Exceptional Flux Compactifications

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String Phenomenology

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Based on arXiv:1202.0770 and work in progress.

In collaboration with G. Dibitetto and D. Roest.

NWO
Netherlands Organisation for Scientific Research

- Why exceptional ?

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[Nicolai, Samtleben '00]
[de Wit, Samtleben, Trigiante '02 '05 '07]

- Exceptional amount of SUSY (32 charges) ⇨ Maximal *gauged* supergravity

  i) Ingredients = supergravity multiplet + deformations (*gaugings*)

  ii) Type IIA/IIB string embedding

  iii) Flux backgrounds compatible with absence of branes

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➢ Exceptional global symmetry in 4D ⇨ E_7 exceptional Lie group

Bosonic fields : metric $(\mathbf{1})$ + vectors $(\mathbf{56})$ + scalars $(\mathbf{133})$

Fermionic fields : gravitini $(\mathbf{8}$ of $SU(8) \subset E_7)$ + dilatini $(\mathbf{56})$

Deformation parameters = embedding tensor : fluxes $(\mathbf{912})$

- **912** fluxes from type II strings ?

➢ Fluxes = 10D field strengths threading the 6D internal space

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  - Finger counting

Geometric Flux Backgrounds

$$\left\{ \begin{array}{lcccc} \text{metric (vielbein)} & : & \omega \equiv \partial_{[m}\, e_{n]}{}^{p} & \rightarrow & 90 \\ B_2 & : & H_3 \equiv \partial_{[m}\, B_{np]} & \rightarrow & 20 \\ \varphi & : & H_1 \equiv \partial_m\, \varphi & \rightarrow & 6 \\ C_{p=\text{odd/even}} & : & G_{p+1} \equiv d\, C_p & \rightarrow & 32 \end{array} \right.$$

148 fluxes ...

... so what is missing ?

$$\boxed{148 < 912}$$

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Non-Geometric Fluxes !!

Q , R ; P , H' , G' , Q', P' ...

[Shelton, Taylor, Wecht '05 '06]
[Aldazabal, Cámara,Font, Ibañez '06]
[Font, A.G. , Moreno '08]
[A.G. , Weatherill '09]
[Aldazabal, Andrés, Cámara, Grana '10]

- Non-geometry : a theoretical challenge

  - Genuine stringy backgrounds ?

$$\text{global } E_7 \text{ symmetry} = \text{U-duality}$$

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  - What objects (sources) are behind ?

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- Beyond ordinary geometry ?

  DFT/Doubled Geometry

  Generalised Geometry

[Hull, Zwiebach '09]
[Hohm, Hull, Zwibach '10]
[Gualtieri '04]
[Grana, Minasian, Petrini, Tomasiello '04 '05]
[Grana, Minasian, Petrini, Waldram '08]
[Coimbra, Strickland-Constable, Waldram '11]

