

Title: Working with John Brodie

Date: Oct 14, 2006 04:00 PM

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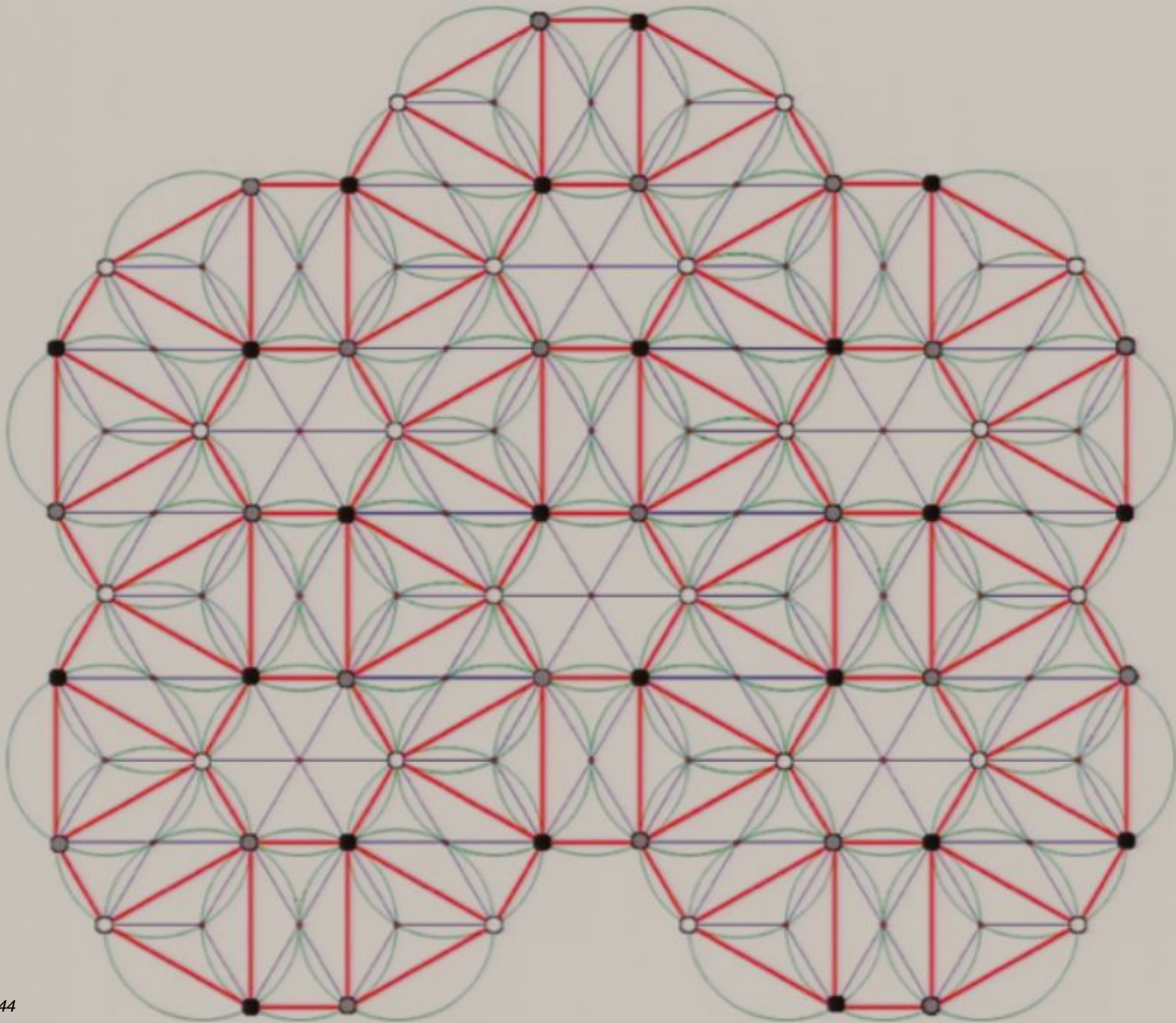
Abstract:

# Working with John Brodie

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# Plethystic Exponential

- Introduce the Plethystic Exponential

$$g(q) = \exp \left( \sum_{k=1}^{\infty} \frac{f(q^k)}{k} \right)$$

- counting BPS operators in the chiral ring of N=1 supersymmetric gauge theory



- I first met John in fall 1995 when he was a student at Princeton University

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- After a short period it became clear that we share many interests in physics research and we had many fruitful discussions



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- I was working on branes and making various efforts to realize supersymmetric gauge theories on branes in a hope to get some non-perturbative information



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- The brane setup for supersymmetric gauge theories which was constructed by Witten and myself

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- The brane setup for supersymmetric gauge theories which was constructed by Witten and myself
- The work of Elitzur, Gaiotto, & Kutasov on the realization of Seiberg Duality in such setups

