Induced Charge in D7-brane Inflation

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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

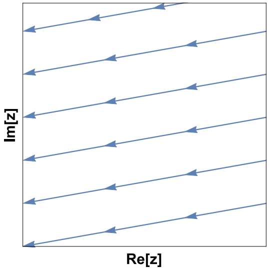
- Complex structure moduli and axio-dilaton modulus are stabilized by ISD flux. But, Kähler moduli enjoy no-scale structure.
- Kähler moduli can be stabilized by the non-perturbative potential. Typically, obtained vacuum is AdS.

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

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.)

$$S_{D7} \supset -\mu_7 \int_{\mathbb{R}^{1,3}\times D} (\mathrm{Vol}_{\mathbb{R}^{1,3}} - C_4) \wedge \frac{1}{2}\mathcal{F}_+ \wedge \star_4 \mathcal{F}_+ \\ -\mu_7 \int_{\mathbb{R}^{1,3}\times D} (\mathrm{Vol}_{\mathbb{R}^{1,3}} + C_4) \wedge \frac{1}{2}\mathcal{F}_- \wedge \star_4 \mathcal{F}_- + \mathcal{O}(\mathcal{F}^4).$$

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

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

the inflaton potential is

$$V = 2\mu_7 \int_D h^{-1} \frac{1}{2}\mathcal{F}_- \wedge \star_4 \mathcal{F}_- = \frac{g_s^2 \mu_3 h^{-1}}{2} |G^{(2,1)} z_3 - G^{(0,3)} \bar{z}_3|^2.$$

Higgs-otic Inflation

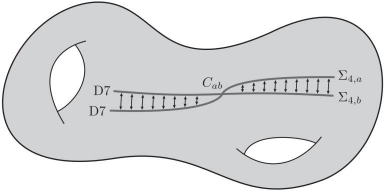
- $Q^{\overline{D3}}(z_3) = \frac{\mu_7}{\mu_3}\int_D \frac{1}{2}\mathcal{F}_-(z_3)\wedge\star_4\mathcal{F}_-(z_3) = \frac{2h^{-1}}{\mu_3}V(z_3)$.
- Typical scale of the potential studied in Ibanez et al., 14 is

$$V\alpha'^2 \simeq \mathcal{O}(1).$$

- Corresponding scale of the $\overline{D3}$ charge is

$$Q^{\overline{D3}} \simeq 4\pi^3\alpha'^2 hV = h\mathcal{O}(100).$$

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.
- $\frac{\mu_7}{\mu_3}\int_D \frac{1}{2}\mathcal{F}\wedge \star_4 \mathcal{F} \simeq \frac{\mu_7}{\mu_3}\frac{\int_D (J\wedge\mathcal{F})^2}{\int_D J\wedge J} = \mathcal{O}(10)$. Hebecker et al.12;

Backreaction on the Non-perturbative Superpotential

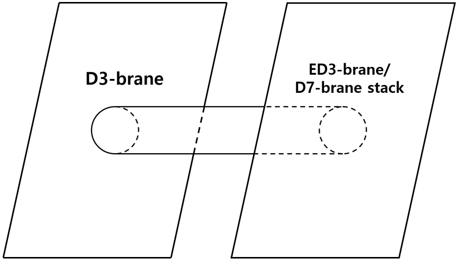
- "Everything which is not forbidden is allowed."
- One loop corrected superpotential for a holomorphic divisor $\{z|f(z)=0\}$ is of following form in the presence of D3-brane.

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

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

Ganor 96; Berg, Haack, and Kors 04; Baumann, Dymarsky, Klebanov, McAllister, and Murugan 06;

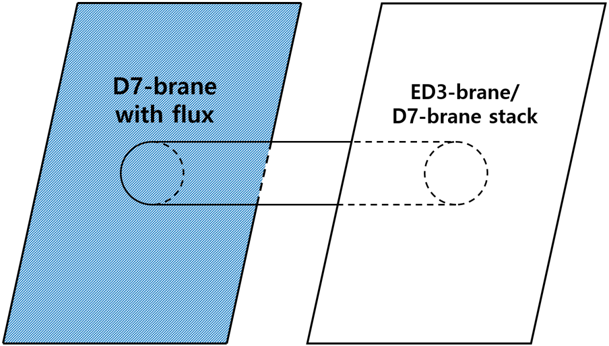
Dual Pictures of the One Loop Pfaffian



- 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.

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

One Loop Pfaffian in D7-brane inflation



- Would there be correction to the non-perturbative superpotential?
- If there is, could the dependence be suppressed?

Suppressing the backreaction?

- 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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  The D3-brane tension corrects the volume!

$$\int_D \mathcal{F} \wedge \mathcal{F} = \int_D \mathcal{F}_+ \wedge \star_4 \mathcal{F}_+ - \mathcal{F}_- \wedge \star_4 \mathcal{F}_- = 0.$$

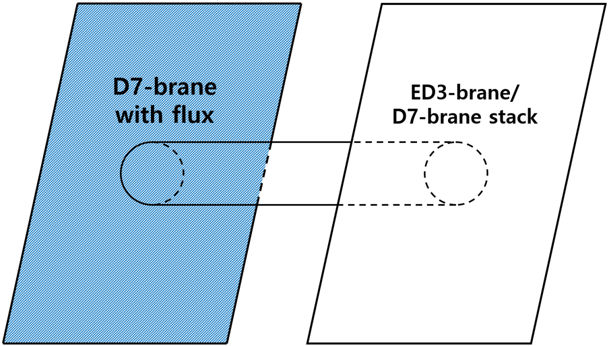
Backreaction with the induced charge.

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

$$W = Af(z)^{(Q^{\overline{D3}}+Q^{D3})/n}e^{-T/n},$$

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.

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

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

- 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, $\mathrm{Im}\tau^{(0)-1} = g_s \to 0$.
- Take large volume limit, $\Phi_{+,c} \to 0$. Note that $\mathrm{Im}\tau^{(0)}\Phi_{+,c} \to 0$.
- Compute the perturbed DBI action of a divisor that is homologous to the inflaton divisor.

The Leading Correction to the Pfaffian

- For a divisor D with flux $\mathcal{F}$, the pfaffian is

$$A(z_3)_\alpha = \prod_{i=1}^{N}\left(\left|\vartheta_1\left(\frac{z_3-\theta^i z_{3,\alpha}}{L}|U\right)\right| \exp\left(-\frac{\pi(\mathrm{Im}(z_3-\theta^i z_{3,\alpha})^2)}{L^2\mathrm{Im}U}-\log|\eta(U)|\right)\right)^{\frac{(Q_\alpha^{D3}+Q_\alpha^{\overline{D3}}+Q_D^{D3}+Q_D^{\overline{D3}})}{N_c}}.$$

- $Q^{D3}=\frac{\mu_7}{\mu_3}\int_D \frac{1}{2}\mathcal{F}_+\wedge\star_4\mathcal{F}_+$, and $Q^{\overline{D3}}=\frac{\mu_7}{\mu_3}\int_D \frac{1}{2}\mathcal{F}_-\wedge\star_4\mathcal{F}_-$.
- 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.