

# Flat MKW solutions from M-theory on $G_2$ -structures

## Outline :

- 1) Intro & Motivation
- 2) M-theory on  $T^7/\mathbb{Z}_2^3$  & twisted tori
- 3) KK monopoles &  $G_2$ -structures
- 4) No-go for dS & MKW solutions
- 5) Higher derivative corrections
- 6) Towards dS extrema ?

## 1) Intro & Motivation

- $MKW_4 \times \underbrace{M_7}_{\text{Ricci flat}}$  are interesting M-theory backgrounds for model building:

SM / GUT constructions ? (see Andreas Braun's &  
→ struggle for chiral matter ... Bobby Acharya's talks)

2 goals

Starting point for dS model building  
↓

Swampland ? (OSV '18, ...)

- Compare w/ KKLT:

Type IIB on  $MKW_4 \times CY_3$  w/  $G_{(3)} \neq 0$

+

- i) NP corrections to fix Kähler moduli

$$W_{NP} = A e^{i\alpha T}, \quad \rightarrow \text{SUSY } AdS_4$$

- ii) Add  $\overline{D3}$ 's to get to  $dS_4$ .

→ Here we have a purely "dilatonic" real flat direction !

→ This offers a new opportunity: making use of just higher derivative corrections for uplift.

## 2) M-theory on $T^7/\mathbb{Z}_2^3$ & twisted tori

Example of singular  $G_2$  manifold.  $[(b^0, b^1, b^2, b^3) = (1, 0, 0, 7)]$

→ EFT 4D  $N=1$  sugra + 7 X M's  $\{\Phi^\alpha\}_{\alpha=1,\dots,7}$

$$K(\Phi, \bar{\Phi}) = - \sum_{\alpha} \log(-i(\Phi^\alpha - \bar{\Phi}^\alpha))$$

In principle one may deform  $T^7/\mathbb{Z}_2^3$  by adding

- gauge fluxes ( $G_{(4)}$  &  $G_{(7)}$ )
- $G_2$  torsion ("trivial": metric flux  $\omega_{mn}{}^P \neq 0$ )

$$W(\Phi) = \underbrace{c_0}_{G_{(7)}} + \underbrace{c_{1\alpha}}_{G_{(4)}} \Phi^\alpha + \underbrace{c_{2\alpha\beta}}_{\omega} \Phi^\alpha \Phi^\beta \quad \rightarrow \omega_{[mn}{}^r \omega_{\beta]r}{}^q = 0$$

$$V = e^K (-3|W|^2 + |DW|^2)$$

EOM's  
→ VAC.

$$\partial_I V \Big|_{\Phi_0} \stackrel{!}{=} 0$$

↓  
1, ..., 14 ?

## 3) More general $G_2$ -structures & KK

→  $\omega_{[mn}{}^r \omega_{\beta]r}{}^q \neq 0$  is a magnetic source for 11D  $e_A{}^M$ !

(spacetime filling KK6)

$$V_\omega = -\sqrt{g_7} R_7|_{G_2} \quad (\text{for a } G_2 \text{ str.})$$

$$d\Phi_{(3)} = (\tau_0) *_7 \Phi_{(3)} + 3\tau_1 \wedge \Phi_{(3)} + *_7 \tau_3$$

$$d(*_7 \Phi_{(3)}) = 4\tau_1 \wedge *_7 \Phi_{(3)} + \tau_2 \wedge \Phi_{(3)}$$

$\tau \leftrightarrow \omega$   
dictionary

linear  $1 \leftrightarrow 1$ !

