Symplectic deformations of d=4 gauged supergravities

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Based on:
1209.0760 [Dall'Agata, GI, Trigante];
1405.2437 [Dall'Agata, GI, Marrani];
+ work in progress [GI]

NIKHEF

Gauged Supergravities

- **Consistent truncations of higher dim. models**
  Solution generation, test of compactification schemes,
  Black Holes physics & AdS/CFT||CMT, …

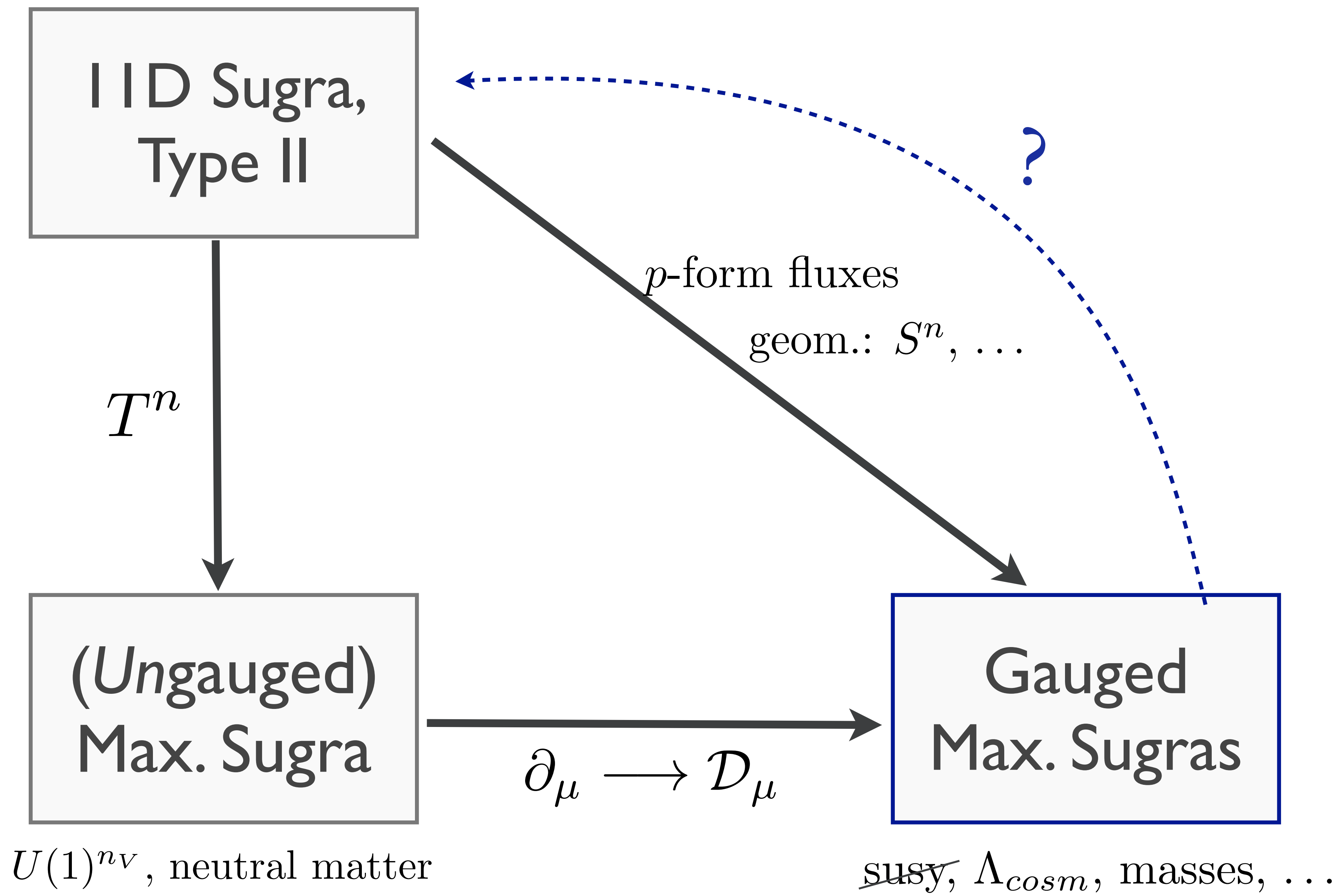
- **e.g. 11d sugra on S^7 → N=8 SO(8) gauged supergravity:**
  $AdS_4 x S^7$, physics of M2 branes, deformations of ABJ(M)

- **Extended SUSY → relation with U-dualities of String/M-theory**
  U-dualities in gauged sugra turn on 'non-geometric fluxes'

