

# Axion monodromy in warped throats



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In collaboration with  
S. Franco, D. Galloni, A. Retolaza, arXiv:1405.7044

c.f. Marchesano's talk

Planck 2014, Paris, May 2014

# Axion monodromy inflation

Silverstein, McAllister, Westphal, ...

- Recent interest in large field inflation (BICEP2)
- Scalars with shift symmetry (axions) are well protected  
continuous symmetry broken by non-pert effects to a discrete periodicity
- String theory axions have sub-Planckian decay constant

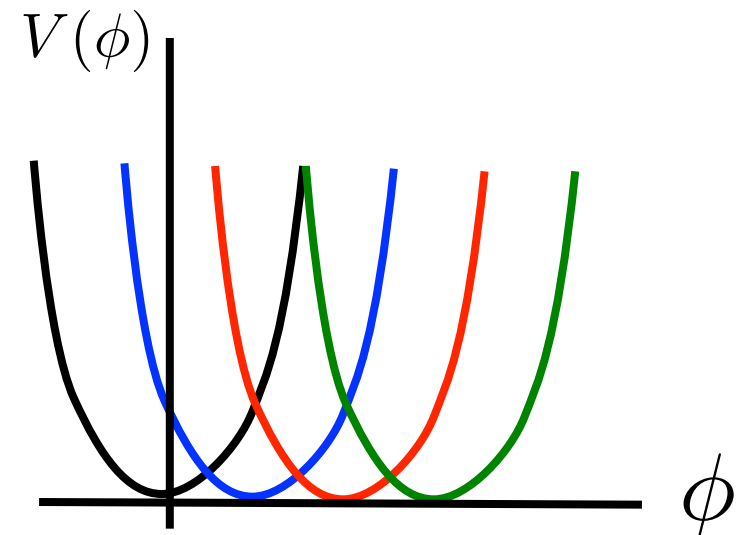
Axion monodromy:

Potential is periodic but multivalued

Field theory analogue:

theta dependent vacuum energy

in large N pure gluodynamics **Witten**



# New and better axion monodromy inflation

Marchesano, Shiu, A.U.

Monodromy idea is nice, but early models are cumbersome

Beautiful general framework “F-term axion monodromy”  
(although susy not crucial) c.f. Marchesano’s talk

A nice class: axions in flux compactifications

10d Chern-Simons  $\Rightarrow$  modified field strengths

$$\int_{10d} B_2 \wedge F_p \wedge F_{p+2} \quad \Rightarrow \quad \tilde{F}_{p+2} = dC_{p+1} + B_2 \wedge F_p$$

Integrating over fluxed CY with  $\phi = \int_{\Sigma_2} B_2$ ,  $M = \int_{\Pi_p} F_p$

Change in axion induces extra flux

$$\Delta\phi \rightarrow \Delta \int_{\Sigma_2 \times \Pi_p} \tilde{F}_{p+2} = \phi M$$

# New and better axion monodromy inflation

Marchesano, Shiu, A.U.

## A nice class: axions in flux compactifications

Change in axion induces extra flux

$$\Delta\phi \rightarrow \Delta \int_{\Sigma_2 \times \Pi_p} \tilde{F}_{p+2} = \phi M$$

