The low energy effective actions of the II A and II B superstrings are the corresponding maximal supergravities which contain all the perturbative and non-perturbative corrections.

Eleven dimensional supergravity is thought to be another low energy limit of an underlying theory

A great deal of our understanding has been derived from these supergravity theories.
i.e. brane solutions ie M2
Duff Stelle 1991.

The maximal supergravity theories in D dimensions have an E_{11-D} symmetry (D = 4 has E_7 Cremmer Julia 1979).

The scalars form a non-linear realization ($E_7/SU(8)$ in D = 4).

In 2001 I proposed that a non-linear realization of the Kac-Moody symmetry E_{11} is an extension of D = 11 supergravity

It contains generators with Lorentz indices i.e $R^{a_1 a_2 a_3}$

$\rightsquigarrow g = \ldots e^{A_{a_1 a_2 a_3} R^{a_1 a_2 a_3}} \ldots$

(D = 11 supergravity is a non-linear realization).

hep-th 10104081

Kac-Moody Algebras.

Group theory began with matrix groups. and their Lie algebras.

Introducing the Cartan subalgebra

Lie algebra. $\Rightarrow$ we find roots (positive and simple)

($su(3)$) $\qquad \alpha_a$, $a = 1, 2$.

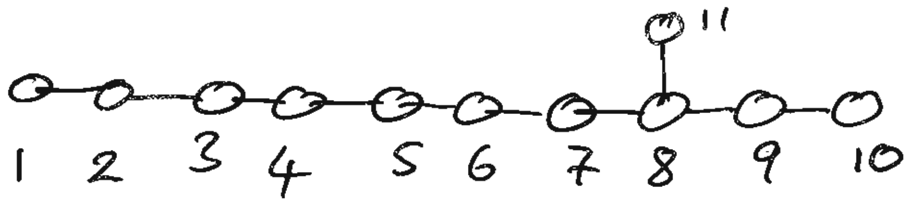
$\Rightarrow$ Cartan matrix A_{ab} $\left\{ \begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix} \right\}$

$\Rightarrow$ Dynkin Diagram.

Serre realized that with three relations one could uniquely go from the Dynkin Diagram to the Lie algebra

Cartan had tacitly assumed A_{ab} was positive definite. Dropping this we find affine and the general Kac-Moody algebras.

E_{11} has the Dynkin diagram



We can analyse the adjoint representation of E_{11} with respect to its A_{10} subalgebra in terms of the number of times the root α_{11} occurs (the level).

level.	generator	field
0	$K^a{}_b$	$h_a{}^b$
1	$R^{a_1 a_2 a_3}$	$A_{a_1 a_2 a_3}$
2	$R^{a_1 \dots a_6}$	$A_{a_1 \dots a_6}$
3	$R^{a_1 \dots a_8, b}$	$h_{a_1 \dots a_8, b}$
4.	R^a	A_a
4	$R^{(ab)}{}_c$	$A_{(ab)}{}^c$
4	$R^{a_1 a_2 a_3}{}_{b_1 b_2}$	$A_{a_1 a_2 a_3}{}^{b_1 b_2}$
⋮		

The E_{11} non-linear realization at low levels has

$$g = e^{x_a P^a} \cdots e^{h_a{}^b(x) K^a{}_b}$$
$$e^{A_{a_1a_2a_3}(x) R^{a_1a_2a_3}} \cdot e^{A_{a_1 \ldots a_6}(x) R^{a_1 \ldots a_6}}$$

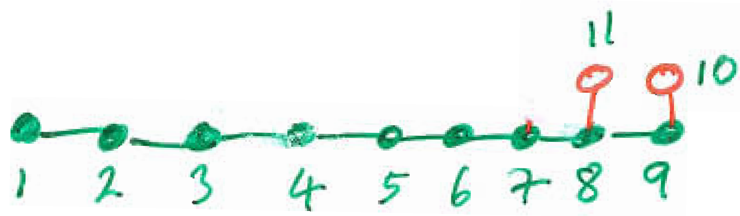
$\rightsquigarrow$ $D = 11$ supergravity

- level 3 has the dual graviton hep-th 10005270 0104081

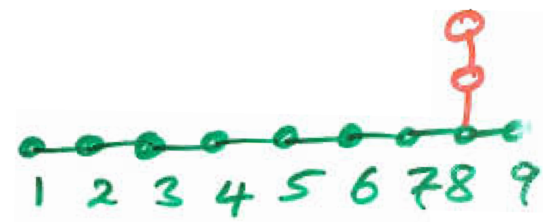
However E_{11} leads to an infinite number of fields. What are they?