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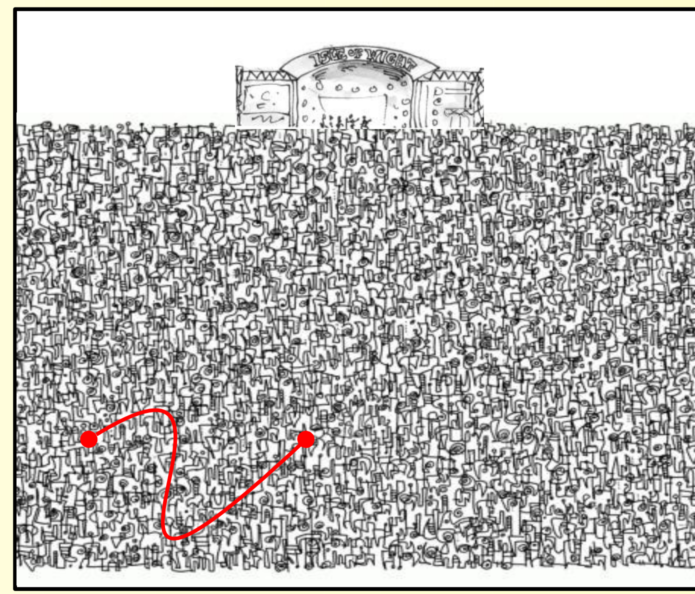
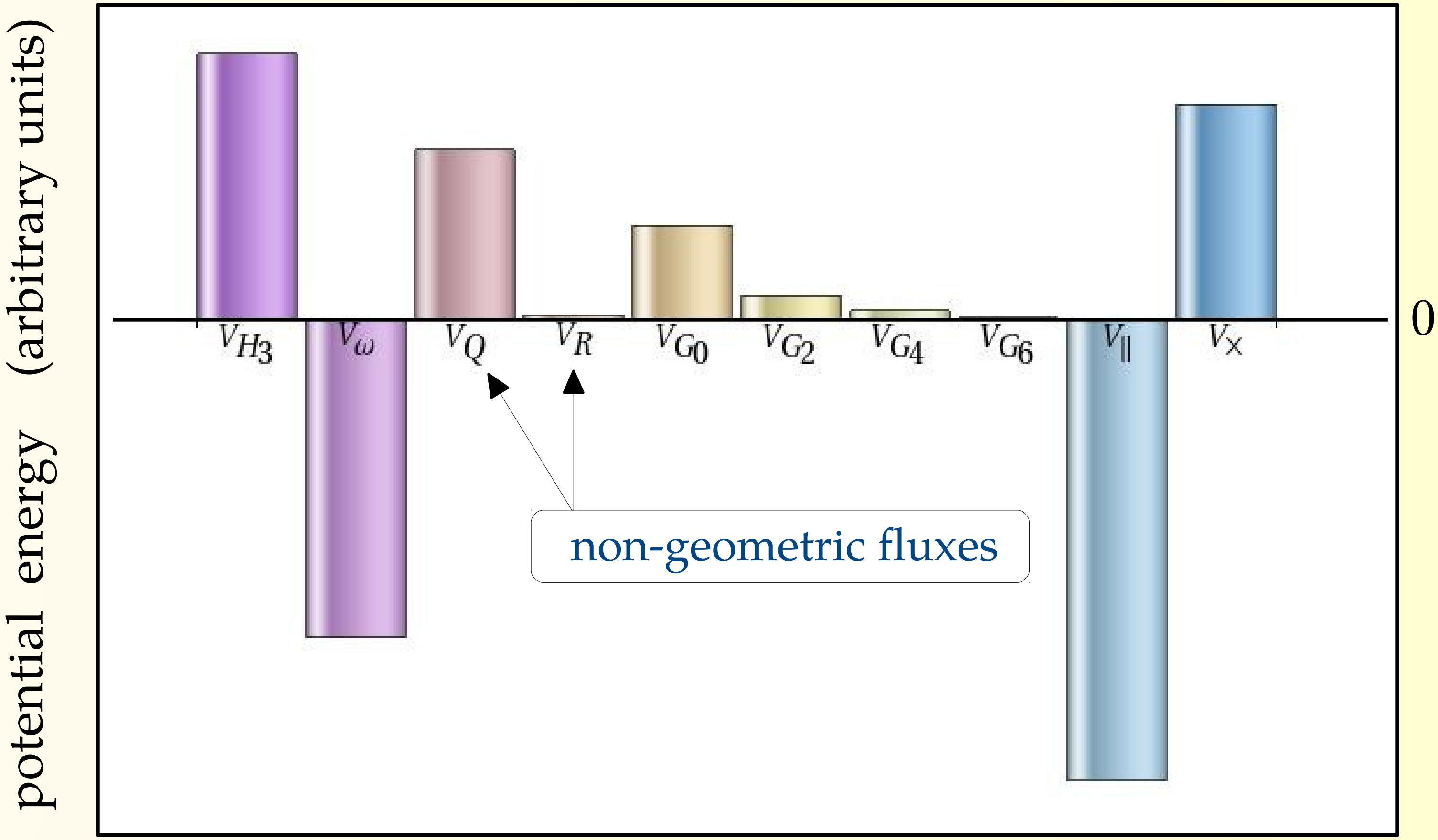


Rock festival backgrounds go beyond Euclidean geometry ...

… can we infer who is playing ?

