AdS$_3$ vacua through Exceptional Field Theory

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Joint work with G. Larios, H. Samtleben, M. Galli and E. Malek

[arXiv:2011.11658, arXiv:2111.01167, arXiv.2306.12487, arXiv.2309.03261, arXiv.2405.xxx]

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Motivations

Bulk

Supergravity

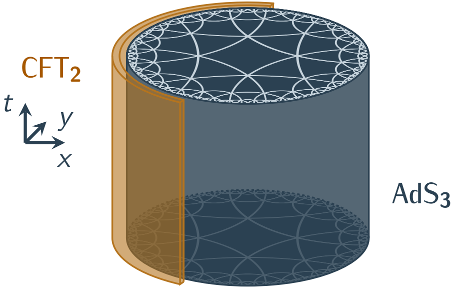
on AdS $\times\ \mathcal{M}$

$\Updownarrow$

Boundary

Conformal fields

theory (CFT)



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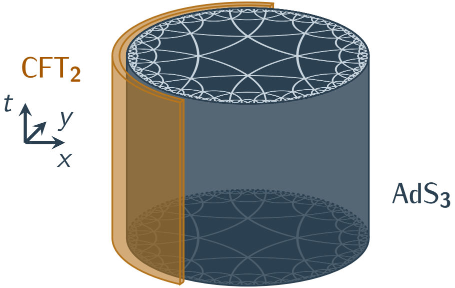

Field operator map: $(\phi, m) \longleftrightarrow (\mathcal{O}, \Delta)$

$$\left\langle \exp\left(\int \mathrm{d}^d x\, \mathcal{O}\, \phi^{(0)} \right) \right\rangle_{\text{CFT}} = e^{-S_{\text{sugra}}[\phi]}\Big|_{\text{boundary}},$$

Recent progress in understanding $\mathrm{AdS}_3/\mathrm{CFT}_2$:

$$\mathrm{AdS}_3 \times S^3 \times S^3 \times S^1 \quad \longleftrightarrow \quad \text{WZW on } \mathrm{Sym}^N(\mathrm{SU}(2) \times \mathrm{U}(1))$$

[Eberhardt, Gaberdiel, Li (2017)]

$$\mathrm{AdS}_3 \times S^3 \times \mathrm{T}^4 \quad \longleftrightarrow \quad \text{WZW on } \mathrm{Sym}^N(\mathrm{T}^4)$$

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$\Longrightarrow$ marginal deformations

Continuous deformations preserving the conformal symmetry.

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compact manifold

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Example: fields on $AdS_3 \times S^1$ $\qquad \varphi^{(4d)}(x^\mu, y) = \sum_n \phi_n^{(3d)}(x^\mu)\, e^{iyn/R}.$

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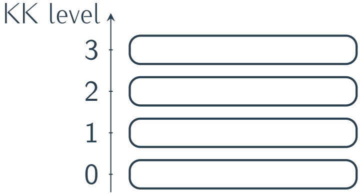
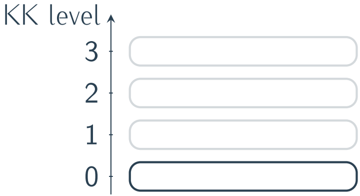
Compactification leads to towers of
massive Kaluza–Klein modes.



Consistent truncations

Consistent truncation:
Restriction to a finite subset of KK modes such that every solution of the truncated theory defines a solution of the full theory.



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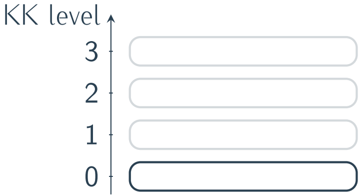

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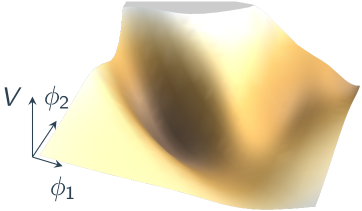

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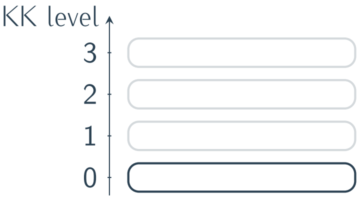