Ten dimensional E_{11} theories

For ten dimensions we need A_9 e $sl(10)$ (gravity) we can choose in two ways.



II A



II B.

hep-th/0107181
Schnakenburg
West.

Kleinschmidt, Schnakenburg, West 0309198

vels of the two decompositions into A_9 (1) subalgebras discussed in the is the data obtained for the IIA case. All the listed levels are

A_9 weight	E_8^{+++} element α	α^2	$ht(\alpha)$	μ	
[0,0,0,0,0,0,0,1,0]	(0,0,0,0,0,0,0,0,0,0,1)	2	1	1	$R^{c_1c_2}$
[0,0,0,0,0,0,0,0,1]	(0,0,0,0,0,0,0,0,0,1,0)	2	1	1	R^{c_1}
[0,0,0,0,0,0,1,0,0]	(0,0,0,0,0,0,0,1,1,1,1)	2	4	1	$R^{c_1c_2c_3}$
[0,0,0,0,1,0,0,0,0]	(0,0,0,0,0,1,2,3,2,1,2)	2	11	1	$R^{c_1\ldots c_5}$
[0,0,1,0,0,0,0,0,0]	(0,0,0,1,2,3,4,5,3,1,3)	2	22	1	$R^{c_1\ldots c_7}$
[1,0,0,0,0,0,0,0,0]	(0,1,2,3,4,5,6,7,4,1,4)	2	37	1	$R^{c_1\ldots c_9}$
[0,0,0,1,0,0,0,0,0]	(0,0,0,0,1,2,3,4,3,2,2)	2	17	1	$R^{c_1\ldots c_6}$
[0,0,1,0,0,0,0,0,1]	(0,0,0,1,2,3,4,5,3,2,3)	2	23	1	$R^{c_1\ldots c_7,b}$
[0,1,0,0,0,0,0,0,0]	(0,0,1,2,3,4,5,6,4,2,3)	0	30	1	$R^{c_1\ldots c_8}$
[0,1,0,0,0,0,0,1,0]	(0,0,1,2,3,4,5,6,4,2,4)	2	31	1	$R^{c_1\ldots c_8,b_1b_2}$ new
[1,0,0,0,0,0,0,0,1]	(0,1,2,3,4,5,6,7,4,2,4)	0	38	1	fields
[0,0,0,0,0,0,0,0,0]	(1,2,3,4,5,6,7,8,5,2,4)	-2	47	2	$R^{a_1\ldots a_{10}}$
[1,0,0,0,0,0,1,0,0]	(0,1,2,3,4,5,6,8,5,2,5)	2	41	1	
[0,0,0,0,0,0,0,1,0]	(1,2,3,4,5,6,7,8,5,2,5)	0	48	1	
[0,0,0,0,0,1,0,0,0]	(1,2,3,4,5,6,8,10,6,2,6)	2	53	1	
[0,1,0,0,0,0,0,0,1]	(0,0,1,2,3,4,5,6,4,3,3)	2	31	1	
[1,0,0,0,0,0,0,0,0]	(0,1,2,3,4,5,6,7,5,3,3)	0	39	0	
[0,1,0,0,0,0,1,0,0]	(0,0,1,2,3,4,5,7,5,3,4)	2	34	1	
[1,0,0,0,0,0,0,0,2]	(0,1,2,3,4,5,6,7,4,3,4)	2	39	1	
[1,0,0,0,0,0,0,1,0]	(0,1,2,3,4,5,6,7,5,3,4)	0	40	1	
[0,0,0,0,0,0,0,0,1]	(1,2,3,4,5,6,7,8,5,3,4)	-2	48	2	
[0,1,0,0,1,0,0,0,0]	(0,0,1,2,3,5,7,9,6,3,5)	2	41	1	
[1,0,0,0,0,0,1,0,1]	(0,1,2,3,4,5,6,8,5,3,5)	2	42	1	
[1,0,0,0,0,1,0,0,0]	(0,1,2,3,4,5,7,9,6,3,5)	0	45	1	
[0,0,0,0,0,0,0,1,1]	(1,2,3,4,5,6,7,8,5,3,5)	0	49	1	
[0,0,0,0,0,0,1,0,0]	(1,2,3,4,5,6,7,9,6,3,5)	-2	51	3	
[1,0,0,0,0,0,1,0,0]	(0,1,2,3,4,5,6,8,6,4,4)	2	43	1	
[0,0,0,0,0,0,0,0,2]	(1,2,3,4,5,6,7,8,5,4,4)	2	49	1	
[0,0,0,0,0,0,0,1,0]	(1,2,3,4,5,6,7,8,6,4,4)	0	50	0	

