Type IIB S-folds:
New solutions and consistent truncations

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INFN Padova

TFI meeting Napoli
04/09/24

Based on : [2407.11593] Guarino, Rudra, Trigiante & CS
[To appear] Guarino, Rudra, Trigiante & CS

Universal black hole

In M-theory and Type IIA

The universal black hole

[Romans '92]
[Caldarelli, Klemm, '98]

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The universal black hole

$$\mathcal{L}_{N=2} = \left(\frac{R}{2} - \Lambda\right) \star 1 - \frac{1}{2} H \wedge \star H$$

[Romans ‘92]
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$$ds^2 = -f(r)\, dt^2 + f(r)^{-1}\, dr^2 + r^2\, ds^2_{\Sigma_g}$$

$$f(r) = \left(\frac{r}{L_{AdS_4}} - \frac{L_{AdS_4}}{2r}\right)^2$$

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$$s = \frac{A(\Sigma_g)}{4} = L^2_{AdS_4} \frac{(\mathrm{g}-1)\pi}{2}$$

Field theory dual

Azzurli, Benini, Bobev, Crichigno, Hristov, Min, Zaffaroni,… '15 – '17

Deep UV:

AdS_4

CFT_3

Field theory dual

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flow →

Deep UV: Deep IR

AdS_4 Universal BH AdS_2

CFT_3 CFT_1

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flow

Deep UV: → Deep IR

AdS_4	Universal BH	AdS_2
CFT_3	on $\Sigma_g \times S^1$ with *topological* twist (this means we have turned-on the right magnetic fluxes for R-symmetry)	CFT_1

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Deep UV: Deep IR

On shell-action

$$I = L^2_{AdS_4} \frac{(g-1)\pi}{2}$$

AdS_4

Universal BH

BH entropy

$$S_{BH} = L^2_{AdS_4} \frac{(g-1)\pi}{4}$$

AdS_2

CFT_3 CFT_1

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Deep UV: | Deep IR

On shell-action | BH entropy

AdS_4 $\quad I = L^2_{AdS_4} \frac{(g-1)\pi}{2}$ Universal BH $S_{BH} = L^2_{AdS_4} \frac{(g-1)\pi}{4}$ $\quad AdS_2$

CFT_3 $\quad$ CFT_1

on $\Sigma_g \times S^1$ with *topological* twist

(this means we have turned-on the right magnetic fluxes for R-symmetry)

F_{S^3} $\quad$ $\log Z_{\Sigma_g \times S^1}$

Free energy on S^3 | Top. twisted index

The universal black-hole embedded

M-theory

[Benin, Hristov, Zaffaroni ‘15]

Massive type IIA [Guarino, Varela 15]
[Guarino, Tarrio 17]

[Hosseini, Hristov, Passias17]
[Benini, Khachatryan, Milan 17]

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- S^7 compactification
- $\mathcal{N} = 8\ SO(8)$-gauged

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- Restrict to $U(1)^2$-inv

$$\mathcal{N} = 2 \; n_v = 3 \; n_h = 1$$

$$U(1)^3 \times \mathbb{R}\text{-gauging}$$

[Hosseini, Hristov, Passias17]
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- Univ. BH and horizon solutions
- SU(N) CS_k on $S^1 \times \Sigma_g$

[Hosseini, Hristov, Passias17]
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Universal black hole in type IIB

From 10 to 4 dimensions

D= 10 Type IIB SUGRA

↓

Compactification on
$$S^5 \times S^1$$
with a $SL(2,\mathbb{Z})$ monodromy along the S^1

Type IIB S-folds:

D= 10 Type IIB SUGRA

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D=4 N=8 gauged SUGRA

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$$G_{gauge} = [SO(6) \times SO(1,1)] \times \mathbb{R}^{12}$$

Type IIB S-folds:

Dictionary

D= 10 Type IIB SUGRA ⟷ D = 56 $E_{7(7)}$-Exceptional Field Theory

Compactification on
$S^5 \times S^1$
with a $SL(2,\mathbb{Z})$ monodromy
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Generalized
Scherk-Schwarz Ansatz
[Inverso, Samtleben,
Trigiante]