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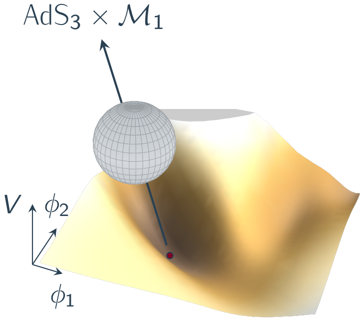

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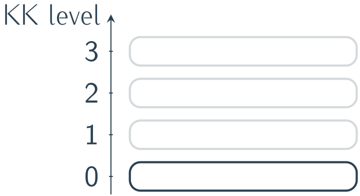

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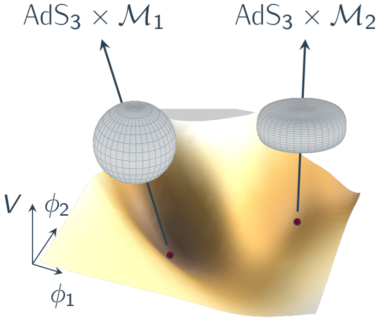

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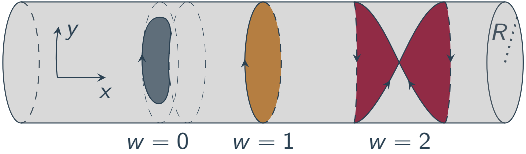

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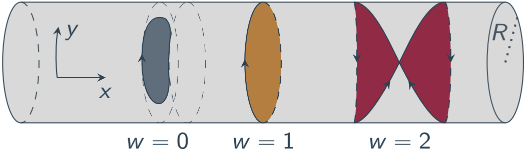

Winding number: w
Momentum along y: p

Energy: $M^2 = \frac{p^2}{R^2} + \frac{w^2 R^2}{\alpha'^2} \implies$ invariant under $\begin{cases} R \to \alpha'/R, \\ w \leftrightarrow p. \end{cases}$

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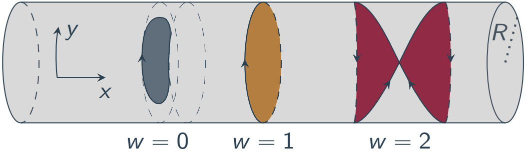

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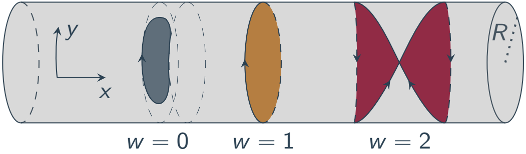

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U duality: Further symmetry enhancement. For type II: $\mathrm{E}_{d+1(d+1)}$.

Exceptional Field Theory

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Today:

- Duality symmetries provide powerful tools to study the AdS/CFT correspondence,
- Exceptional Field Theory makes it possible to build consistent truncation and compute Kaluza-Klein spectra.

From 10d to 3d and $E_{8(8)}$ ExFT

From IIB to maximal supergravity in 3d

10d IIB sugra
$\mathcal{N} = (2,0)$

$$e^{-1}\mathscr{L}_{\text{IIB}} = e^{-\phi}\,\hat{R} - e^{-\phi}\,\partial_{\hat{\mu}}\hat{\phi}\partial^{\hat{\mu}}\hat{\phi} - \frac{1}{12}\,G^{\alpha}_{\hat{\mu}\hat{\nu}\hat{\rho}}M_{\alpha\beta}G^{\beta\,\hat{\mu}\hat{\nu}\hat{\rho}} + \ldots$$

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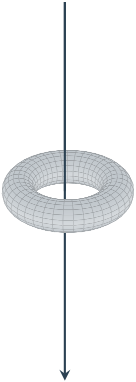

3d max. sugra
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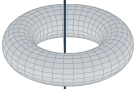

$E_{8(8)}$ global symmetry
after **dualization/reorganisation** of the fields.

