Title: Fractional branes and dynamical SUSY breaking

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Abstract: Fractional branes and dynamical SUSY breaking

Fractional branes and dynamical SUSY breaking

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Princeton University

September 2005

Based on: hep-th/0505040: Franco, Hanany, Saad and Uranga

See also : hep-th/0502113: Franco, Hanany and Uranga

Outline

- AdS/CFT correspondence and extensions
- Fractional branes and RG flows
- The conifold cascade
- Complex deformations and toric geometry
- Classifying fractional branes
- DSB from fractional branes
    - Complex cone over dP_1
    - Combining fractional branes
    - Cones over $Y^{p,q}$ manifolds

AdS/CFT correspondence and extensions

AdS/CFT Correspondence

$\mathcal{N} = 4\ SU(N)$ SYM $\leftrightarrow$ Type IIB on $AdS_5 \times S^5$

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Extend the duality by looking for:

Less SUSY

- Place D3-branes at a singularity
- SUGRA: $AdS_5 \times S^5 \rightarrow AdS_5 \times X^5$

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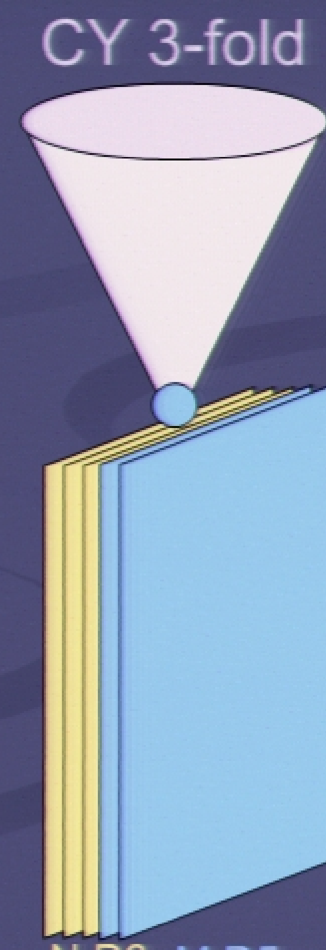
Break conformal invariance

- Add fractional D3-branes (wrapped D5-branes)
- SUGRA: turn on 3-form flux



Quiver theories

Gauge theories that typically arise in our constructions:

- Product gauge group $\prod_{i=1}^{k} SU(d^i)$
- Bifundamental matter

$SU(N_1)$	$SU(N_2)$
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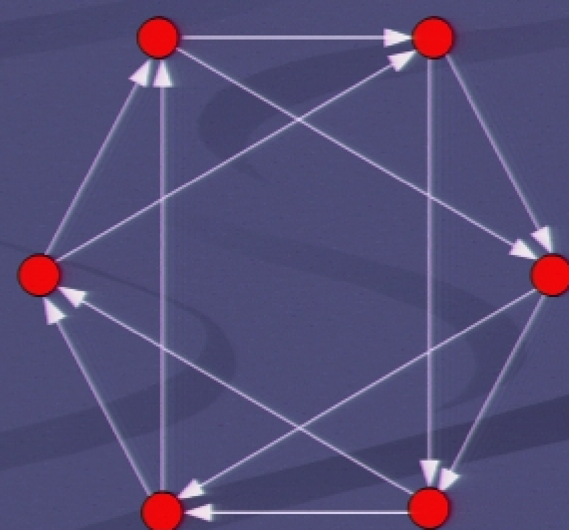
Quiver diagram: simple diagrammatic way of encoding the matter content of a gauge theory



Fractional branes and RG flows: the conifold

Regular and fractional branes ⟷ Anomaly free rank assignments

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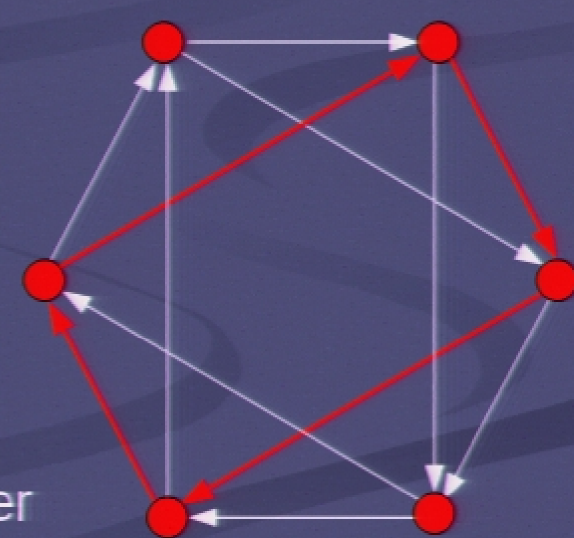
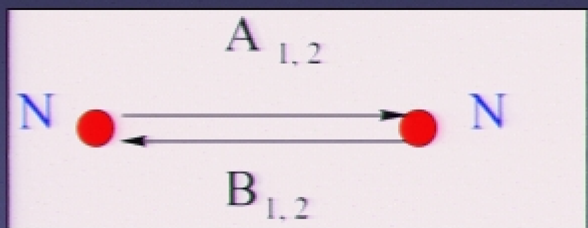


Superpotential terms: oriented polygons in the quiver

Fractional branes and RG flows: the conifold

Regular and fractional branes ⟷ Anomaly free rank assignments



$$W = \frac{\lambda}{2}\epsilon^{ij}\epsilon^{kl}\,\mathrm{Tr}\,A_i B_k A_j B_l$$

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N D3-branes	SU(N) × SU(N)	conformal

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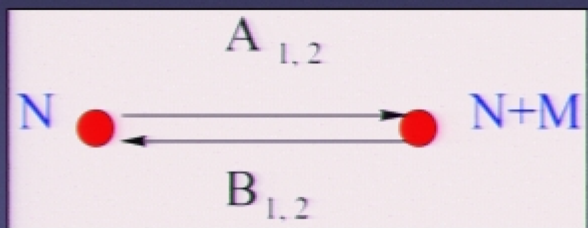

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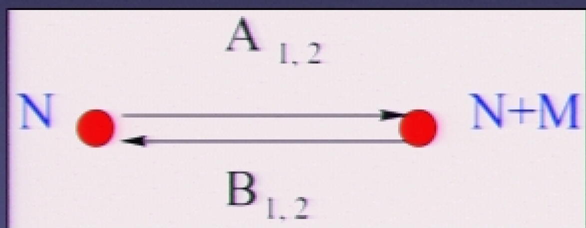

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$$\beta_i = \frac{d(8\pi^2/g_i^2)}{d\ln\mu}$$

$$\beta_1 = 3\,[N + (R_A - 1)(N+M) + (R_B - 1)(N+M)]$$

$$\beta_2 = 3\,[(N+M) + (R_A - 1)N + (R_B - 1)N]$$

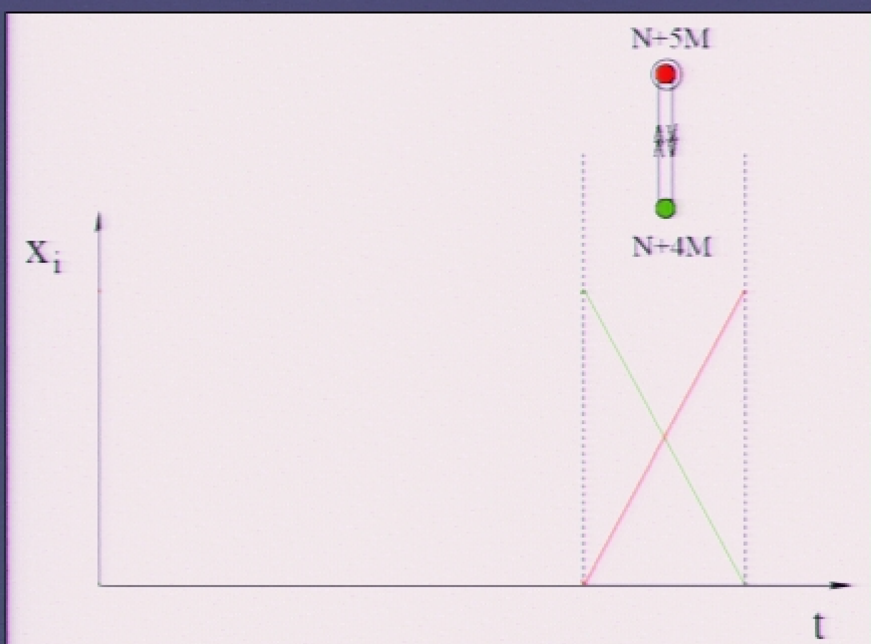
$$R(A) = 1/2 + \mathcal{O}(M/N)^2 \qquad \Rightarrow \qquad \boxed{\beta_1 = -3M}$$

$$R(B) = 1/2 + \mathcal{O}(M/N)^2 \qquad \qquad \boxed{\beta_2 = \;\;3M}$$

Duality Cascade

Duality Cascade	go beyond infinite coupling by switching to an alternative Seiberg dual description
	Klebanov and Strassler

The conifold example



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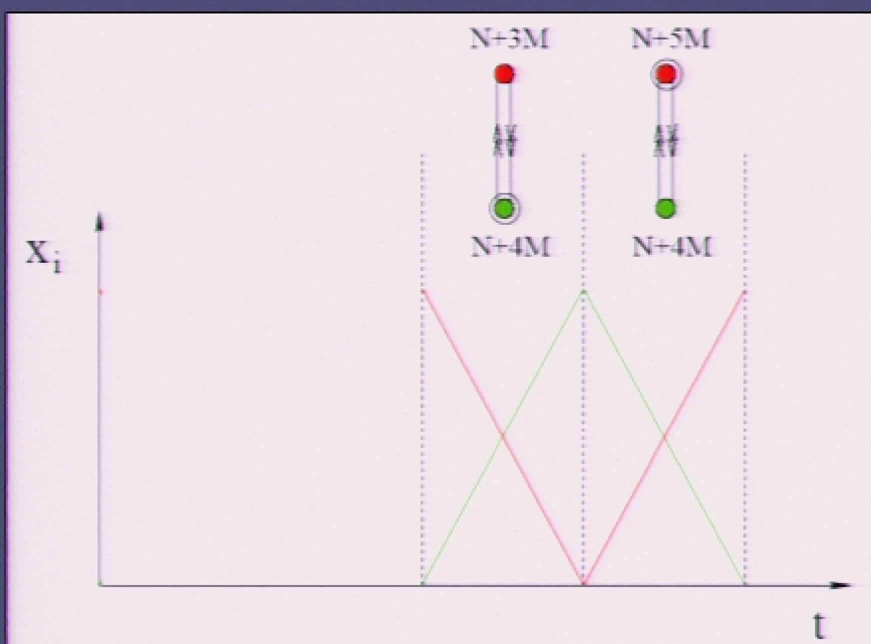

