have a SCFT UV completion. This requires adding tensor multiplet with the coupling constant identified with the scalar vev [Seiberg, 1997].
- 6d gauge theories suffer from gauge anomalies whose cancellation usually requires adding a tensor multiplet. These also constrain the matter content.

Brane configurations for 6d SCFT's

- Consider the system made from an $O8^-$-plane and $2N$ D6 branes partitioned by an NS5-brane. Gives an $USp(2N) + (2N + 8)F$ gauge theory on the D6 branes [Hanany, Zaffarony, 1998].
- D6-brane charge conservation leads to anomaly cancelation condition.
- Motion of the NS5-brane is identified with the tensor branch.
- Adding more NS5-branes leads to a $USp\ X\ SU\ \ldots X\ SU$ quiver.
- Adding an NS5-brane stuck on the $O8^-$-plane changes the first group to $SU(2N) + 1AS$.
- One can also add D8-branes, leading to additional flavors.



The 6d anomaly polynomial

- Besides gauge anomalies there can also be anomalies involving global currents.
- These include the Lorentz group, the $SU(2)_R$ symmetry and flavor symmetries.
- Conveniently packaged in an 8-form called the anomaly polynomial.
- There are known techniques to calculate it [Ohmori, Shimizu, Tachikawa, Yonekura, 2014].
- For very Higgsable 6d SCFT's compactified on a torus: related to the central charges of the resulting 4d theory [Ohmori, Shimizu, Tachikawa, Yonekura, 2015].

5d gauge theories with a 6d SCFT UV completion

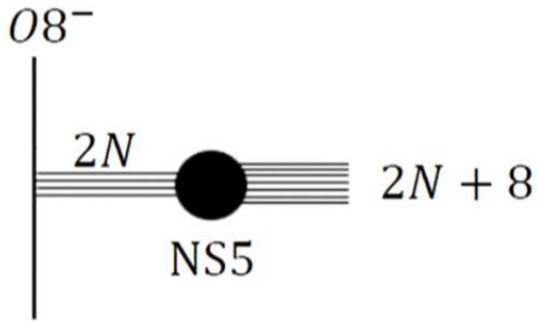
- Some 5d N=1 gauge theories have 6d N= (1,0) SCFT's as their UV completion.
- 5d gauge theory generated from a 6d SCFT by a mass deformation associated with compactification of the 6d SCFT on a circle of radius R.
- 5d gauge theory has a space of relevant deformations: $\frac{1}{R}$ and holonomies of background gauge fields.
- By taking all these to zero one approaches the 6d SCFT.

5d gauge theories with a 6d SCFT UV completion: examples

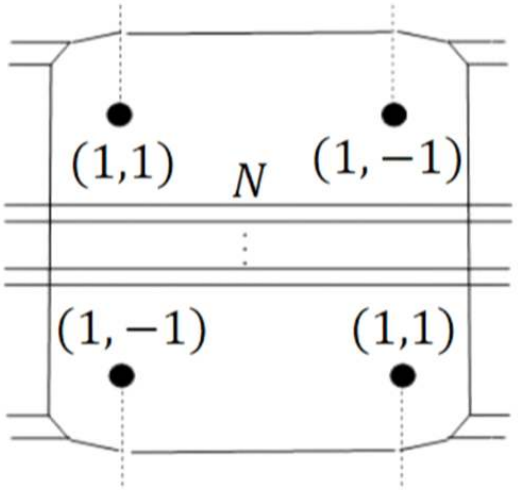
- Maximally supersymmetric Yang-Mills and the 6d (2,0) theory [Douglas, 2011][Lambert, Papageorgakis, Schmidt-Sommerfeld ,2011].
- $SU(2) + 8F$ and the rank 1 E-string theory [Ganor, Morrison, Seiberg, 1997].
- Apparent from the string theory construction: a D4-brane immersed in an $O8^- + 8D8$-branes.
- Another hint from the gauge theory perspective: instantons lead to an enhanced affine $E_8^{(1)}$ global symmetry.