Fields: $g_{\mu\nu}(x)$, $\quad M_{\bar{M}\bar{N}}(x) \in E_{8(8)}/SO(16)$

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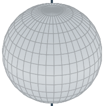

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gauged
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Gauging $G \subset \mathrm{E}_{8(8)}$ through an embedding tensor $X_{\bar{M}\bar{N}}$:

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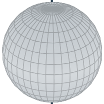

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$E_{8(8)}$ exceptional field theory (1)

[Hohm, Samtleben (2014)]

- Same reorganization for the 10d fields $\left(\hat{g}_{\hat{\mu}\hat{\nu}}, \hat{\phi}, \hat{C}_{(0)}, \hat{C}^{\alpha}_{(2)}, \hat{C}_{(4)}\right)$:

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in the adjoint of $E_{8(8)}$ and subject to section constraints

$$\begin{cases} \eta^{MN}\partial_M \otimes \partial_N = 0, \\ f^{MN}{}_{P}\partial_M \otimes \partial_N = 0, \\ (\mathbb{P}_{3875})_{MN}{}^{KL}\partial_K \otimes \partial_L = 0. \end{cases}$$

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- Internal coordinate dependence $\Longrightarrow$ non-abelian gauge structure:

$E_{8(8)}$ generalised diffeomorphisms $\mathcal{L}^{E_{8(8)}}_{(\Lambda,\Sigma)}$.

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(2)

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Consistent truncation and Kaluza-Klein spectra within ExFT

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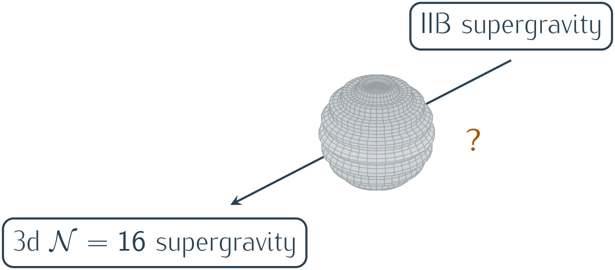

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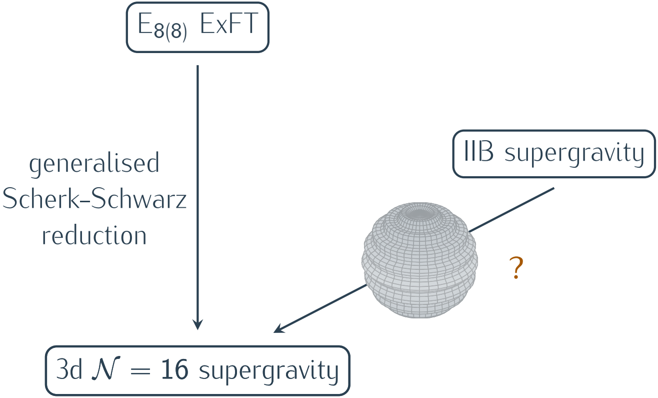

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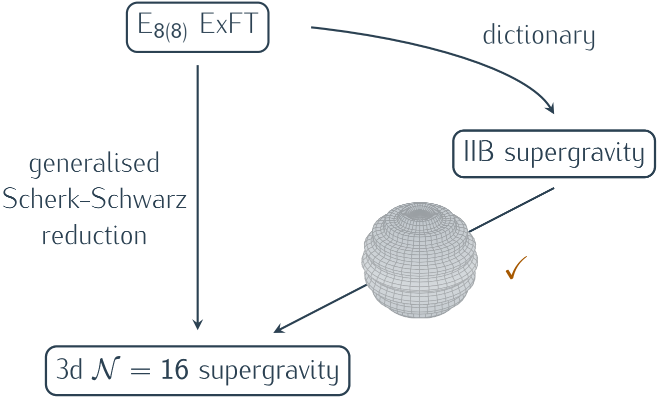

Consistent truncation

[Galli, Malek (2022)]

Generalized Scherk-Schwarz ansätze in terms of twist matrix $U_M{}^{\bar{M}} \in \mathrm{E}_{8(8)}$ and scale factor ρ:

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Embedding tensor of the 3d theory!