D=4 N=8 gauged SUGRA

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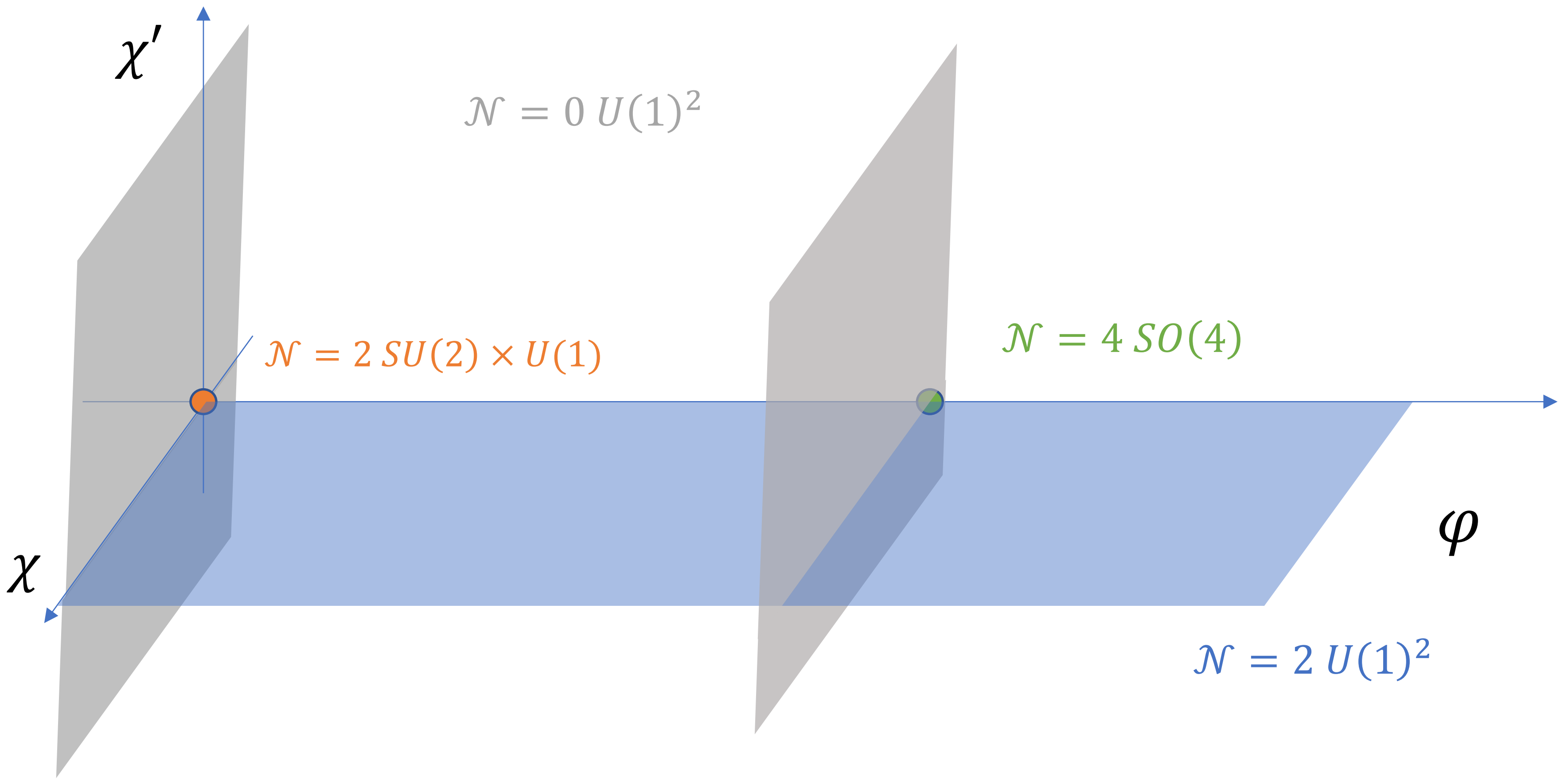
The AdS_4 asymptotics

[Guarino, CS]
[Guarino, CS, Trigiante]



For other types of S-folds AdS_4 see also
[Gallerati, Samtleben, Trigiante], [Bobev, Gautasson, van Muiden]

