E_{10} and the BKL-Limit of M Theory

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AEI, Golm

based on work done with

T. Damour & M. Henneaux

(AEI-2002-054/IHES/P/02/48, to appear)

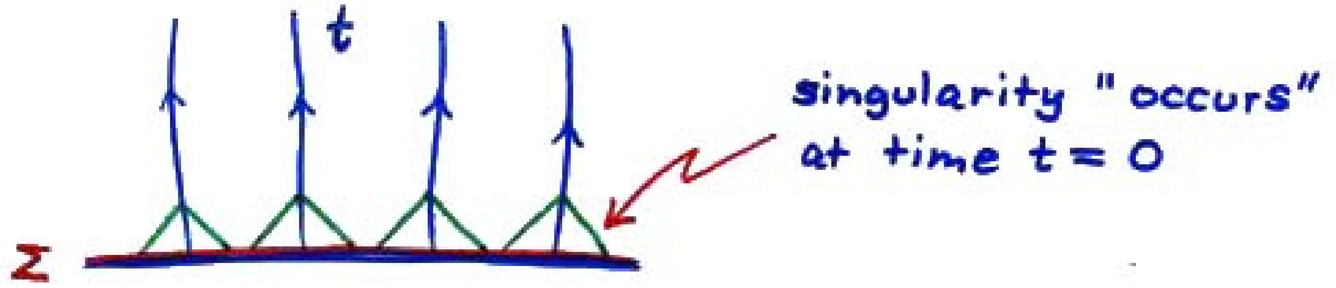
with thanks to: A. Feingold
T. Fischbacher

BKL : the basic picture

Belinskii, Khalatnikov, Lifshitz

Misner, Chitre, ...

describe generic behavior of EFE's near a spacelike singularity



spacelike ⟷ causal decoupling

spatial gradients ⋘ time derivatives

If true: EFE's reduce to continuous superposition of ODE's at each $\vec{x} \in \Sigma$

→ dimensional reduction of Einstein's theory to one dimension (almost!)

"Small tension limit" of Einstein action

$$S = \int dt \int d^d\vec{x} \left[\rho_b (\partial_t h)^2 - T_b (\partial_x h)^2 \right] + \ldots$$

take $T_b \to 0 \implies c = \sqrt{T_b/\rho_b} \to 0$

Recall $T_s \to 0$ limit of string theory

→ ∞ many massless states

Hints of (enormous!) underlying hidden symmetry of string theory?

(Gross, 1988)

e.g. Janteen, gr-qc/01020…

Hamiltonian description

metric ansatz $ds^2 = -dt^2 + \sum_{a=1}^{d} e^{-2\beta^a} \omega_a \otimes \omega_a$

$\omega^d = dx^d$

$\omega^{d-1} = dx^{d-1} + \mathcal{N}_{d-1,d}\, dx^d$

$\vdots$ (Iwasawa)

We seek an "effective low energy theory" for diagonal metric degrees of freedom

$$S = \left(\int d^d\vec{x}\right) \int dt \left\{ \underbrace{N^{-1} G_{ab} \dot\beta^a \dot\beta^b}_{ⓐ} - \underbrace{N V(\beta)}_{ⓑ} \right\}$$

ⓐ Zeroth order approximation = dimensional reduction of Einstein's theory to one (time) dimension

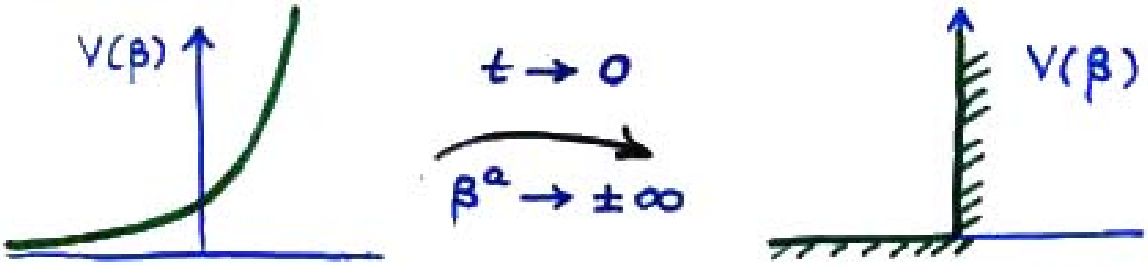
G_{ab} = DeWitt metric in truncated Wheeler-DeWitt superspace $\mathcal{S}_d \ni \{\beta^a\}$
Lorentzian signature $(- + \ldots +)$

ⓑ Effective potential $V(\beta)$ from "integrating out" off-diagonal metric components, spatial inhomogeneities, matter fields, ...