- **Challenge/guide study of generalised geometry / 'non-geometry'**

Gauged Supergravities

Lect. notes: Samtleben 0808.4076



'Symplectic deformations'

- **SO(8) gauged N=8 sugra is *not unique!* 'ω deformation'** [Dall'Agata, GI, Trigiante]

  Challenge for uplift: Generalised Geometry, Exceptional Field Theory,…?
  [de Wit, Nicolai; Godazgar Godazgar Nicolai; Lee, Strickland-Constable, Waldram; Hohm, Samtleben; Aldazabal, Grana, Marques, Rosabal; …]

  Challenge for 3d dual:
  ~ ABJ(M) with $\mathcal{N}$=8 susy, *large-N* parity breaking, residual *em dualities*

- **Similar deformations for many other models, not only N=8!**

  de Roo–Wagemans,
  some N=2 truncations of SO(8) → extra tools in lower N?
  → Black holes, domain walls, …

  ↙ Still today!

- ***Confusion* on non-triviality, range, discrete duality symmetries**

  A correct understanding is crucial to discuss uplifts/3d duals

‘Symplectic deformations’

Can we *precisely* characterize ‘ω-like’ deformations for general G_{gauge}, $N \leq 8$?

Plan

- Review: inequivalent SO(8) gauged maximal supergravities
- Symplectic deformations for general gaugings

PARENTAL

ADVISORY

CONTAINS EMBEDDING TENSOR

SO(8) gauged maximal supergravities

11D Supergravity

↓ (AdS$_4$ x) S^7

[De Wit, Nicolai '80s]

Maximal D=4 Supergravity
SO(8) Gauge Group

- AdS$_4$/CFT$_3$; ABJ(M)
- 'Top-Down' AdS/CMT
- Test for our understanding of compactifications!

Expectation: unique

Surprise: there's ∞-ely many!!

[Dall'Agata, GI, Trigiante '12]

SO(8) gauged maximal supergravities

What is an **'ω-deformation'** of the de Wit–Nicolai theory?

An $\mathrm{SL}(2,\mathrm{R})$ twist of the $\mathrm{E}_{7(7)}/\mathrm{SU}(8)$ coset reprs $\mathcal{V}(\Phi)$:

$$\mathcal{V}(\Phi) \quad \longrightarrow \quad \underbrace{\left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right)}_{\mathrm{SL}(2,\mathbb{R}) \not\subset \mathrm{E}_{7(7)}} \mathcal{V}(\Phi)$$

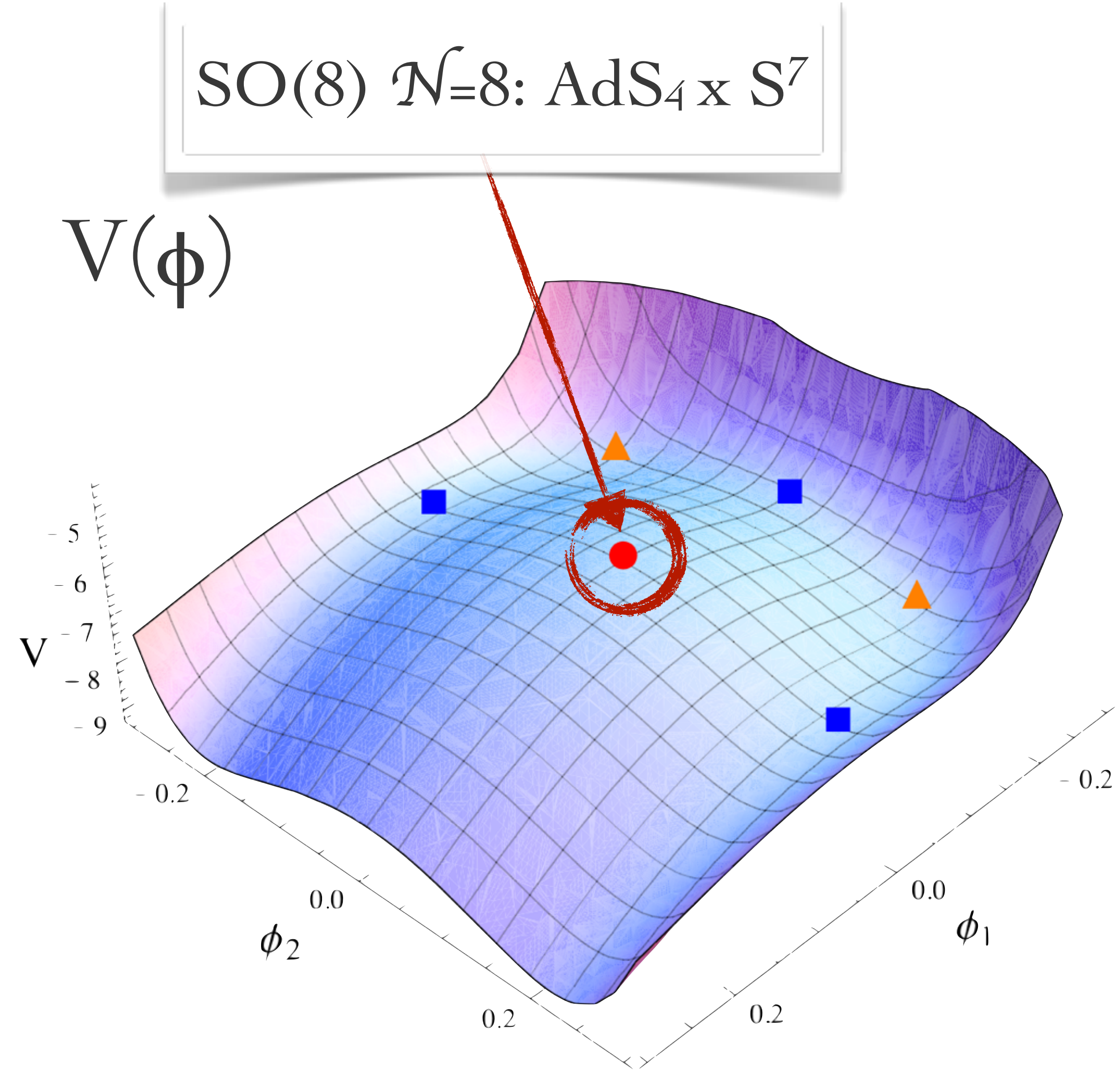
[Dall'Agata, GI, Trigiante]
[Dall'Agata, GI, Marrani]