[2407.11593] Guarino, Rudra, Trigiante, CS

From $\mathcal{N} = 8$ to $\mathcal{N} = 2$

See also [Bobev, Gautasson, van Muiden ‘24]
for a different 4d truncation

[2407.11593] Guarino, Rudra, Trigiante, CS

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Nothing surprising here

Uplift of universal BH

[Imagine a series of ugly, but reasonable, formulas for IIB fields]

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$(0, \pi/4) \Rightarrow$ NH limit of univ. BH with $\mathcal{N} = 2\ SU(2)$ asymptotics

Uplift of the scale separated solution

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- Check the SUGRA approximation

$$g_S \ll 1 \text{ and } \alpha' R \ll 1$$

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Requires $\gamma = \frac{\pi}{4}$ so that $AdS_2 \ltimes M_8 \Rightarrow AdS_2 \times M_8$

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$\lambda \gg 1$ or $\lambda \ll 1$

$$L_{AdS_2} \propto \cosh^{-1}\lambda \qquad L_{\mathbb{H}^2} \propto \frac{1}{\sqrt{2}} \qquad L_{S^1} \propto T\cosh^{-1}\lambda \qquad vol_{S^5} \propto \cosh^5\lambda$$

Exotic consistent truncations

$\mathcal{N} = 4\ SO(4)$-gauged truncation of Type IIB

From $\mathcal{N} = 8$ to $\mathcal{N} = 2$

Consistent truncation $\Leftrightarrow$ $G_{inv} \subset G_{gauge} \times G_{global}$

$$\subset [SO(6) \times SO(1,1)] \times \Gamma$$

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$$\mathcal{N} = 2 \;\; n_v = 3 \;\; n_h = 4$$

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Conjectured in [Gauntlett, Varela '07]
Proven in [Coimbra, Strickland-Constable, Waldram, '14]
[Cassani, Josse, Petrini, Waldram, '19]

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$SU(4)_S, SU(4)_R, \mathrm{SO}(6)_\mathrm{g}$ and $SU(8)$

$$\begin{pmatrix} SU(4)_R & 0 \\ 0 & SU(4)_S \end{pmatrix}$$

$SO(6)_g$ is the diagonal subgroup of $SU(4)_R \times SU(4)_S \subset SU(8)$

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$\mathcal{N} = 4$ $SO(4)$-gauging

[Cassani, Josse, Petrini, Waldram, ‘19]
[Malek ‘17]

Technical statement

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Not $SU(4)_S$-inv $\longrightarrow$ $T_{\mathcal{N}=8}$

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$$T_{\mathcal{N}=8} = T^{int}_{\mathcal{N}=4} \oplus T^{non\ int}$$

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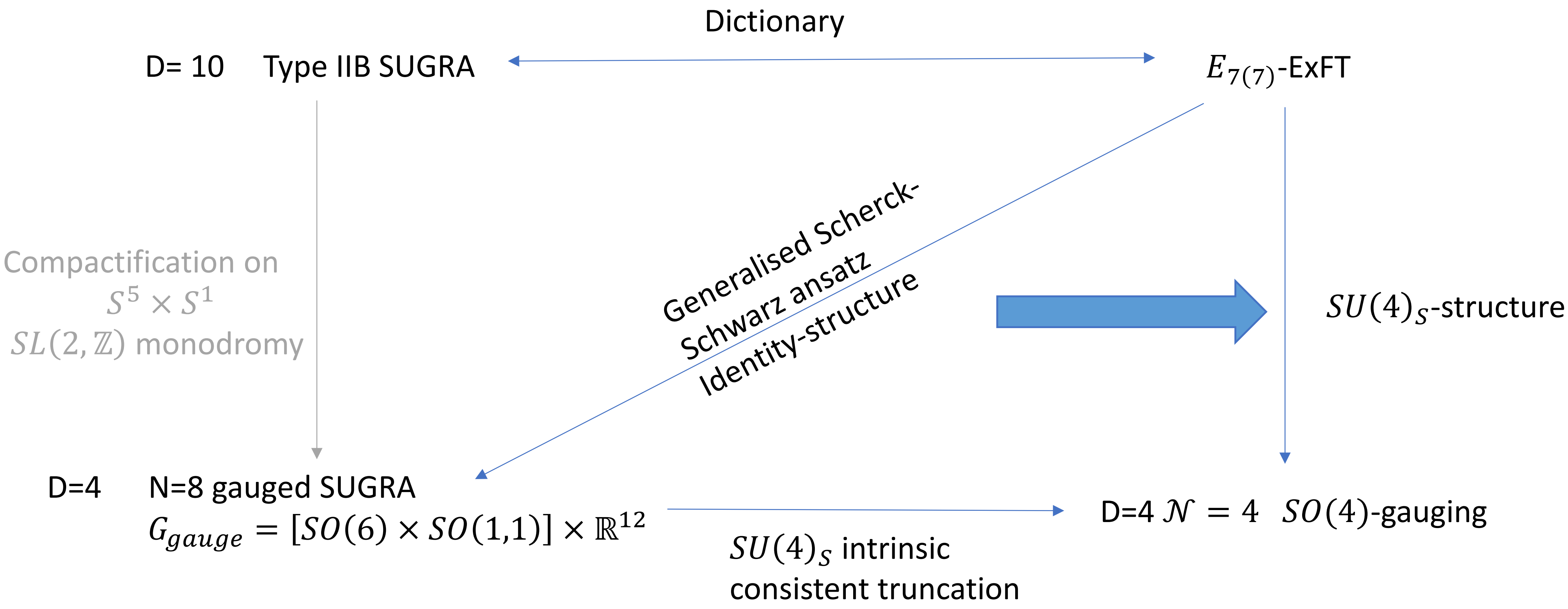
Not $SU(4)_S$ -inv