Kinetic term for (p+2)-form leads to  $V \sim m^2 \phi^2$

Alternative effective field theory, contact with **Kaloper, Sorbo, Lawrence**

$$\int_{10d} B_2 F_p F_{p+2} \rightarrow \int_{4d} M \phi F_4$$

## Monodromy

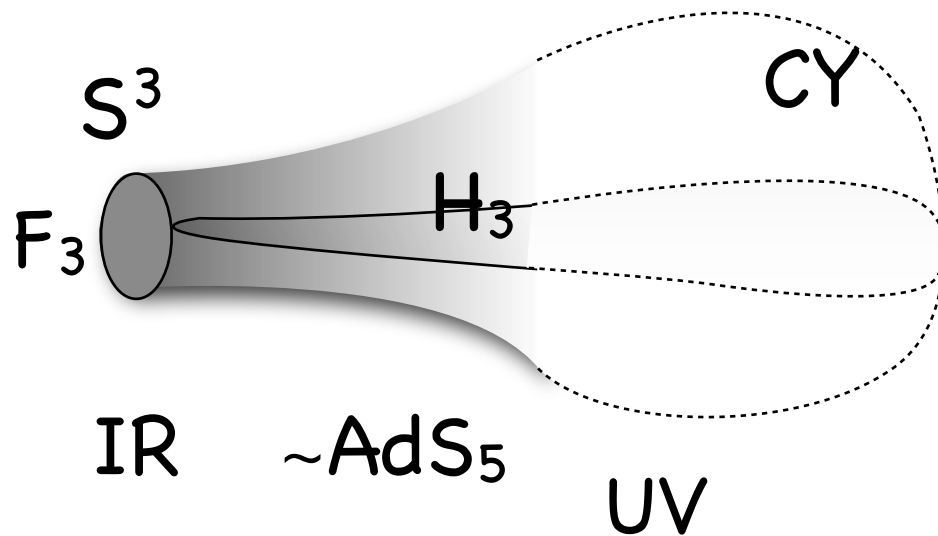
Multiple branches connected by domain walls changing (p+2)-form flux. They are D(6-p) on (4-p)-cycle

# Scales and warped throats

- Fluxes enter into moduli stabilization and inflaton potential

Require mild hierarchy between the two scales

- Explore use of warped throats



Randall, Sundrum;  
Verlinde; Klebanov, Strassler;  
Giddings, Kachru, Polchinski

$$m_{\text{IR}} \sim M_{\text{UV}} e^{-\frac{2K}{3M g_s}}$$

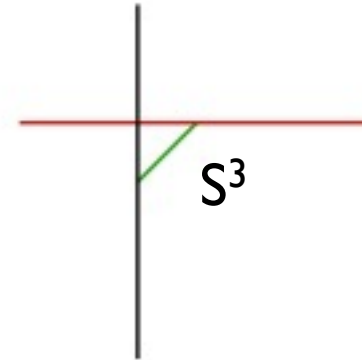
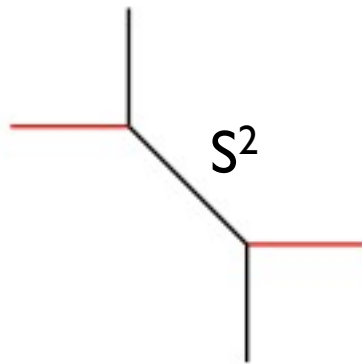
$$\int_{10d} F_3 \wedge B_2 \wedge F_5 \rightarrow M \int_{4d} \phi F_4$$

Need throats with 2- and 3-cycles at its bottom

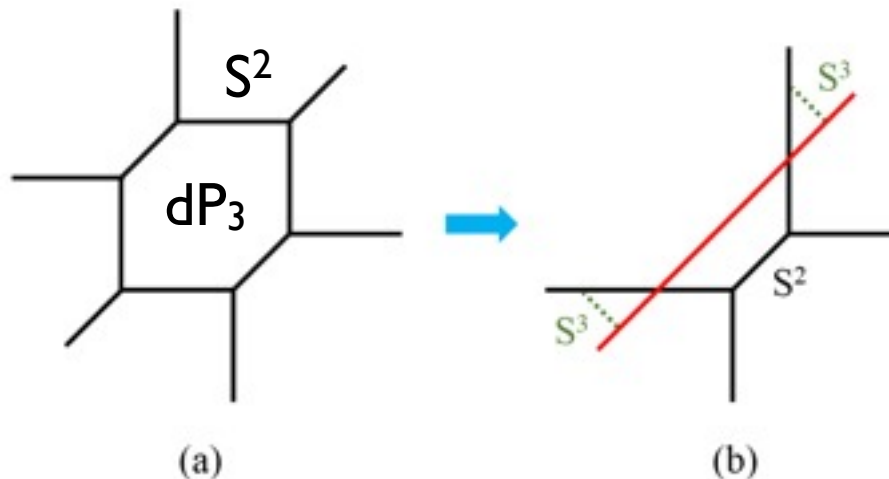
# More general throats Franco, Hanany, A.U.