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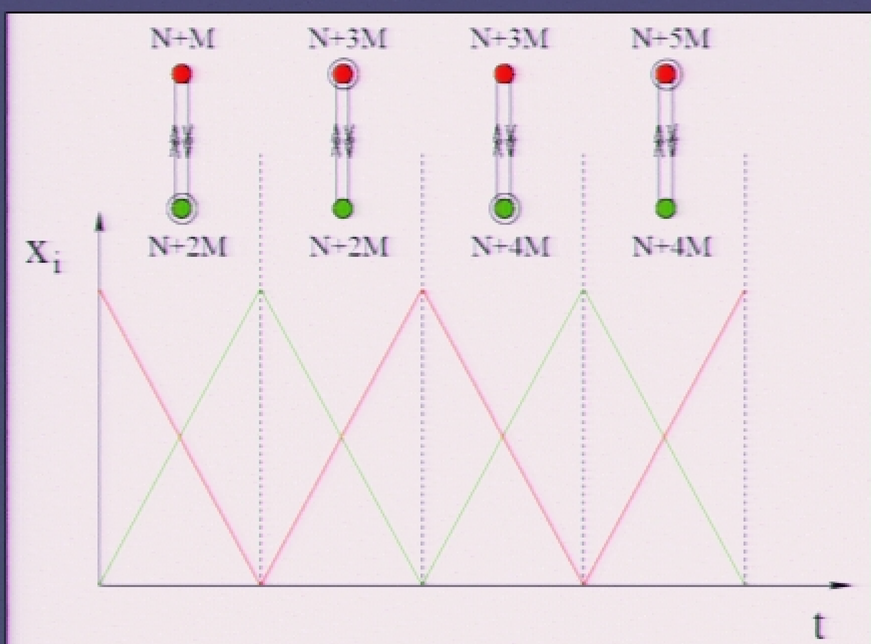

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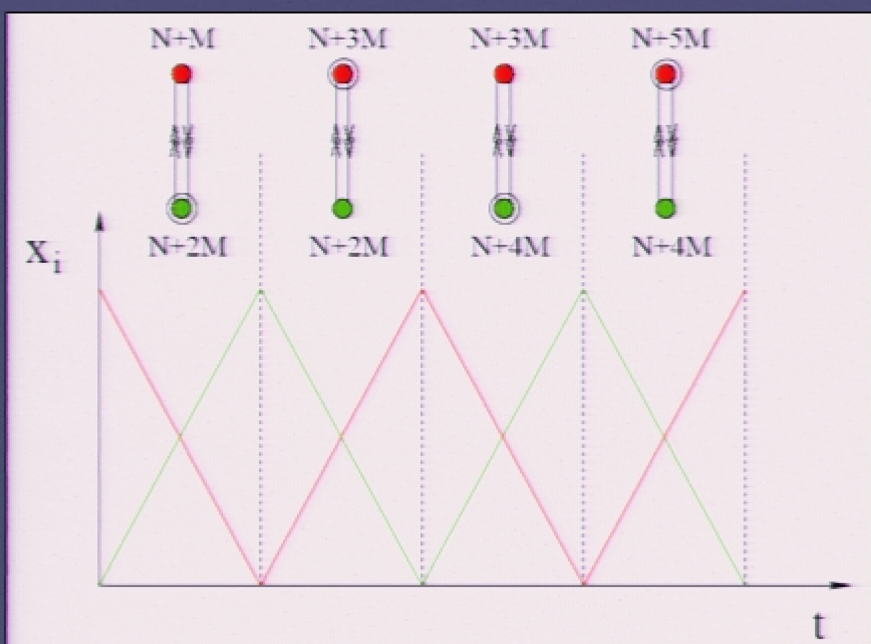
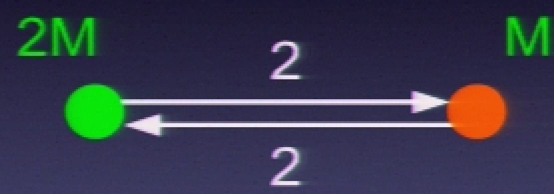


- Periodic flow
- # D5-branes: $M = \text{const}$
- # D3-branes: $N \sim t = \log \mu$

The end of the cascade

● : 2M colors with 2M flavors

The end of the cascade



- : 2M colors with 2M flavors ⟶ quantum corrected moduli space

$$\det M - B\tilde{B} = \Lambda^{4M}$$

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$$\downarrow$$

Deformed conifold

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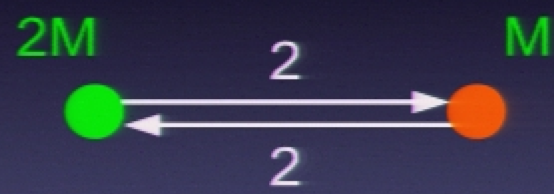

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Deformed conifold

- Logarithmic RG flow
- In the IR: confinement and chiral symmetry breaking

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} This behavior is nicely captured by a SUGRA dual

Klebanov and Strassler

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Related developments

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- Brane tilings: towards the gauge theory dual of an arbitrary toric singularity

Complex deformations and toric geometry

Toric varieties

- Admit an $U(1)^d$ action. T^d fibrations
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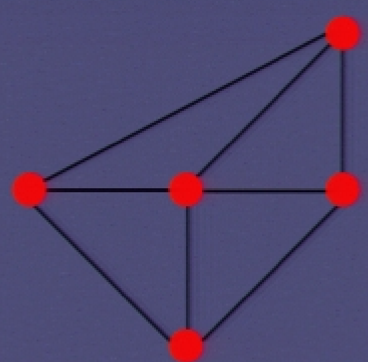

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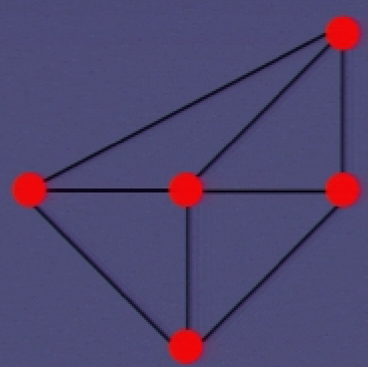

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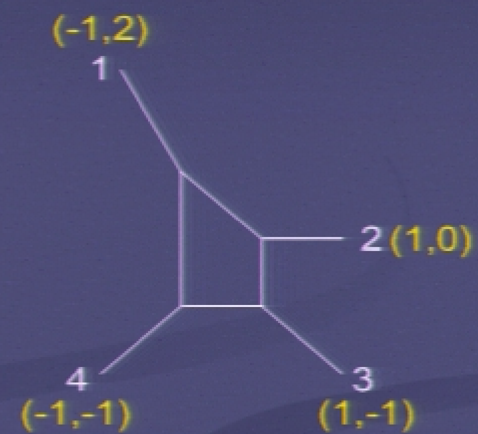

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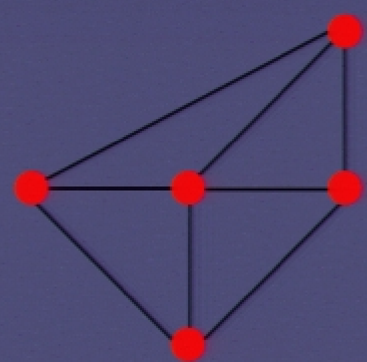

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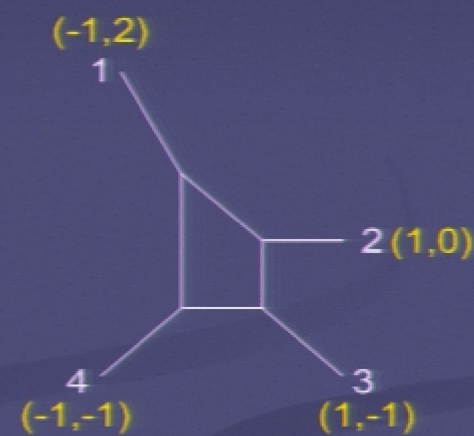

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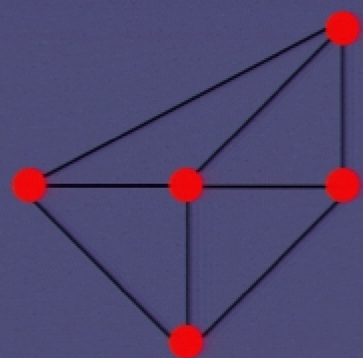

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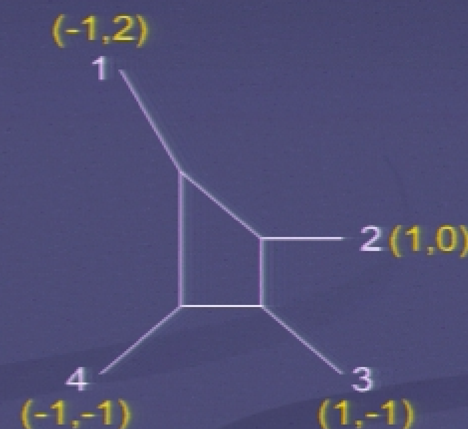

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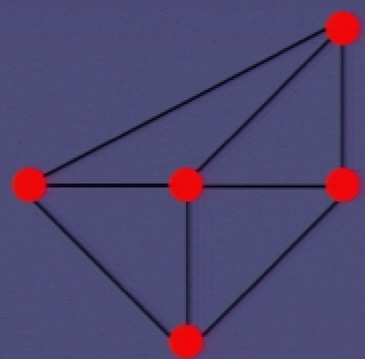

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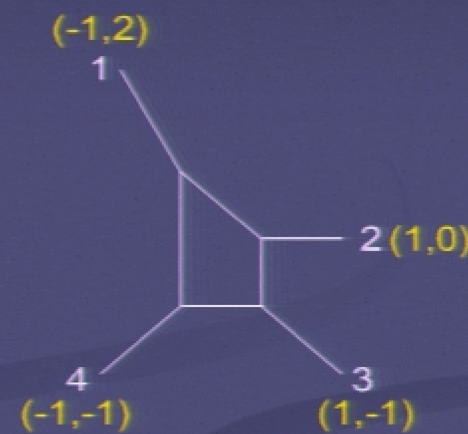

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Unobstructed complex deformations ⟷ Decomposition of toric polytope into Minkowsky sum