Generally: $V(\beta) \sim \sum_A c_A e^{w_A(\beta)}$

where
- $c_A > 0$ for leading terms
- $w_A(\beta)$ = linear form in β

Misner, Chitre: dynamics simplifies as $t \to 0$

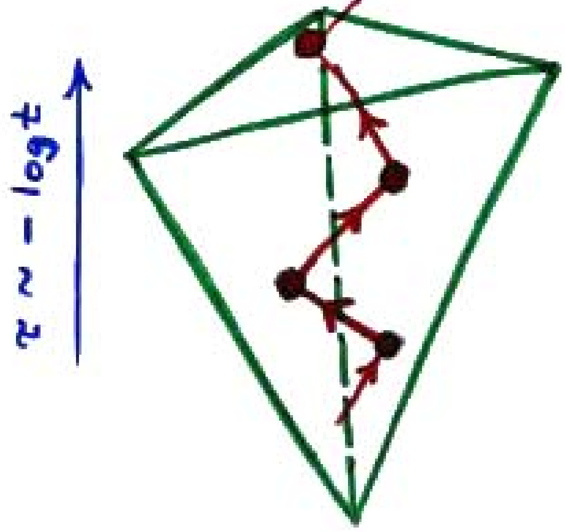


Toda Wall Sharp Wall

Hamiltonian constraint (from δN)

$$G_{ab} \dot{\beta}^a \dot{\beta}^b + V(\beta) = 0$$

In sharp wall limit $V(\beta) = 0$ or ∞



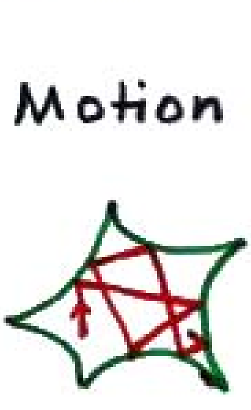
→ free Kasner flight

● collisions against walls $w_A(\beta) = 0$

→ { Infinitely many collisions: chaotic oscillations à la BKL

Finitely many collisions: "AVD" }

Motion can be projected onto $G_{ab}\beta^a\beta^b = -1$



$\Rightarrow$ relativistic ($m^2 = 0$) hyperbolic billard!

Crucial insight: dominant walls form fundamental Weyl chamber of some indefinite Kac Moody algebra $\mathfrak{g}(A)$

Damour, Henneaux (2000)

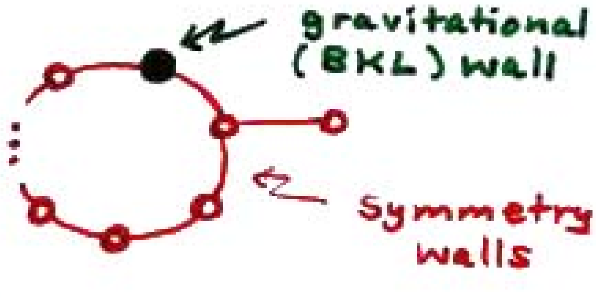
⇒ identify truncated WDW superspace $\mathcal{S}_d$ with CSA $\mathfrak{h}$ of $\mathfrak{g}(A)$!

- Chaotic oscillations à la BKL if $\mathfrak{g}(A)$ hyperbolic KM algebra
- AVD if $\mathfrak{g}(A)$ indefinite, but not hyperbolic (e.g. E_n for $n \geq 11$)

Damour, Henneaux, Julia, N.

Examples:

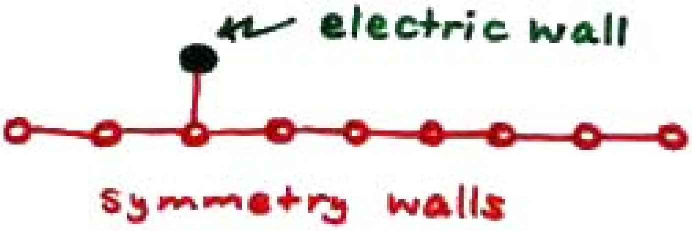
(i) pure gravity in $D = d+1$ dimensions



AE_d :

hyperbolic for $d \leq 9$

(ii) $D = 11$ supergravity



E_{10} :

maximal rank hyperbolic

Our Goal: extend these considerations beyond leading order and beyond CS/

Main Idea: search for map that relates the time evolution of the geometrical **M Theory** data at each spatial point [the fields and all their spatial gradients] to a null geodesic motion on the ∞-dimens coset space $E_{10}/K(E_{10})$.

cf. conjectured appearance of E_{10} in $D=1$ reduction of $D=11$ SUGRA

(Julia, 1983)

Results [Damour, Henneaux, N., to appear]

- construct map to low orders & recover Toda wall Hamiltonians
- show that coset space $E_{10}/K(E_{10})$ can accommodate all geometrical data (and much more).

Or:

- E_{11} ? West, hep-th/0104081
- (truncated) super-Borcherds ?