all [illegible] fields and their duals except $R^{c_1\ldots c_9}$ which is needed for massive IIA.

on E_8^{+++} with such a field where one does not need to include 13

; the data obtained for the IIB case.

A_9 weight	E_8^{+++} element α	α^2	$ht(\alpha)$	μ	
[0,0,0,0,0,0,0,0,0,0]	(0,0,0,0,0,0,0,0,0,1,0)	2	1	1	R
[0,0,0,0,0,0,0,0,1,0]	(0,0,0,0,0,0,0,0,1,0,0)	2	1	1	$R^{a_1a_2}$
[0,0,0,0,0,0,0,0,1,0]	(0,0,0,0,0,0,0,0,1,1,0)	2	2	1	$R^{a_1a_2}$
[0,0,0,0,0,0,1,0,0,0]	(0,0,0,0,0,0,1,2,2,1,1)	2	7	1	$R^{a_1..a_4}$
[0,0,0,1,0,0,0,0,0,0]	(0,0,0,0,1,2,3,4,3,1,2)	2	16	1	$R^{a_1..a_6}$
[0,0,0,1,0,0,0,0,0,0]	(0,0,0,0,1,2,3,4,3,2,2)	2	17	1	$R^{a_1...a_6}$
[0,1,0,0,0,0,0,0,0,0]	(0,0,1,2,3,4,5,6,4,1,3)	2	29	1	$R^{a_1..a_8}$
[0,0,1,0,0,0,0,0,0,1]	(0,0,0,1,2,3,4,5,4,2,2)	2	23	1	$R^{a_1...a_7,b}$
[0,1,0,0,0,0,0,0,0,0]	(0,0,1,2,3,4,5,6,4,2,3)	0	30	1	$R^{a_1..a_8}$
[0,1,0,0,0,0,0,0,0,0]	(0,0,1,2,3,4,5,6,4,3,3)	2	31	1	$R^{a_1..a_8}$ new
[0,0,0,0,0,0,0,0,0,0]	(1,2,3,4,5,6,7,8,5,1,4)	2	46	1	$R^{a_1..a_{10}}$
[0,1,0,0,0,0,0,0,1,0]	(0,0,1,2,3,4,5,6,5,2,3)	2	31	1	$R^{ab,a_1..a_8}$
[1,0,0,0,0,0,0,0,0,1]	(0,1,2,3,4,5,6,7,5,2,3)	0	38	1	$R^{a,b_1...b_9}$
[0,0,0,0,0,0,0,0,0,0]	(1,2,3,4,5,6,7,8,5,2,4)	-2	47	2	$R^{a_1.....a_{10}}$.
[0,1,0,0,0,0,0,0,1,0]	(0,0,1,2,3,4,5,6,5,3,3)	2	32	1	
[1,0,0,0,0,0,0,0,0,1]	(0,1,2,3,4,5,6,7,5,3,3)	0	39	1	
[0,0,0,0,0,0,0,0,0,0]	(1,2,3,4,5,6,7,8,5,3,4)	-2	48	2	$R^{a_1..a_{10}}$
[0,0,0,0,0,0,0,0,0,0]	(1,2,3,4,5,6,7,8,5,4,4)	2	49	1	$R^{a_1....a_{10}}$
[1,0,0,0,0,0,1,0,0]	(0,1,2,3,4,5,6,8,6,2,4)	2	41	1	
[0,0,0,0,0,0,0,1,0]	(1,2,3,4,5,6,7,8,6,2,4)	0	48	1	$R^{a_1a_2}$
[0,1,0,0,0,1,0,0,0]	(0,0,1,2,3,4,6,8,6,3,4)	2	37	1	
[1,0,0,0,0,0,0,1,1]	(0,1,2,3,4,5,6,7,6,3,3)	2	40	1	
[1,0,0,0,0,0,1,0,0]	(0,1,2,3,4,5,6,8,6,3,4)	0	42	1	
[0,0,0,0,0,0,0,0,2]	(1,2,3,4,5,6,7,8,6,3,3)	0	48	0	
[0,0,0,0,0,0,0,1,0]	(1,2,3,4,5,6,7,8,6,3,4)	-2	49	3	
[1,0,0,0,0,0,1,0,0]	(0,1,2,3,4,5,6,8,6,4,4)	2	43	1	
[0,0,0,0,0,0,0,1,0]	(1,2,3,4,5,6,7,8,6,4,4)	0	50	1	$R^{a_1a_2}$.