- Non-geometric fluxes and de Sitter vacua

[de Carlos, A.G. Moreno '09]



Sources : type IIA fluxes and D6-branes/O6-planes

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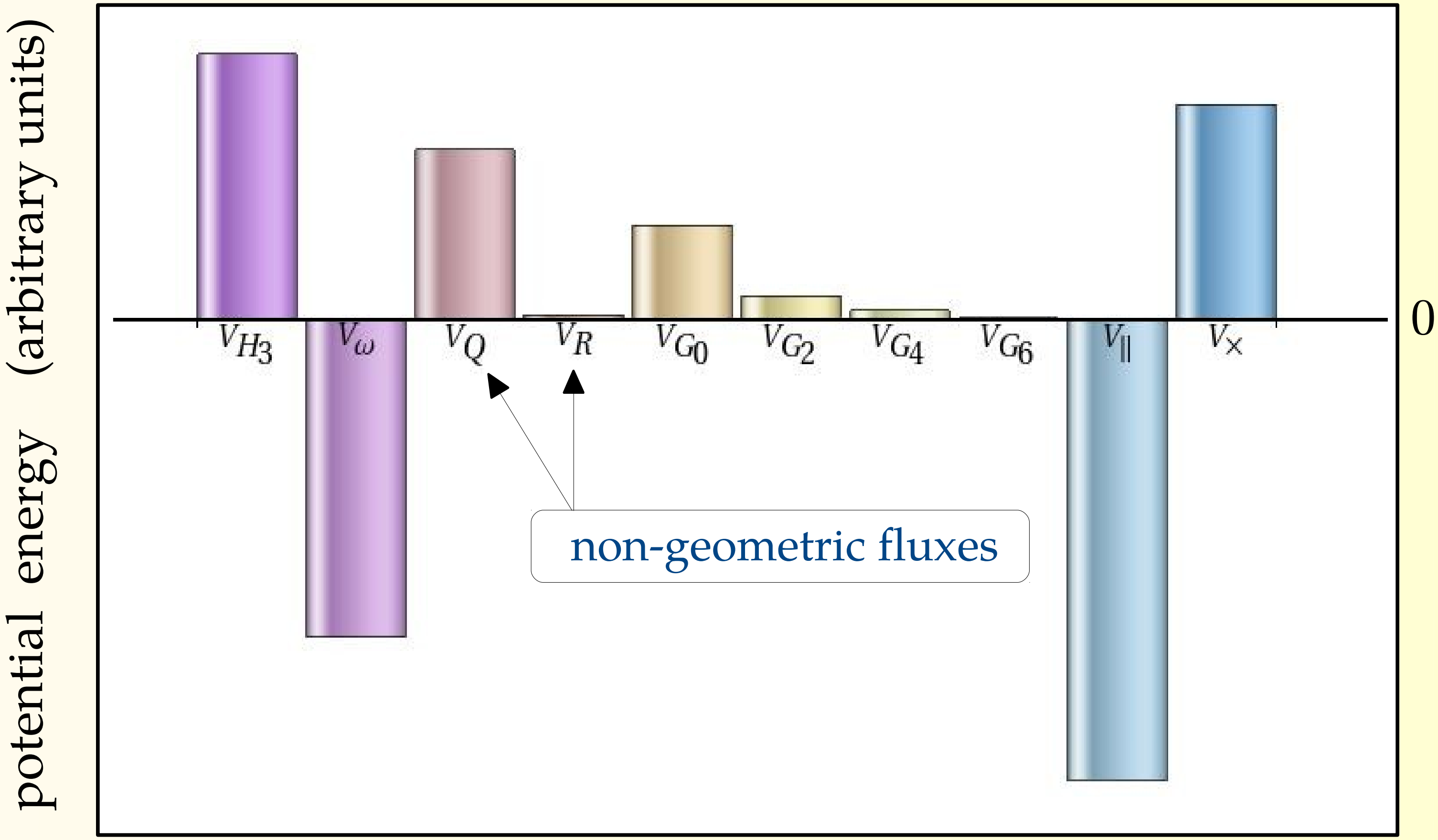

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… so let's explore moduli stabilisation in maximal SUGRA with general fluxes !!