Labordère, Julia, ...

Proceed formally : $D = 1$ σ-model for

$$\mathcal{V} = \mathcal{V}(t) \in E_{10}/K(E_{10})$$

"maximal compact" subgroup, see below

$$v(t) := \frac{d\mathcal{V}}{dt}\mathcal{V}^{-1}(t) \in e_{10} \equiv \mathrm{Lie}(E_{10})$$

The Lagrangian is

$$\mathcal{L}(t) = \frac{1}{n(t)} \langle v_{sym}(t) \mid v_{sym}(t) \rangle \quad (*)$$

where

- $n(t)$ = "lapse"
- $v_{sym} := v - \omega(v)$

  with ω = Chevalley involution

  $\omega(h_i) = -h_i$, $\omega(e_i) = -f_i$, $\omega(f_i) = -e_i$

  defines maximal "compact" subgroup $K = \omega(K) \subset E_{10}$
- $\langle \cdot | \cdot \rangle$ = standard invariant bilinear form on KM algebra

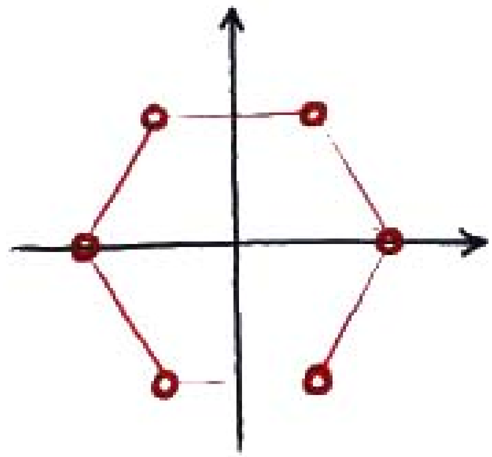
There are no other polynomial Casimir invariants on E_{10} but there do exist transcendental invariants [Kac Peterson] by which (*) could be modified. ("nonperturbative" effects ?)

Unfortunately, working out the σ-model Lagrangian $\mathcal{L}$ explicitly is not so easy even in the simplest cases ...

Recall rank 2 KM algebras:

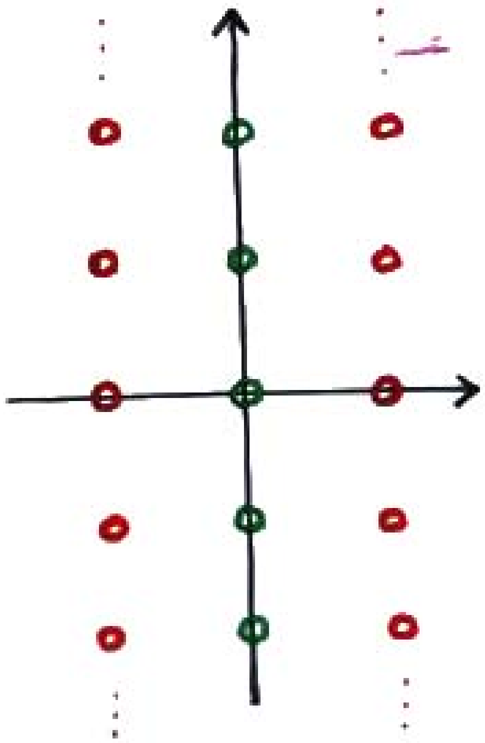
$$A = \begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix}$$