By change of symplectic frame,
equivalent to e.m. rotation **of vector fields** in gauge connection:

$$\mathcal{D}_\mu \equiv \partial_\mu - g\big(\cos\omega\, A_\mu^{AB} + \sin\omega\, A^{(\mathrm{dual})}_{\mu\, AB}\big)\, t^{\mathrm{SO}(8)}_{AB}$$

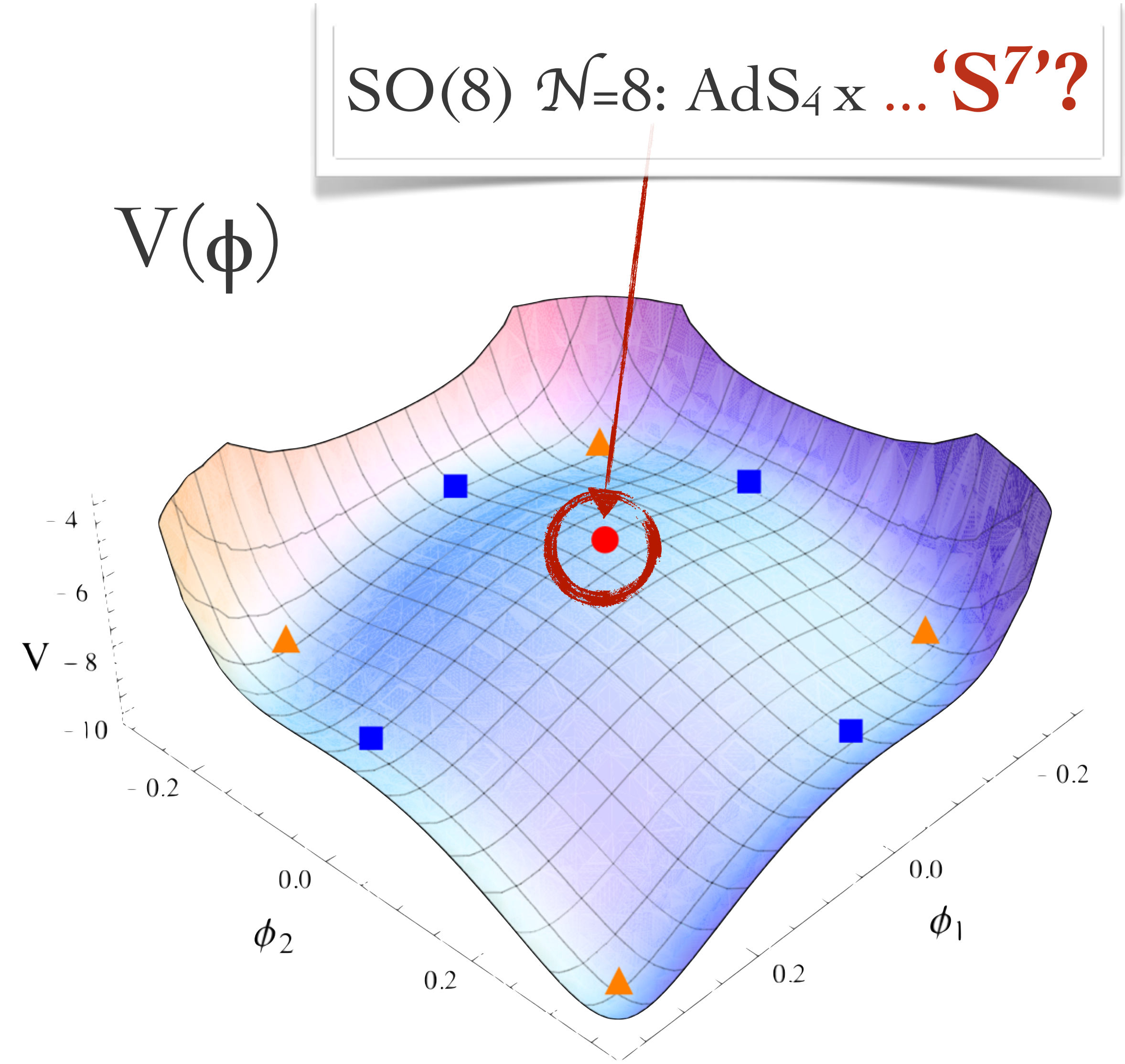
…plus rescalings of **gauge coupling** and **constant θ-term** $\int \mathrm{Tr} F \wedge F$