 Use toric geometry and geometric transitions

Ex: resolved conifold  $\Rightarrow$  deformed conifold



Generalization: e.g. dP<sub>3</sub>



Axion monodromy increases the flux in 5d base of CY cone

# Holographic dual

Franco, Hanany, A.U.

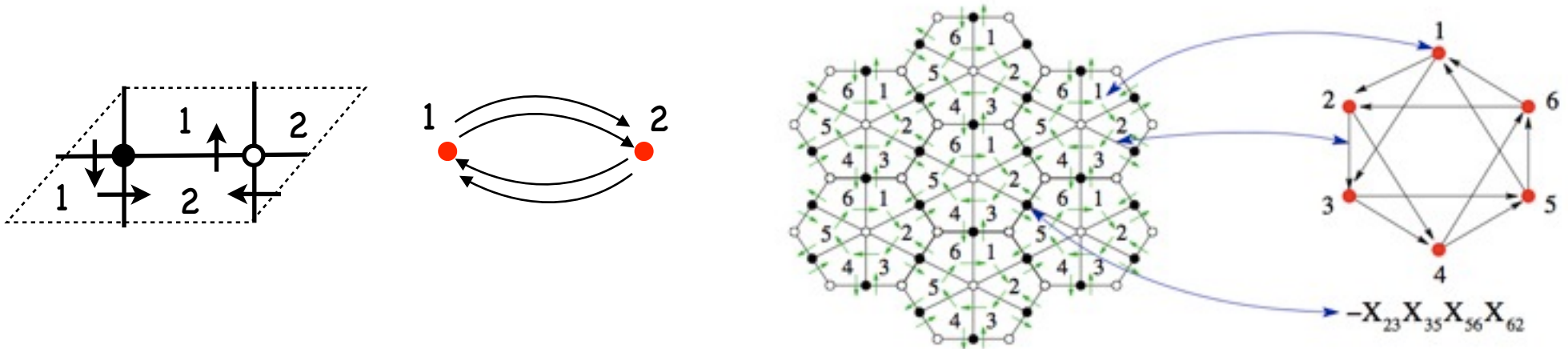


Warped throats have a holographic field theory dual

Toric geometries  $\Rightarrow$  Brane tilings / dimer diagrams



Obtained from fractional D3-branes on the “resolved” side



Regular D3s (equal ranks): conformal theory, dual to AdS5

Fractional D3s (diff. ranks): RG is a Seiberg duality cascade

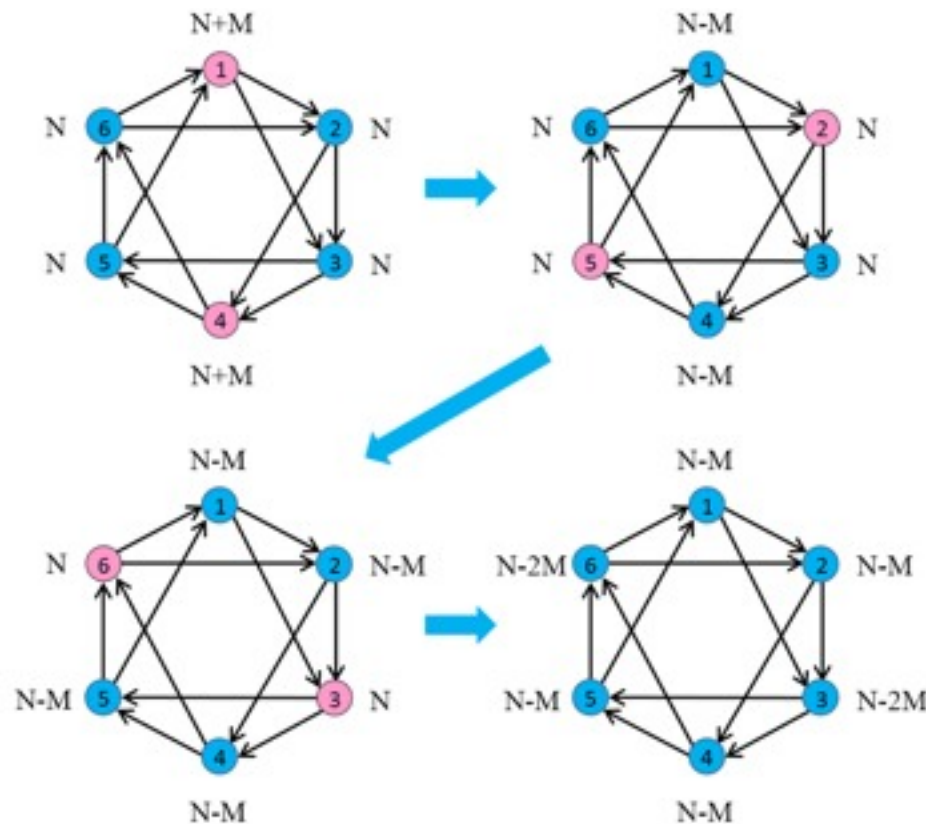
IR theory has complex deformed moduli space Klebanov, Strassler

D5s wrapped on 2-cycles turn into F3 flux on 3-cycles

# Axion monodromy as Seiberg duality

Franco, Galloni,  
Retolaza, A.U.

- ⌚ Axion is dual to gauge coupling of some gauge factor
- ⌚ Axion monodromy is dual to a chain of Seiberg dualities increasing the overall number of D3-branes