Example: $SU(N+2)_0 + (2N+8)F$ and the (D_{N+4}, D_{N+4}) conformal matter

[Hayashi, Kim, Lee, Taki, Yagi, 2015]



T − duality
$+ O7^-$ resolution



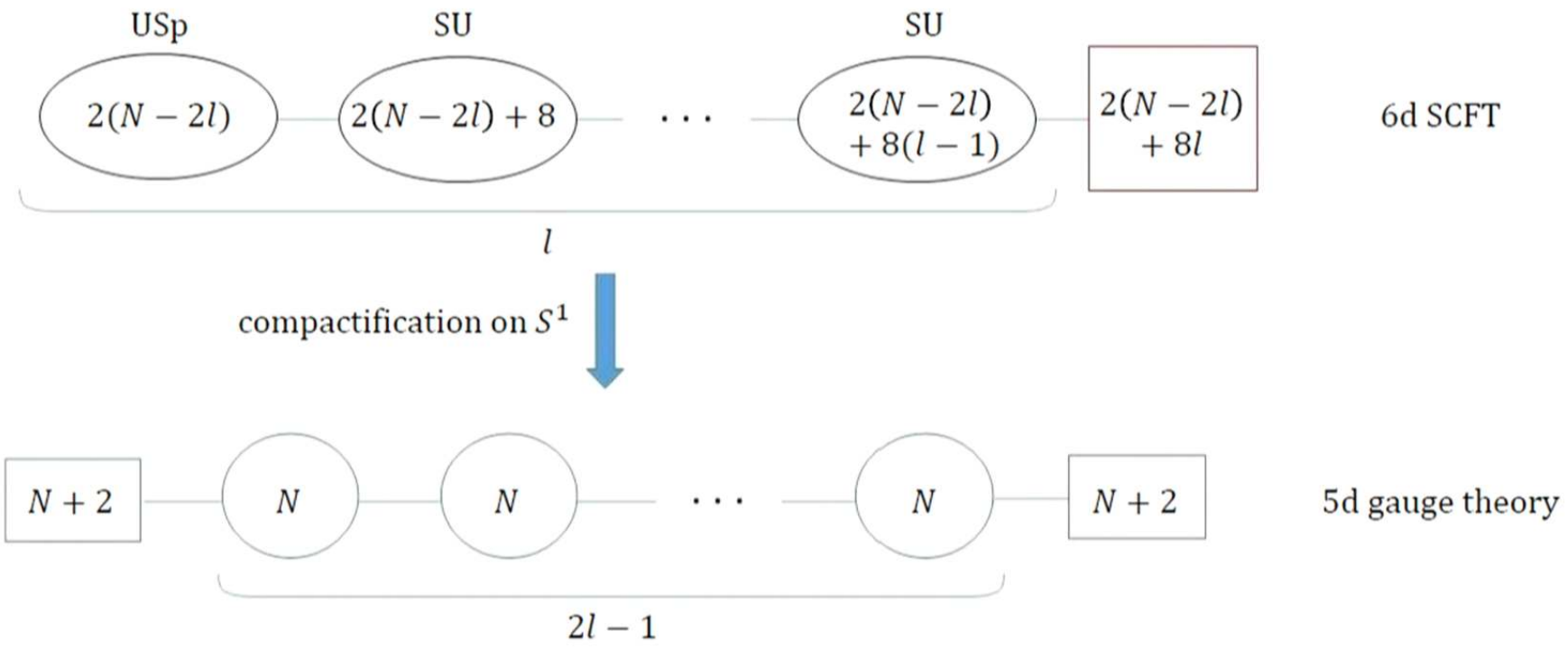
(D_{N+4}, D_{N+4}) conformal matter: one dimensional tensor branch leading to 6d gauge theory $USp(2N) + (2N+8)F$.