Schnakenburg West 0107181
Kleinschmidt, Schnakenburg West 0309198.

Find a doublet and quadruplet of 10 forms (confirmed by a study of IIB supergravity)

- For II A and II B we get precisely the expected supergravity fields together with their duals.

- In II A we get an additional nine form i.e. Roman's theory.

- We find space-filling forms whose presence was confirmed by closing the supersymmetry algebra

∃ a 1-1 correspondence between the fields in the non-linear realisation of D=11, II A and II B.

hep-th/0402140

$A_{a_1..a_q} \Leftrightarrow \hat{R}^{a_1..a_q}$

$R^{ab}{}_{c} \Leftrightarrow A_{ab}{}^{c}$

E_{11} root

$\alpha = (0,1,2,3 \ldots 7,4,1,4)$

massive II A is contained in the D = 11 theory, but beyond the supergravity approximation

Equating $g^{D=11} = g^{IIB}$ say

we also find a quantitative comparison

(ie $\Lambda^{D=11}$ on S^2 with τ = axion of II B)

Duality Symmetries in E_{11}

Generators in E_{11} are multiple commutators of R^{abc} and $K^a{}_b$ and so have $3l$ indices.

$R^{a_1 \dots a_8, b}$ is level 3.

Those with no blocks of 10 or 11 indices are of the form

$h^a{}_b$, $A_{a_1 a_2 a_3}$, $A_{a_1 \dots a_6}$, $A_{a_1 \dots a_8, b}$

with any number of blocks of 9 indices ie $A_{a_1 a_2 a_3, b_1 \dots b_9}$.

– The little group is $SO(9)$ and so E_{11} contains all possible descriptions of the basic fields i.e all possible duality transformations.

Riccioni West
hep-th 10612001

– It lifts the infinite duality symmetry found in two dimensions to eleven.

E_{11} and gauged Supergravities

– In dimension D E_{11} predicts the number of D-1 forms $A_{a_1 \ldots a_{D-1}}$ whose field strength $F_{a_1 \ldots a_D} = D\, \partial_{[a_1} A_{a_2 \ldots a_D]}$ leads to a cosmological constant.

ie $\mathcal{L} \sim F^2 \rightsquigarrow F_{a_1 \ldots a_D} = m\, \epsilon_{a_1 \ldots a_D}$

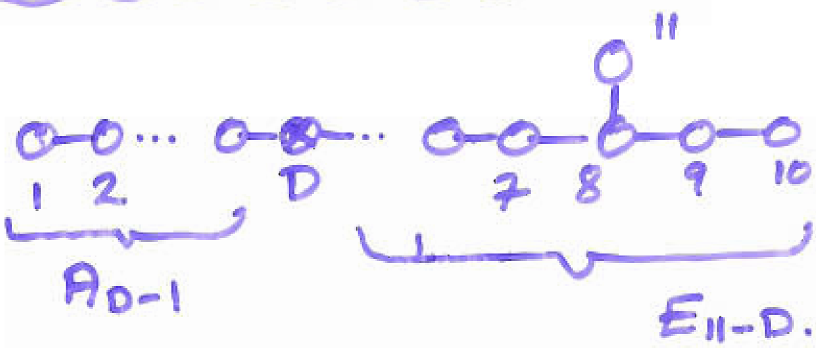
– In D = 10 IIA we have one $A_{a_1 \ldots a_9} \rightsquigarrow$ Romans theory.