Truncations of truncations

Consistent of course



Uplift of the $U(1)^2$ subsector

4 dimensions

$$\{\tau = \chi + i\, e^{-\phi}, A_1, A_2\}$$

Type IIB metric

$$ds^2 = \Delta^{-1}\left(\frac{1}{2}\, ds^2_{ext} + g_{mn}\, Dx^M\, Dx^N\right)$$
$$g_{mn} dx^m\ dx^n = \ d\alpha^2 + d\eta^2 + {f_1}^{-1}\, vol_1 + {f_2}^{-1}\, vol_2$$
$$vol_i = d\theta_i^2 + \sin^2\theta_i\ d\varphi_i$$
$$f_1 = 1 + 2\, e^{-\phi}\cos^2\alpha$$
$$f_2 = 1 + 2\, e^{\phi}\, |\tau|^{-2} \sin^2\alpha$$
$$D\varphi_i = d\varphi_i + A_i$$

Conclusion and outlook

Summary and outlook

- We have built
  - A universal BH that asymptotes any $\mathcal{N} = 2$ S-fold
  - A scale separated $AdS_2 \times \mathbb{H}^2$ solution (with uplift)

    Can be understood as AdS_2 S-folds

  - A consistent truncation of Type IIB SUGRA to $\mathcal{N} = 4$ SO(4)-gauged SUGRA
    - New IIB solutions
    - A laboratory for non-geometric solutions and AdS/CFT

Thank you

Uplift of a universal BH

Does it match what you had in mind?

$$ds_{10}^2 = \Delta^{-1}\left(\tfrac{1}{2}\, ds_4^2 + g_{mn}\, Dy^m\, Dy^n\right)$$

$$Dy^n = dy^n + A_\mu{}^n\, dx^\mu$$

$$g_{mn}\, dy^m dy^n = d\eta^2 + d\alpha^2 + \frac{\cos^2\alpha}{2+\cos(2\alpha)} ds^2_{\mathrm{S}^2_1} + \frac{\sin^2\alpha}{2-\cos(2\alpha)} ds^2_{\mathrm{S}^2_2}$$

$$\mathbb{B}^1 = \tfrac{1}{\sqrt{2}}\tfrac{1}{r} dt \wedge d(e^{-\eta}\sin\alpha\ \cos\theta_2) + \tfrac{\cosh\theta}{2\sqrt{2}} d\phi \wedge d(e^{-\eta}\cos\alpha\ \cos\theta_1) - 2\sqrt{2}\, e^{-\eta}\ \cos\alpha\, \widetilde{\mathrm{vol}}_1\ ,$$