$SU(N+2) + (2N+8)F$ gauge.
Has an affine $D^{(1)}_{2N+8}$ global symmetry.

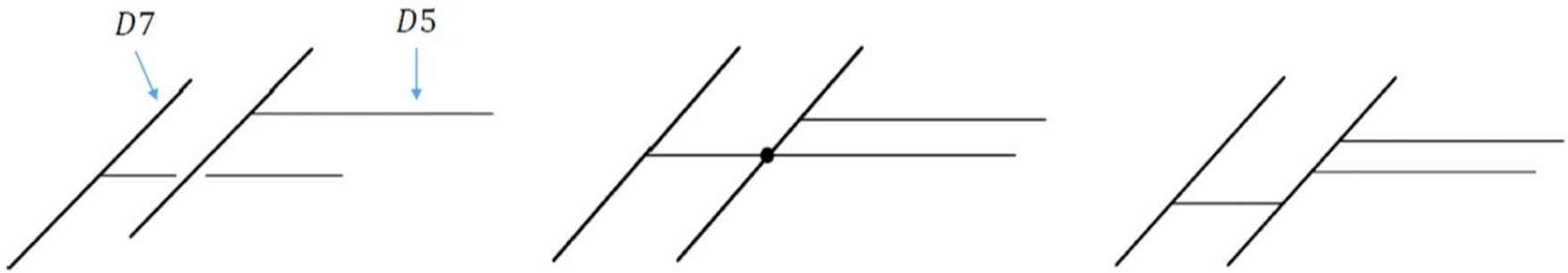
2. Determining the 6d SCFT UV completion using brane webs

- Many other 5d gauge theories suspected to lift to 6d.
- With brane web presentations: quivers of SU groups with fundamentals, or with USp or $SU + 1AS$ ends.
- We wish to determine the 6d SCFT also for these.
- The strategy is to first generalize the previous example to a certain class of theories.
- Additional theories can then be determined by connecting them to theories in this class via Higgs branch flows.
- By following the breakings we can determine the 6d SCFT.

