Thraxions: Ultralight Throat Axions

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Setup: (Compact) Klebanov-Strassler solution

[Klebanov, Strassler '00]
[Giddings, Kachru, Polchinski '02]

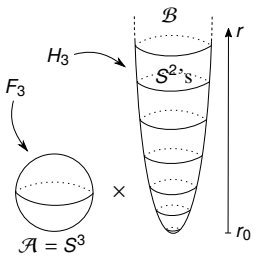
- IIB solution on $\mathbb{R}^{1,3} \times_w$ *def.cfd.*
- internal space: 'KS throat'
- deformation parameter z: c.s.m.

  $|z|$ = volume of 3-sphere

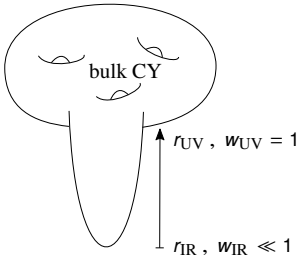
  $\varphi = \arg z$ = 'orientation' of throat
- c.s.m. z stabilized by M and K
- normalize warp factor to 1 in UV / bulk CY,

  s.t. $w_{\rm IR}^3 \propto |z| \ll 1$ $\qquad \left(w(r) = e^{A(r)}\right)$

non-compact



compact

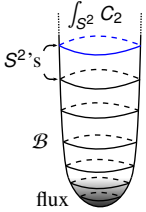


$M = \int_{\mathcal{A}} F_3$ $\qquad$ $K = \int_{\mathcal{B}} H_3$

Idea: Axion Monodromy in Throats

- consider 'axions' $\int_{S^2} C_2$, $\int_{S^2} B_2$ on background with $S^2 = \partial\mathcal{B}$

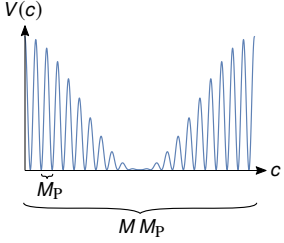
  $\Rightarrow$ manifest monodromy from flux energy density of $\int_{\mathcal{B}} F_3 = \int_{S^2} C_2$



- backreacted potential? surprising result in throat:

  finite monodromy, very small potential

  of scale $\Lambda \sim e^{-S_{\rm eff}} < e^{-M_{\rm P}/f_{\rm eff}}$



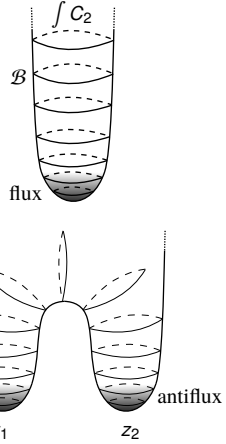
Local Throat Physics: Monodromies

(F-term) axion monodromy
[Silverstein, Westphal '08], [McAllister, Silverstein, Westphal '08]
[Marchesano, Shiu, Uranga '14], [Hebecker, Kraus, Witkowski '14]
[Hebecker, Moritz, Westphal, Witkowski '16]

- F-term axion monodromy from IR fluxes $\int_{\mathcal{B}} F_3 = \int_{S^2_{\rm UV}} C_2 \equiv (2\pi\alpha')\, c$,
  rigid throat background expectation and result
  $V_{\rm flux}(c) \sim w_{\rm IR}^4 c^2$

- UV end of the $\mathcal{B}$-cycle?
  → double throat: IR fluxes on both sides for control
  no net flux added in compact double throat ⇒ flux and antiflux

- geometry: simultaneous deformation of two conical singularities
  → one c.s.m. $z = z_1 = z_2$ and shared $\mathcal{B}$-cycle for both throats



multi conifold geometry
[Cachazo, Intriligator, Vafa '01], [Aganagic, Beem, Seo, Vafa '08]
[Retolaza, Uranga, Westphal '15]

Local Throat Physics: Backreaction via local SUSY restoration

- z locally stabilized by F-terms with additional F_3-flux

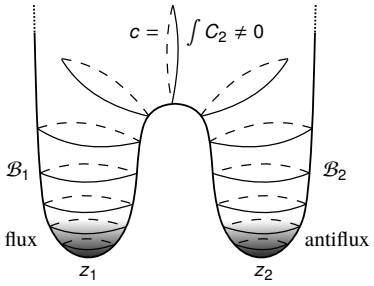
  $\arg z = \varphi = \frac{c}{M}$

- independent local backreaction of (anti)fluxes on $\mathcal{B}_{1,2}$

  $\varphi_{1,2} = \pm \frac{c}{M}$

- deformation away from c.s.m. space $z \equiv z_1 \equiv z_2$?!

  there must be potential enforcing $z_1 = z_2$!