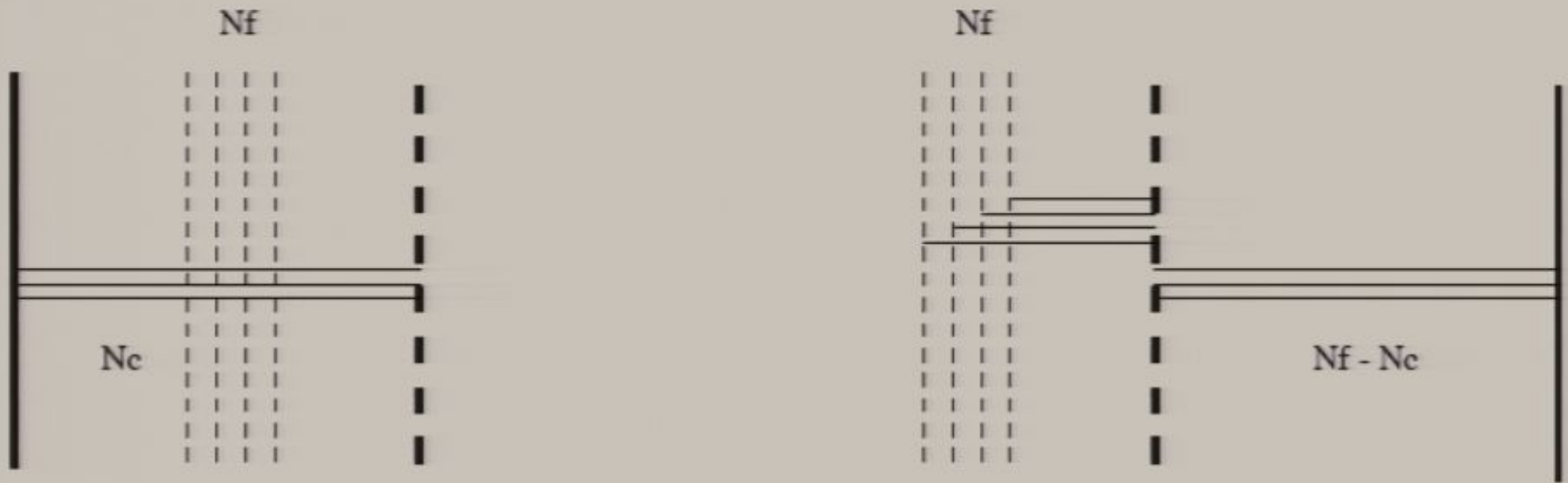
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- Our work contained many new results but soon after publication it became controversial



- Not due to the dualities we computed but rather due to the statement on Chiral Symmetry
- Let us see this in detail
- We will show the brane configuration for
- SQCD:  $SU(N_c)$  with  $N_f$  flavors

# Brane Configuration SQCD



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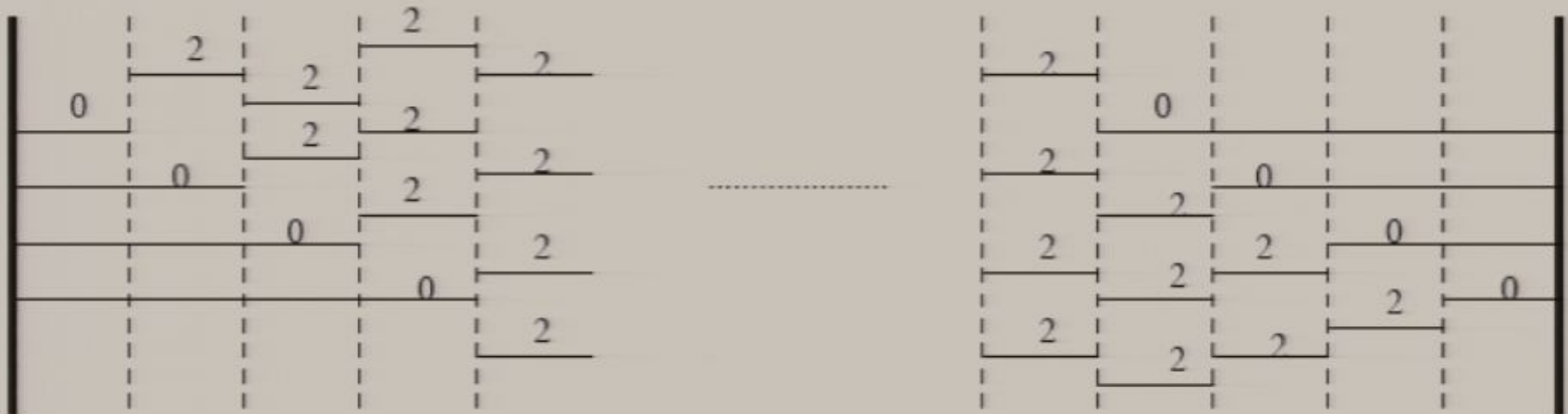
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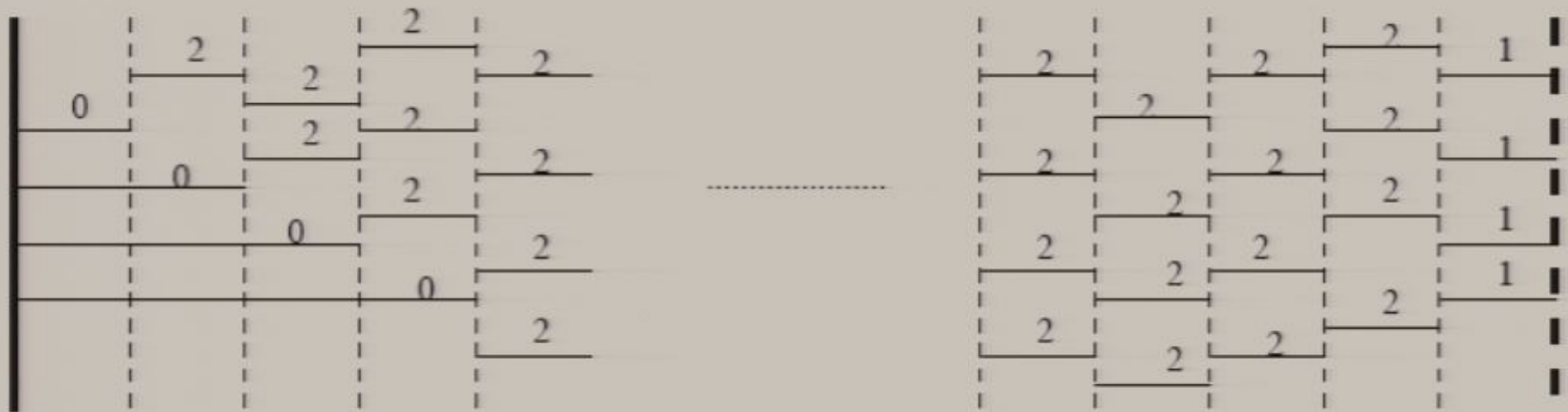
- In the first talk John gave in Princeton on this work, he termed these brane configurations as
- Feynman Diagrams of the 90's

