On (4+6)-dimensional SUSY vacua with geometric or non-geometric fluxes

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arXiv:1411.6640 by D. A. and A. Betz,
arXiv:1507.00014 by D. A.

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MITP, Mainz, Germany

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$Q_a{}^{bc}, R^{abc}$ do not appear there... but in **10D β-supergravity**!

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CY: $\nabla_a \eta_+ = 0 \Leftrightarrow \mathrm{d}J = 0, \mathrm{d}\Omega = 0$ (Kähler with holom. Ω)
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Plan:
- Present new geometric vacua obtained + comments
- Brief review of β-supergravity
- Develop tools for SUSY vacua with non-geometric fluxes

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$$e^\phi = g_s e^{3A} \ , \ H = 0 \ ,$$
$$\frac{g_s F_2}{\sqrt{\tilde{g}_{33} \tilde{g}_{44} \tilde{g}_{66}}} = -\tilde{g}^{33} \partial_3 (e^{-4A}) e^4 \wedge e^6 + \tilde{g}^{44} \partial_4 (e^{-4A}) e^3 \wedge e^6 - \tilde{g}^{66} \partial_6 (e^{-4A}) e^3 \wedge e^4$$

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$$\mathrm{d}e^5 = \mathrm{d}e^6 = 0\ ,\quad f^2{}_{15} = -f^1{}_{25} = f^4{}_{35} = -f^3{}_{45} = q$$

Example ($\mathrm{SU}(2)_\perp$ str.): O_6 and D_6 wrapping 125, $A(y^3, y^4, y^6)$

$$g_{ab}e^a e^b = g_{mn}\mathrm{d}y^m \mathrm{d}y^n\ ,\ \tilde{g}_{ab} = g_{ab}|_{A=0}\ ,$$
$$g_{ab} = \mathrm{diag}(e^{2A}t_1, e^{2A}t_1, e^{-2A}t_2, e^{-2A}t_2, e^{2A}t_3, e^{-2A}t_3(\tau_6)^2)\ ,$$
$$e^\phi = g_s e^{3A}\ ,\ H = 0\ ,$$
$$\frac{g_s F_2}{\sqrt{\tilde{g}_{33}\tilde{g}_{44}\tilde{g}_{66}}} = -\tilde{g}^{33}\partial_3(e^{-4A})e^4 \wedge e^6 + \tilde{g}^{44}\partial_4(e^{-4A})e^3 \wedge e^6 - \tilde{g}^{66}\partial_6(e^{-4A})e^3 \wedge e^4$$
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Indeed: all known vacua with localized D_p, O_p: T-dual to T^6
"New vacua" (not T-dual to T^6): smeared sources.

Particularities of the vacua

$$\frac{g_s F_2}{\sqrt{\tilde{g}_{33}\tilde{g}_{44}\tilde{g}_{66}}} = -\tilde{g}^{33}\partial_3(e^{-4A})e^4\wedge e^6 + \tilde{g}^{44}\partial_4(e^{-4A})e^3\wedge e^6 - \tilde{g}^{66}\partial_6(e^{-4A})e^3\wedge e^4$$

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Only found SUSY flux vacua on 1 of the 3.

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Other 2 alg. $\Rightarrow$ solvmanifolds **not CY**, but **Ricci flat Kähler**

$$\mathrm{d}J = 0 \ , \ \mathrm{d}\Omega = W_5 \wedge \Omega$$

β-supergravity

Lagrangian $\tilde{\mathcal{L}}_\beta(f, Q, R)$

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To see the fluxes, Q, better to use flat tangent space indices

$$Q_c{}^{ab} = \partial_c \beta^{ab} - 2\beta^{d[a} f^{b]}{}_{cd} \ , \quad R^{abc} = 3\beta^{d[a} \nabla_d \beta^{bc]}$$

arXiv:0807.4527 by M. Graña, R. Minasian, M. Petrini, D. Waldram
arXiv:1109.0290 by G. Aldazabal, W. Baron, D. Marqués, C. Núñez

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arXiv:1106.4015, 1202.3060, 1204.1979 by D. A., O. Hohm, M. Larfors, D. Lüst, P. Patalong
arXiv:1210.1591, arXiv:1211.0030, arXiv:1304.2784
by R. Blumenhagen, A. Deser, E. Plauschinn, F. Rennecke, C. Schmid

Idea: field redef. $(g_{mn}, b_{mn}, \phi) \leftrightarrow (\tilde{g}_{mn}, \beta^{mn}, \tilde{\phi})$, β antisym.