Obs: monodromy cascade is different from RG cascade



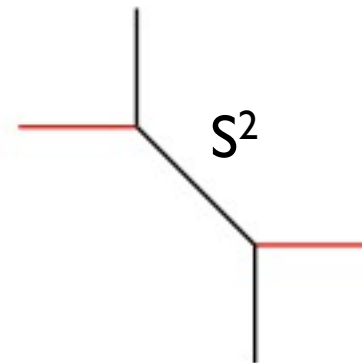
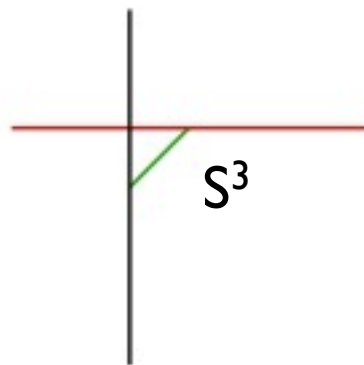
# The type IIA picture



$$\int_{10d} F_2 \wedge B_2 \wedge F_6 \rightarrow M \int_{4d} \phi F_4$$

Need throats with only 2-cycles at its bottom: “resolved”

Can be obtained from geometries with 2- and 3-cycles via geometric transitions



D6s wrapped on 3-cycles turn into F2 flux on 2-cycles

Vafa



Easier to embed in global compactifications

No need of 1-cycles

# Inflation and conclusions

- Chaotic inflation below bulk scales
- Can accommodate higher powers Marchesano, Shiu, A.U;  
McAllister, Silverstein,  
Westphal, Wrase
- Interesting field theory dual picture  
A bit like theta angle in large N gluodynamics
- Local approach: subsequent global embedding, SM, ...
- Open questions in axion monodromy:
  - Susy and the saxion
  - Backreaction of flux, and maximum field range
  - Reheating

**Thank you!**