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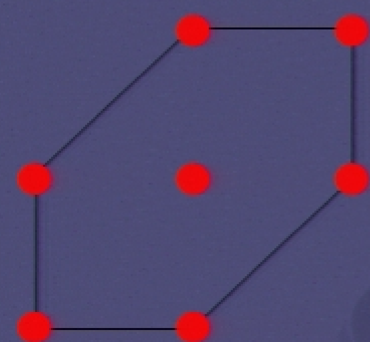
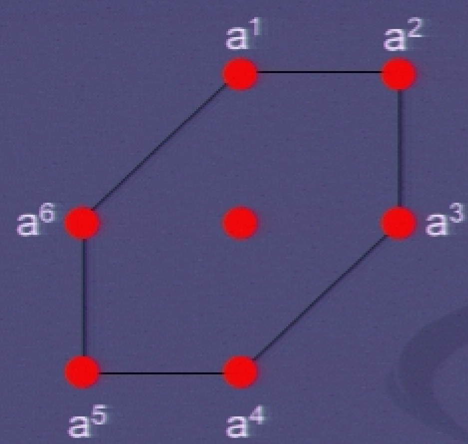


Obstructed deformations

Unobstructed complex deformations ⟷ Decomposition of toric polytope into Minkowsky sum

- a^i: vertices of toric diagram i = 1 to N



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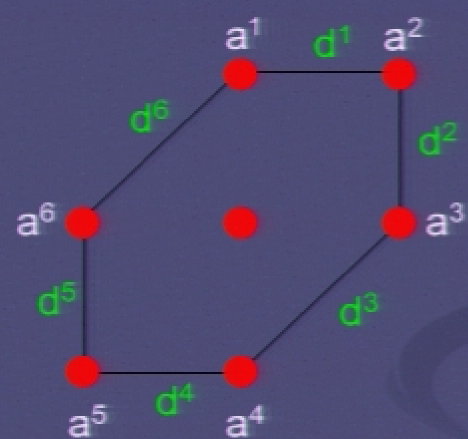

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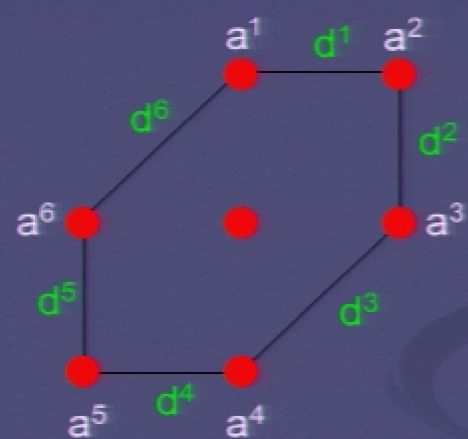

$$\sum_{i=1}^{N} (t_i)^k \, d^i = 0 \qquad 0 < k \leq K$$

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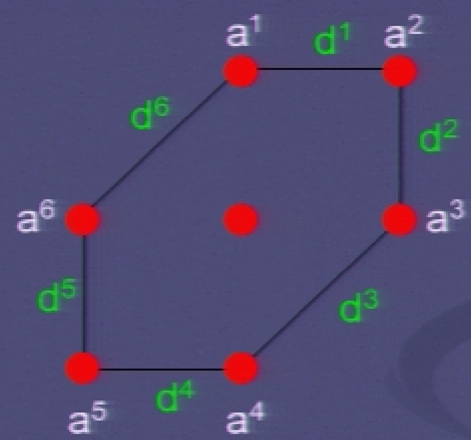

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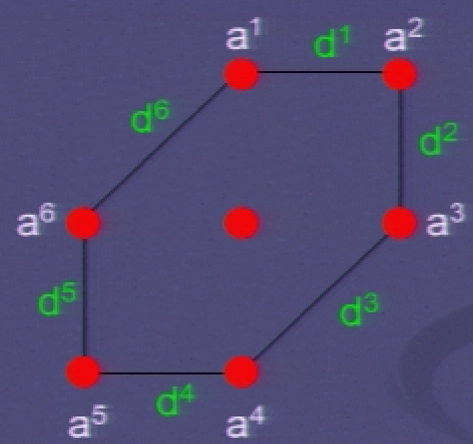

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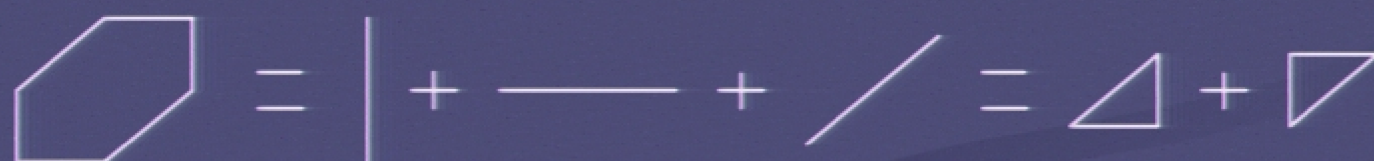

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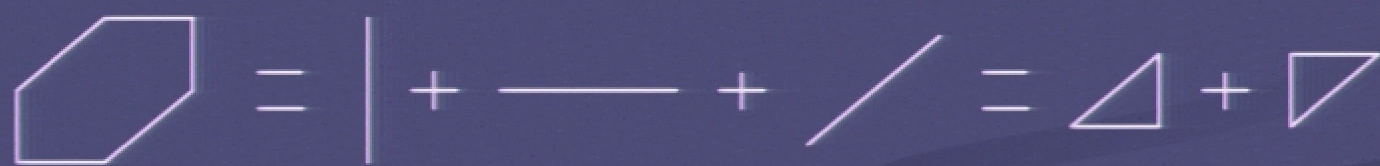

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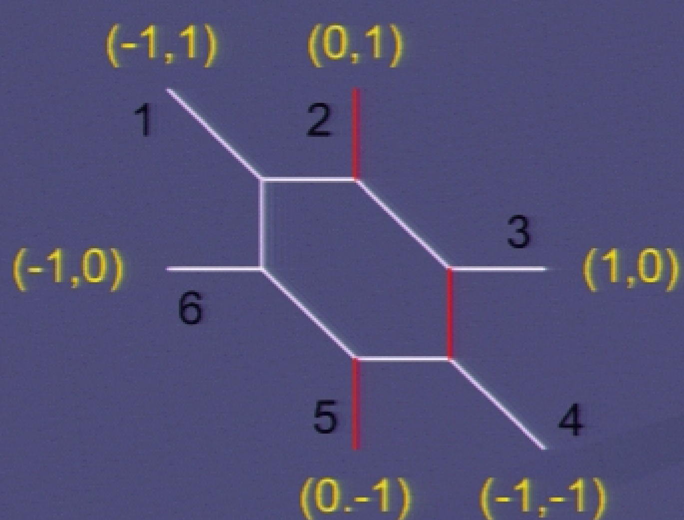

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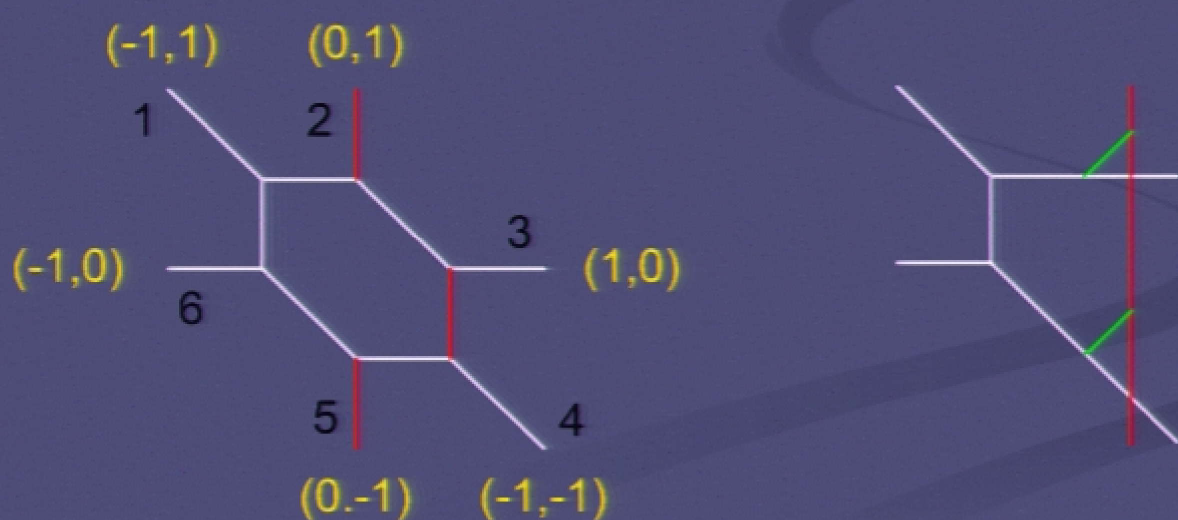

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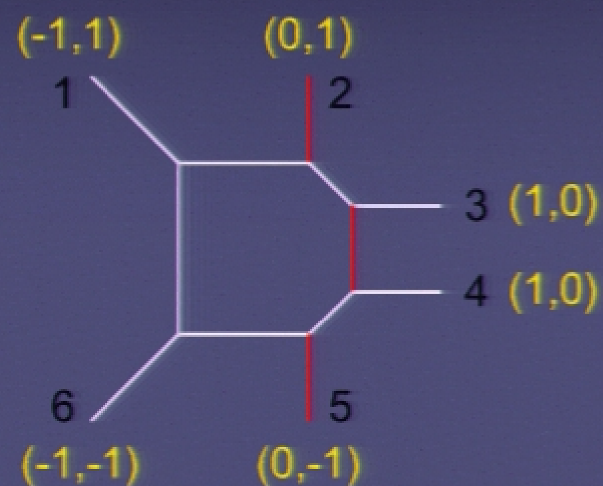

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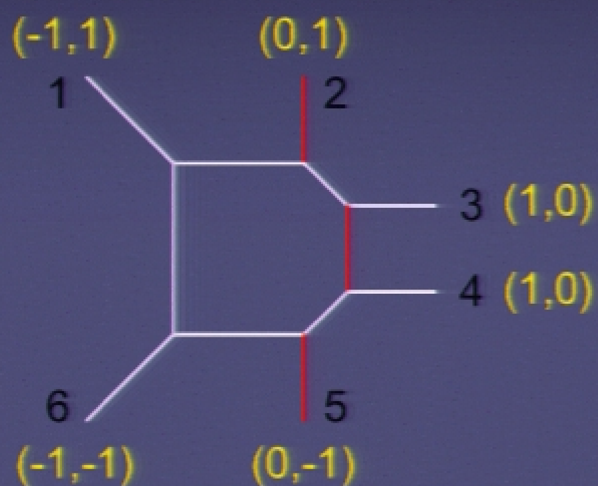