#### 4) No-go for dS & more ...

$$V = \underbrace{\lambda^I \partial_I V}_{=0} + \underbrace{V_0}_{\text{onshell!}} \quad (\text{specific case of MN})$$

$\leq 0$

$$\lambda^I = (0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1)$$

$M_{Kw_4}$  (if any!) occurs where  $(V_0 = 0)$ , i.e.

$$c_0 = c_1 = 0 \quad (\text{NO FLUX!})$$

$$\begin{cases} V = 0, \\ \partial_I V = 0. \end{cases} \quad \begin{array}{c} \cancel{1), 2)} \\ \cancel{3)} \\ 4) \end{array} \quad \begin{array}{c} \text{SUSY} \\ \cancel{\text{SUSY}} \\ \cancel{\text{SUSY}} \end{array} \quad (\text{different 1-parameter families of } \tau\text{'s})$$

$$\rightarrow M_{Kw_4} \times \underbrace{M_7}_{\substack{\text{Ricci flat,} \\ \text{SUSY}}}, \quad m_I^2 = \begin{cases} > 0 & \text{all BUT ...} \\ 0 & \underline{\text{overall vol}} \end{cases}$$

#### 5) Higher derivatives & dS?

$$2\kappa_{11}^2 \equiv (2\pi)^5 l_{11}^9$$

Only dimensionful coupling:  $\ell_{11}$

$$S_{1\text{-loop}} = (2\pi)^{-5} \int d^{11}x \sqrt{-g_{11}} \sum_{m=1}^{\infty} \ell_{11}^{2m-11} R_{11}^{(m)}$$

$$S_{\text{NLO}} = \frac{1}{2\kappa_{11}^2} \int d^{11}x \sqrt{-g_{11}} \left( R_{11} + \kappa_{11}^{4/3} R_{11}^{(4)} \right)$$

In Duff & Ferrara, 2011 it was argued that the matter content of the quantum resolved theory should determine the corrections

$$\xi(M_7) \equiv 7b^0 - 5b^1 + 3b^2 - b^3$$

reduces to  $\chi_E(M_6)$  when  $M_6 \times S^1 = M_7$ .

In our case  $M_7$  should be a Ricci flat 7-manifold w/ the same topological data given by the Joyce resolution.

$T^7/\mathbb{Z}_2^3$  has  $8 \times T^3 \times (\mathbb{C}^2/\mathbb{Z}_2)$  singularities

$$\{U_j\}_{j=1, \dots, 8}$$

$\rightarrow$  SU(2) hol. and as.  $\mathbb{C}^2/\mathbb{Z}_2$

Here  $U_j$  is Eguchi-Hanson

$$\frac{T^3 \times U_j}{\mathbb{Z}_2} \rightarrow 2 \text{ ineq.} \rightarrow 2^8 = 256 \xrightarrow{\substack{\text{ineq. res.} \\ (\text{in principle!})}} p = 0, \dots, 8 \quad \text{really ineq.}$$

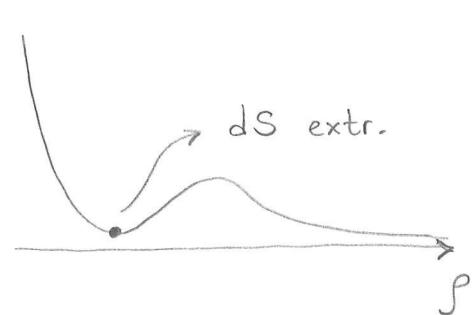
$$(b^0, b^1, b^2, b^3) = (1, 0, 8+p, 47-p)$$

$$\xi(M_7^{(p)}) = 4(p-4) \rightarrow \text{either signs!}$$

In my EFT<sub>4</sub>, this results in

$$K = \underbrace{K_{\text{tree}}}_{-\# \log \rho} - \kappa_{11}^{4/3} \xi(M_7) \frac{c}{\rho^3} \xrightarrow{\text{O}(1)}$$

$$+$$



Add  $G_{(7)}$ , correct the  $\tau$ 's

$$\downarrow V = V_0 \rho^{-3/2} + V_1 \rho^{-15/2} + V_2 \rho^{-21/2}$$

$$\downarrow \text{tree} \quad \downarrow \delta K_1 \quad \downarrow \delta K_1, G_{(7)}$$

If  $\rho = O(N^{2/3})$ ,  $a_0 = O(N^2)$ ,  $\tau = O(N)$  ...

$$\begin{cases} V = 0 + O(N^{-3}), \\ \varepsilon_V = 0 + O(N^{-2}), \\ \gamma_V = (>0) + O(N^{-1}). \end{cases}$$