• Scalar dynamics and fermion mass terms

- Dynamics encoded in the flux-induced fermion masses $\mathcal{A}_{\mathcal{I}\mathcal{J}}(\phi)$ and $\mathcal{A}_{\mathcal{I}}{}^{\mathcal{J}\mathcal{K}\mathcal{L}}(\phi)$

$$\mathcal{L}_{\text{fermi}} = \frac{\sqrt{2}}{2}\,\mathcal{A}_{\mathcal{I}\mathcal{J}}\,\overline{\psi}_{\mu}{}^{\mathcal{I}}\,\gamma^{\mu\nu}\,\psi_{\nu}{}^{\mathcal{J}} + \frac{1}{6}\,\mathcal{A}_{\mathcal{I}}{}^{\mathcal{J}\mathcal{K}\mathcal{L}}\,\overline{\psi}_{\mu}{}^{\mathcal{I}}\,\gamma^{\mu}\,\chi_{\mathcal{J}\mathcal{K}\mathcal{L}} + \mathcal{A}^{\mathcal{I}\mathcal{J}\mathcal{K},\mathcal{L}\mathcal{M}\mathcal{N}}\,\overline{\chi}_{\mathcal{I}\mathcal{J}\mathcal{K}}\,\chi_{\mathcal{L}\mathcal{M}\mathcal{N}} + \text{h.c.}$$

gravitino-gravitino   gravitino-dilatino   dilatino-dilatino (dependent)

[Le Diffon, Samtleben, Trigiante '11]
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  - Scalar potential

$$V(\phi) = -\frac{3}{4}\,|\mathcal{A}_1|^2 + \frac{1}{24}\,|\mathcal{A}_2|^2 \qquad \text{where} \qquad \begin{cases} |\mathcal{A}_1|^2 = \mathcal{A}_{\mathcal{I}\mathcal{J}}\, \mathcal{A}^{\mathcal{I}\mathcal{J}} \\ |\mathcal{A}_2|^2 = \mathcal{A}_{\mathcal{I}}{}^{\mathcal{J}\mathcal{K}\mathcal{L}}\, \mathcal{A}^{\mathcal{I}}{}_{\mathcal{J}\mathcal{K}\mathcal{L}} \end{cases}$$

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- E.O.M's for maximally symmetric solutions (critical points of V)

$$\mathcal{C}_{\mathcal{I}\mathcal{J}\mathcal{K}\mathcal{L}}(\phi)\,|_{\text{SD}} = 0 \qquad \text{where} \qquad \mathcal{C}_{\mathcal{I}\mathcal{J}\mathcal{K}\mathcal{L}} = \mathcal{A}^{\mathcal{M}}{}_{[\mathcal{I}\mathcal{J}\mathcal{K}}\,\mathcal{A}_{\mathcal{L}]\mathcal{M}} + \frac{3}{4}\,\mathcal{A}^{\mathcal{M}}{}_{\mathcal{N}[\mathcal{I}\mathcal{J}}\,\mathcal{A}^{\mathcal{N}}{}_{\mathcal{K}\mathcal{L}]\mathcal{M}}$$

