Vacua of Maximal Supergravity & Λ_{cosm}

Gianluca Inverso
Universitá di Roma Tor Vergata

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Based on Dall'Agata, G.I. arXiv:1112.3345 [hep-th]

Strings & Fundamental Interactions

Electromagnetism
Nuclear Weak
Nuclear Strong

} described by Quantum Field Theory

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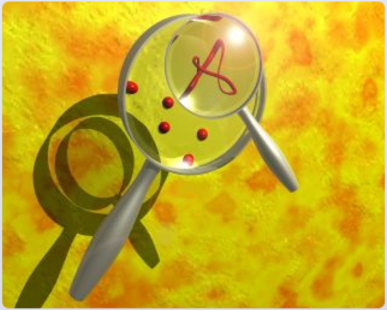
$\hookrightarrow$ Candidate: String Theory



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Electromagnetism
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Gravity? $\rightsquigarrow$ General Relativity is classical!

$\hookrightarrow$ Candidate: String Theory

- $\star$ $D = 9 + 1$ spacetime dimensions (even $10 + 1$: M-theory)
- $\star$ Supersymmetry!!
- $\star$ ...

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- compactify extra dimensions

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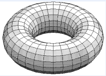

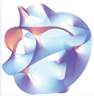

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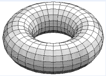

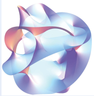

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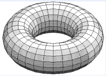

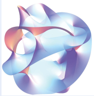

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gravity + vectors + scalars + fermions

Gen. Relativity ☺ | *Gauge interactions* ☺ | *higgs* ☺, *moduli* ☹ | ☺

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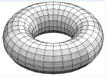

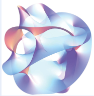

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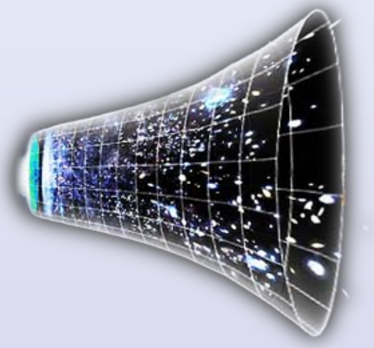

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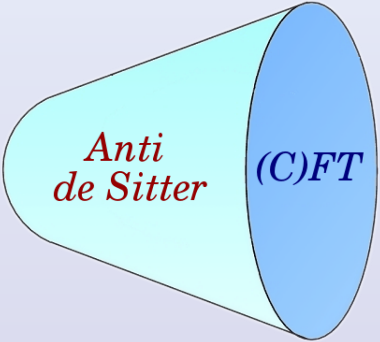

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AIM: study gauge theories and their vacua in Maximal Supergravity

Overview

✓ Supergravity & Λ_{cosm}

- Maximal Supergravity in 4D

- Gauge Interactions, Vacua & Λ_{cosm}

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- ✓ renewed interest for *finiteness??*

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New Approach:

- choice parametrized by one matrix Θ $\left\{ \begin{array}{l} G_{gauge} \\ \text{“charges”} \end{array} \right.$

  [de Wit et al. 2007]

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⋆ redundancy: $V(\phi, \Theta) = V(0, \widetilde{\Theta})$

[also Dibitetto et al 2011]

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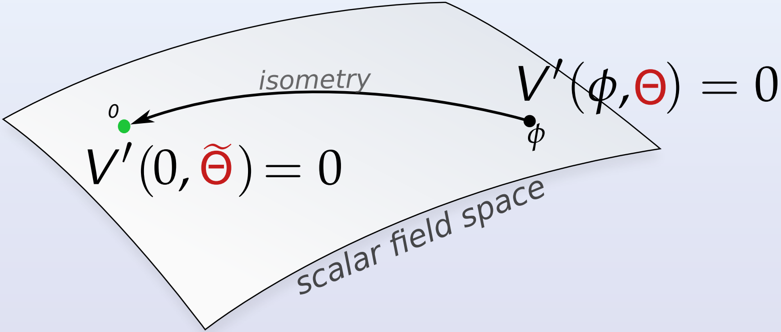