$$\mathbb{B}^2 = -\tfrac{1}{\sqrt{2}}\tfrac{1}{r} dt \wedge d(e^{\eta}\cos\alpha\ \cos\theta_1) - \tfrac{\cosh\theta}{2\sqrt{2}} d\phi \wedge d(e^{\eta}\sin\alpha\ \cos\theta_2) - 2\sqrt{2}\, e^{\eta}\ \sin\alpha\, \widetilde{\mathrm{vol}}_2\ ,$$

$$\begin{aligned}\widetilde{F}_5 = &\ 6\,\widetilde{\mathrm{vol}}_5 - 4\sin(2\alpha)\, d\eta \wedge \widetilde{\mathrm{vol}}_1 \wedge \widetilde{\mathrm{vol}}_2 \\ &+ \tfrac{r^2}{4}\sinh\theta\left(2\, d(\cos^2\alpha) - 3d\eta\right) \wedge dt \wedge dr \wedge d\theta \wedge d\phi \\ &+ \tfrac{1}{r^2} dt \wedge dr \wedge (\cos\theta_2 \widetilde{\mathrm{vol}}_2 - \cos\theta_1 \widetilde{\mathrm{vol}}_1) \wedge \left(d(\cos^2\alpha) - d\eta\right) \\ &- \tfrac{1}{\ldots} dt \wedge dr \wedge (\sin^2\theta_1\, D\varphi_1 + \sin^2\theta_2\, D\varphi_2) \wedge d(\cos^2\alpha) \wedge d\eta\end{aligned}$$

Back-up slides

How to comapctify?

$E_{7(7)}$-ExFT as a guide

$(g_{\mu\nu}, M_{MN}, A_\mu{}^M, B_{\mu\nu\,M}, B_{\mu\nu\,\alpha})$

D = 56 $E_{7(7)}$-Exceptional Field Theory [Hohm, Samtleben]

Dictionary

$(g_{\mu\nu}, \mathbb{B}^{\alpha}_{\mu\nu}, m_{\alpha\beta}, F_5)$

D= 10 Type IIB SUGRA

Compactification

Generalized
Scherk-Schwarz Ansatz
[Inverso, Samtleben, Trigiante]

D=4 N=8 gauged SUGRA

$G_{gauge} = [SO(6) \times SO(1,1)] \times \mathbb{R}^{12}$

Advantage of the method :

- Consistent truncation
- Uplift possible (and not so hard for certain gauge groups)
- Allows to compute the masses of higher-level excitation (i.e. higher modes in KK spectrum)

Uplift of the $\mathcal{N} = 4$ S-fold

[Inverso, Samtleben, Trigiante ‘16]
[Guarino, CS]

Solution on $AdS_4 \times S^1_\eta \times S^5$
The S^5 is deformed and preserves an $SO(4) \sim SO(3) \times SO(3)$ and is understood as :

$$S^5 \sim S^2_1 \times S^2_2 \times I_\alpha$$

Metric : $ds^2_{10} = \Delta^{-1} [\frac{1}{2}\, ds^2_{AdS_4} + d\eta^2 + d\alpha^2 + \frac{\cos^2(\alpha)}{2+\cos(2\alpha)} ds^2_{S_1} + \frac{\sin^2(\alpha)}{2-\cos(2\alpha)}\, ds^2_{S_2}]$

$$ds^2_{S_i} = d\theta^2 + cos\theta^2 d\varphi_i^2$$

Warp factor : $\Delta^{-4} = 4 - \cos^2(2\alpha)$

Five-form : $F_5 = (1 + *)\, f(\alpha)\, Vol_{S^5}$

Dilaton : $e^{\phi} = e^{-\eta} \frac{\sqrt{2-\cos(2\alpha)}}{\sqrt{2+\cos(2\alpha)}}$

Axion : $C_0 = 0$

2-Form : $B_2 = -2\sqrt{2}\, e^{-\eta} \frac{\cos^3(\alpha)}{2+\cos(2\alpha)}\, vol_{S_1}$

$C_2 = 2\sqrt{2}\, e^{\eta} \frac{\sin^3(\alpha)}{2-\cos(2\alpha)}\, vol_{S_2}$

Generating a family of solutions :