$[= sl(3)]$



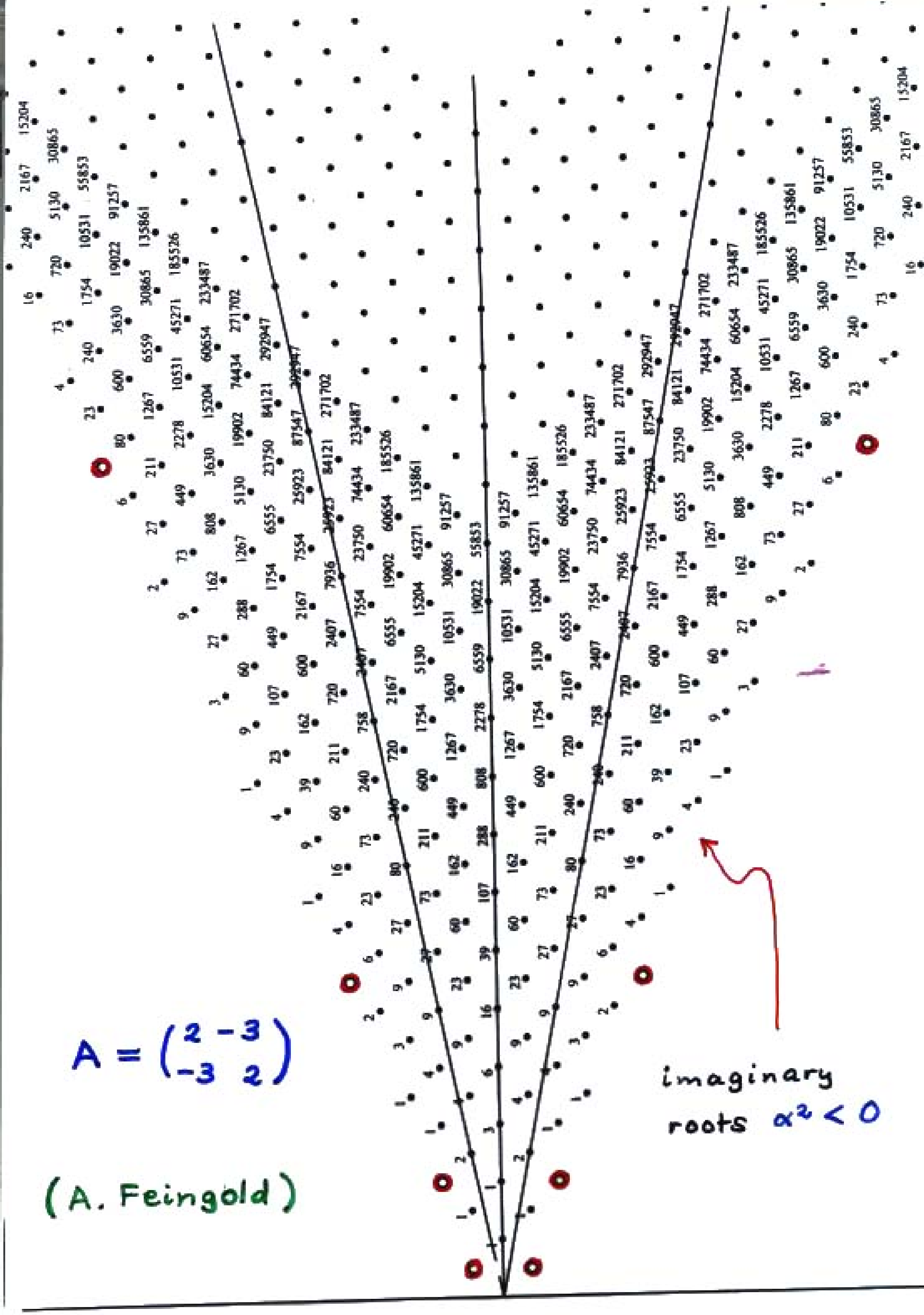
$$A = \begin{pmatrix} 2 & -2 \\ -2 & 2 \end{pmatrix}$$

$[= \widehat{sl(2)}_{c.e.}]$



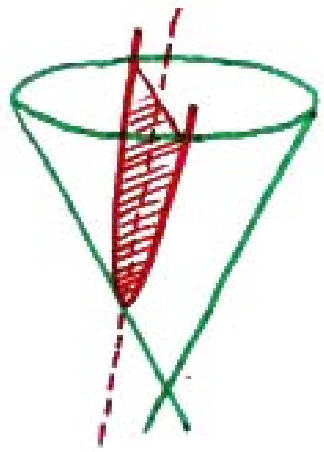
o real roots $\alpha^2 = 2$

o null roots $\alpha^2 = 0$


$A = \begin{pmatrix} 2 & -3 \\ -3 & 2 \end{pmatrix}$
imaginary roots $\alpha^2 < 0$
(A. Feingold)

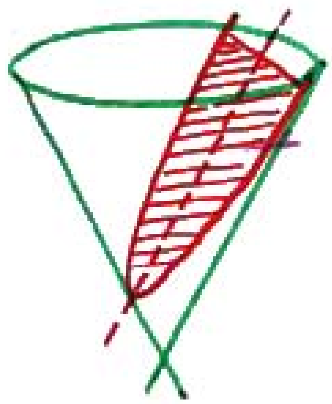
How to "slice" a hyperbolic KM algebra

w.r.t. hyperbolic subalgebra (with hyperbolic weight diagrams): has not been tried so far, but would be most informative.

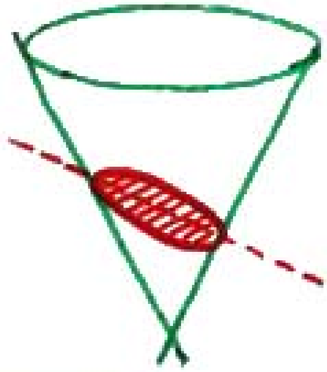


w.r.t. affine subalgebra (with parabolic weight diagrams): only results for affine levels $0, \pm 1, \pm 2$.

