Induced Charge in D7-brane Inflation

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1 Introduction
  - Inflation in String Theory
  - D7-brane Inflation Scenarios
  - The One Loop Pfaffian

2 Backreaction of Monodromy Charge

3 Conclusion
Large field inflation

- Large field inflation is sensitive to quantum gravity effects.
- String compactification involves many moduli fields.
- Important task is then to generate sufficient masses for moduli fields.
**KKLT Scenario**

- Complex structure moduli and axio-dilaton modulus are stabilized by ISD flux. But, Kähler moduli enjoy no-scale structure.
- Kähler moduli can be stabilized by the non-perturbative potential. Typically, obtained vacuum is AdS.

\[ W = \int_X G \wedge \Omega + A(\chi) e^{-T}, \]

where \( T \) is a Kähler modulus.
- AdS is uplifted to dS with positive energy, such as \( \overline{D3} \).
Higgs-otic Inflation

- D7 brane monodromy inflation in the F-term axion monodromy inflation framework.
  Marchesano, Shiu, Uranga 14; Ibanez, Marchesano, Valenzuela 14; Bielleman, Ibanez, Pedro, Valenzuela 15; Bielleman, Ibanez, Pedro, Valenzuela, Wieck 16;
- D7 brane is probing a flux background on a toroidal orientifold. e.g.) $(T^4 \times T^2)/\mathbb{Z}_4$ with ISD flux. D7 brane is wrapping $T^4$.
- 2 form flux $B = -\frac{g_s}{2i} (G^{(0,3)} z_3 - G^{(2,1)} \bar{z}_3) dz_1 \wedge dz_2 + c.c.$
Higgs-otic Inflation

- Probe D7-brane action with the flux $\mathcal{F} = \mathcal{F}_+ + \mathcal{F}_-$ includes following terms ($C_6$ is fixed to be zero in ISD solution.)

$$S_{D7} \supset - \mu_7 \int_{\mathbb{R}^{1,3} \times D} (\text{Vol}_{\mathbb{R}^{1,3}} - C_4) \wedge \frac{1}{2} \mathcal{F}_+ \wedge \star_4 \mathcal{F}_+$$

$$- \mu_7 \int_{\mathbb{R}^{1,3} \times D} (\text{Vol}_{\mathbb{R}^{1,3}} + C_4) \wedge \frac{1}{2} \mathcal{F}_- \wedge \star_4 \mathcal{F}_- + \mathcal{O}(\mathcal{F}^4).$$

- In the ISD background, $\text{Vol}_{\mathbb{R}^{1,3}} = C_4|_{\mathbb{R}^{1,3}}$.
- In warped metric ansatz,

$$ds^2 = h^{-1/2} ds_{\mathbb{R}^{1,3}}^2 + h^{1/2} ds_X^2,$$

the inflaton potential is

$$V = 2\mu_7 \int_{D} h^{-1} \frac{1}{2} \mathcal{F}_- \wedge \star_4 \mathcal{F}_- = \frac{g_s^2 \mu_3 h^{-1}}{2} \left| G^{(2,1)} \bar{z}_3 - G^{(0,3)} \bar{z}_3 \right|^2.$$
Higgs-otic Inflation

\[ Q^{D3}(z_3) = \frac{\mu_7}{\mu_3} \int_D \frac{1}{2} F_-(z_3) \wedge *_4 F_-(z_3) = \frac{2h^{-1}}{\mu_3} V(z_3). \]

Typical scale of the potential studied in Ibanez et al., 14 is

\[ V \alpha'^2 \simeq O(1). \]

Corresponding scale of the $D3$ charge is

\[ Q^{D3} \simeq 4\pi^3 \alpha'^2 h V = hO(100). \]
Fluxbrane Inflation

- D7 brane inflation with small susy breaking relative flux. 
  Hebecker, Kraus, Lust, Steinfurt, and Weigand 11; Hebecker, Kraus, Kuntzler, Lust, and Weigand 12;
- Constant flux $\mathcal{F}$ is turned on initially.
  \[ \frac{\mu_7}{\mu_3} \int_D \frac{1}{2} \mathcal{F} \wedge \star_4 \mathcal{F} \simeq \frac{\mu_7}{\mu_3} \int_D (J \wedge \mathcal{F})^2 \int_D J \wedge J = \mathcal{O}(10). \]  
  Hebecker et al. 12;
Backreaction on the Non-perturbative Superpotential

- “Everything which is not forbidden is allowed.”
- One loop corrected superpotential for a holomorphic divisor \( \{ z | f(z) = 0 \} \) is of following form in the presence of D3-brane.

\[
W = Af(z_{D3})^{1/n}e^{-T/n},
\]

where \( z_{D3} \) is the position of the D3-brane.