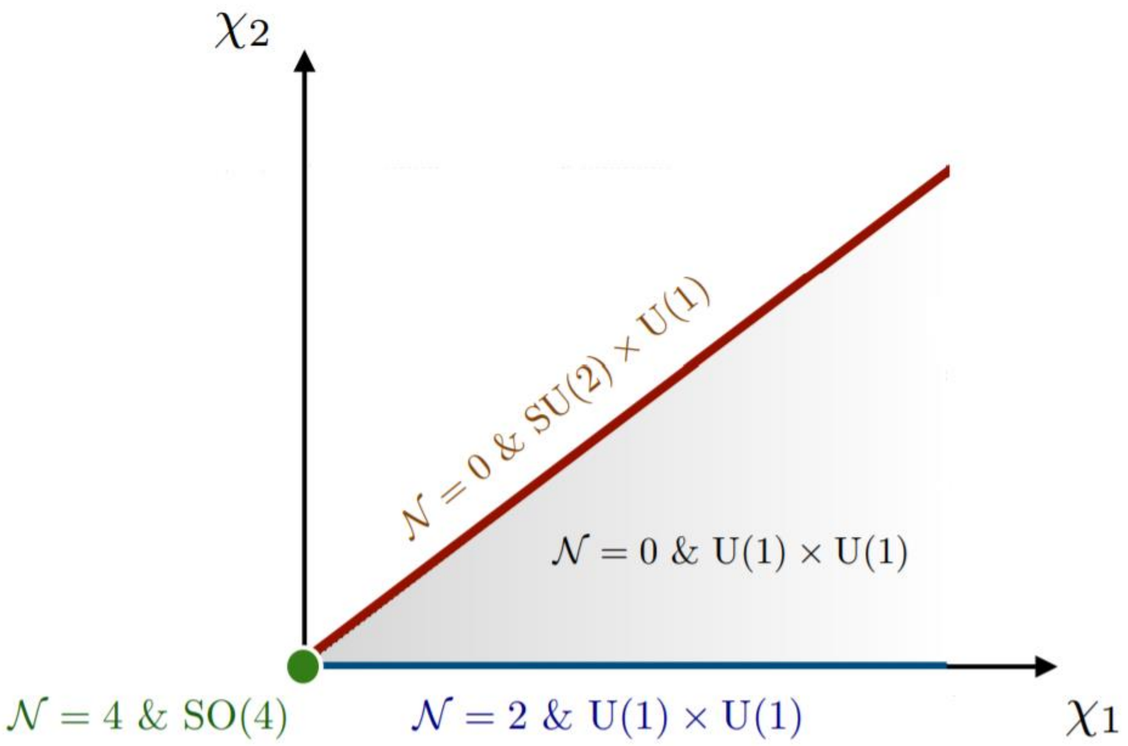
The « $\mathcal{N} = 4$ family » [Guarino, CS]

$\mathcal{N} = 4$ locus with $SO(4) \sim SO(3) \times SO(3)$ symmetry

$\mathrm{R}ank(SO(4)) = 2 \quad \Rightarrow \quad$ 2D moduli space $\quad (\chi_1, \chi_2)$.

Discrete symmetries : $\chi_1 \leftrightarrow \chi_2$ and $\chi_i \leftrightarrow -\chi_i$

The values of χ_i modify the residual symmetry.
modify the masses of excitations



Deformations of the S-fold

What is the uplift of the N=4 family ? [Giambrone, Guarino, Malek, Samtleben, Trigiante, CS]

Equivalent uplift up to *local* change of coordinates :

$$\varphi_i' = \varphi_i + \chi_i\, \eta$$

Concretely :

Metric : $ds_{10}^2 = \Delta^{-1}\,[\frac{1}{2}\, ds_{AdS_4}^2 + d\eta^2 + d\alpha^2 + \frac{\cos^2(\alpha)}{2+\cos(2\alpha)} ds_{S_1}^2 + \frac{\sin^2(\alpha)}{2-\cos\,(2\alpha)}\, ds_{S_2}^2]$

$$ds_{S_i}^2 = d\theta^2 + cos\theta^2 d\varphi_i^2 \;\rightarrow\; ds'^2_{S_i} = d\theta^2 + cos\theta^2 d\varphi'^2_i$$
$$= d\theta^2 + cos\theta^2 d(\varphi_i + \chi_i\, \eta)\text{^}2$$