- Using the rules we derived in the work with Witten it was easy to see that this theory describes  $SU(N_c)$  with  $N_f$  fundamental flavors and  $W=0$

# Higgs branch N=2 theory

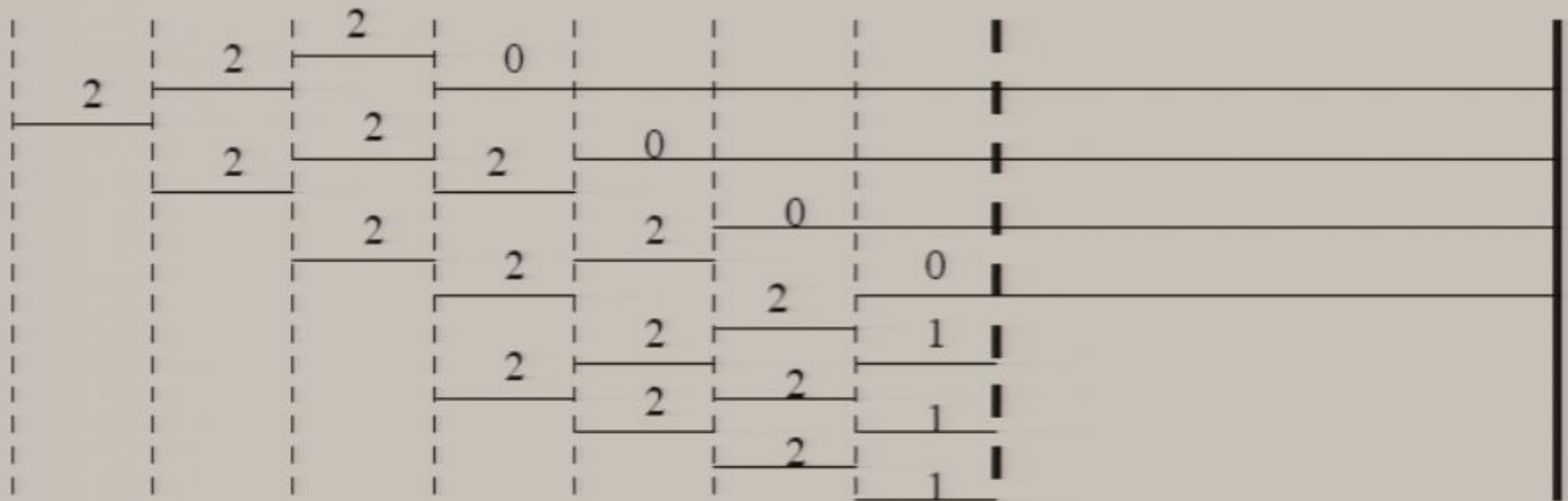


# Higgs branch N=1 theory





# Higgs branch Seiberg