Schnakenburg West 0204207.

– Thus E_{11} predicts the pattern of gauged maximal supergravities. It agrees precisely with many years of previous work (de Wit, Nicolai, Samtleben ...)

E_{11} provides a unified framework and D = 11 origin for all gauged maximal supergravities. (up to level 14)

E_{11} in D dimensions



- A_{D-1} leads to gravity and E_{11-D} is an internal symmetry. The forms are

	G	1	2	3	4	5	6	7
7	$SL(5,R)$	$\overline{10}$	5.	$\overline{5}$	10	24.	$\overline{40} \oplus \overline{15}$	$70 \oplus 45 \oplus 5$
6	$SO(5,5)$	16	10	$\overline{16}$	45	144	$320 \oplus \overline{126} \oplus 10$	
5	E_6	27	$\overline{27}$	78	351	$\overline{1728} \oplus \overline{27}$		
4	E_7	56	133	912	$8645 \oplus 133$			
3	E_8	248	$3875 \oplus 1$					

— We find a 'democratic' formulation ie field A_p plus its dual A_{D-p-2}, but also $D-1$ deformation forms and D space-filling forms.

Riccioni, West 0705.0752
Bergshoeff, de Baetselier, Nutma 0705.1304

For $D=4$ ie E_7. we have 912 of three forms.

$$912 \text{ of } E_7 = 36 + \overline{36} + \underset{\text{of } SL(8)}{420 + \overline{420}}$$

The $\overline{36}$ is ϕ^{ij} which contains the singlet $\phi_{ij}\eta^{ij}$ of $SO(8)$ giving the $AdS_4 \times S_7$ gauging

Mike 1984
Chris
Bengt.

There is very considerable evidence for an E_{11} symmetry of the low energy dynamics of the under-lying theory ie M-theory. more correctly E-theory.

The l_1 representation of E_{11}

— The fundamental representation associated with node 1 is l_1 contains

$$P_a, Z^{ab}, Z^{a_1 \ldots a_5}, Z^{a_1 \ldots a_7, b}, Z^{a_1 \ldots a_8}, \ldots$$

hep-th 0307098.

— This is the multiplet of brane charges

— Decomposing the l_1 multiplet to D dimensions one finds E_{11-D} multiplet of brane charges.

The l representation in D dimensions

D	G	Z	Z^a	Z^{ab}	$Z^{a_1a_2a_3}$	$Z^{a_1 \cdot a_4}$	$Z^{a_1 \cdot a_5}$
7	SL(5,R)	10	$\overline{5}$	5	$\overline{10}$	24 + 1	40 + 15 + 10
6	SO(5,5)	$\overline{16}$	10	16	45 + 1	$\overline{144}$ + $\overline{16}$	
5	E_6	$\overline{27}$	27	78 + 1	$\overline{351}$ + $\overline{27}$		
4	E_7	56	133 + 1	912 + 56			
3	E_8	248	3875 + 248 + 1				

hep-th/0406150
0412336

- Agrees, where previously calculated with the U-duality multiplets of brane charges but it provides a unified (Pioline, Rabinovici, Obers, ...) framework with D=11 origin

- Gives an origin for the many exotic charges.

E_{11}, l_1 and Dynamics

Let us consider the non-linear realization $E_{11} \otimes_s l_1$

$$g = e^{x^a P_a} e^{x_{ab} Z^{ab}} \cdots e^{h_a{}^b (x^a, x_{ab}) K^a{}_b}$$

$$\cdot e^{A_{a_1 a_2 a_3}(x^a, x_{ab}, \dots) R^{a_1 a_2 a_3}} \cdots$$

$$= g_e g_A$$

– The fields $h_a{}^b$, $A_{a_1 a_2 a_3}$ depend on an infinite number of coordinates of a generalized space-time $x^a, x_{ab}, \dots$

– Encodes all possible ways of measuring space-time, particles, branes, …

– Automatically incorporates U-duality.

