Higher derivative corrections from the DBI action

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arXiv 1602.00699 SB, L. Ibañez, F.Pedro, I. Valenzuela and C. Wieck

Introduction

We address the following questions

- What is the form does the action for the position modulus of a brane take?
- How can we describe this action in an effective 4d SUSY theory?

Introduction

The DBI action

Higher derivative operators

Summary & outlook

Introduction

The bosonic massless states of the open string sector for a single p-brane are

- a $U(1)$ gauge boson, A_μ
- 3 complex scalars, φ^i

The effective brane action is

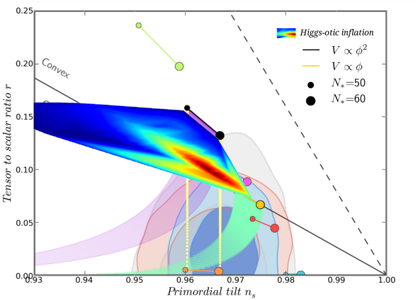
$$S_{brane} = S_{DBI} + S_{CS}$$

- S_{CS} gives the topological couplings to the RR fields
- S_{DBI} contains the Nambu-Goto action and Yang-Mills action

Introduction

The DBI is relevant for studies of inflation because

- The brane postionis described by the DBI action and is a possible inflaton candidate
- α' corrections can be computed and flatten the potential
- Axion monodromy to protect the theory along large field excursions



The DBI action

The DBI action for a stack of branes is

$$\int d^{p+1}x e^{-\phi}\sqrt{-det(P[E_{MN}+E_{Mi}(Q^{-1}-\delta)^{ij}E_{jN}]+\sigma F_{MN})det(Q_{mn})}$$

where

- $P[]$ the pullback to the brane worldvolume
- $E_{MN}=g_s^{1/2}G_{MN}-B_{MN}$
- F_{MN} the field strength of the gauge fields on the brane
- $Q_{mn}=\delta_{mn}+i\sigma[\varphi_m,\varphi_p]E_{pn}$

The DBI action

We can factorise the determinant

$$det(g_s^{1/2}\eta_{\mu\nu} + g_s^{1/2}\partial_\mu\varphi_m\partial_\nu\varphi_n)$$
$$det(g_s^{1/2}g_{ab} + \sigma\mathcal{F}_{ab})$$
$$det(g_{mn} + i\sigma[\varphi_m, \varphi_p](g_s^{1/2}g_{pn} - B_{pn}))$$

Where we have

- assumed a toroidal compactification
- ignored Wilson lines and gauge bosons
- assumed no mixed tensors

The DBI action

Expanding the first determinant and squareroot, we find:

$$\mathcal{L} = V_{p-3} f(\phi)\big(1 + \sigma^2 \partial\phi_i \partial\bar{\phi}_i - \frac{1}{2}\sigma^4 \left[\sum_{i \neq j} (\partial\phi_i \partial\bar{\phi}_j)(\partial\phi_j \partial\bar{\phi}_i) + \sum_{i,j} (\partial\phi_i \partial\phi_j)(\partial\bar{\phi}_i \partial\bar{\phi}_j) \right] \big)$$

Where

- $f(\phi) = \sqrt{det(...)}$ whose exact form depends on the brane and the fluxes
- however, the determinant is always a perfect square for SUSY setups
- and the scalar potential is $V(\phi) = a^{-1}(f(\phi) - 1)$

The constant $a \propto (\mu_p V_{p-3})^{-1}$ and has mass dimension -4

The DBI action

In general we find

- $V(\phi)|\partial\phi|^2$
- no correction to the scalar potential nor terms like $V_0(\phi)^2$
- no terms of the form $\Box\phi$, $\partial_\mu\partial_\nu\phi$, ...

For simplicity we focus on a single D7-brane such that the action is

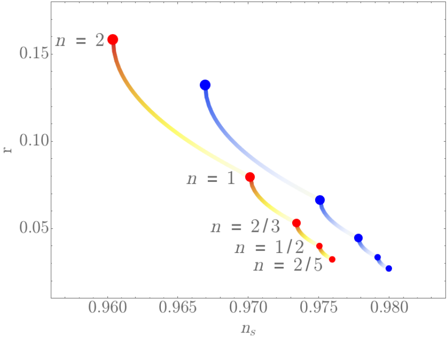
$$\mathcal{L} = -(1 + aV(\phi))\partial\phi\partial\phi^* + |\partial\phi\partial\phi|^2 - V(\phi)$$

which is exact to all orders in $V(\phi)$ and to first order in $\alpha'\partial\phi$