Introduction of higher KK modes

[Malek, Samtleben (2019,2020)]

$$
\begin{cases}
\mathcal{M}_{MN}(x,Y) = U_M{}^{\bar{M}}(Y)\,U_N{}^{\bar{N}}(Y)\,M_{\bar{M}\bar{N}}(x), \\[2ex]
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Fluctuation ansatz:

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with $\mathcal{Y}^\Sigma(Y)$ **scalar** harmonics of the internal manifold.

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with $\mathcal{Y}^\Sigma(Y)$ **scalar** harmonics of the internal manifold.

Plugging into the ExFT e.o.m. and linearizing w.r.t. the fluctuation gives mass matrices for all fields (including fermions).

Vectors: $$M^{\bar{M}\,\Sigma}{}_{\bar{N}}{}^{\Omega} = \left(\eta^{\bar{M}\bar{P}} + \delta^{\bar{M}\bar{P}}\right) \left(X_{\bar{P}\bar{N}} \delta^{\Sigma\Omega} + f_{\bar{P}\bar{N}}{}^{\bar{Q}} \mathcal{T}_{\bar{Q}}{}^{\Sigma\Omega}\right).$$

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$\Longrightarrow$ access to KK spectrum around any vacuum in the potential!

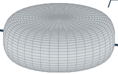
Example: $\mathrm{AdS}_3 \times \boldsymbol{S}^3 \times \mathrm{T}^4$

$\mathrm{AdS}_3 \times S^3 \times \mathrm{T}^4$ and deformations

[Eloy, Larios (2023)]

(ω, ζ) deformation of the $\mathrm{AdS}_3 \times S^3 \times \mathrm{T}^4$ vacuum:

$10d$ IIB



$\mathrm{AdS}_3 \times M^4 \times \mathrm{T}^3$

$\mathcal{N}_{3\mathrm{d}} = 0$

Remaining isometries: $\mathrm{U}(1)_{\mathrm{L}} \times \mathrm{U}(1)_{\mathrm{R}} \times \mathrm{U}(1)^4$.

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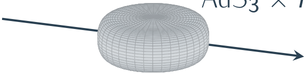

$AdS_3 \times M^4 \times T^3$

$\mathcal{N}_{3d} = 0$

Remaining isometries: $U(1)_L \times U(1)_R \times U(1)^4$.

$$e^{\hat{\phi}} = \Delta^2,$$

$$d\hat{s}^2 = ds^2(AdS_3) + ds^2(M^3_{\omega,\zeta}) + \delta_{ij}\, dy^i dy^j + \left[dy^7 + e^{\omega}\zeta\Delta^4\left(\cos^2\alpha\, d\beta - \sin^2\alpha\, d\gamma\right)\right]^2,$$

$$\hat{H}_{(3)} = 2\mathrm{Vol}(AdS_3) + \sin(2\alpha)\,\Delta^8 e^{2\omega}\, d\alpha \wedge (d\beta + \zeta dy^7) \wedge \left((\zeta^2 + e^{-2\omega})d\gamma - \zeta dy^7\right),$$

with

$$ds^2(M^3_{\omega,\zeta}) = d\alpha^2 + e^{\omega}\Delta^4\left(\cos^2\alpha\, d\beta^2 + (\zeta^2 + e^{-2\omega})\sin^2\alpha\, d\gamma^2\right) - e^{2\omega}\zeta^2\Delta^8\left(\cos^2\alpha\, d\beta - \sin^2\alpha\, d\gamma\right)^2.$$

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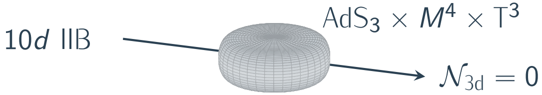

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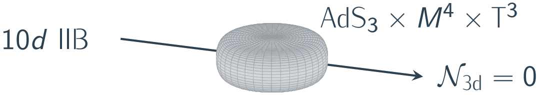
(ω, ζ) deformation of the AdS$_3$ × S^3 × T^4 vacuum:



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Effect on the spectrum: $(\Delta = \ldots + \sqrt{\ldots + \sum (2\pi\, p_a)^2})$