Generalization: adding NS5-branes

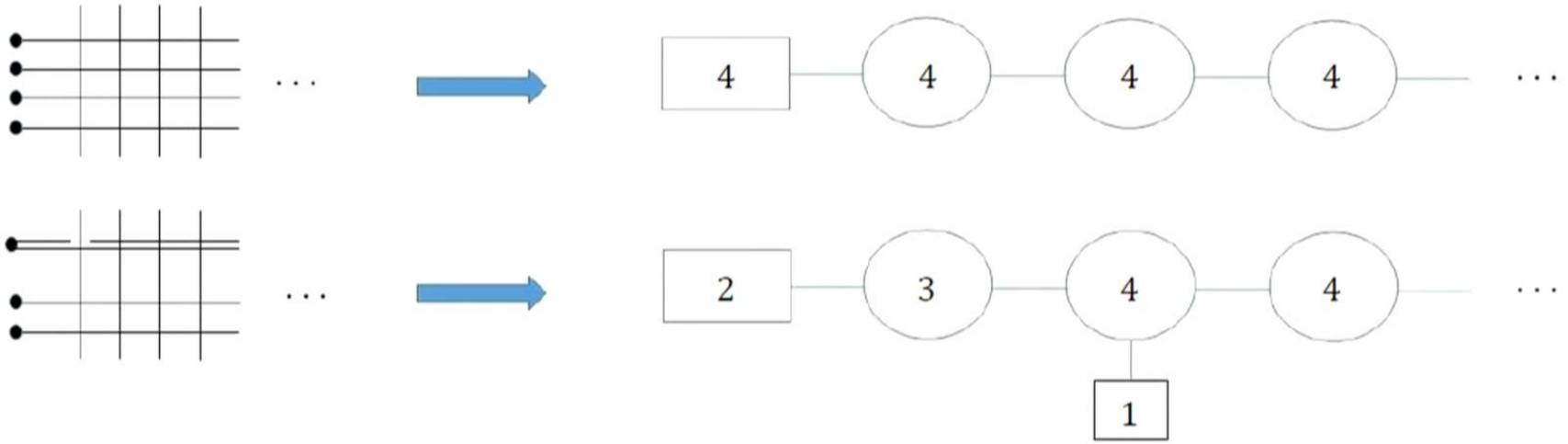


Higgs branch flow



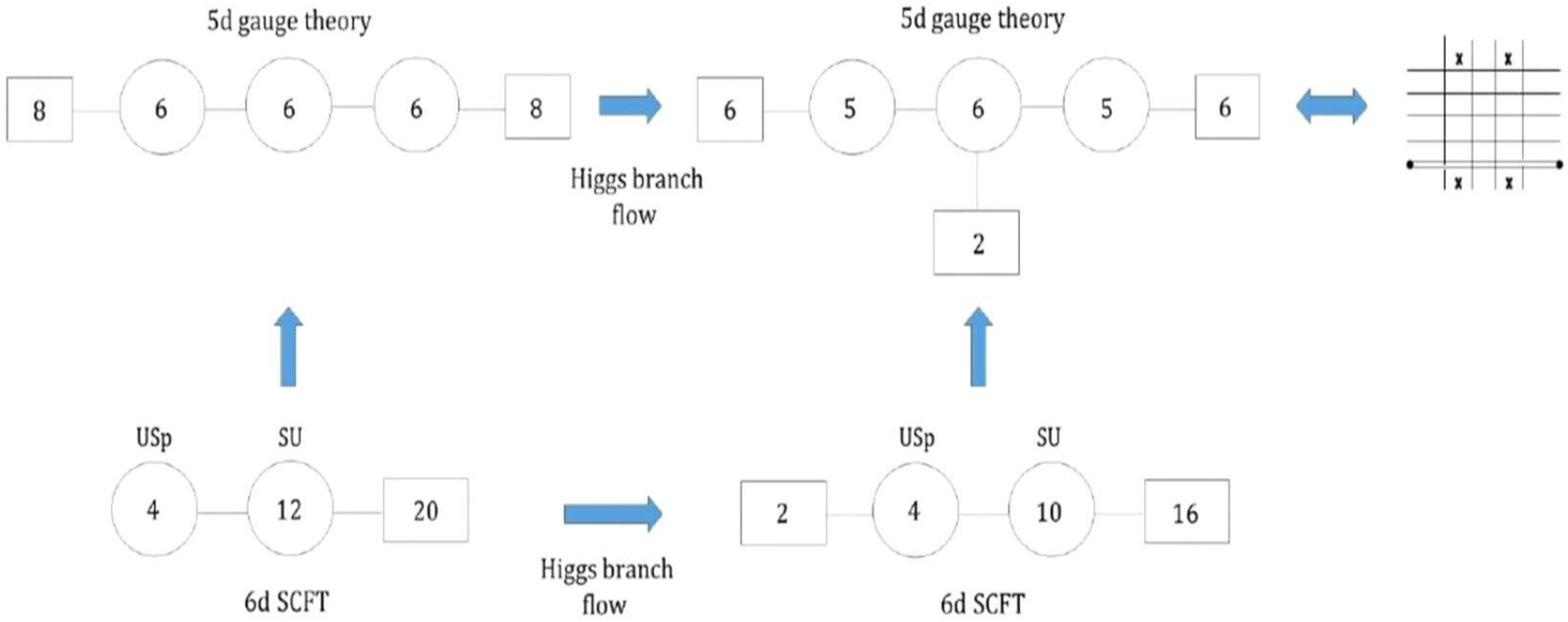
- Higgs branch flow in the 5d theory described by breaking a 5-brane on a 7-brane. This forces several 5-branes to end on the same 7-brane.
- Correspondingly in the 6d theory: breaking a D6-brane on a D8-brane.