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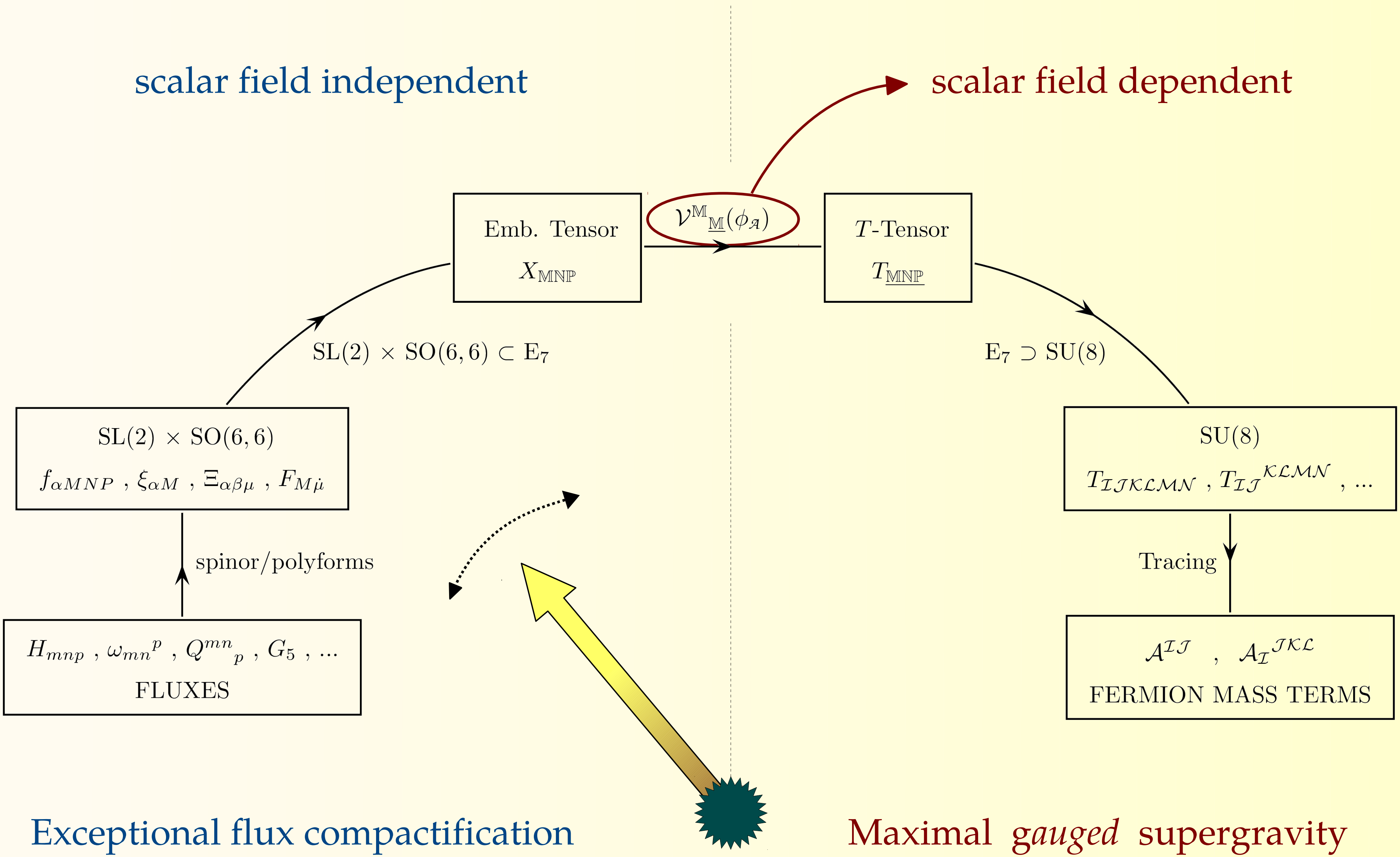
- SUSY preserved

$$\#\ \text{Eigenvalues}\,(\mathcal{A}_{\mathcal{I}\mathcal{J}}) = \sqrt{-\frac{1}{6}\, V_0}$$

[Le Diffon, Samtleben, Trigiante '11]
[de Wit, Samtleben, Trigiante ''07]

- From fluxes to fermion masses and *viceversa*

[Dibitetto, A.G, Roest '11 '12 , in progress ...]



- How to use the flux $\Leftrightarrow$ fermi masses dictionary ?

1) Embedding type II flux backgrounds into maximal SUGRA, derive the fermion masses and study maximally symmetric solutions.

2) Embed SUGRA backgrounds into type II toroidal flux compactifications and explore their geometric/non-geometric nature.

• Example 1 : From type II fluxes to SUGRA

- Type IIA orientifold models including SO(3)-invariant gauge and metric fluxes

[Derendinger, Kounnas, Petropoulos, Zwirner '04]
[Dall'Agata, Villadoro, Zwirner '09]

$$\left(G_{p=0,2,4,6} \;,\; H_3 \right) \;+\; \omega \;\subset\; f_{\alpha MNP}$$

- Four AdS_4 solutions

solution 1	solution 2	solution 3	solution 4
$\mathcal{N}=1$ SUSY	~~SUSY~~	~~SUSY~~	~~SUSY~~
stable	unstable	stable	unstable
$m^2 = -2/3$	$m^2 = -4/5$	$m^2 > 0$	$m^2 = -4/3$
$V = -1$	$V = -32/27$	$V = -8/15$	$V = -32/27$

$(*)$ $m^2 \equiv$ lightest mode (B.F. bound $= -3/4$)