Physical effects: AdS$_4$ vacua



ω = 0

[de Wit, Nicolai; Warner]



ω = π/8

[Dall'Agata, GI, Trigiante]

Further: *vacua, domain walls, black holes, …* [Borghese Dibitetto Guarino Roest Varela'12; Dall'Agata GI '12; Guarino'13; Varela Tarrio'13; Anabalon Astefanesei'13]

Discrete dualities/identifications

CRUCIAL: range of ω-parameter

$$S^1/\mathrm{D}_8, \qquad \text{fundamental domain: } \omega \in [0, \pi/8]$$

How can I figure it out *a priori*, and/or for other G_{gauge}?

Some **confusion** in the literature: parity? triality?

More confusion: N<8 truncations, meaning of **ω**

NB: ω rotation is *not* the missing U(1) in R-symmetry!

(**ω** is not a field redefinition)

The general case (N=8)

[Dall'Agata, GI, Marrani]

For <u>fixed</u> G_{gauge} in $E_{7(7)}$, we want to classify inequivalent gauged theories

THM*: all gauged theories for same chosen, fixed G_{gauge} in $E_{7(7)}$ are parameterized by symplectic twists in the coset reprs:

$$\mathcal{V}(\Phi) \quad \longrightarrow \quad S\mathcal{V}(\Phi), \qquad S \in \mathcal{N}_{Sp(56,\mathbb{R})}(G_{gauge})$$

Normalizer

$Sp(56,R)$: most general duality redefinitions of vector fields [Gaillard, Zumino]

Must remove ***local field redefinitions:***

- $E_{7(7)}$ on scalars (SU(8) on fermions)
- $GL(\#_{vectors},\, R)$ on vectors

$$\mathfrak{S} \;\equiv\; \mathcal{S}_{GL(28,\mathbb{R})}(X) \;\backslash\; \mathcal{N}_{Sp(56,\mathbb{R})}(G_{gauge}) \;/\; \mathcal{N}_{\mathbb{Z}_2\ltimes E_{7(7)}}(G_{gauge})$$

Stabilizer

Embedding tensor = 'gauging parameters'

Symplectic Deformations are:

Symplectic twists of the coset representatives of the NLSM

or equivalently

Different (e.m. dual) choices of vectors in gauge connection

Compatibility with the structure of the *same* gauging is required

The general case (N=8)

[Dall'Agata, GI, Marrani]

$$\mathfrak{S} \;\equiv\; \mathcal{S}_{\mathrm{GL}(28,\mathbb{R})}(X) \setminus \mathcal{N}_{\mathrm{Sp}(56,\mathbb{R})}(\mathrm{G}_{\mathrm{gauge}}) \;/\; \mathcal{N}_{\mathbb{Z}_2 \ltimes \mathrm{E}_{7(7)}}(\mathrm{G}_{\mathrm{gauge}})$$

Stabilizer

Embedding tensor = 'gauging parameters'

- Constructive definition of *all* deformations & identifications!
- Scary? We can actually compute $\mathfrak{S}$!!!!!