dual



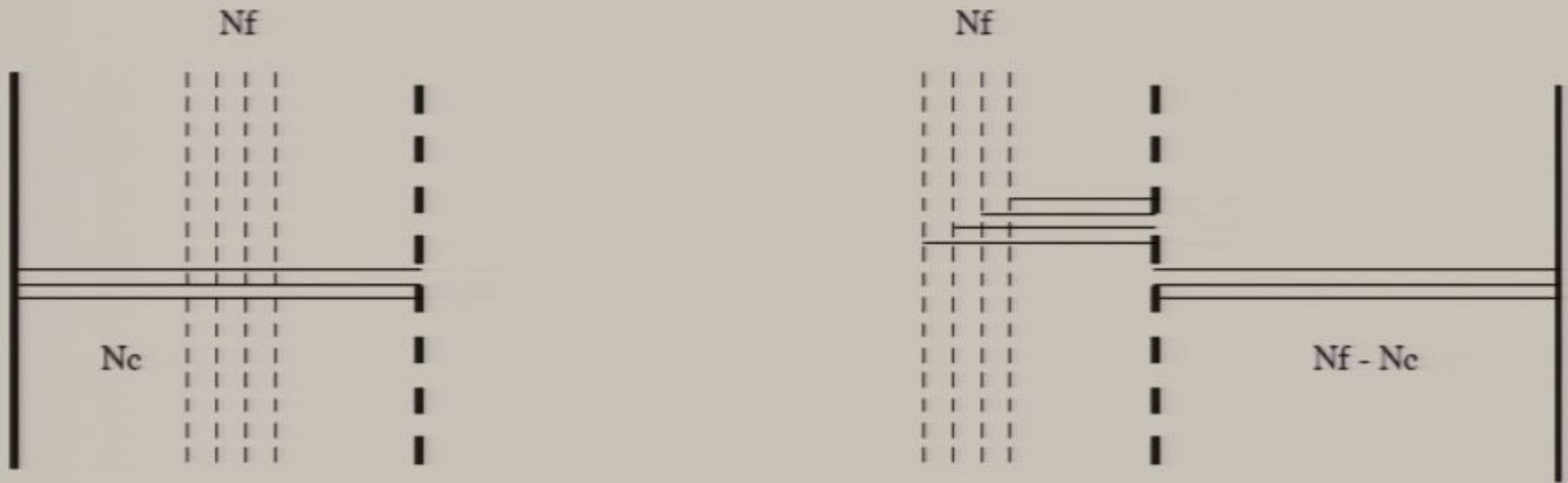
- This was not the controversial part

- This theory has a global symmetry
- $SU(N_f) \times SU(N_f)$
- This led to a puzzle

# Puzzle

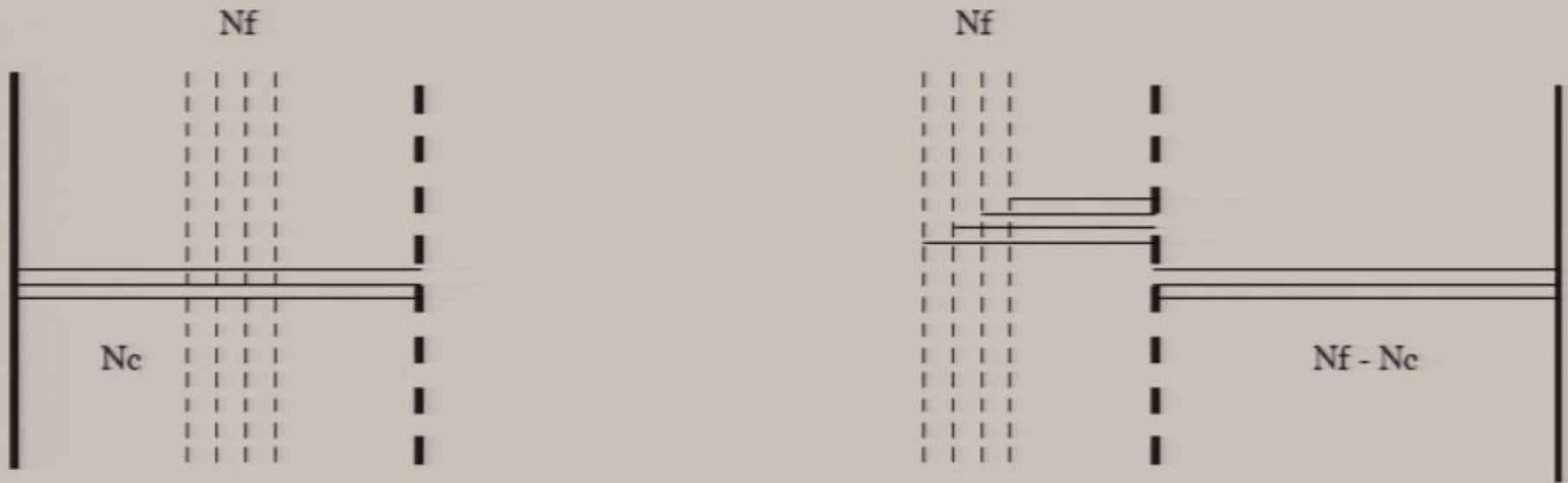
- How can we see this chiral symmetry in the brane setup?