Feingold, Frenkel (1983)
Kac, Moody, Wakimoto (1988)

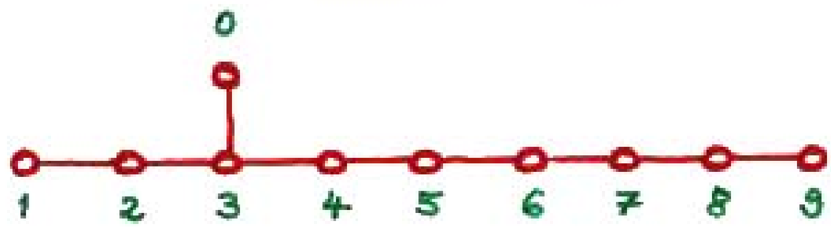


w.r.t. finite subalgebra (finite weight diagrams): the "bottom-up-approach"



Problem: must understand structure of algebra "deep inside" forward light cone!

E_{10}



write $\alpha = \ell\alpha_0 + \sum_{j=1}^{9} m^j \alpha_j$

with $\ell \equiv \ell(\alpha)$ = "level" w.r.t. A_9

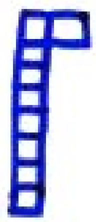
> Thus, we decompose E_{10} into irreps of its $A_9 \equiv sl(10)$ sub-algebra for all levels ℓ [$\to GL(10)$].

Irreps of A_9 are characterized by their highest weights $\Lambda \equiv \alpha$, or equivalently their Dynkin labels – $(p_1, \ldots, p_9)$ where

$$p_k := (\Lambda, \alpha_k) \geq 0$$

$$= \#(\text{columns with } k \text{ boxes in associated Young tableau})$$

e.g. $(001\,000\,000)$ 

$(100\,000\,010)$ 

etc.

For E_{10} the A_9 irreps which can appear at a given level ℓ must obey

$$m^i = S^{i3}\ell - \sum_{j=1}^{9} S^{ij} p_j \qquad (1)$$

where S = inverse Cartan matrix of A_9.

Strong constraint because all m^i, p_j must be non-negative integers!

Also h.w. Λ must be a root (Serre!)

$$\Lambda^2 = \sum_{i,j=1}^{9} p_i S^{ij} p_j - \frac{1}{10}\ell^2 \leq 2 \qquad (2)$$

Finding a completely explicit description of E_{10} in terms of infinite towers of $GL(10)$ irreps is thus reduced to the problem of determining their outer multiplicities $n_i = n(\ell, \mathcal{R}_i)$.

In particular,

$$\text{mult}_{E_{10}}(\Lambda) = \sum n_i \, \text{mult}_{\mathcal{R}_i}(\Lambda)$$

multiplicity of Λ as a root of E_{10}

outer multiplicity

(inner) multiplicity of Λ as a weight of the A_9 irrep $\mathcal{R}_i$

→ low level irreps

$\ell = 0$ adjoint of $GL(10) \leftrightarrow K^a{}_b$

$\ell = 1$ $(001\,000\,000) \leftrightarrow E^{abc}$

$\ell = 2$ $(000\,001\,000) \leftrightarrow E^{a_1 \dots a_6}$

$\ell = 3$ $(100\,000\,010) \leftrightarrow E^{a_1 \dots a_8 | b}$

up to here: see also West, hep-th/0104081; Cremmer, Julia, Lu, Pope (for E_8)

Clearly,

$\ell = 0$ Graviton $\leftrightarrow G_{ab} = G_{ba}$

$\ell = 1$ 3-Form $\leftrightarrow A_{abc}$

$\ell = 2$ Dual 6-Form $\leftrightarrow A_{a_1 \dots a_6}$

$\ell = 3$ "Dual Graviton" $\leftrightarrow A_{a_1 \dots a_8 | b}$

But we can go further:

$\ell = 4$ $(001\,000\,001)$, $(200\,000\,000)$

$\ell = 5$ $(000\,001\,001)$, $(100\,100\,000)$

$\ell = 6$ $(100\,000\,011)$, $(010\,010\,000)$, $(100\,000\,100)$, $(000\,000\,010)$

so far: outer multiplicity $= 1$

The basic correspondence

choose special frame $\theta^a(x) = E^a{}_i(x)\,dx^i$

$$ds^2 = -N\,dt^2 + G_{ab}\,\theta^a\theta^b$$

$$\mathcal{F} = \frac{1}{3!}F_{tabc}\,dt\wedge\theta^a\wedge\theta^b\wedge\theta^c +$$

$$+\frac{1}{4!}F_{abcd}\,\theta^a\wedge\theta^b\wedge\theta^c\wedge\theta^d$$

with $d\theta^a = \frac{1}{2}C^a{}_{bc}\,\theta^b\wedge\theta^c$

$\Rightarrow$ **D = 11 SUGRA eqs. of motion**

Cremmer, Julia, Scherk (1978)