Higgs branch flow and quiver tails



- This can be used to map the starting quiver to more general cases.
- Previous construction instruct us to do the same mapping on the 6d SCFT.

A simple example

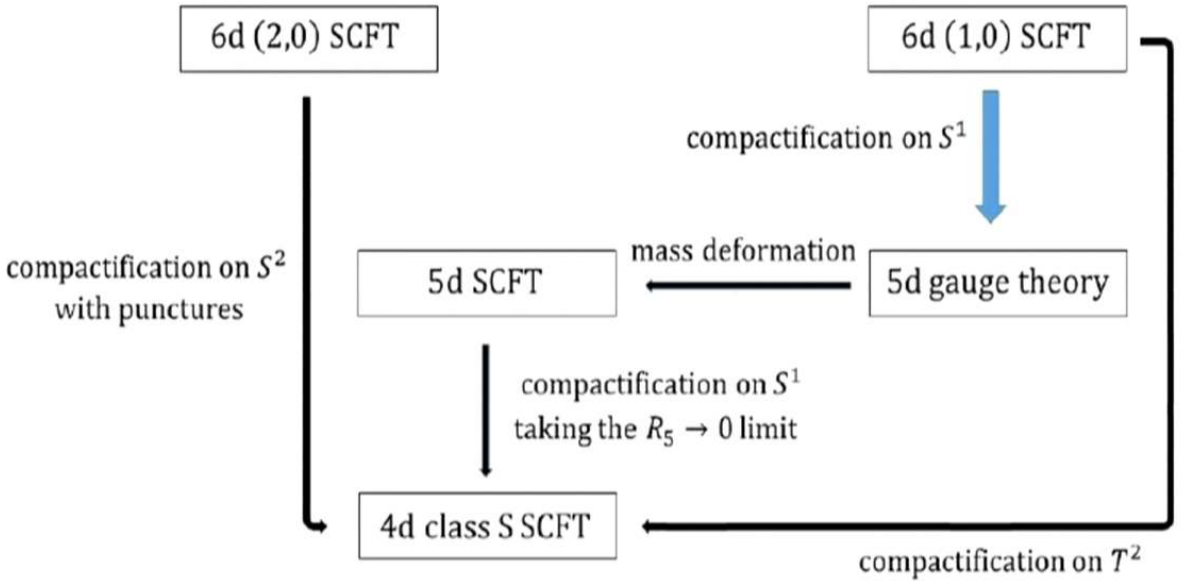


For what theories can this be applied?