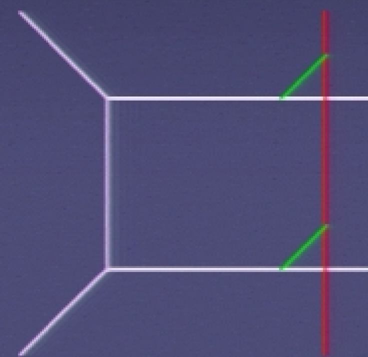

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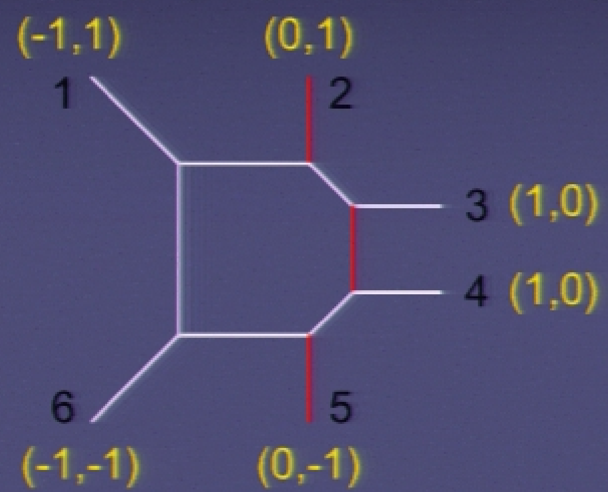

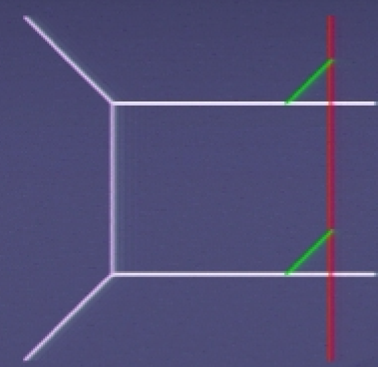

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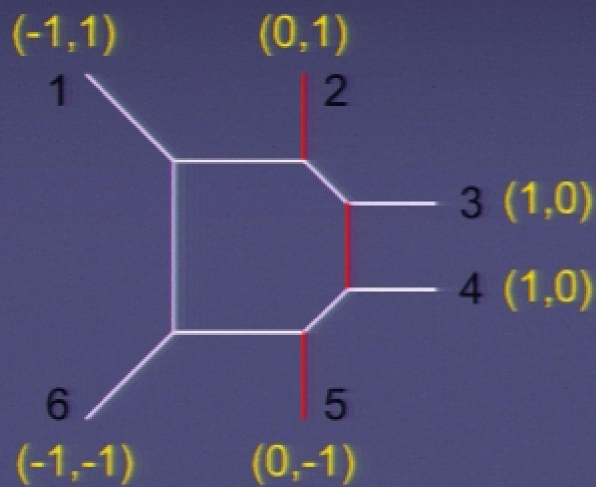

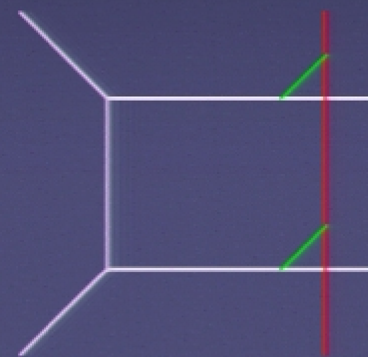

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DSB fractional branes

- All other rank assignments. Typically a gauge group generates an ADS superpotential

Franco, Hanany, Saad and Uranga
Berenstein, Herzog, Ouyang and Pinansky
Bertolini, Bigazzi and Cotrone

An example in detail: dP1

Complex cone over dP_1

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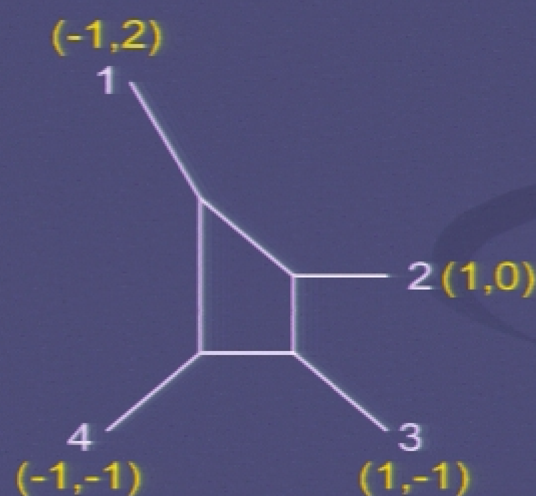

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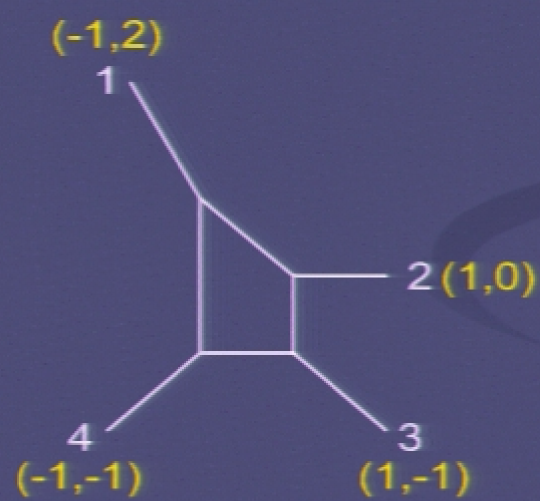

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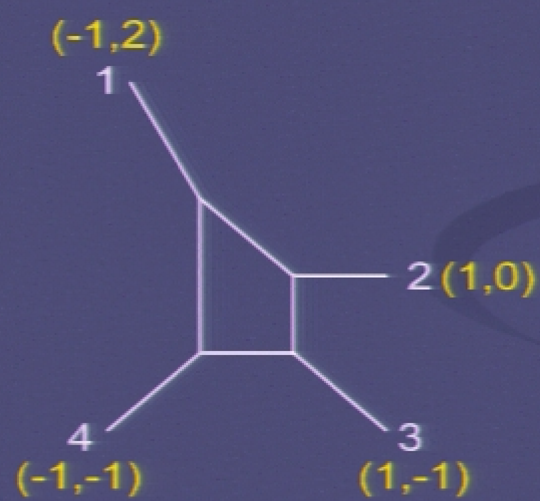
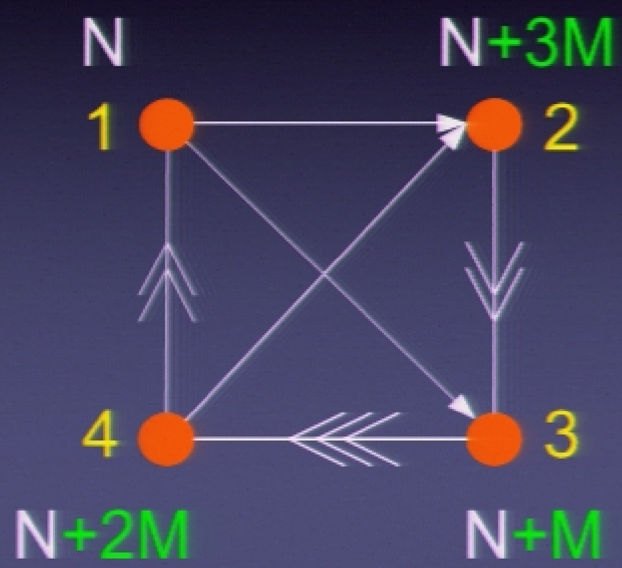


No decomposition of the (p,q) web → Complex deformation is obstructed → What happens at the IR bottom of the cascade?

Field theory analysis

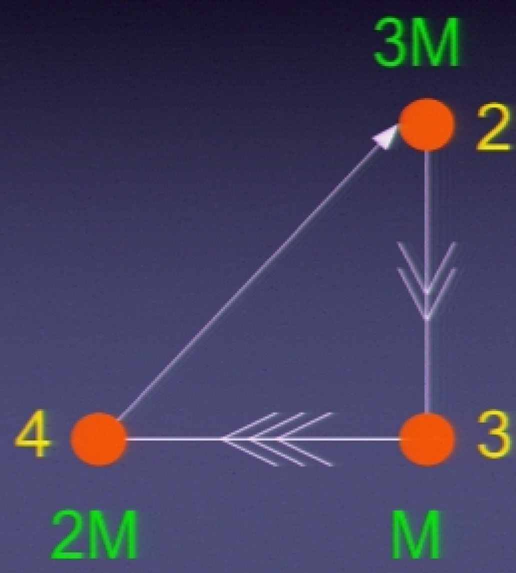


Global symmetry:

$SU(2) \times U(1)_F \times U(1)_R \times U(1)_B$

$$W = \epsilon_{\alpha\beta} X_{23}^{\alpha} X_{34}^{\beta} X_{42} + \epsilon_{\alpha\beta} X_{34}^{\alpha} X_{41}^{\beta} X_{13} - \epsilon_{\alpha\beta} X_{12} X_{23}^{\alpha} X_{34}^{3} X_{41}^{\beta}$$

Field theory analysis



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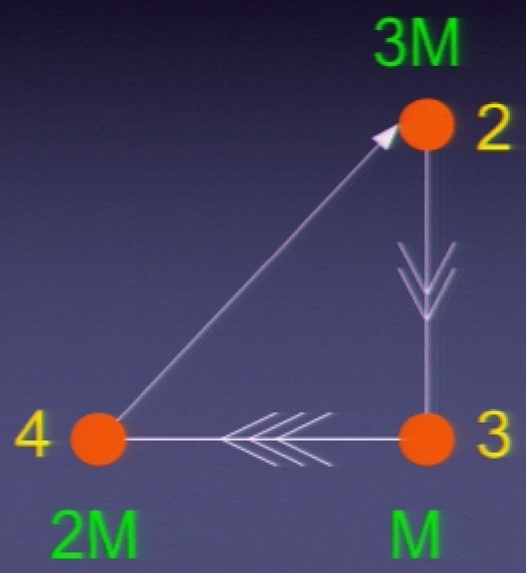

Fractional branes

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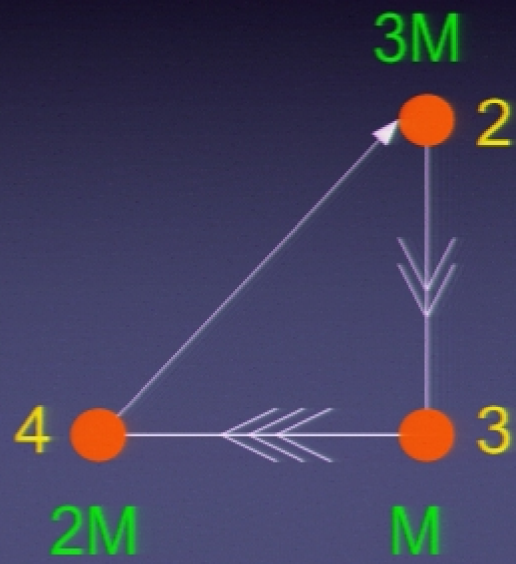