# Brane Configuration SQCD



- Answer: Tune the NS' brane and the D6 branes on the same  $x_6$  position
- D6 splits on the NS' and have two gauge groups instead of one.
- $SU(N_f)$  gauge group on each semi-infinite D6 brane

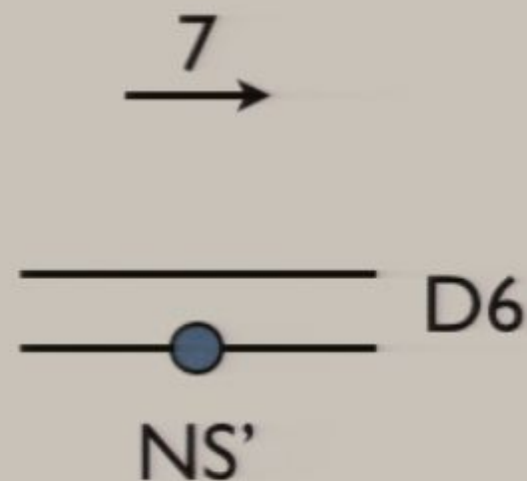
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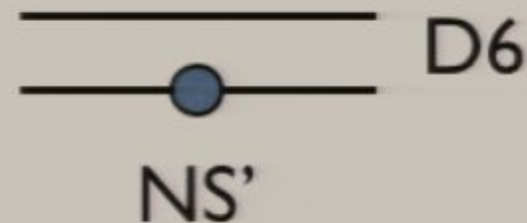
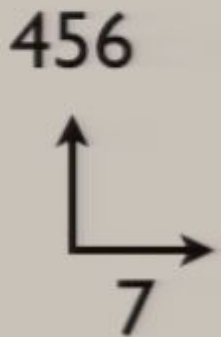


- To be clear, recall the directions of the branes
- NS 012345
- NS' 0123 89
- D4 0123 6
- D6 0123 789



# 6d theory on D6 branes

- To put the D6 on NS' we need to tune 3 directions
- This amounts to setting a mass of a 6d vector multiplet to zero
- 456 directions are 6d FI triplet

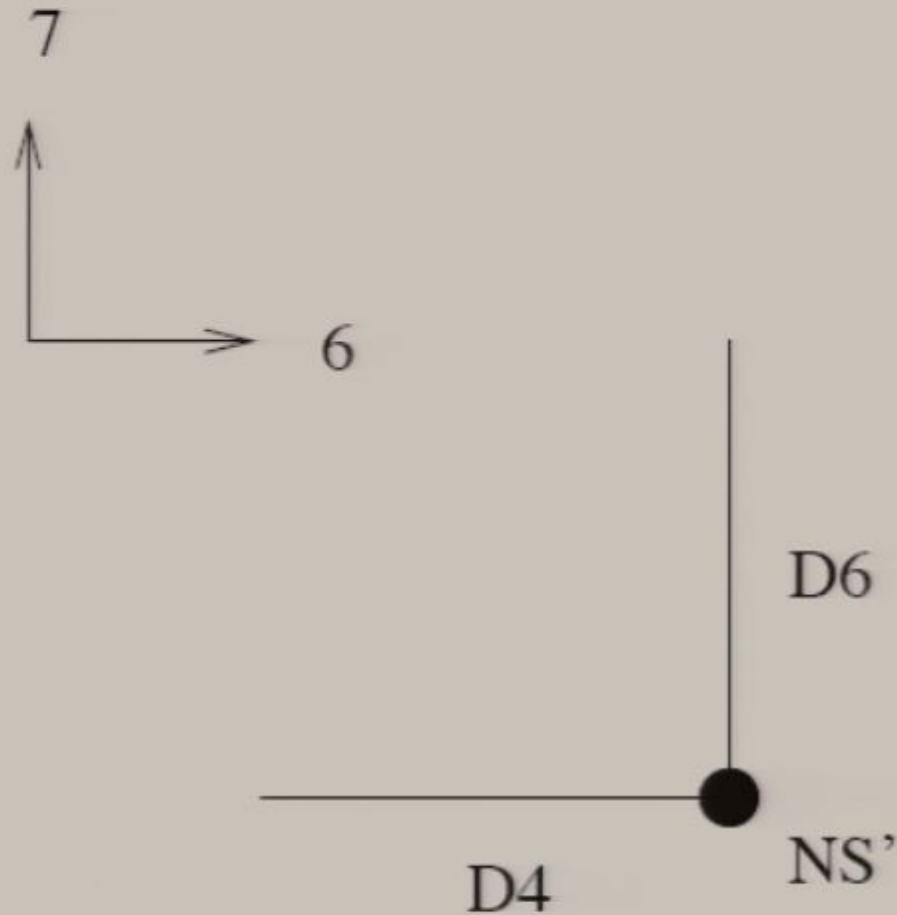


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# Chiral Symmetry

- The gauge symmetry on the split D6 branes becomes  $SU(N_f) \times SU(N_f)$  and chiral symmetry becomes visible
- motion of D6 along 45 directions Higgses (spontaneous breaking) the D6 theory down to  $SU(N_f)$
- gives a mass to the quarks which indeed break chiral symmetry explicitly

