Minkowski 3-forms (in flux compactifications)

S. Bielleman

November 19, 2015

Based on hep-th 1507.06793 SB, L. Ibañez, I. Valenzuela

Why 3-forms are special

C_3 usually not considered seperatly in QFT since:

$$\mathcal{L} \supset F_4 \wedge F_0 \Rightarrow \partial_\mu F_0 = 0 \Rightarrow F_0 = q$$

$\Rightarrow$ C_3 has no propagating degrees of freedom

Brown and Teitelboim '87, Bousso and Polchinski '00 ...

Why 3-forms are special

C_3 usually not considered seperatly in QFT since:

$$\mathcal{L} \supset F_4 \wedge F_0 \Rightarrow \partial_\mu F_0 = 0 \Rightarrow F_0 = q$$

$\Rightarrow$ C_3 has no propagating degrees of freedom

Contribution to the cc

$$S = \int d^4x \sqrt{-g} \left(\frac{1}{2} R - \frac{1}{48} {F_4}^2 - \Lambda_{bare} \right)$$

Putting the 4-form on shell we are left with an effective cc:

$$\Lambda = \Lambda_{bare} + \frac{1}{48} q^2$$

Brown and Teitelboim '87, Bousso and Polchinski '00 ...

Coupling of F_4 to a single scalar ϕ

In general the 4-form will have couplings to other fields.

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{2}R - \frac{1}{2}(\partial\phi)^2 - \frac{1}{48}{F_4}^2 + m\phi \star F_4\right)$$

Coupling of F_4 to a single scalar ϕ

In general the 4-form will have couplings to other fields.

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{2}R - \frac{1}{2}(\partial\phi)^2 - \frac{1}{48}{F_4}^2 + m\phi \star F_4\right)$$

This leads to interesting physics after integrating out the 4-form

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{2}R - \frac{1}{2}(\partial\phi)^2 - \frac{1}{2}(q + m\phi)^2\right)$$

There is a potential for ϕ that respects the shift symmetry!

$$\phi \to \phi + n \qquad q \to q - mn$$

Inflation in effective field theory

In models of large field inflation:

- $V(\phi) < M_{pl}$
- $\Delta\phi > M_{pl}$

Problems in a theory with other degrees of freedom.

Integrating out leads to higher order terms such as

$$\mathcal{L}_{corr} = \frac{a_i}{M^{2i}}\phi^{4+2i} + \frac{b_i}{M^{2i}}(\partial\phi)^2\phi^{2i}$$

Kaloper Sorbo mechanism

Interpret ϕ as the inflaton with potential

$$V_0 = \frac{1}{2}(q + m\phi)^2$$

That respects the shift symmetry

$$\phi \to \phi + n \qquad q \to q - mn$$

Kaloper and Sorbo '08

Kaloper Sorbo mechanism

Interpret ϕ as the inflaton with potential

$$V_0 = \frac{1}{2}(q + m\phi)^2$$

That respects the shift symmetry

$$\phi \to \phi + n \qquad q \to q - mn$$

- Subplanckian energy densities
- Shift symmetry $\Rightarrow$ quantum corrections under control
- Higher order terms go as powers of V_0 due to shift symmetry

Kaloper and Sorbo '08

IIA flux compactifications

IIA field content in the democratic formalism:

- NSNS field B_2 with field strength H
- RR fields C_p with $p = 1, 3, 5, 7, 9$
- Field strengths: $G_{p+1} = F_{p+1} - H \wedge C_{p-2} + \mathcal{F} e^B$

Bergshoeff, Kallosh, Ortin, Roest and Van Proeyen '01

IIA flux compactifications

IIA field content in the democratic formalism:

- NSNS field B_2 with field strength H
- RR fields C_p with $p = 1, 3, 5, 7, 9$
- Field strengths: $G_{p+1} = F_{p+1} - H \wedge C_{p-2} + \mathcal{F} e^B$

We expand the field strengths on internal harmonics:

$$F_0 = -m \;, \quad F_2 = \sum_i q_i \omega_i \;, \quad F_4 = F_4^0 + \sum_i e_i \tilde{\omega}_i$$

$$F_6 = \sum_i F_4^i \omega_i + e_0 dvol_6 \;, \quad F_8 = \sum_a F_4^a \tilde{\omega}_a \;, \quad F_{10} = F_4^m dvol_6$$