A plot

Using

$$\mathcal{L} = -\frac{1}{2}(1 + aV(\varphi))\partial\varphi\partial\varphi - V(\varphi)$$
$$V = V_0\phi^n$$



Higher derivative operators

Here we will consider

$$\mathcal{L} = \int d\theta^2 d\overline{\theta}^2 K(\Phi, \overline{\Phi}, D_\alpha \Phi, D^{\dot{\alpha}} \overline{\Phi}) + \int d\theta^2 W(\Phi) + hc$$

We are looking for a correction to the Kähler potential that is:

- 4th order in the fields
- 4th order in spacetime derivatives

and that reproduces the DBI action.

Higher derivative operators

All relevant dimension 8 operators can be written as a combination of

$$\mathcal{O}_1 = |\Phi|^2 D^2\Phi \bar{D}^2\bar{\Phi} \qquad \mathcal{O}_3 = |\Phi|^2 D\bar{D}\bar{\Phi}\bar{D}D\Phi$$

$$\mathcal{O}_2 = \bar{D}^2\bar{\Phi}(D\Phi)^2\bar{\Phi} \qquad \mathcal{O}_4 = \Phi^2 D\bar{D}\bar{\Phi}D\bar{D}\bar{\Phi}$$

- The operators on the left contain $|F|^4 \sim V_0^2$
- Since these are dimension 8 operators they come with a cut-off scale Λ^{-4}

There are other interesting combinations see eg. J. Khoury, J. Lehners and B. Ovrut, arXiv: 1012.3748 and D. Cuipke, J. Louis and A. Westphal, Arxiv: 1505.07023

Higher derivative operators

The desired correction can be written as

$$\begin{aligned}\Delta K &= \frac{1}{\Lambda^4}\left(c_1\mathcal{O}_3 + c_2(\mathcal{O}_4 + \bar{\mathcal{O}}_4)\right)\\ &= \frac{1}{\Lambda^4}\left(c_1|\Phi|^2 D\bar{D}\bar{\Phi}\bar{D}D\Phi + c_2(\Phi^2 D\bar{D}\bar{\Phi}D\bar{D}\bar{\Phi} + hc)\right)\end{aligned}$$

This correction contains

- a term $|F|^2|\partial\phi|^2 \sim V_O|\partial\phi|^2$
- a lot of terms of the form $\Box\phi$, $\partial_\mu\partial_\nu\phi$, ...
- kinetic terms for F

Higher derivative operators

- kinetic terms for F

Even though F has kinetic terms, it is nondynamical below the cut-off scale as can be seen from a redefinition

$$\mathcal{L} \supset -|F|^2 + \frac{g(\phi)}{\Lambda^4}\partial F \partial F^*$$
$$\Rightarrow -m^2|\tilde{F}|^2 + \frac{g(\phi)}{\Lambda^2}\partial \tilde{F} \partial \tilde{F}^*$$

where $m = \Lambda$

If we set $c_2 = 0$ then

$$a \propto \frac{c_1}{\Lambda 4} \propto M_s^{-4}$$

Supergravity

We can couple our new Kähler potential to gravity

$$S = \int d^2\Theta \left[\frac{3}{8}(\overline{\mathcal{D}}^2 - 8R)e^{-\frac{1}{3}K} + W\right] + h.c.$$

which, luckily, has been done for us[3]

Some noteworthy effects

- Non-minimal coupling between ϕ and R: $|\partial\phi|^2 R$ and $R_{\mu\nu}\partial^\mu\phi\partial^\nu\phi$
- A correction to the scalar potential: $\Delta V = |F|^2|M|^2$

These are not captured by the DBI!

[3] arXiv 1109.0293 Baumann, Green and arXiv 1605.00651 Cuipke

Summary & outlook

- We have found the following form from the DBI

$$\mathcal{L} = -(1 + aV(\phi))\partial\phi\partial\bar{\phi} - V(\phi) + \mathcal{O}(\partial^4)$$

- We argue that this can be described by a correction to the canonical Kähler potential given by a linear combination of

$$\mathcal{O}_3 = |\Phi|^2 D\bar{D}\bar{\Phi}\bar{D}D\Phi$$
$$\mathcal{O}_4 = \Phi^2 D\bar{D}\bar{\Phi}D\bar{D}\bar{\Phi}$$

- Follow-up questions include the effect on moduli stabalisation and the effect of the gravitational corrections.

Thank you