# Chiral multiplets



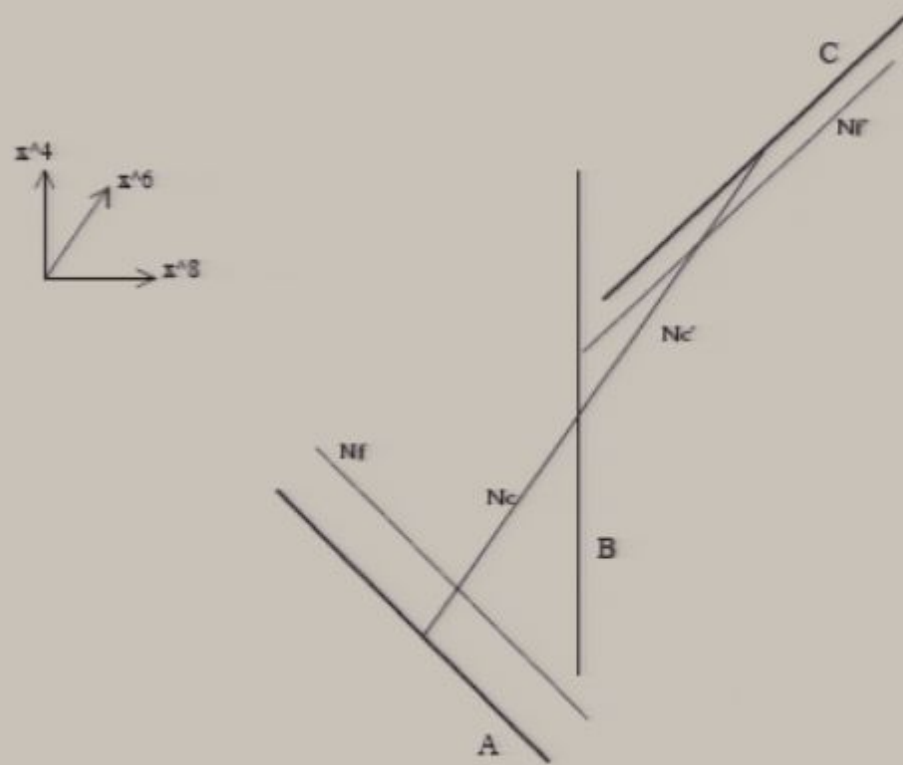
- This was probably the most controversial statement we made - many people criticized that chiral fermions can not be localized in space
- later this statement was generalized to other dimensions less than 4 by taking T duality on any or all of 123 directions

# Insightful and intuitive

- This work still continues to be influential as one of the first models to introduce chiral matter using branes in string theory

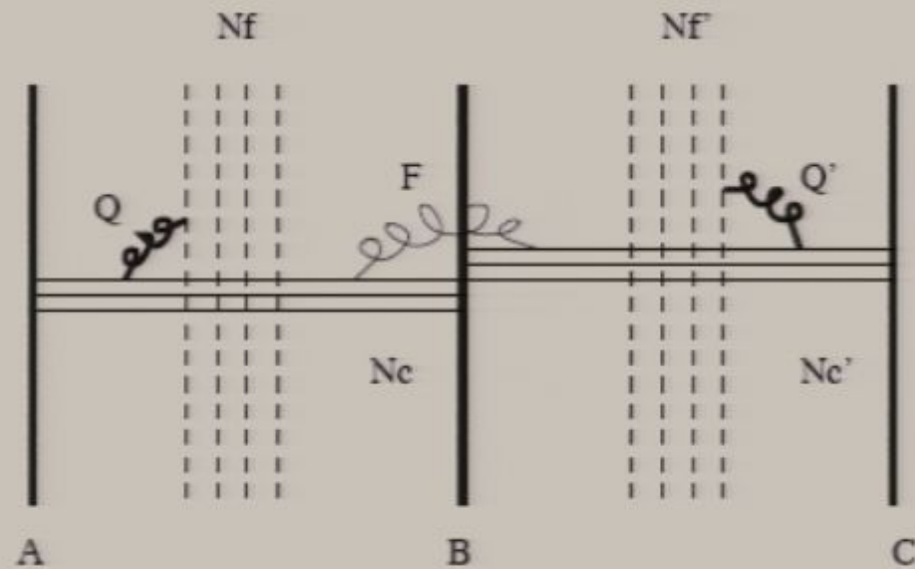
- Later Elitzur Givon Kutasov & Sarkisian did a world sheet computation which showed that this was precisely the case