– The Cartan form is given by

$$g^{-1} dg = \underbrace{g_A^{-1} g_e^{-1} d g_e g_A}_{\text{generalized veirbein}} + \underbrace{g_A^{-1} d g_A}.$$

Close contact with generalized geometry

E_{11} and Brane Dynamics

We consider the non-linear realization of $E_{11} \otimes_s l_1$ in the form

$$g = g_\ell \, g_A .$$

where

$$g_\ell = e^{X^a(\xi) P_a} \, e^{X_{ab}(\xi) Z^{ab}} \cdots\cdots$$

$$g_A = e^{h_a{}^b(x) K^a{}_b} \, e^{A_{a_1a_2a_3}(X) R^{a_1a_2a_3}} \cdots\cdots$$

ξ are brane world volume coordinates

The Cartan forms are

$$g^{-1} dg = g_A^{-1}(g_\ell^{-1} dg_\ell) g_A + g_A^{-1} dg_A .$$

$$= \nabla_n X^a P_a + \nabla_n X_{ab} Z^{ab} + \cdots\cdots$$

We find that

$$\nabla_n X^a = \partial_n X^\mu e_\mu{}^a$$

$$\nabla_n X_{ab} = \partial_n X_{\mu\nu} (e^{-1})_a{}^\mu (e^{-1})_b{}^\nu - \partial_n X^\mu e_\mu{}^c A_{cab}$$

$$\vdots$$

where $e_\mu{}^a = (e^h)_\mu{}^a$.

Setting all except $X^a(\xi)$ and $h_a{}^b(x)$ (ie $IGL(D)$) we find the bosonic brane action, $\int d\xi \det(D_n X^a)$

For the M2 brane, the equation of motion at lowest order is

$$\sqrt{-\gamma}\, \gamma^{nm} D_m X^b \eta_{ba} = \epsilon^{nmr} D_m X_{ab} D_r X^b + \cdots$$

where $\gamma_{nm} = D_n X^a \eta_{ab} D_m X^b$.

Mike 1990.

Dimensionally reducing to ten dimensions X^a $a = 1, \ldots, 10$, $Y^a = X^{a11}$ leads to the Duff Doubled string formulation (1990).

One also recovers the five brane equations at lowest order.

Gauged Supergravity and l_1

Consider the non-linear realisation of $E_{11} \otimes_s l_1$ in $D=5$.

E_{11} generators

$$\underset{E_6}{R^{\alpha}},\ \underset{(\overline{27})}{R^{am}},\ \underset{(27)}{R^{a_1a_2}{}_m},\ \underset{(78)}{R^{a_1a_2a_3\alpha}},\ \underset{\overline{351}}{R^{a_1\ldots a_4}{}_{[MN]}},\ \ldots$$

l_1 generators

$$P_a,\ \underset{(\overline{27})}{Z^N},\ \underset{(27)}{Z^a{}_N},\ \underset{78}{Z^{a_1a_2\alpha}},\ \underset{1}{Z^{a_1a_2}},\ \underset{\overline{351}}{Z^{a_1a_2a_3}{}_{[MN]}}\ \ldots$$

Consider the group element

$$g = g_e\, g_E.$$

where

$$g_e = e^{x^a P_a}\, e^{y_N(Z^N + g\,\theta^N_\alpha R^\alpha)}\, e^{y^N_a(Z^a_N + g W_{NM} R^{am})},\ \ldots$$

$$g_E = e^{A_{am}(x) R^{am}}\, e^{A_{a_1a_2}{}^{m}(x) R^{a_1a_2}{}_m} \cdots\cdots$$

Generalized space-time is a slice in $E_{11} \otimes_s l_1$

The gauge invariant forms derived from $g^{-1}\partial_\mu g$ are

$$F_{a_1 a_2, M} = 2\,\partial_{[a_1} A_{a_2],M} + g\, X^{[NP]}_{M} A_{[a_1,N} A_{a_2],P} - 4g\, W_{MN} A^{N}_{a_1 a_2}$$

$$F^{M}_{a_1 a_2 a_3} = 3\,\partial_{[a_1} A^{M}_{a_2 a_3]} + \frac{3}{2}\,\partial_{[a_1} A_{a_2,N} A_{a_3],P}\, d^{MNP}$$