SO(8) gauging: $(\mathrm{SL}(2,\mathrm{R})/\mathrm{Z}_2)/\mathrm{Z}_8$, g_{gauge}, ω, constant θ-term

remove g_{gauge} rescalings and θ-term: S^1/D_8 ✓

done for most of the known gaugings of N=8

Symplectic deformations of N=8 gaugings

Focus on deformations relevant classically (eg no θ-terms)

$$\mathrm{SO}(8),\ \mathrm{SO}(4,4): \qquad \mathfrak{S}_{\mathrm{red}} = S^1/\mathrm{D}_8, \qquad \text{fundamental domain: } \omega \in [0, \pi/8].$$
$$\mathrm{SO}(p, 8-p),\ p \neq 0, 4: \qquad \mathfrak{S}_{\mathrm{red}} = S^1/\mathrm{D}_4, \qquad \text{fundamental domain: } \omega \in [0, \pi/4].$$

General gaugings in SL(8,R), SU*(8):

$$[\mathrm{SO}(p,q) \times \mathrm{SO}(p',q')] \ltimes N^r \subset \mathrm{SL}(8,\mathbb{R}),$$
$$[\mathrm{SO}^*(2p) \times \mathrm{SO}^*(2p')] \ltimes N^r \subset \mathrm{SU}^*(8).$$

$$\mathrm{ISO}(p, 7-p): \quad \omega = 0 \quad \text{or} \quad \omega \neq 0 \quad (\mathrm{mod}\ \pi/2).$$

$$\mathrm{Re}(\mathrm{SO}(4,\mathbb{C}) \times \mathrm{SO}(4,\mathbb{C})) \ltimes T^{16}: \quad \begin{cases} \omega \in (0, \pi/4] & \text{same real form,} \\ \omega \in (0, \pi/2) & \text{different real forms.} \end{cases}$$

Physical effects

- **SO(4,4):** **slow roll** dS vacua in maximal sugra! [Dall'Agata, GI]

- **SO(6,2):** existence of vacua *only* for **ω=π/4**,
  leads to HUGE family of Minkowski models! [Dall'Agata, GI; Catino, Dall'Agata, GI, Zwirner]

- **ISO(7):** existence of (**AdS, stable**) vacua [Dall'Agata, GI; Borghese, Guarino, Roest]

- **SO*(4)^2 x T^{16}**, N=0 Minkowski vacuum with:

  - gravitini masses M_1 (×2), M_2 (×2), M_3 (×2), M_4 (×2).

  - M_i/M_j are **moduli** $\langle\phi\rangle$, *except* for $\dfrac{M_1\,M_2}{M_3\,M_4} = \tan\omega.$

  - Hints at **ω** as truncated modulus (for this theory)

Generic gauged theories

[Dall'Agata, GI, Marrani; and GI, to appear]

Can play same game for **less/no supersymmetry**, even **rigid** theories :

$$\mathfrak{S} = \mathcal{S}_{\mathrm{GL}(n_V,\mathbb{R})}(X,\, \Theta^{\mathrm{matter}}) \setminus \mathcal{N}_{\mathrm{Sp}(2n_V,\mathbb{R})}(\mathrm{G}^{\mathrm{adj}}_{\mathrm{gauge}}) \;/\; \mathcal{N}_{\mathrm{G_d} \rtimes \mathrm{Out}(\mathrm{G_d})}(\mathrm{G}^{\mathrm{adj}}_{\mathrm{gauge}})$$

An elementary example: **YM theory** with simple group: SU(N)

role of cosets $\mathcal{V}(\Phi)$ is taken by constant matrix related to $\mathbf{g_{YM}}$, $\boldsymbol{\theta}$:

$\mathfrak{S}$ = **choice of complex coupling** τ (not surprising)

- Analysis for **several truncations/new theories**. Some surprises!

Concluding…

- **Inequivalent gauged theories sharing same G_{gauge}, e.g. SO(8)**
  implications & challenges for uplifts, exceptional geometry
- **A good understanding in D=4 is crucial for uplifts/3d duals!**

- **=> Symplectic deformations for general gaugings**
  many **physical effects:** vacua, ~~susy~~, slow roll, $\not{P}$, $\not{CP}$, black holes, …
- Important step in **classification of gaugings**

- **N < 8:** some **surprises**;
- *extra tools*? Evidence for uplifts/duals? **Toy models?**

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Thank you!