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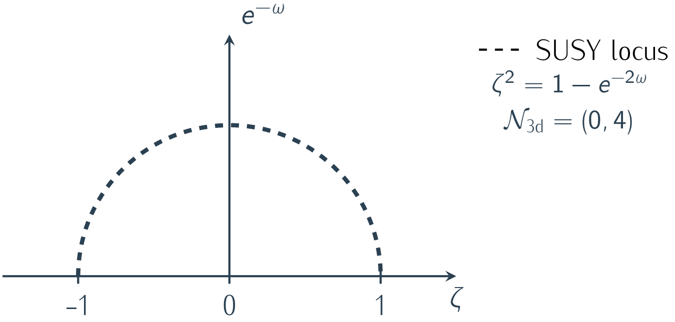

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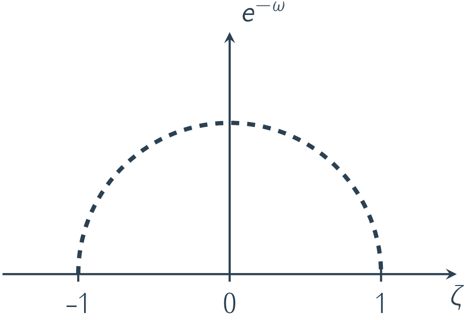
$$m^2_\mathrm{scalar}\, \ell^2_\mathrm{AdS} \geq -1$$



- - - SUSY locus

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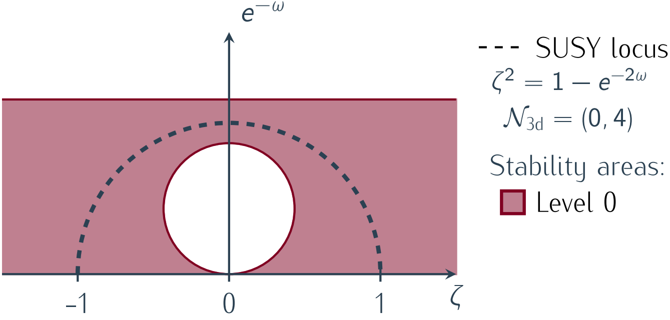

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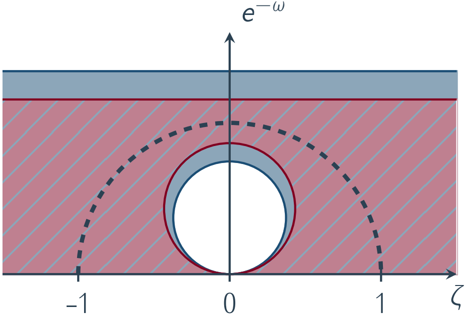

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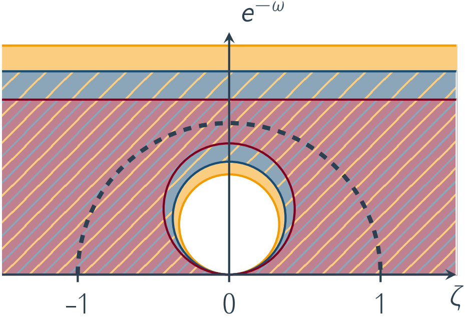

- - - SUSY locus
$\zeta^2 = 1 - e^{-2\omega}$
$\mathcal{N}_{3d} = (0,4)$

Stability areas:
- Level 0
- Level 1
- Level 2

First example of a full family of non-SUSY (pert.) stable AdS_3 vacua.

Conclusion and perspectives

- ExFT gives efficient tools for the analysis of consistent truncations and Kaluza-Klein spectra.

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- ExFT gives efficient tools for the analysis of consistent truncations and Kaluza-Klein spectra.
- New families of AdS_3 vacua, with supersymmetric subfamilies and non-susy BF stability
  $\Longrightarrow$ first candidates for $2d$ non-supersymmetric holographic conformal manifold.
- Up to 15 deformation parameters, for $S^3 \times T^4$ and $S^3 \times S^3 \times S^1$, including TsT.
- Described by $J\bar{J}$ deformations of the worldsheet theory.
- CFT? Possible non-pert. decay channel? Cubic couplings?

Thanks for listening!