$$\partial_t\left(G^{ac}\partial_t G_{cb}\right) = \frac{1}{6}G\,F^{a\beta\gamma\delta}F_{b\beta\gamma\delta} -$$

$$-\frac{1}{72}G\,\mathcal{F}^{\alpha\beta\gamma\delta}F_{\alpha\beta\gamma\delta}\,\delta^a_b - 2\,G\,R^a{}_b(\Gamma, C)$$

$$\partial_t\left(G\,F^{tabc}\right) = \frac{1}{144}\varepsilon^{abcdefghij}F_{tdef}\,F_{ghij}$$

$$+\frac{3}{2}G\,F^{de[ab}C^{c]}{}_{de} - G\,C^e{}_{de}F^{dabc} - \partial_d\left(G\,F^{dabc}\right.$$

$$\partial_t F_{abcd} = 6\,F_{te[ab}C^e{}_{cd]} + 6\,\partial_{[a}F_{tbcd]}$$

Demaret, Hanquin, Henneaux, Spindel (1985)

Borel gauge for $E_{10}/K(E_{10})$ σ-model:

$$\mathcal{V} = \exp X_h(t)\cdot\exp X_A(t)$$

$$e^a{}_i \equiv \left(\exp h(t)\cdot K\right)^a{}_i \longrightarrow \quad g_{ab} = e_a{}^i e_{bi}$$

$$X_A(t) = \frac{1}{3!} A_{abc} E^{abc} + \frac{1}{6!} A_{a_1 \dots a_6} E^{a_1 \dots a_6}$$

$$+ \frac{1}{9!} A_{a_1 \dots a_8 | a_9} E^{a_1 \dots a_8 | a_9} + \dots$$

Equations of motion match (keeping first order spatial gradients) with:

- $g_{ab}(t) = G_{ab}(t, x)$ (x fixed!)
- $\mathring{A}_{abc}(t) = F_{tabc}(t, x)$
- $\mathring{A}_{a_1 \dots a_6}(t) + 10\, A_{[a_1 a_2 a_3}(t) \mathring{A}_{a_4 a_5 a_6]}(t) =$

$$= -\frac{1}{4!} \varepsilon_{a_1 \dots a_6}{}^{b_1 \dots b_4} F_{b_1 b_2 b_3 b_4}(t, x)$$

- $\mathring{A}_{a_1 \dots a_8 | a_9}(t) + 42\, A_{\langle a_1 a_2 a_3}(t) \mathring{A}_{a_4 \dots a_9 \rangle}(t)$

$$- 42\, \mathring{A}_{\langle a_1 a_2 a_3}(t) A_{a_4 \dots a_6 \rangle}(t) +$$

$$+ 280\, A_{\langle a_1 a_2 a_3}(t) A_{a_4 a_5 a_6}(t) \mathring{A}_{a_7 a_8 a_9 \rangle}(t)$$

$$= \frac{3}{2} \varepsilon_{a_1 \dots a_8 bc} \left(C_{a_9}{}^{bc}(x) + \frac{2}{9} \delta^b_{a_9} C_d{}^{cd}(x) \right)$$

where $\langle \dots \rangle$ = projector onto (100000010

But how to continue beyond first order in spatial gradients?

[This will be the acid test of the idea!]

Search for "affine" roots ($m^2 = 0$) in (1) and (2) reveals existence of three infinite towers of E_{10} elements:

$$(001\,000\,00n) \qquad E_{a_1 \dots a_n}{}^{b_1 b_2 b_3}$$

$$(000\,001\,00n) \qquad E_{a_1 \dots a_n}{}^{b_1 \dots b_6}$$

$$(100\,0001n) \qquad E_{a_1 \dots a_n}{}^{b_1 \dots b_8 | c}$$

Truncation $a_1 = \dots = a_n = 1$ and $b_1, \dots, c \in \{2, \dots, 10\}$ yields all elements of affine subalgebra $E_9 \subset E_{10}$

Comparison with linear system of $D=2$ maximal supergravity suggests that we should associate

$$E_{a_1 \dots a_n}{}^{b_1 b_2 b_3} \longleftrightarrow \partial^{a_1} \dots \partial^{a_n} A_{b_1 b_2 b_3}$$

$$E_{a_1 \dots a_n}{}^{b_1 \dots b_6} \longleftrightarrow \partial^{a_1} \dots \partial^{a_n} A_{b_1 \dots b_6}$$

$$E_{a_1 \dots a_n}{}^{b_1 \dots b_8 | c} \longleftrightarrow \partial^{a_1} \dots \partial^{a_n} A_{b_1 \dots b_8 | c}$$

[dual potentials à la Geroch in reduction to $D = 2$, i.e. $\partial^a \to \partial^1$]

BUT THERE IS MUCH MORE ...