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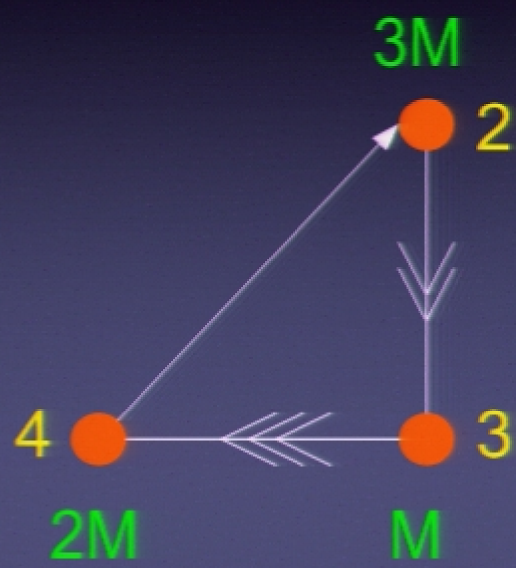

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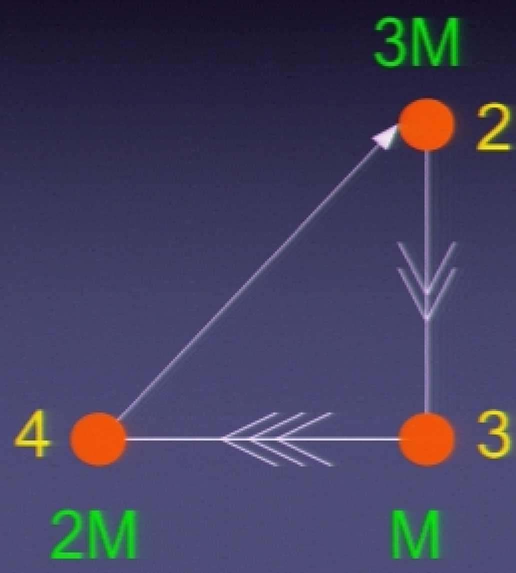

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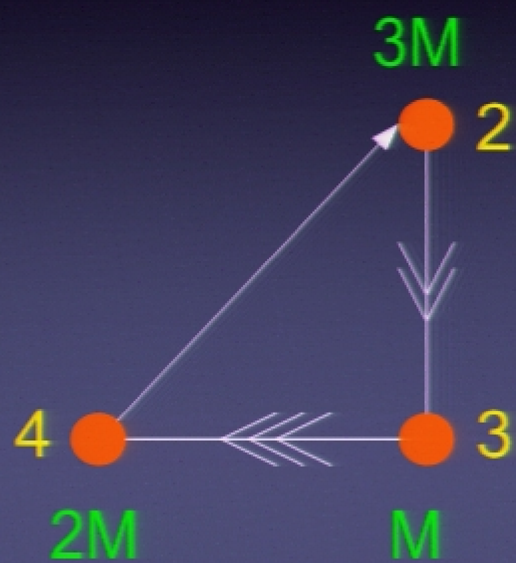

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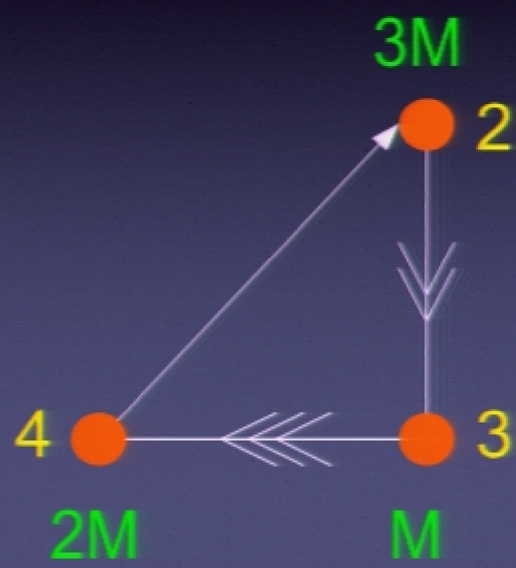

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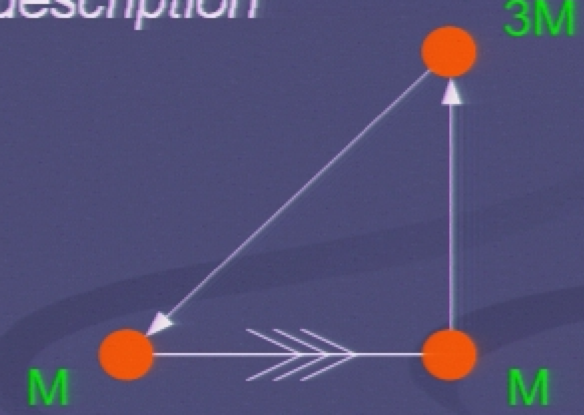

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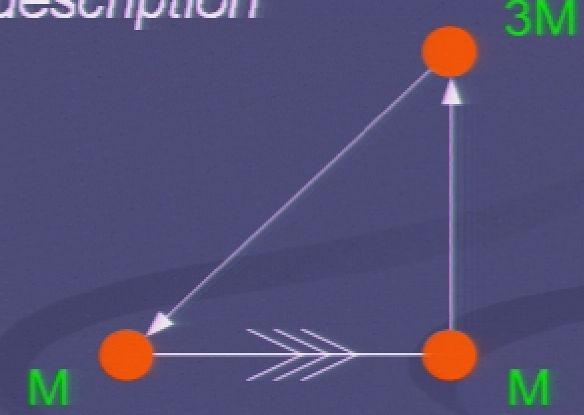

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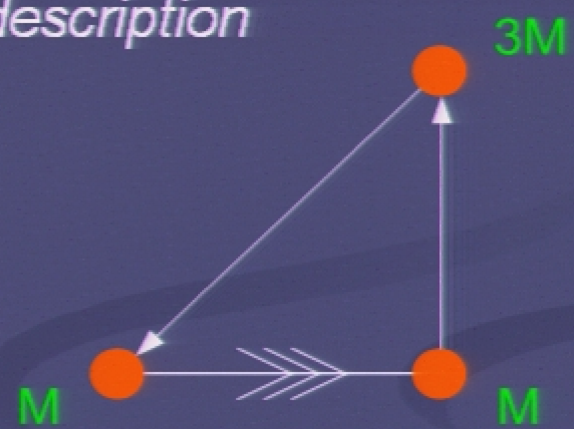

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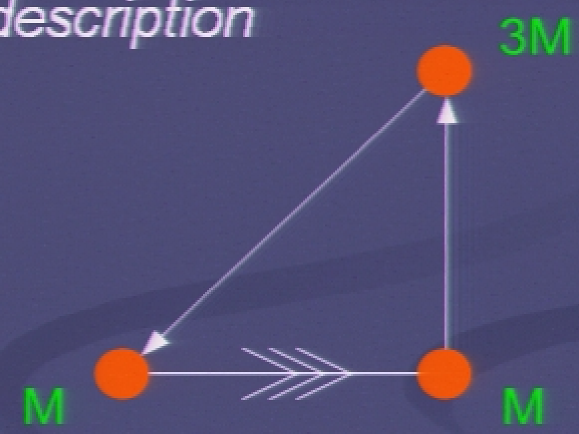

$$W = M_{34}Z_{43} + 2\left(\frac{\Lambda^8}{M_{34}}\right)^{1/2}$$

$$V_F = |M_{34}|^2 + \left|Z_{43} + \Lambda^4 M_{34}^{-3/2}\right|^2 \longrightarrow \begin{array}{l} M_{34} \to 0 \\ Z_{43} \to \infty \end{array}$$

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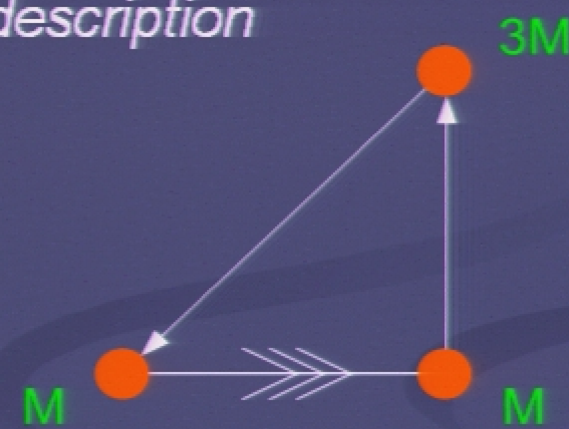

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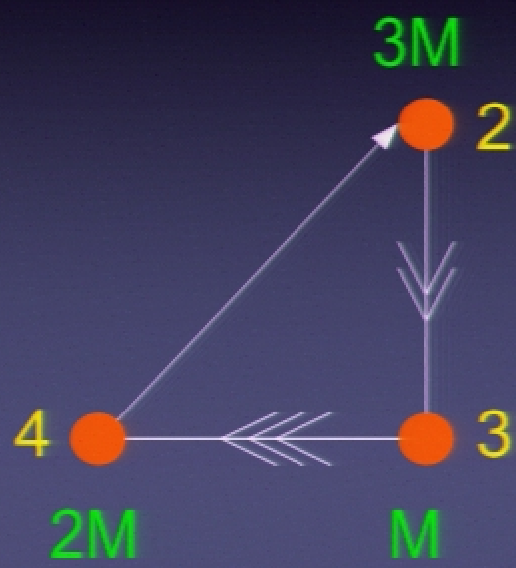

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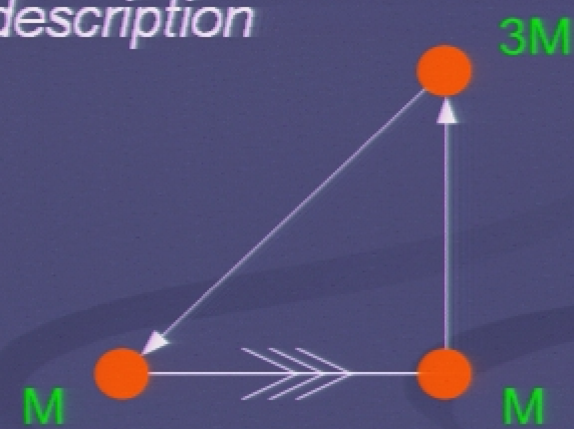

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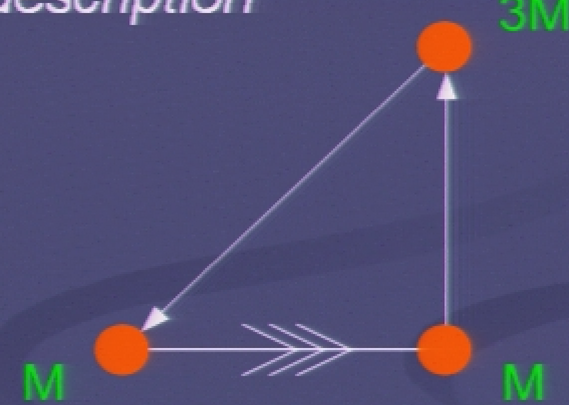