Study Θ and $V(0, \Theta) \rightsquigarrow \begin{cases} \text{several new vacua} \\ \text{different gauge theories!} \end{cases}$

new	G_{gauge}	$G_{residual}$	Λ_{cosm}	$m^2_{scalars}$ $(multipl.)$
✓	$SO(2,6)$	$SO(2)\times SO(6)$	Mink	$2^{(2)}, 1/2^{(20)}, 0^{(48)}$
	$CSO(2,0,6)$	$SO(2)$		
✓	$SO(4)\times SO(2,2)\ltimes T^{16}$	$SO(2)^2\times SO(4)$	Mink	$4^{(4)}, 2^{(12)}, 1^{(16)}, 0^{(38)}$
✓	$SO(2)^2\ltimes T^{20}$	$SO(2)^2$		
	$SO(8)$			
✓	$SO(7,1)$	$SO(7)$	AdS	$2^{(1)}, -4/5^{(27)}, -2/5^{(35)}, 0^{(7)}$
✓	$SO(7)\ltimes T^7$			
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✓	$SO(3,5)$	$SO(3)\times SO(5)$	dS	$-2^{(1)}, 4^{(5)}, 2^{(30)}, 4/3^{(14)}, -2/3^{(5)}, 0^{(15)}$

$$g_{gauge}=1;\ \ \text{when } \Lambda\neq 0,\ m^2/|\Lambda|$$

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[Dall'Agata, G.I., 1112.3345]

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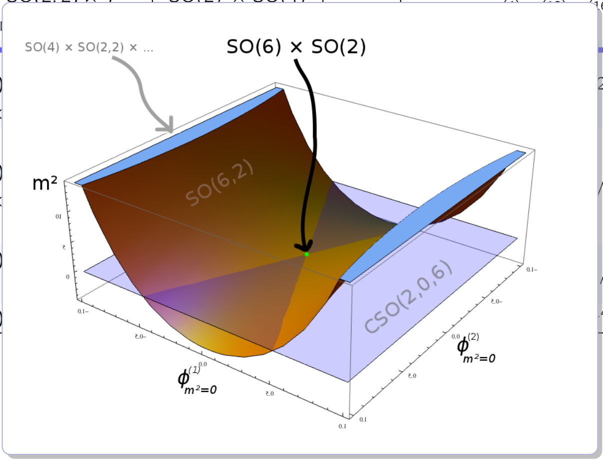

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Thank You!

M-theory compactified on T^7 $\longrightarrow$ $D=4$ Maximal Sugra

Classical theory enjoys a large duality group: $E_{7(7)}(\mathbb{R})$

$$\mathfrak{e}_{7(7)} \quad \ni \quad t_{\alpha\, M}{}^{N} \equiv \begin{pmatrix} \Lambda_{AB}{}^{CD} & \Sigma_{ABCD} \\ \star\Sigma^{ABCD} & \Lambda'^{AB}{}_{CD} \end{pmatrix}$$

$\Lambda \in \mathfrak{sl}(8,\mathbb{R})$ generate global symmetries of $S_{ungauged}$
(this is a choice of symplectic frame)

$\mathbf{56} = \mathbf{28} + \mathbf{28}_{(\text{dual})}$ vector fields:

$$\delta A_\mu^M = A_\mu^N \, (\epsilon^\alpha t_\alpha)_N{}^M$$

Scalar fields ϕ parametrize $E_{7(7)}/SU(8)$

$E_{7(7)}/SU(8)$ can be represented by coset generators:

$$t_{\mathrm{Re}\,\phi} = \begin{pmatrix} \Lambda^{sym} & \\ & -\Lambda^{sym} \end{pmatrix}, \quad t_{\mathrm{Im}\,\phi} = \begin{pmatrix} & \Sigma^{+} \\ {}_\star\Sigma^{+} & \end{pmatrix}$$