$$- 6g\, X^{(MN\cdot)}_{P} A^{P}_{[a_1 a_2} A_{a_3]N}$$

$$+ \frac{1}{2} g\, X^{(NP)}_{R}\, d^{RQM} A_{[a_1,N} A_{a_2,P} A_{a_3]Q} + 3g\,\Theta^{M}_{\alpha} A^{\alpha}_{a_1 a_2 a_3}$$

$$F^{\alpha}_{a_1 \ldots a_4} = 4\,\partial_{[a_1} A^{\alpha}_{a_2 \ldots a_4]} - 2/3\,\partial_{[a_1} A_{a_2,M} A_{a_3,N} A_{a_4]}$$

$$\cdot\, d^{MNQ} D^{\alpha P}_{Q} - 4\,\partial_{[a_1} A^{M}_{a_2 a_3} A_{a_4],N} D^{\alpha N}_{M}$$

$$+ 4g\, D^{\alpha}{}_{M}{}^{P}\, \Theta^{M}_{\beta} A_{[a_1,P} A^{\beta}_{a_2 \ldots a_4]} + 16\, D^{\alpha P}_{M} W_{PN} A^{MN}_{a_1 \ldots a_4}$$

$$- 4g\, D^{\alpha}{}_{M}{}^{P} W_{PN} A^{M}_{[a_1 a_2} A^{N}_{a_3 a_4]}$$

$$- 4g\, D^{\alpha}{}_{M}{}^{P} X^{(MR)}_{Q} A_{[a_1,P} A_{a_2,R} A^{Q}_{a_3 a_4]}$$

$$- \frac{1}{6} g\, X^{(MN)}_{R}\, d^{RPS} D^{\alpha Q}_{S} A_{[a_1,M} A_{a_2,N} A_{a_3,P} A_{a_4,Q]}.$$

The dynamics are given by the duality relations i.e

$$V_{mij} F^{m}_{a_1 a_2 a_3} = \frac{1}{8} \epsilon_{a_1 a_2 a_3 b_1 b_2} V^{m}_{ij} F_{m}^{b_1 b_2}.$$

Find all $D = 5$ gauged supergravities.

Local E_{11}

It was proposed to close E_{11} with the conformal group.

level 0

$P_a, K^a{}_b$ + conf $\rightarrow$ general coordinate

level 1

$R^{a_1 a_2 a_3}$ + conf $\rightarrow$ gauge transformations

It is likely that all rigid E_{11} transformations become local.

Alternatively we can add generators

level 0

$K^a{}_b, \quad K^{ab}{}_c, \quad \ldots \quad , K^{a_1 \ldots a_n}{}_c, \ldots$ (Einstein)

level 1

$R^{a_1 a_2 a_3}, \quad K^{b, a_1 a_2 a_3}, \ldots \quad K^{b_1 \ldots b_s, a_1 a_2 a_3}, \ldots$

We take this algebra with just P_a.

Borel $E_{11} \oplus [R^{abc}, P_d] = 0$

$\oplus \; [K^{ab}{}_c, P_d] = \delta^{(a}_d K^{b)}{}_c, \ldots$

Note only Borel E_{11}.

Such an algebra is consistent and gives the massless maximal supergravities.

If we deform say in $D=5$

$$[R^{a\,m}, P_b] = g\delta^a_b \Theta^m{}_\alpha R^\alpha.$$

we find a <u>unique</u> algebra which leads to the gauged supergravities.

Gauged supergravities arise from all such deformations.

E_{11}, locality and Space-time

	Advantage	Disadvantage
$E_{11} \otimes_s l_1$	leads to gauged supergravities	where are the local symmetries
	well defined algebra	precise nature of space-time slice
local E_{11}	leads to gauged supergravities	what is the precise algebra
	super efficient calculation	where is full E_{11}

E_{11} is telling us something about space-time.

The low energy effective actions of the II A and II B superstrings are the corresponding maximal supergravities which contain all the perturbative and non-perturbative corrections.

Eleven dimensional supergravity is thought to be another low energy limit of an underlying theory

A great deal of our understanding has been derived from these supergravity theories.

i.e. brane solutions ie M2

Duff Stelle 1991.