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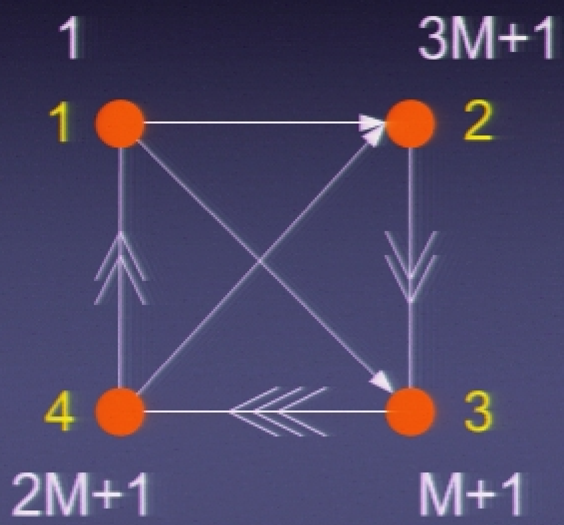
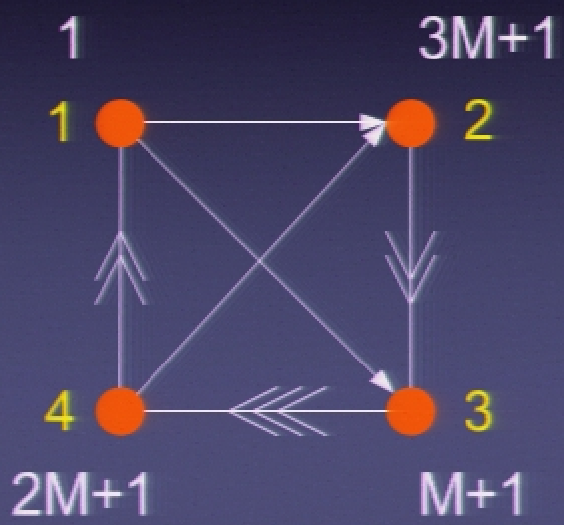
15

D3-brane probe analysis



$SU(3M+1) \times SU(M+1) \times SU(2M+1)$

D3-brane probe analysis



Flat direction: $X_{42}\, Y_{23}\, Z_{34}$

SU(3M+1) × SU(M+1) × SU(2M+1)

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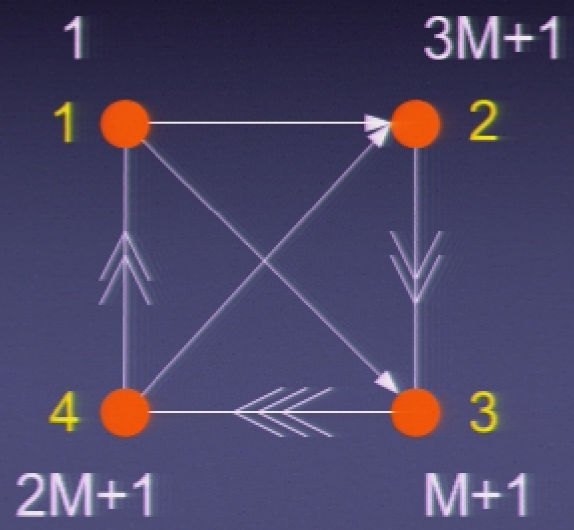

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$SU(3M+1)$ 2M+2 flavors

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ADS superpotential for mesons

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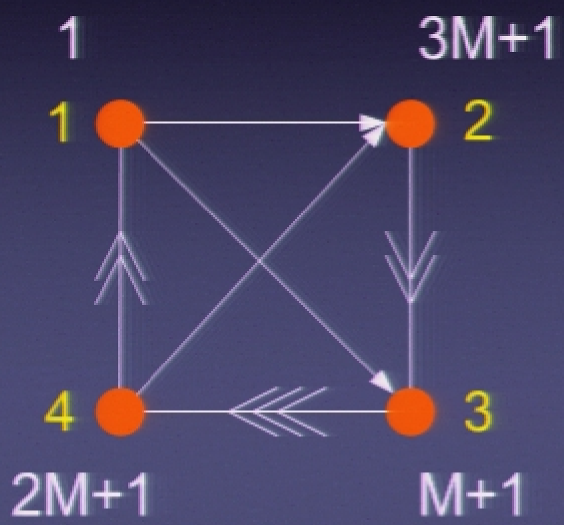

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SU(3M+1) 2M+2 flavors

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ADS superpotential for mesons

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$$M = \begin{pmatrix} X_{12}\, X_{23} & X_{12}\, Y_{23} \\ X_{42}\, X_{23} & X_{42}\, Y_{23} \end{pmatrix}$$

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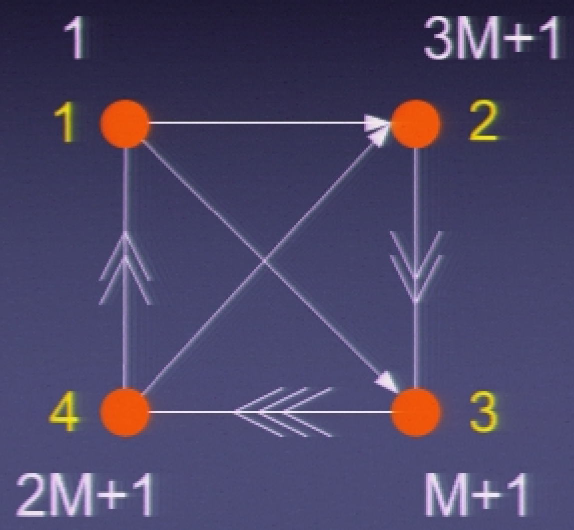

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The D3-brane is repelled from the origin → Not a complex deformation preserving CY with ISD fluxes

Combining fractional branes

different types of fractional branes
that independently lead to SUSY
RG flows

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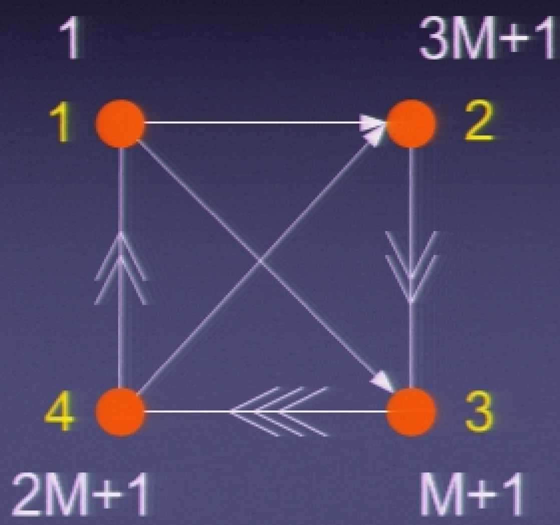

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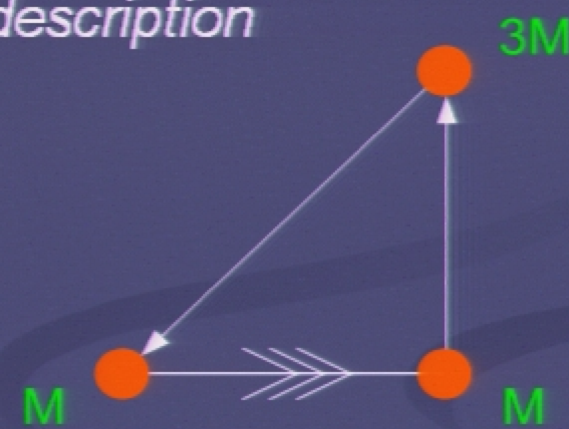

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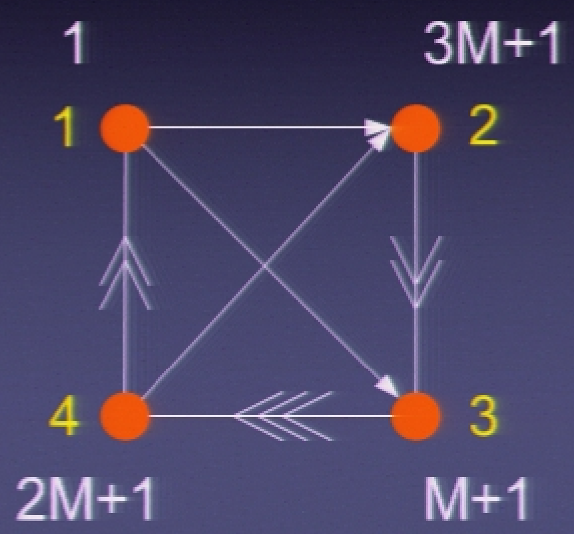

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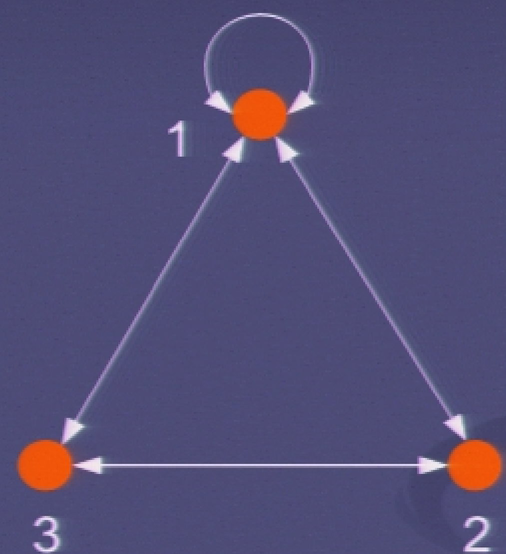
Example: Suspended Pinch Point (SPP)



$x\,y = z\,w^2$

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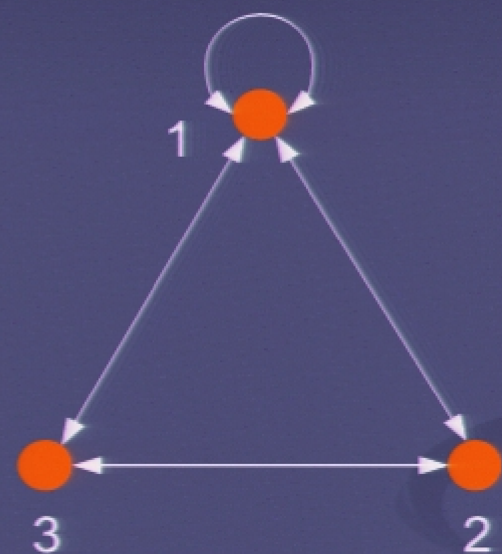