Ganor 96; Berg, Haack, and Kors 04; Baumann, Dymarsky, Klebanov, McAllister, and Murugan 06;
Dual Pictures of the One Loop Pfaffian

- Open string one-loop correction to the gauge coupling of D7-branes stack. $8\pi^2/g^2 = \mu_3 T$. Berg, Haack, and Kors 04;
- Closed string channel computation of the corrected volume of the holomorphic divisor. Baumann et al. 06;
- The warp factor gets correction so do the Kähler moduli as well.

$$ds^2 = h^{-1/2}ds^2_{\mathbb{R}^{1,3}} + h^{1/2}ds^2_X.$$


Would there be correction to the non-perturbative superpotential?
If there is, could the dependence be suppressed?
Hope that the backreaction is negligible in a case where the distance between the inflaton divisor and the moduli stabilizing divisor is large enough. e.g Higgs-otic inflation. Bielleman et al., 16; Ruehle and Wieck 17;

Turn on the 2 form flux such that the flux induces vanishing net D3 brane charge. e.g Fluxbrane inflation. Hebecker et al., 12;
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\[ G^{(2)}(x; x_0) \sim \log \left| \frac{x - x_0}{L} \right| . \]

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The D3-brane tension corrects the volume!

\[ \int_D \mathcal{F} \wedge \mathcal{F} = \int_D \mathcal{F}_+ \wedge \star_4 \mathcal{F}_+ - \mathcal{F}_- \wedge \star_4 \mathcal{F}_- = 0. \]
Backreaction of Monodromy Charge

Backreaction with the induced charge.

- Up to the leading order, following dependence is thus expected

\[ W = Af(z)(Q^{D3} + Q^{D3})/ne^{-T/n}, \]

where \( z \) is the distance measured from the condensing D7 branes to the inflaton D7 brane.

- Any correction? What is the precise form of the pfaffian in the computable examples such as Type IIB theory on a toroidal orientifold?
We carry out the closed string channel computation.

Follow a prescription studied by Gandhi, McAllister, and Sjörs 11;
Perturbing ISD background

- We assume a static warped metric ansatz.

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\[ ds^2 = h^{-1/2}(z)ds_{\mathbb{R}^{1,3}}^2 + h^{1/2}(z)ds_X^2, \]

\[ \tilde{F}_5 = (1 + \star_{10})d\alpha \wedge dx_0 \wedge dx_1 \wedge dx_2 \wedge dx_3, \]

- The background is assumed to be ISD. \( \star_6 G = iG, \Phi_- = h^{-1} - \alpha = 0. \)

- We perturb the background by adding the fluxed D7 branes.

- Truncate the equations up to \( \mathcal{O}(\alpha'^2) \) order.

- Take weak coupling limit, \( \text{Im} \tau(0)^{-1} = g_s \rightarrow 0. \)

- Take large volume limit, \( \Phi_{+,c} \rightarrow 0. \) Note that \( \text{Im} \tau(0)\Phi_{+,c} \rightarrow 0. \)

- Compute the perturbed DBI action of a divisor that is homologous to the inflaton divisor.
For a divisor $D$ with flux $\mathcal{F}$, the pfaffian is

$$A(z_3)_{\alpha} = \prod_{i=1}^{N} \left| \vartheta_1 \left( \frac{z_3 - \theta^i z_{3,\alpha}}{L} \right) \right| \exp \left( -\frac{\pi (\text{Im}(z_3 - \theta^i z_{3,\alpha})^2)}{L^2 \text{Im} U} - \log |\eta(U)| \right)^{\frac{(Q^D_{\alpha} + Q^D_{\alpha} + Q^D_{D} + Q^D_{\bar{D}})}{N_c}}.$$ 

- $Q^D = \frac{\mu_7}{\mu_3} \int_D \frac{1}{2} \mathcal{F}^+ \wedge \star_4 \mathcal{F}^+$, and $Q^{\bar{D}} = \frac{\mu_7}{\mu_3} \int_D \frac{1}{2} \mathcal{F}^- \wedge \star_4 \mathcal{F}^-$. 
- Elliptic theta type of the one loop pfaffian could cause the inflaton to be trapped in a false vacuum. Ruehle and Wieck 17;
Conclusion

- Tension induced from $\mathcal{F}$ perturbs the metric and the Kähler moduli.
- The backreaction of the induced charge on the non-perturbative superpotential in the D7 brane inflation scenarios is generic and sizable.
- It is important to incorporate the effect of the induced charge.