Thraxions: Potential from $\varphi_1 \neq \varphi_2$

- deformation asymptotically *almost* not visible

  $\rightarrow$ *approximate* $U(1)$-symmetry parametrized by φ

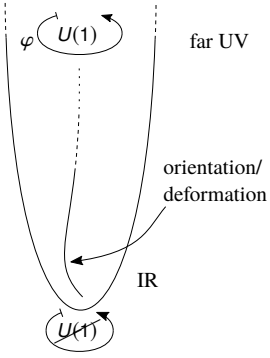
- potential from gluing together $\varphi_1 \neq \varphi_2$ in *almost* symmetric region

  $$V_{\cancel{U(1)}}(\varphi_1 - \varphi_2) = \Lambda_{\cancel{U(1)}}|_{\text{UV}}\ (1 - \cos(\varphi_1 - \varphi_2))$$

- 10d action: $\Lambda_{\cancel{U(1)}}|_{\text{UV}} \propto w_{\text{IR}}^6$ $\quad (\ll V_{\text{flux}}\ !)$

$\Rightarrow$ finite monodromy for 'thraxion' c, decay constant enhanced by M

$$V_{\text{eff}}(c) = w_{\text{IR}}^6\, \Lambda\ (1 - \cos(c/M))$$



Thraxions: Superpotential proposal (for complexified thraxion)

- independent throats + potential from gluing enforced by Lagrange multiplier G gives

  $$W = W_{\mathrm{GVW}}(z_1) + W_{\mathrm{GVW}}(z_2) + \frac{G}{2\pi}(z_1 - z_2)$$

- $\left(\pm \frac{G}{2\pi} z_i\right)$ can be absorbed in $W_{\mathrm{GVW}}(z_i)$ as additional G_3-(anti)flux term on $\mathcal{B}_i$-cycle!

- promote $G = (c - \tau b)$ to dynamical field

- Kähler potential given by resolved side (kinetic term from UV geometry) [Grimm, Louis '04]

- integrating out along mass hierarchy gives $W_{\mathrm{eff}}(G)$ with

  $$V_{\mathrm{eff}} \supset w_{\mathrm{IR}}^6 \, \Lambda \, (1 - \cos(c/M)) \qquad (+ \text{ non-periodic potential for } b)$$

Thraxions: Drifting monodromies

- superpotential allows for simple generalization to multi throats

  $W_{\text{eff}}(G) \approx w_{\text{IR}}^3 \sum_{k=1}^{n} \Lambda_i \, \exp(i\, G/M_k)$

  M_k stabilizes k-th throat (subject to topology)

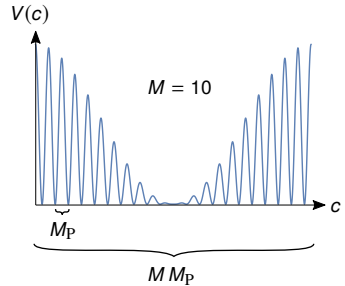
- each throat k backreacts with different orientation c/M_k

  original vacuum reached only after $f_{\text{eff}} = \text{LCM}(M_k)\, f_c$

- example: thraxion on quintic orientifold

  $\frac{16}{2}$ conical sing. deformed by fluxes M, $M{+}1$, $-M$, $-M{-}1$, ...

  $f_{\text{eff}} \approx M^2 f_c$, $f_{\text{mod}} \approx M f_c$



Conclusions

- thraxion present in generic IIB CY compactification (that can develop multiple conical sing.)
- flux-enhanced (super-)Planckian decay constant with approximately Planckian modulation
- interpreting as instanton induced $W_{\text{eff}} \propto w_{\text{IR}}^3 \propto \exp(-S_{\text{eff}})$, have $S_{\text{eff}} \cdot f_{\text{eff}}/q > M_{\text{P}}$ parametrically
- ED1's on S^2 coupling to C_2 have charge $q = f_{\text{eff}}/\Pi_{\text{ED1}} = \text{LCM}(M_k)$
  $\rightarrow$ sLWGC satisfied with very coarse sublattice (quintic example above: $110\,\mathbb{Z} \subset \mathbb{Z}$)
- classical process that connects flux vacua at $\varphi = 2\pi \frac{P}{M}$, $P \in \mathbb{Z}_{2M}$,
  dual to distinct vacua of KS gauge theory (due to gaugino condensates)
- saxion $b = \int_{S^2} B_2$ governs relative throat lengths $\propto \frac{|z_1|}{|z_2|}$ of multi throat geometries
  $\rightarrow$ only weakly stabilized at a scale w_{IR}^6 (perturbatively)