$\hookrightarrow$ representatives $L(\phi)_M{}^N$

This is a **real** basis. Complex $SU(8)$ covariant basis?
Cayley matrix + "triality":

$$S_{\underline{M}}{}^N \equiv \frac{1}{4\sqrt{2}} \begin{pmatrix} \Gamma_{ij}{}^{AB} & \Gamma_{ijAB} \\ -i\Gamma^{ijAB} & i\Gamma^{ij}{}_{AB} \end{pmatrix} \quad \longrightarrow t_\phi = \begin{pmatrix} & \phi \\ \bar{\phi} & \end{pmatrix}$$

Vacua of θ ξ gaugings

Gauging in (Q)FT

In every Field Theory:

- $t_\alpha \equiv$ global symm. generators G
- Vector bosons A_μ^M, $M = 1, \ldots, n_v$

$$\textit{Gauge interactions} \longleftrightarrow \text{sungroup } G_{gauge} \subset G, \text{ local}$$

$$\text{connection: } D_\mu = \partial_\mu - g A_\mu^r \, t_r$$

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A_μ^M	t_α

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$$A_\mu^M \quad \underbrace{m_M{}^r \quad n_r^\alpha}_{\Theta_M{}^\alpha} \quad t_\alpha$$

Embedding Tensor

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Embedding Tensor

$$D_\mu = \partial_\mu - g\, A_\mu^M\ \Theta_M{}^\alpha\ t_\alpha$$

$\Theta_M{}^\alpha$ in Maximal $D = 4$ SUGRA

$$\Theta_M{}^\alpha \in \mathbf{912} \text{ of } E_{7(7)}$$

$\Theta_M = \begin{pmatrix} \Theta_\Lambda \\ \Theta^\Lambda \end{pmatrix} \longrightarrow \Theta^\Lambda$ couples to *e.m. dual* vectors $A_{\mu\,\Lambda}$!

$\Rightarrow$ Locality: $\Theta_\Lambda{}^{[\alpha}\Theta^{\Lambda\beta]} = 0$

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$$CSO(p,q,r) : \Theta = \begin{pmatrix} \theta_{8\times 8} \\ 0 \end{pmatrix} \text{ (very schematic...)}$$

$$2\theta^2 - \theta\,\mathrm{Tr}\,\theta = 8\Lambda_{cosm}$$

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here: $SO(p,q),\ SO(p,q) \times SO(p',q') \times T^r : \Theta = \begin{pmatrix} \theta_{8\times 8} \\ \xi_{8\times 8} \end{pmatrix}$

$$\Lambda_{cosm} \sim 2\,\mathrm{Tr}(\theta^2 + \xi^2) - \theta\,\mathrm{Tr}\,\theta - \xi\,\mathrm{Tr}\,\xi \qquad \theta\,\xi \propto \mathbb{1}$$

Duality vs Symplectic frame

There are two embeddings to specify
in a $\mathcal{N} = 8$ Sugra model:

embedding tensor – symplectic frame

$$\Theta_M{}^\alpha \qquad \mathcal{E}_M{}^N$$

$$G_{gauge} \quad \subset \quad E_{7(7)} \quad \subset \quad Sp(56, \mathbb{R})$$

symmetry duality ????

NB: different action on fields!!

embedding tensor:

$$X_M = \Theta_M{}^\alpha \; t_\alpha \qquad \delta L(\phi) = X_M L(\phi)$$

$$\begin{matrix} \cap & & \cap \\ \mathfrak{g}_{gauge} & \subset & \mathfrak{e}_{7(7)} \end{matrix}$$

symplectic frame:

$$\mathcal{E} \in GL(28)\backslash Sp(56,\mathbb{R})/E_{7(7)}$$

$$t_\alpha \quad \rightarrow \quad t'_\alpha = \mathcal{E}\, t_\alpha\, \mathcal{E}^{-1}$$

$$\begin{matrix} \cap & & \cap & \\ \mathfrak{e}_{7(7)} & \neq & \mathfrak{e}'_{7(7)} & \subset \mathfrak{sp}(56,\mathbb{R}) \end{matrix}$$

$$\Theta_M{}^\alpha \quad \rightarrow \quad \mathcal{E}_M{}^N \Theta_N{}^\alpha$$