# Duality: a product of two gauge groups

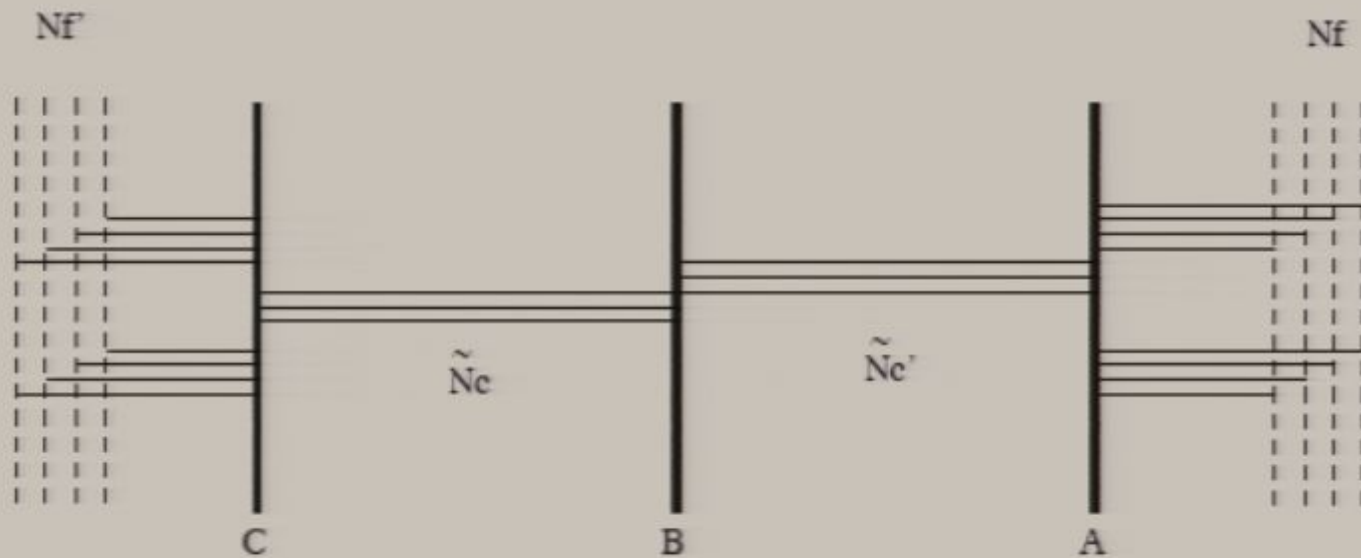




# $SU(N_c) \times$ $SU(N_c')$



# Seiberg dual



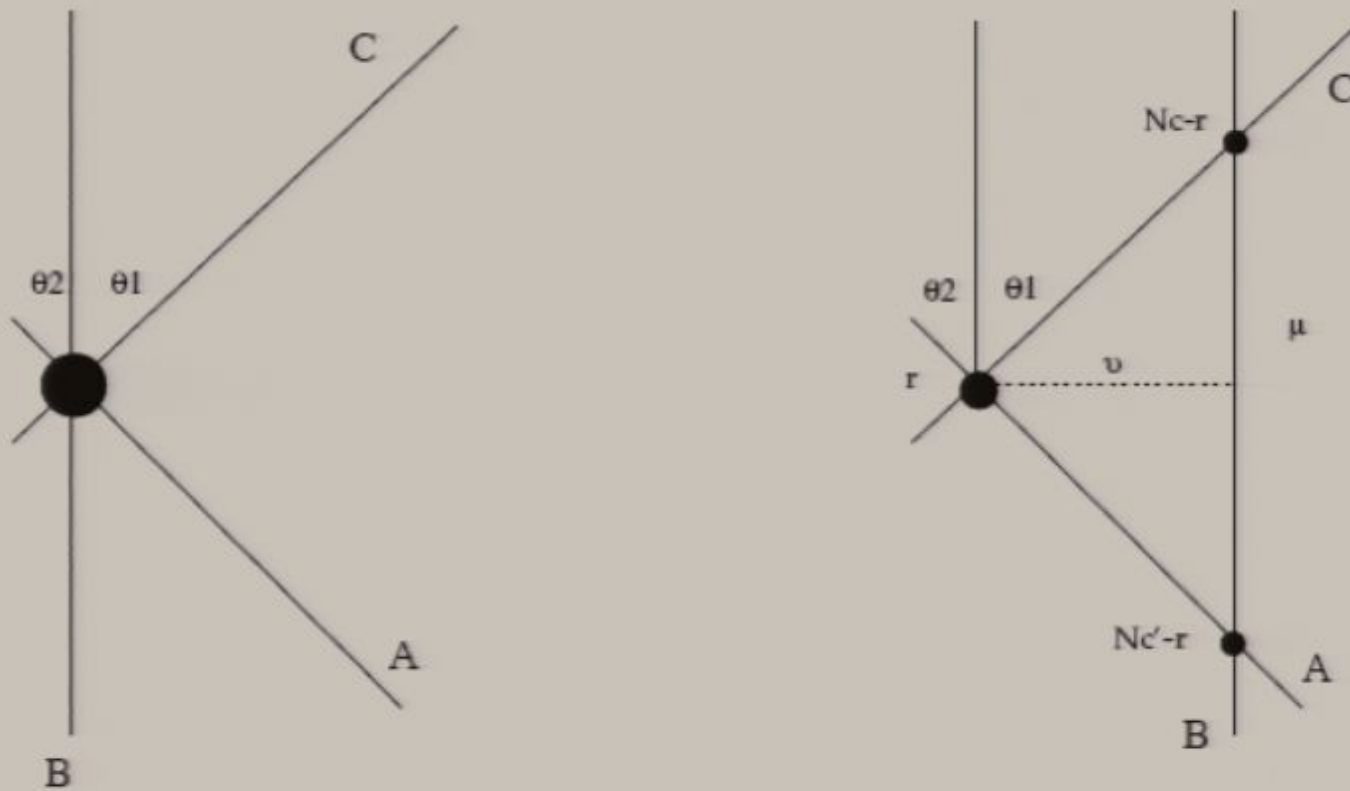
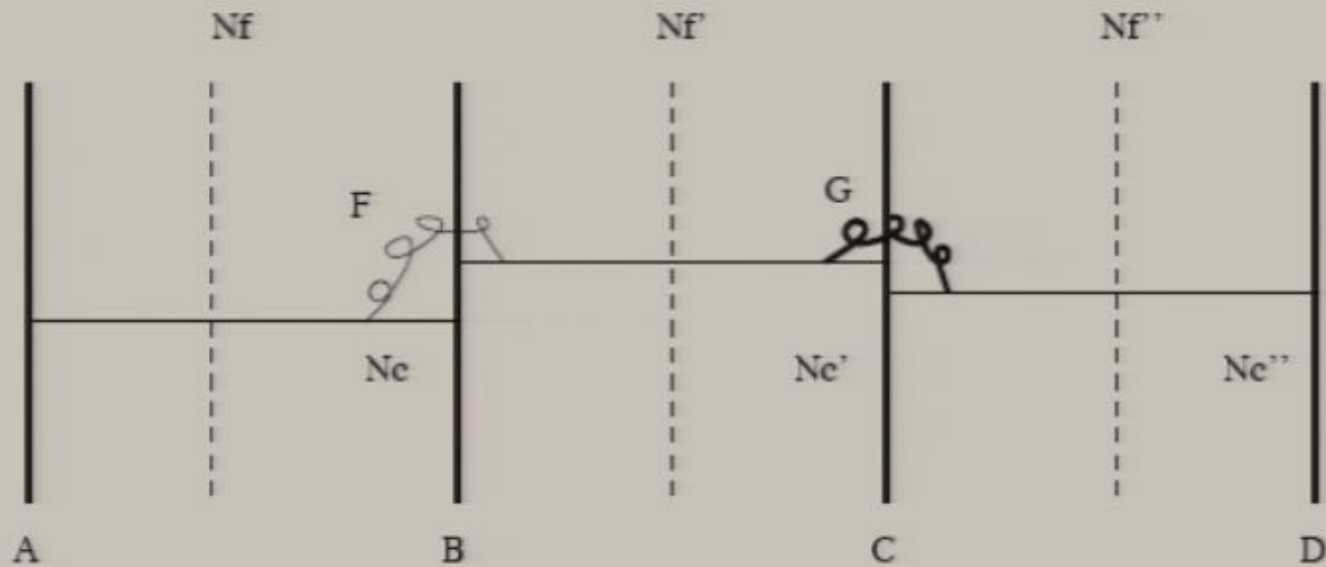
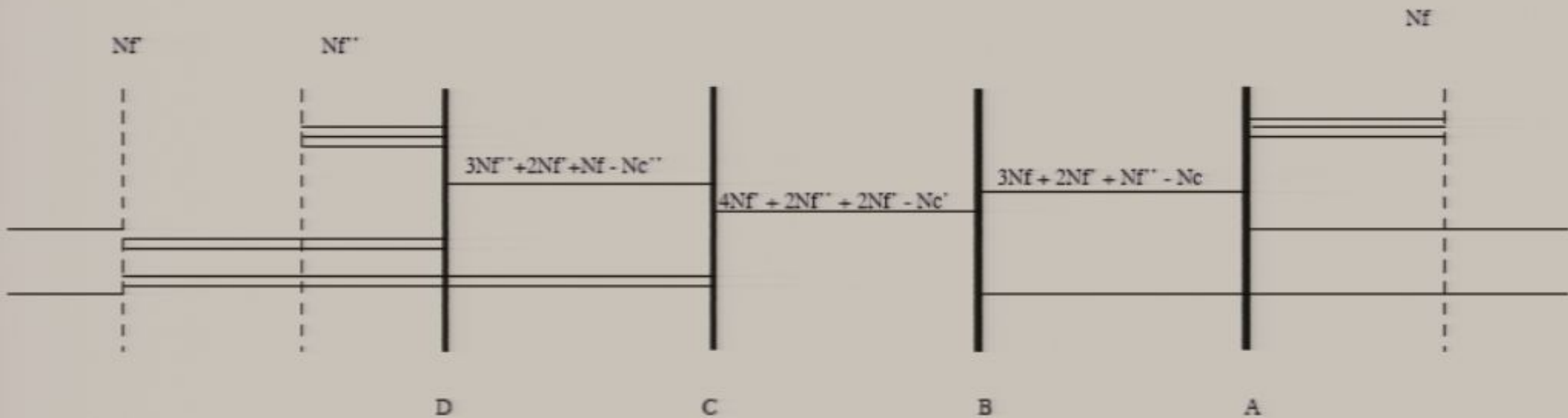


Fig. 7: We see the NS 5-brane configuration in the  $(x^4, x^8)$  plane. The brane configuration on the right has a superpotential  $W = (F\tilde{F})^2$ . The configuration on the left is the same theory perturbed by a mass term  $W = (F\tilde{F})^2 + \mu F\tilde{F}$ . The dotted lines are not branes.

# 3 gauge group factors



# Dual of 3 gauge groups





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