Bärwald, Gebert, N. [NP B510 (98) 721]

Table 3: E_{10} Root Multiplicities

Λ	Λ	$\ell(\Lambda)$	ht(Λ)	Λ^2	mult(Λ)	$\Delta(\Lambda)$
$\delta + \Lambda_8$	[3, 7, 11, 15, 19, 23, 27, 18, 9, 13]	3	145	-16	167116	35064
5δ	[0, 5, 10, 15, 20, 25, 30, 20, 10, 15]	0	150	0	8	0
$3\delta + \Lambda_0$	[1, 5, 10, 15, 20, 25, 30, 20, 10, 15]	1	151	-8	2464	254
$\delta + 2\Lambda_0$	[2, 5, 10, 15, 20, 25, 30, 20, 10, 15]	2	152	-12	22712	3514
$2\Lambda_7$	[4, 8, 12, 16, 20, 24, 28, 18, 8, 14]	4	152	-16	167133	35047
$2\delta + \Lambda_1$	[2, 6, 10, 15, 20, 25, 30, 20, 10, 15]	2	153	-14	63020	11536
Λ_6	[4, 8, 12, 16, 20, 24, 28, 18, 9, 14]	4	153	-18	425227	101170
$\Lambda_0 + \Lambda_1$	[3, 6, 10, 15, 20, 25, 30, 20, 10, 15]	3	154	-16	167099	35081
$\delta + \Lambda_2$	[3, 7, 11, 15, 20, 25, 30, 20, 10, 15]	3	156	-18	425156	101241
Λ_3	[4, 8, 12, 16, 20, 25, 30, 20, 10, 15]	4	160	-20	1044218	278125
$3\delta + \Lambda_7$	[2, 7, 12, 17, 22, 27, 32, 21, 10, 16]	2	166	-16	166840	35340
$\delta + \Lambda_0 + \Lambda_7$	[3, 7, 12, 17, 22, 27, 32, 21, 10, 16]	3	167	-20	1043926	278417
$\Lambda_1 + \Lambda_7$	[4, 8, 12, 17, 22, 27, 32, 21, 10, 16]	4	169	-22	2485020	733071
$2\delta + \Lambda_8$	[3, 8, 13, 18, 23, 28, 33, 22, 11, 16]	3	175	-22	2483970	734121
$\Lambda_0 + \Lambda_8$	[4, 8, 13, 18, 23, 28, 33, 22, 11, 16]	4	176	-24	5749818	1862196
6δ	[0, 6, 12, 18, 24, 30, 36, 24, 12, 18]	0	180	0	8	0
$4\delta + \Lambda_0$	[1, 6, 12, 18, 24, 30, 36, 24, 12, 18]	1	181	-10	7704	1026
$2\delta + 2\Lambda_0$	[2, 6, 12, 18, 24, 30, 36, 24, 12, 18]	2	182	-16	166840	35340
$\delta + 2\Lambda_7$	[4, 9, 14, 19, 24, 29, 34, 22, 10, 17]	4	182	-24	5750072	1861942
$3\delta + \Lambda_1$	[2, 7, 12, 18, 24, 30, 36, 24, 12, 18]	2	183	-18	424161	102236
$3\Lambda_0$	[3, 6, 12, 18, 24, 30, 36, 24, 12, 18]	3	183	-18	425058	101339
$\delta + \Lambda_6$	[4, 9, 14, 19, 24, 29, 34, 22, 11, 17]	4	183	-26	12971009	4577911
$\delta + \Lambda_0 + \Lambda_1$	[3, 7, 12, 18, 24, 30, 36, 24, 12, 18]	3	184	-22	2483871	734220
$2\delta + \Lambda_2$	[3, 8, 13, 18, 24, 30, 36, 24, 12, 18]	3	186	-24	5746226	1865788
$2\Lambda_1$	[4, 8, 12, 18, 24, 30, 36, 24, 12, 18]	4	186	-24	5749565	1862449
$\Lambda_0 + \Lambda_2$	[4, 8, 13, 18, 24, 30, 36, 24, 12, 18]	4	187	-26	12970045	4578875
$\delta + \Lambda_3$	[4, 9, 14, 19, 24, 30, 36, 24, 12, 18]	4	190	-28	28592513	10931086
$\Lambda_7 + \Lambda_8$	[5, 10, 15, 20, 25, 30, 35, 23, 11, 17]	5	191	-28	28595548	10928051
Λ_4	[5, 10, 15, 20, 25, 30, 36, 24, 12, 18]	5	195	-30	61721165	25411831
$4\delta + \Lambda_7$	[2, 8, 14, 20, 26, 32, 38, 25, 12, 19]	2	196	-20	1040664	281679
$2\delta + \Lambda_0 + \Lambda_7$	[3, 8, 14, 20, 26, 32, 38, 25, 12, 19]	3	197	-26	12959290	4589630
$2\Lambda_0 + \Lambda_7$	[4, 8, 14, 20, 26, 32, 38, 25, 12, 19]	4	198	-28	28589025	10934574
$\delta + \Lambda_1 + \Lambda_7$	[4, 9, 14, 20, 26, 32, 38, 25, 12, 19]	4	199	-30	61711591	25421405
$\Lambda_2 + \Lambda_7$	[5, 10, 15, 20, 26, 32, 38, 25, 12, 19]	5	202	-32	130661924	57690454
$3\delta + \Lambda_8$	[3, 9, 15, 21, 27, 33, 39, 26, 13, 19]	3	205	-28	28559052	10964547
$\delta + \Lambda_0 + \Lambda_8$	[4, 9, 15, 21, 27, 33, 39, 26, 13, 19]	4	206	-32	130632964	57719414
$\Lambda_1 + \Lambda_8$	[5, 10, 15, 21, 27, 33, 39, 26, 13, 19]	5	208	-34	271695444	128129588 •
7δ	[0, 7, 14, 21, 28, 35, 42, 28, 14, 21]	0	210	0	8	0
$5\delta + \Lambda_0$	[1, 7, 14, 21, 28, 35, 42, 28, 14, 21]	1	211	-12	22528	3698
$3\delta + 2\Lambda_0$	[2, 7, 14, 21, 28, 35, 42, 28, 14, 21]	2	212	-20	1040664	281679
$2\delta + 2\Lambda_7$	[4, 10, 16, 22, 28, 34, 40, 26, 12, 20]	4	212	-32	130635596	57716782
$4\delta + \Lambda_1$	[2, 8, 14, 21, 28, 35, 42, 28, 14, 21]	2	213	-22	2474026	744065
$\delta + 3\Lambda_0$	[3, 7, 14, 21, 28, 35, 42, 28, 14, 21]	3	213	-24	5745720	1866294
$\Lambda_0 + 2\Lambda_7$	[5, 10, 16, 22, 28, 34, 40, 26, 12, 20]	5	213	-34	271702532	128122500 •
$2\delta + \Lambda_6$	[4, 10, 16, 22, 28, 34, 40, 26, 13, 20]	4	213	-34	271618575	128206457
$2\delta + \Lambda_0 + \Lambda_1$	[3, 8, 14, 21, 28, 35, 42, 28, 14, 21]	3	214	-28	28558597	10965002
$\Lambda_0 + \Lambda_6$	[5, 10, 16, 22, 28, 34, 40, 26, 13, 20]	5	214	-36	555652661	278885204
$2\Lambda_0 + \Lambda_1$	[4, 8, 14, 21, 28, 35, 42, 28, 14, 21]	4	215	-30	61699285	25433711
$3\delta + \Lambda_2$	[3, 9, 15, 21, 28, 35, 42, 28, 14, 21]	3	216	-30	61620301	25512695
$\delta + 2\Lambda_1$	[4, 9, 14, 21, 28, 35, 42, 28, 14, 21]	4	216	-32	130630342	57722036
$\delta + \Lambda_0 + \Lambda_2$	[4, 9, 15, 21, 28, 35, 42, 28, 14, 21]	4	217	-34	271609694	128215338