$$\begin{aligned} \tilde{g}^{-1} &= (g+b)^{-1} g (g-b)^{-1} \\ \beta &= -(g+b)^{-1} b (g-b)^{-1} \end{aligned} \Leftrightarrow (g+b)^{-1} = (\tilde{g}^{-1} + \beta) \ , \ \frac{e^{-2\tilde{\phi}}}{e^{-2\phi}} = \frac{\sqrt{|g|}}{\sqrt{|\tilde{g}|}}$$

$\Leftrightarrow$ reparametrization of gen. metric $\mathcal{H}$, i.e. new gen. vielbein

Apply the field redefinition to $\mathcal{L}_{\rm NSNS}(g, b, \phi) = \tilde{\mathcal{L}}_\beta(\tilde{g}, \beta, \tilde{\phi}) + \partial(\dots)$

To see the fluxes, Q, better to use flat tangent space indices

$$Q_c{}^{ab} = \partial_c \beta^{ab} - 2\beta^{d[a} f^{b]}{}_{cd} \ , \quad R^{abc} = 3\beta^{d[a} \nabla_d \beta^{bc]}$$

arXiv:0807.4527 by M. Graña, R. Minasian, M. Petrini, D. Waldram
arXiv:1109.0290 by G. Aldazabal, W. Baron, D. Marqués, C. Núñez

$$\begin{aligned} \frac{\tilde{\mathcal{L}}_\beta}{e^{-2\tilde{\phi}}\sqrt{|\tilde{g}|}} =& \mathcal{R}(\tilde{g}) + 4(\partial\tilde{\phi})^2 + 4(\beta^{ab}\partial_b\tilde{\phi} - \mathcal{T}^a)^2 - \frac{1}{2}\eta_{ab} R^{acd} f^b{}_{cd} - \frac{1}{12} R^2 \\ &+ 2\eta_{ab}\beta^{ad}\partial_d Q_c{}^{bc} - \eta_{cd} Q_a{}^{ac} Q_b{}^{bd} - \frac{1}{2}\eta_{cd} Q_a{}^{bc} Q_b{}^{ad} - \frac{1}{4} Q^2 \end{aligned}$$

β-supergravity

Lagrangian $\tilde{\mathcal{L}}_\beta(f, Q, R)$

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10D theory with non-geometric fluxes, uplift 4D ✓

10D Bianchi identities for the fluxes

Standard sugra: $\mathrm{d}H = 0 \Rightarrow \; 2\partial_{[a}H_{bcd]} - 3\, f^{e}{}_{[ab}H_{cd]e} = 0$

$$\mathrm{d}(\mathrm{d}e^a) = 0 \Rightarrow \; \partial_{[b}f^{a}{}_{cd]} - f^{a}{}_{e[b}f^{e}{}_{cd]} = 0 = \mathcal{R}^{a}{}_{[bcd]}$$

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4D, constant fluxes: gaugings of gauged supergravity

$$[Z_a, Z_b] = H_{abc}X^c + f^{c}{}_{ab}Z_c$$
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Jacobi identities $\Leftrightarrow$ Bianchi identities

$$3\, f^{e}{}_{[ab}H_{cd]e} = 0$$
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Automatically satisfied with 10D expressions of f, Q, R

Non-geometry and β-supergravity

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10D origin of Q and R? Usually:
argued to descend from **10D non-geometric bckgds**...

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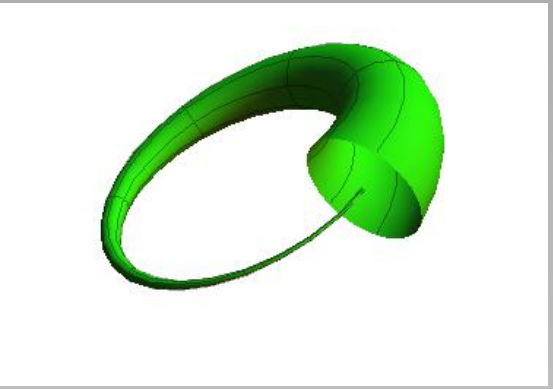

Global issue,
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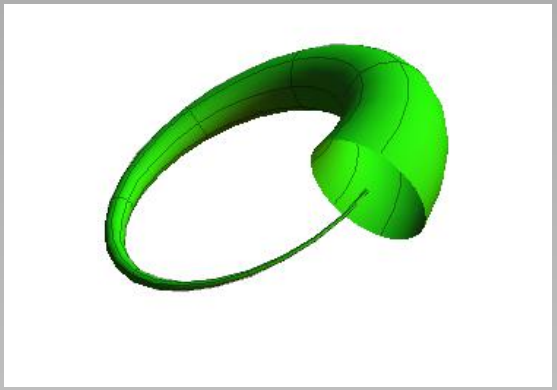

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Two examples: toroidal example and 5^2_2- or Q-brane.