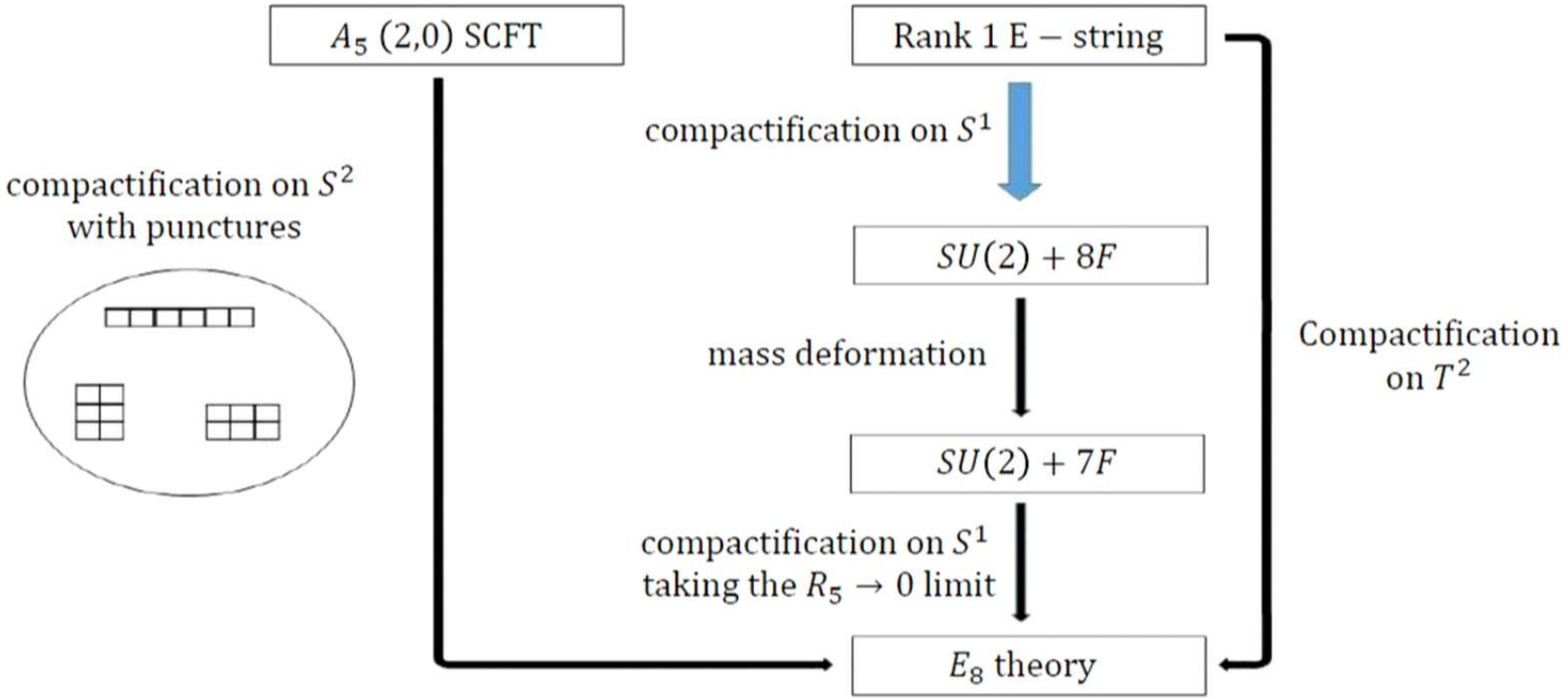
- Appears to be applicable only for linear SU quivers with fundamentals.
- However, the method can still be applied by manipulating the brane web to one related to the previous cases by Higgs branch flows.
- This works for a large class of 5d gauge theories.
- This leads us to conjecture that this can be applied to any 5d gauge theory with a brane web presentation.