↑

affine levels 0, 1, 2 :

Kac, Moody, Wakimoto

[with T. Fischbacher]

$\ell = 7$

1 * (001 000 002)$^+$
1 * (000 100 100)
1 * (110 000 010)
1 * (001 000 010)

1 * (200 000 001)
2 * (010 000 001)
1 * (100 000 000)

outer multiplicities

$\ell = 8$

1 * (000 001 002)$^+$
1 * (000 000 200)
1 * (100 010 010)
1 * (000 001 010)
1 * (011 000 001)

2 * (100 100 001)
2 * (000 010 001)
1 * (210 000 000)
2 * (101 000 000)
2 * (000 100 000)

$\ell = 9$

1 * (100 000 012)$^+$
1 * (010 000 110)
1 * (100 000 020)
1 * (001 010 001)
1 * (200 001 001)
2 * (010 001 001)
4 * (100 000 101)

3 * (000 000 011)
1 * (110 100 000)
1 * (001 100 000)
1 * (200 010 000)
3 * (010 010 000)
4 * (100 001 000)
4 * (000 000 100)

etc. [+ : "affine" irreps]

... a glimpse of E_{10} ...

→ suggests the existence of a huge and hitherto unknown nonlocal symmetry of **Einstein's** theory and/or its generalizations (transcending **Geroch**).

Horatio: ... but this is wondrous strange!

Hamlet: And therefore as a stranger give it welcome.
There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy.

(Hamlet, Act I, Scene V)