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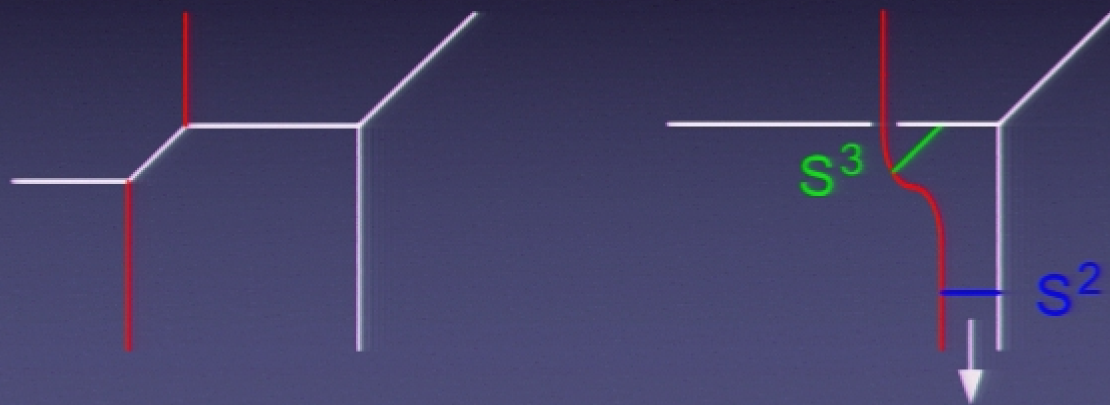
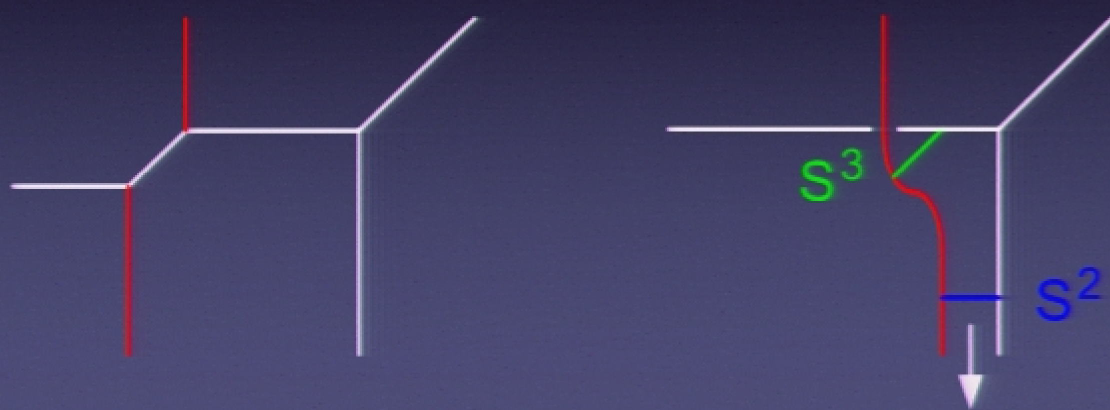
(0,1,0) Complex deformation

(1,0,0) N=2 brane moves along line of A_1 singularities parametrized by z (X_{11})

- both types of fractional branes are incompatible



- both types of fractional branes are incompatible



We expect runaway behavior, with the (1,0,0) brane escaping to infinity

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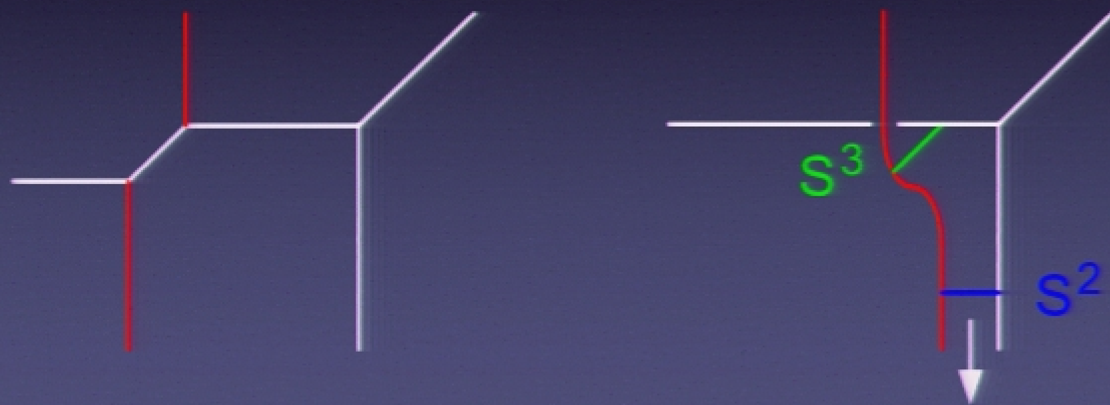

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E.g. consider:

of (0,1,0) branes = P

of (1,0,0) branes = M

P >> M

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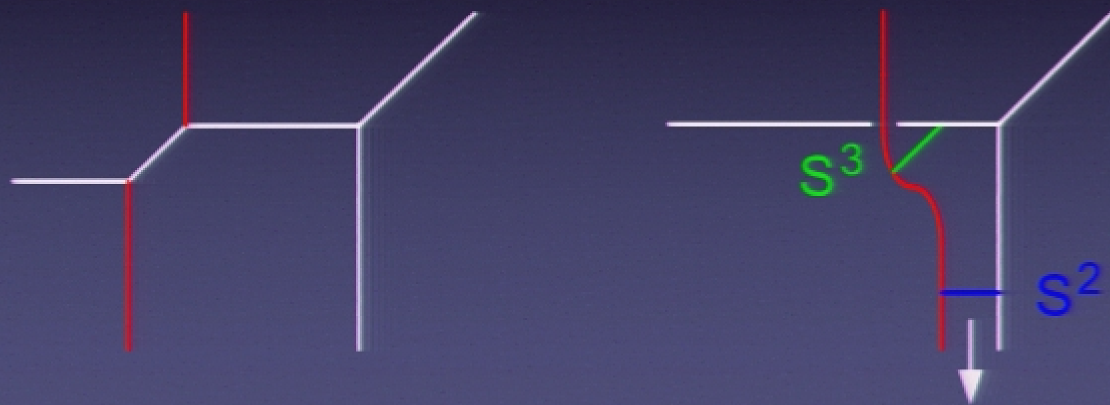

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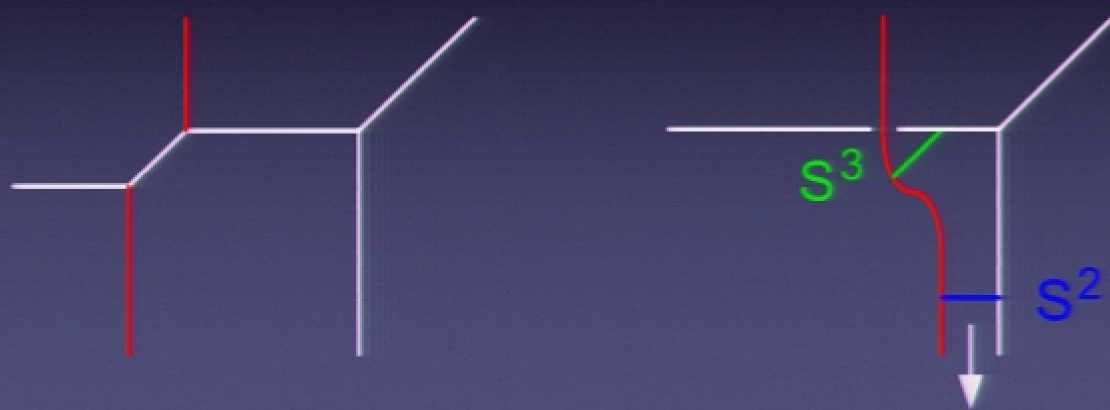

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P >> M

- SU(P) gauge group has M flavors and develops ADS superpotential
- There is no SUSY vacuum and $X_{11} \rightarrow \infty$

$Y^{p,q}$ manifolds

- Infinite family of explicit Sasaki-Einstein metrics

  Gauntlett, Martelli, Sparks and Waldram

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- $S^2 \times S^3$ topology $\rightarrow$ one single type of fractional branes

$Y^{p,q}$ manifolds

- Infinite family of explicit Sasaki-Einstein metrics

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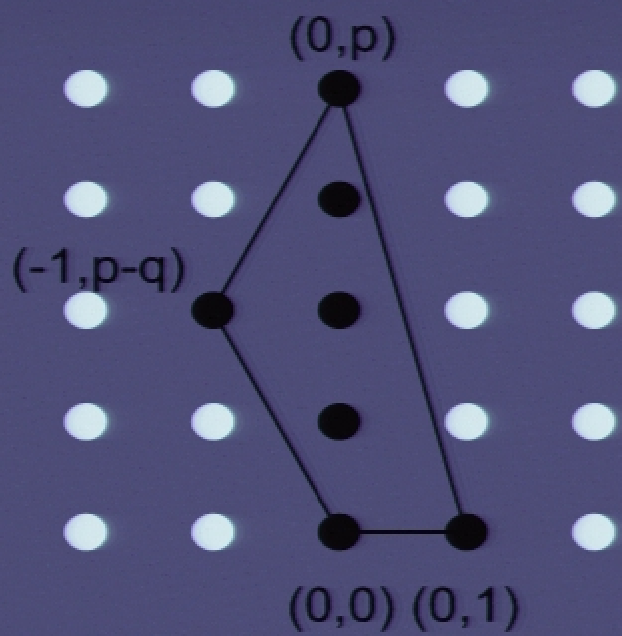

$0 \leq q \leq p$

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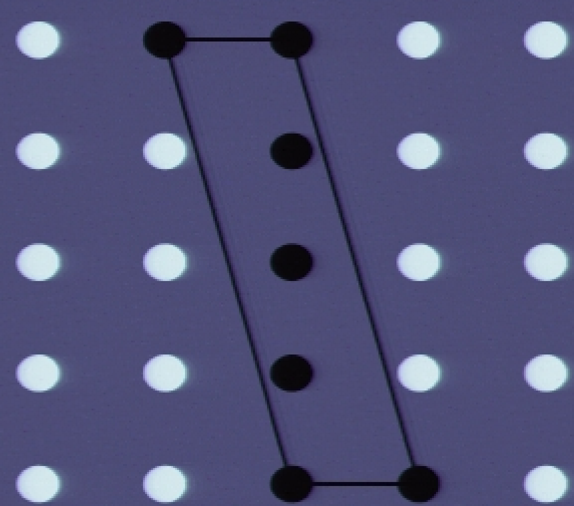