3. Implication to the compactification of the 6d SCFT to 4d on a torus

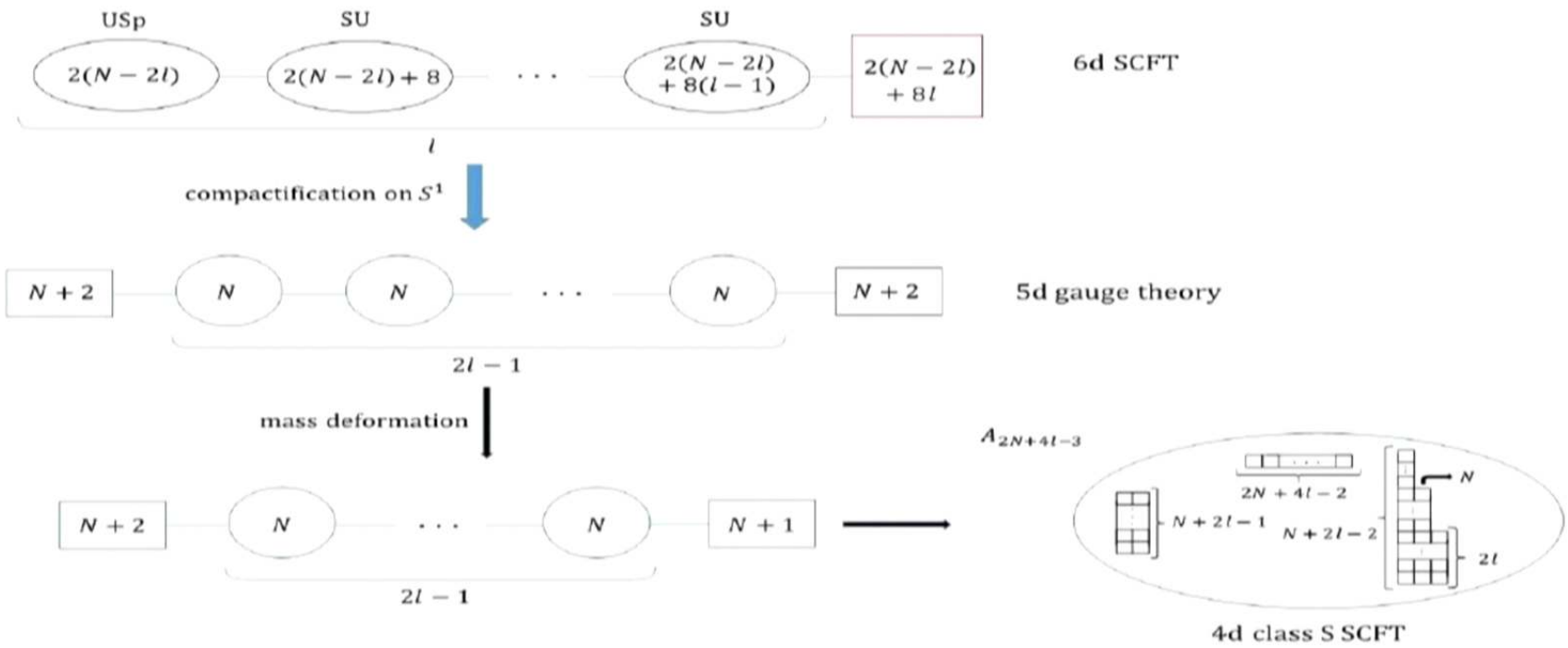
- This method can also be used to determine the result of compactifying the 6d SCFT on a torus.
- This can be checked by comparing the central charges with the ones expected from the 6d anomaly polynomial.