Bergshoeff, Kallosh, Ortin, Roest and Van Proeyen '01

IIA flux compactifications

Scalar fields appear in expanding the 10d fields:

$$B_2 = \sum_i b_i \omega_i \ , \quad C_3 = \sum_I c_3^I \alpha_I$$

IIA flux compactifications

Scalar fields appear in expanding the 10d fields:

$$B_2 = \sum_i b_i \omega_i \ , \quad C_3 = \sum_I c_3^I \alpha_I$$

The 10d action contains terms:

$$G_2 \wedge G_8 \supset F_2 \wedge F_8 + F_0 \wedge B \wedge F_8$$

Which will lead to a contribution to the 4d scalar potential:

$$F_4^a (q_a - m b_a)$$

Which has a shift symmetry:

$$b_i \to b_i + n_i \quad , \quad q_a \to q_a + n_a m$$

IIA flux compactifications

After the dust settles we are left with the following scalar potential coming from the RR forms:

$$V_{RR} = -\frac{1}{2}\left[F_4^0\left(e_0 + b^i e_i + \frac{1}{2}k_{ijk}b^i b^j q_k - \frac{1}{6}k_{ijk}mb^i b^j b^k\right) + \right.$$
$$\left. + F_4^i\left(e_i + k_{ijk}b^j q_k - \frac{1}{2}k_{ijk}mb^j b^k\right) + F_4^a(q_a - mb_a) - kmF_4^m\right]$$

After integrating out F this potential is equivalent to the axionic potential found in Louis and Micu '02

Symmetries

The potential is invariant under the shift:

$$b_i \to b_i + n_i$$

if it is combined with:

$$\begin{aligned} m &\to m \\ q_a &\to q_a + n_a m \\ e_i &\to e_i - k_{ijk} q^j n^k - \frac{1}{2} k_{ijk} n^j n^k m \\ e_0 &\to e_0 - e_i n_i + \frac{1}{2} k_{ijk} q^i n^j n^k + \frac{1}{6} k_{ijk} n^i n^j n^k m \end{aligned}$$

Which leaves each 4-form invariant!

Symmetries

T-duality relates different string theories under transformations of the internal space.

- We find that V_{RR} is invariant under two T-dualities if the 4-forms transform into eachother

$$V_{RR} \propto |F_4^0|^2 + g_{ij} F_4^i F_4^j + g_{ab} F_4^a F_4^b + |F_4^m|^2$$

- This result comes from known transformations of RR fields under T-duality

Recap

We have found

- All axion dependence in the potential comes through 4-forms
- Each 4-form is invariant under shifts as in KS
- Different 4-forms related through T-dualities

$\Rightarrow$ As in KS, corrections to the potential should go as powers of the potential

$\Rightarrow$ Models of large field inflation should be reasonably protected in this setting

---

Eg. Marchesano, Shiu and Urange '14; Ibañez, Marchesano and Valenzuela '14

Thank you.

Type IIB

Type IIB is in principle simpler because we only have to consider:

$$G_3 = F_3 - iSH_3$$

Which after integrating over the internal space leads to couplings

$$G_4^a D^a W_{GVW}$$

Which will lead to the standard no scale potential

$$V \propto |D_A W|^2$$

Application to the cosmological constant problem

Contribution to the cc

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{2}R - \frac{1}{48}{F_4}^2 - \Lambda_{bare}\right)$$

Putting the 4-form on shell we are left with an effective cc:

$$\Lambda = \Lambda_{bare} + \frac{1}{48}q^2$$

If Λ_{bare} is negative or small enough then we can tune q such that $\Lambda = \Lambda_{obs}$[6]

[6] Brown and Teitelboim '87...

Application to the cosmological constant problem

This is not the whole story![7]

- In general, q is quantized $\Rightarrow$ problems with fine tuning
- Did we just move the fune tuning problem to a new parameter?

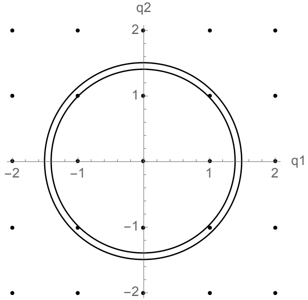
[7] Bousso and Polchinski '00 ...

Application to the cosmological constant problem

This is not the whole story![7]

- In general, q is quantized $\Rightarrow$ problems with fine tuning
- Did we just move the fune tuning problem to a new parameter?

- q is dynamical and will stabilize at a small value using membrame nucleation
- The more 4-forms the easier to get a value of the fluxes such that $\Lambda = \Lambda_{obs}$



[7] Bousso and Polchinski '00 ...