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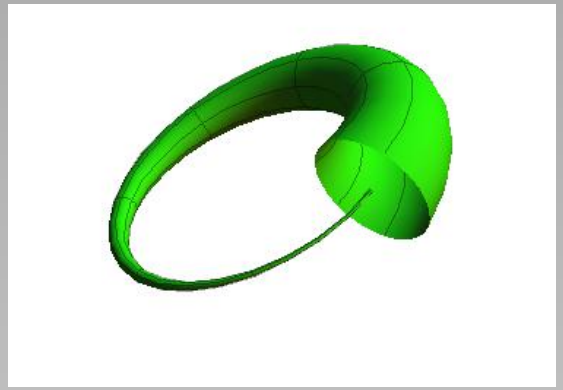

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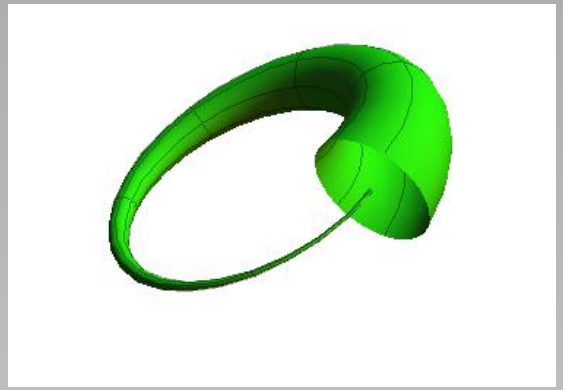

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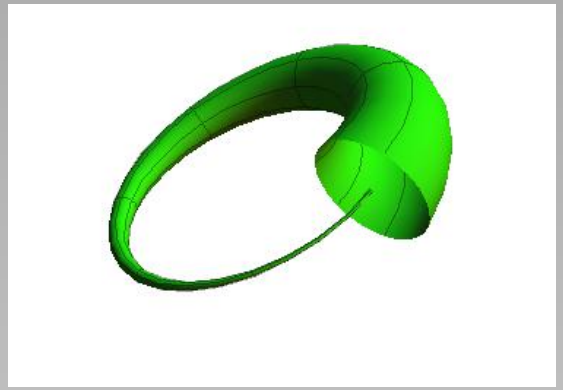

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Supersymmetry with non-geometric fluxes

Fermionic SUSY variations (NSNS sector)

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10D type II sugra: gravitino and dilatino SUSY variations

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$\hookrightarrow$ use them for SUSY variations:

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hep-th/0505212 by M. Graña, R. Minasian, M. Petrini and A. Tomasiello

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4D **superpotential** after dimensional reduction:

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For Q, R: expected from 4D

hep-th/0607015 by J. Shelton, W. Taylor, B. Wecht

arXiv:0705.3410 by M. Ihl, D. Robbins, and T. Wrase

proved in 10D β-supergravity.

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- We showed

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$$\text{for } \beta\text{-SUGRA:} \quad \mathcal{D}\Phi = 2e^{\tilde{\phi}}\mathbf{e}^{\beta\vee}\mathrm{d}(\mathbf{e}^{-\beta\vee}e^{-\tilde{\phi}}\Phi)$$

- $\mathcal{D}$: **Dirac operator** for $Spin(6,6)\times\mathbb{R}^+$ cov. derivative (computed in Gen. Geom., DFT)

arXiv:1107.0008 by O. Hohm, S. K. Kwak and B. Zwiebach

arXiv:1304.1472 by D. Geissbühler, D. Marqués, C. Núñez, V. Penas

$$\mathcal{D}\Phi = \Gamma^A D_A\Phi = \Gamma^A\Big(\partial_A + \tfrac{1}{4}\Omega_A{}^D{}_C\Gamma^{BC}\eta_{DB} - \tfrac{1}{2}\Lambda_A\Big)\Phi$$

Γ^A: Clifford algebra: $\{\Gamma^A,\Gamma^B\} = 2\eta^{AB}$, use the representation Γ^A : $\Gamma^a = 2\tilde{e}^a\wedge$, $\Gamma_a = 2\iota_a$

$\hookrightarrow$ SUSY conditions $\sim$ generalized Dirac equations

- $\mathcal{D}^2 = 0 \Leftrightarrow$ **Bianchi identities** & $\frac{1}{3}H_{abc}R^{abc} + \frac{1}{2}f^a{}_{ab}Q_a{}^{ab} = 0$

Clear for standard supergravity with $\mathrm{d} - H\wedge$

For Q, R: expected from 4D

hep-th/0607015 by J. Shelton, W. Taylor, B. Wecht

arXiv:0705.3410 by M. Ihl, D. Robbins, and T. Wrase

proved in 10D β-supergravity.

- Appears in **RR fluxes**: standard sugra: $F \sim \mathcal{D}C$

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Thank you for your attention!