Implication to the compactification of the 6d SCFT to 4d on a torus



Implication to the compactification of the 6d SCFT to 4d on a torus



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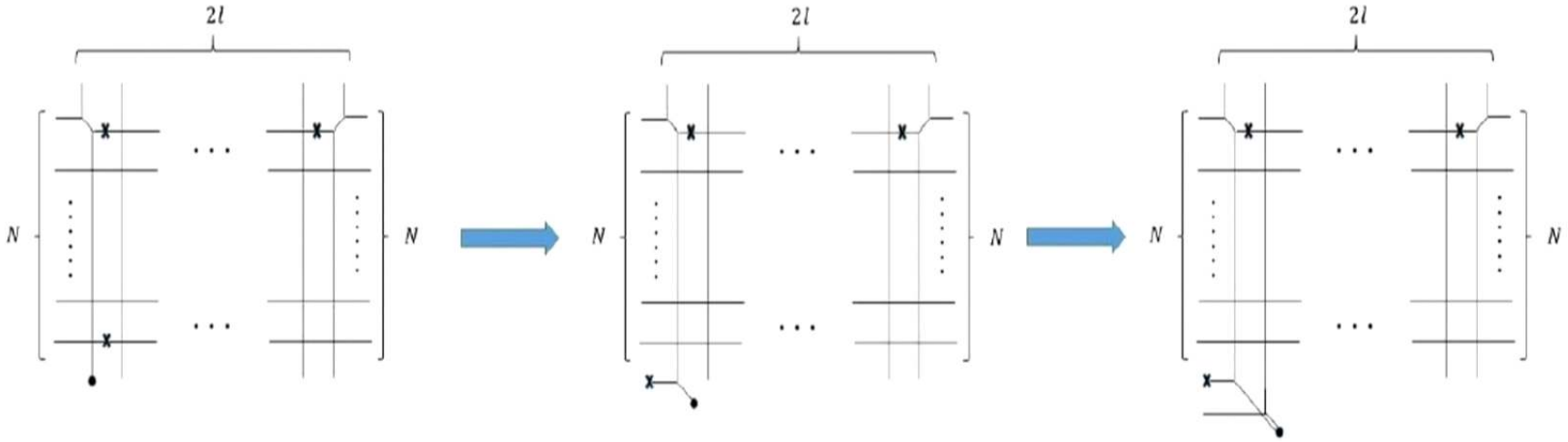
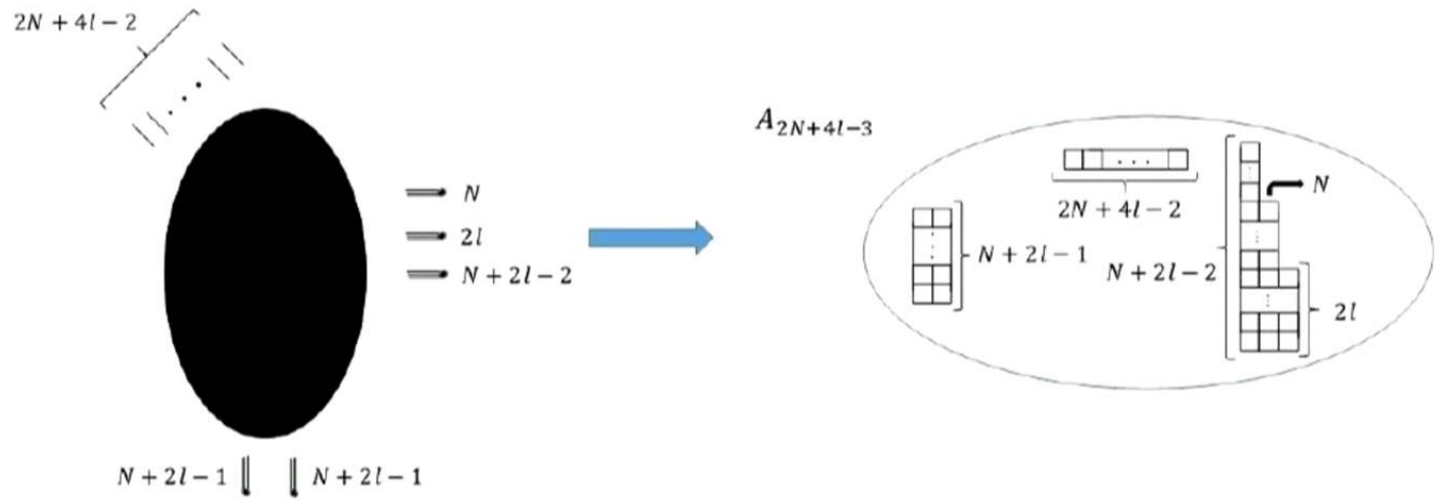


- Starting from the brane web for the 5d $(N+2)F$ $+ SU(N)X \ \ldots X\, SU(N) + (N+1)F$ quiver gauge theory, we perform a long sequence of 7-brane manipulations consisting of moving 7-branes accompanied by Hanany-Witten transitions.

Implication to the compactification of the 6d SCFT to 4d on a torus



- After intense 7-brane manipulation we arrive to the web on the left. For ease of presentation only the external legs are drawn.
- Right: the associated 4d class S theory.

4. Conclusions

- Some 5d gauge theories have a 6d SCFT UV completion. This 6d SCFT can be determined using Higgs branch flow for 5d gauge theories with a brane web representation.
- This can be used to determine the 4d SCFT resulting from the compactification of the 6d SCFT on a torus.

Open questions

- Can every 5d gauge theory, with an brane web representation, be treated in this way?
- Additional systems: webs in the presence of an $O7$-plane, $O5$-plane.

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