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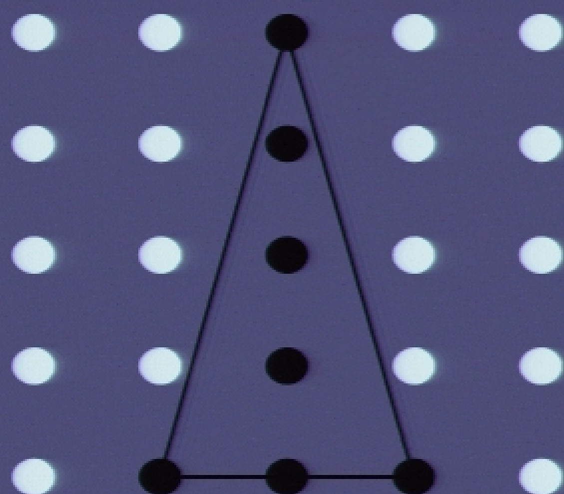

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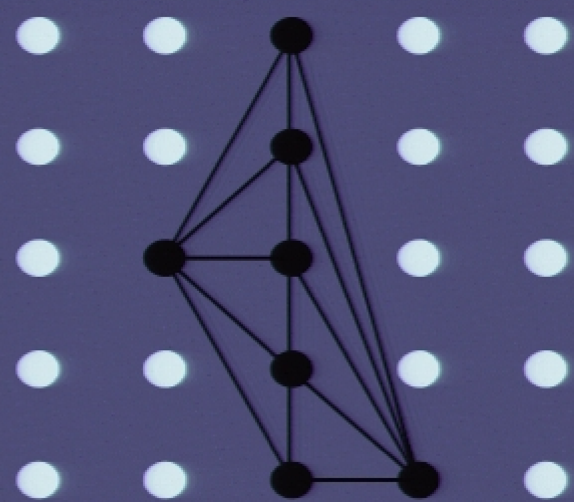

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- Supergravity solutions dual to the UV region of the cascades have been constructed

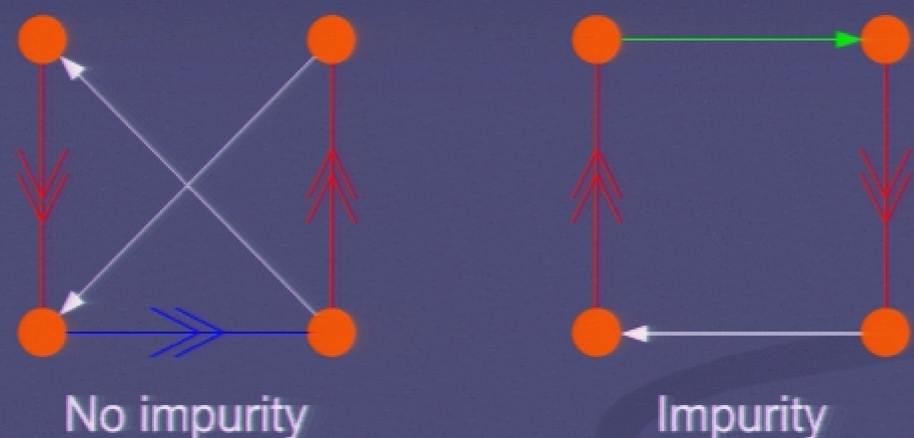
Ejaz, Herzog and Klebanov

- Complex deformation obstructed for all $p \neq q$

Not in contradiction with 1st order complex deformations

Burrington, Liu, Mahato and P. Zayas

- Start from $Y^{p,p} = S^5 / Z_{2p}$ and add (p-q) impurities



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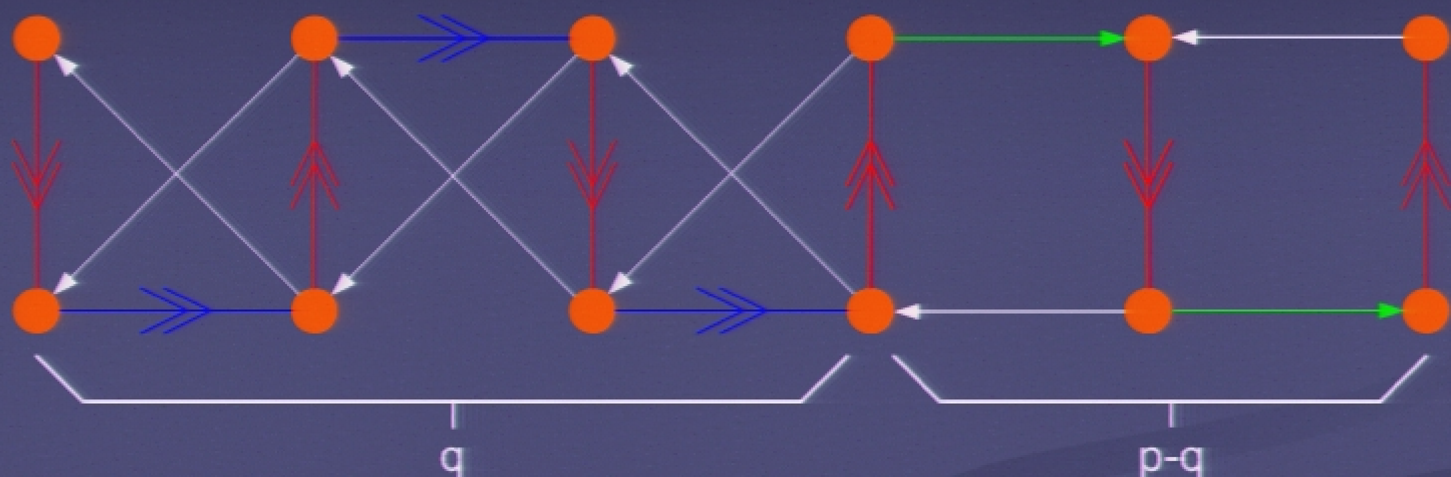
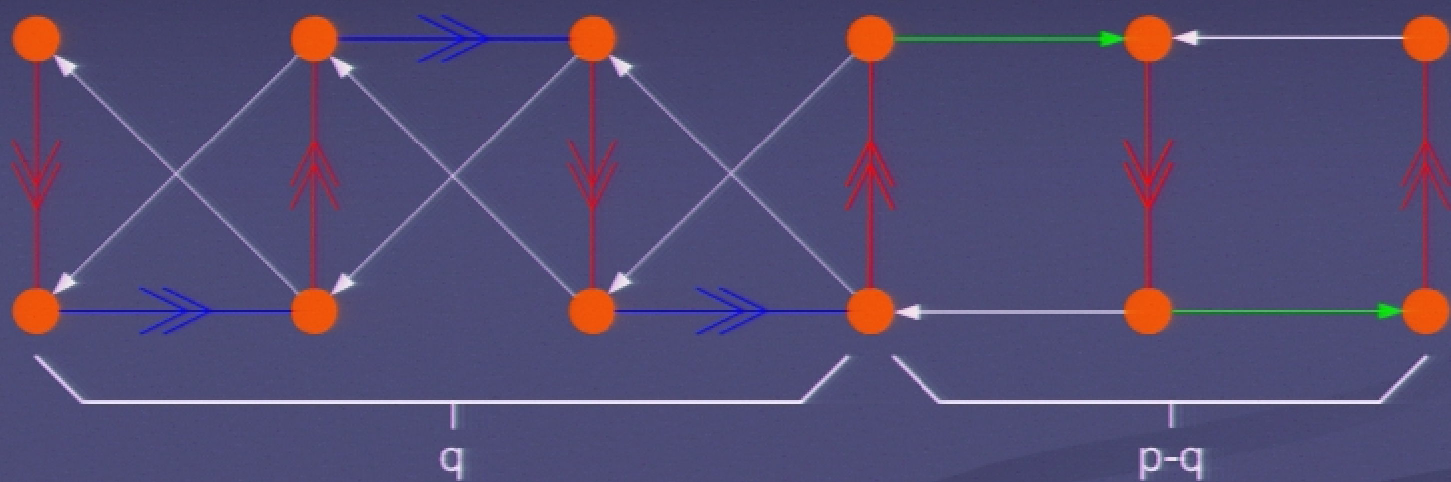


- Complex deformation obstructed for all p ≠ q

Not in contradiction with 1st order complex deformations

Burrington, Liu, Mahato and P. Zayas



- Construct rank vector of fractional brane using baryonic charges of bifundamental fields

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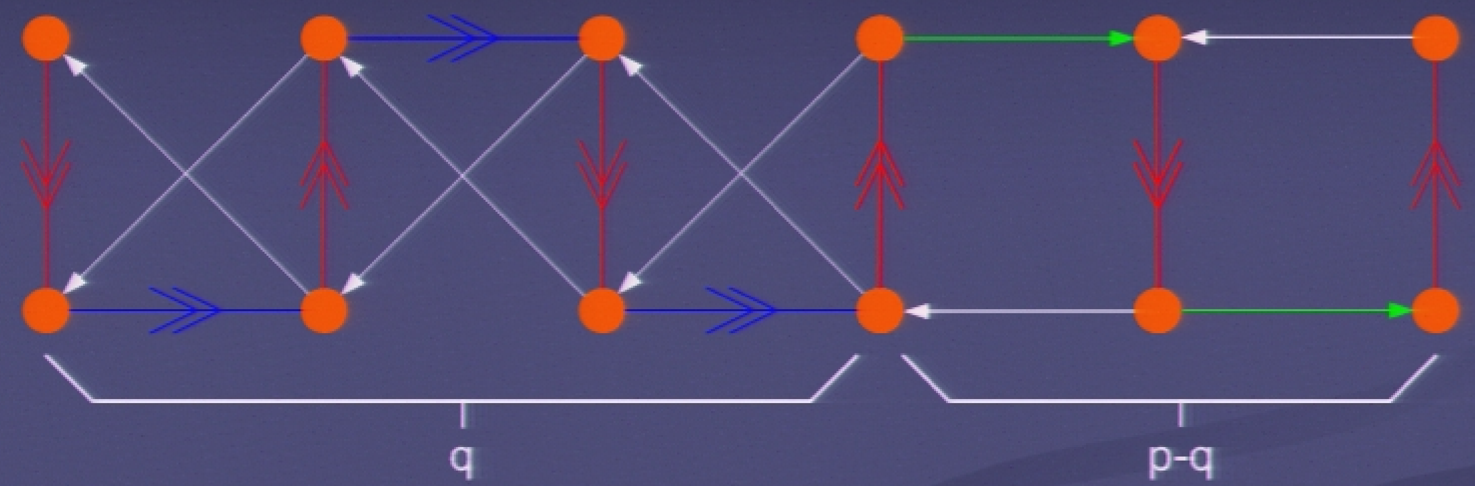

- Construct rank vector of fractional brane using baryonic charges of bifundamental fields
- For the last node:

$$N_F - N_C = -p + q < 0 \quad \text{for} \quad q < p$$

- An ADS superpotential is generated and DSB takes place

Conclusions

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Further directions

- Turn these ideas into a simple mechanism to generate DSB in realistic models