- Unique deformation (*gauging*)

$$G_0 = SO(4) \ltimes Nil_{(22)}$$

- All the solutions correspond to an SU(2) x SU(2) manifold

[Caviezel, Koerber, Körs, Lüst, Tsimpis/Wrase, Zagermann '08, '08]

• Example 2 : From SUGRA to type II fluxes

[Hull, Warner '85]
[Roest, Rosseel '09]
[Dall'Agata, Inverso '11]

- CSO(p,q,r) with $p+q+r=8$ gaugings in maximal SUGRA

- Type IIB flux matrices
$$\begin{cases} M_+ = \begin{pmatrix} G'_3 & 0 \\ 0 & Q \otimes \mathbb{I}_3 \end{pmatrix} \quad , \quad M_- = \begin{pmatrix} H'_3 & 0 \\ 0 & P \otimes \mathbb{I}_3 \end{pmatrix} \\ \tilde{M}_+ = \begin{pmatrix} G_3 & 0 \\ 0 & Q' \otimes \mathbb{I}_3 \end{pmatrix} \quad , \quad \tilde{M}_- = \begin{pmatrix} H_3 & 0 \\ 0 & P' \otimes \mathbb{I}_3 \end{pmatrix} \end{cases}$$

ID	$\frac{1}{\lambda} M_+$ and $\frac{1}{\lambda} \tilde{M}_-$	$\mathcal{N}=8$ gauging	$\mathcal{N}=4$ gauging	$\frac{1}{\lambda^2} V_0$	Mass spectrum
1	$M_+ = (1,1,1,1)$ $\tilde{M}_- = (1,1,1,1)$	SO(8)	$\text{SO}(4)^2$	$-\frac{3}{2}$	$(70\times)\ -\frac{2}{3}$
2	$M_+ = (5,1,1,1)$ $\tilde{M}_- = (1,1,1,1)$	SO(8)	$\text{SO}(4)^2$	$-\frac{5}{2}$	$2\ ,\ (27\times)\ -\frac{4}{5}\ ,\ (35\times)\ -\frac{2}{5}\ ,\ (7\times)\,0$
3	$M_+ = (1,1,1,1)$ $\tilde{M}_- = (1,-3,-3,-3)$	SO(5,3)	SO(4) × SO(1,3)	$\frac{3}{2}$	$-2\ ,\ (5\times)\,4\ ,\ (30\times)\,2\ ,\ (14\times)\,\frac{4}{3}\ ,\ (5\times)\ -\frac{2}{3}\ ,\ (15\times)\,0$
4	$M_+ = (1,-1,-1,-1)$ $\tilde{M}_- = (-1,1,1,1)$	SO(4,4)	SO(1,3) × SO(3,1)	$\frac{1}{2}$	$(2\times)\ -2\ ,\ (36\times)\,2\ ,\ (16\times)\,1\ ,\ (16\times)\,0$
5	$M_+ = (1,1,1,1)$ $\tilde{M}_- = (-1,-1,-1,-1)$	SO(4,4)	SO(4,0) × SO(0,4)	$\frac{1}{2}$	$(2\times)\ -2\ ,\ (36\times)\,2\ ,\ (16\times)\,1\ ,\ (16\times)\,0$
6	$M_+ = (1,0,0,0)$ $\tilde{M}_- = (1,0,0,0)$	CSO(2,0,6)	$\text{CSO}(1,0,3)^2$	0	$(20\times)\,\frac{\lambda^2}{8}\ ,\ (2\times)\,\frac{\lambda^2}{2}\ ,\ (48\times)\,0$

All these SUGRA's are non-geometric !!

• Summary

- Global symmetries (dualities) in SUGRA require unconventional non-geometric fluxes. These rise new questions both about theoretical and phenomenological aspects of string compactifications

- Exploiting the connection between string flux compactifications and *gauged* supergravities might shed light upon these questions

- String embedding vs moduli stabilisation

semisimple gaugings		intermediate gaugings		nilpotent gaugings
moduli stabilisation ✓	$\leftrightarrow$	moduli stabilisation ✓	$\leftrightarrow$	moduli stabilisation ✗
string embedding ✗		string embedding ✓		string embedding ✓
Example 2		Example 1		[de Wit, Samtleben, Trigiante '03]

… still many things to be understood.

Thanks !!