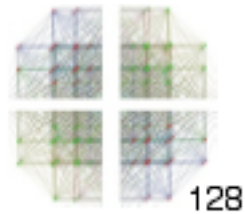
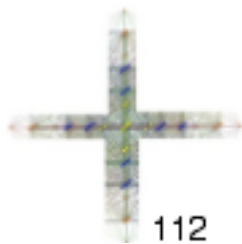
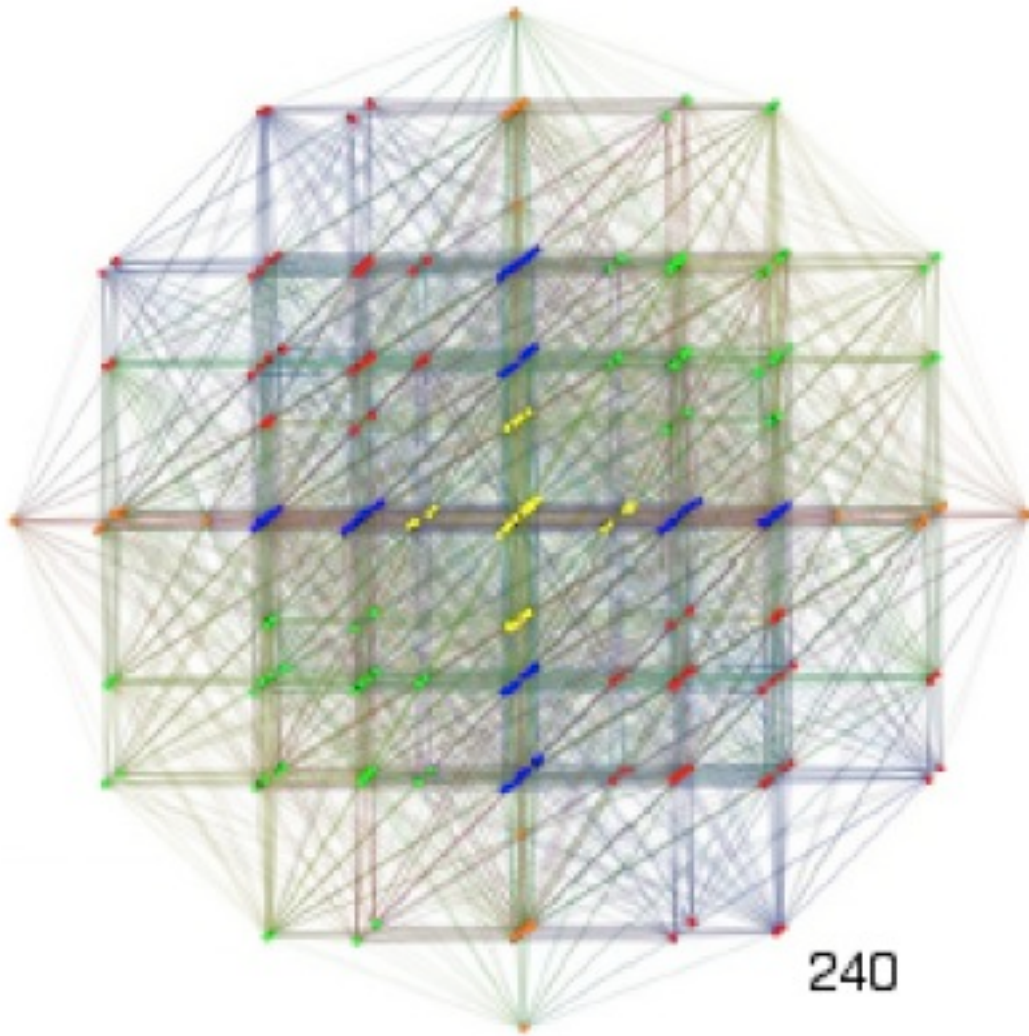


E_8 and $Cl(16) = Cl(8) (x) Cl(8)$



Frank Dodd (Tony) Smith, Jr. – Georgia – 2011

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E8 Physics:
from
Fundamental Fermion Dixon Spinors
to
26-dim String World-Line Theory
to
Kerr-Newman Clouds
to
Schwinger Source Regions
to
Wyler/Hua Force Strengths

Frank Dodd (Tony) Smith, Jr. - 2012

The following seven pages are an outline sketch of how E8 Physics emerges from fundamental spinor fermions to condense into a 26-dim String structure with strings as fermion World-Lines with each fundamental fermion being surrounded by a Quantum Cloud that has Kerr-Newman physical structure corresponding to a Schwinger Source region with complex harmonic Wyler/Hua Green's function propagator. The Wyler/Hua complex bounded domain structure allows realistic calculation of force strength constants and particle masses.

The outline sketch omits many details which are covered in vixra 1108.0027

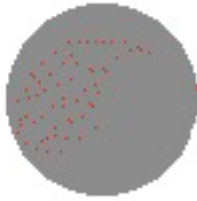
Here are some historical speculation questions:

Could Wyler's Green's function based on harmonic analysis of complex domains have been used by Schwinger to give more detailed models of his finite-region sources ?

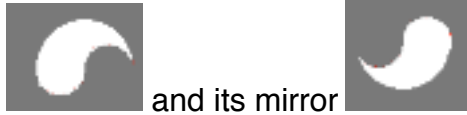
Could Wyler's rejection at IAS Princeton under Dyson in the 1970s have been at least in part due to Dyson's Feynman-type view of point particles as fundamental ?

If Wyler had gone to see Schwinger at UCLA instead of Dyson at IAS Princeton could Wyler and Schwinger together have developed source theory in great enough detail that its advantages (no renormalization etc) would have been clear to most physicists ?

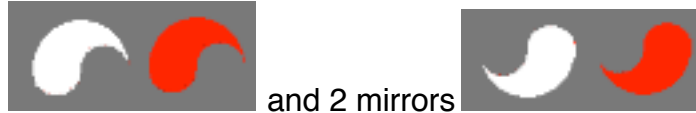
In the beginning there was $Cl(0)$ spinor fermion void



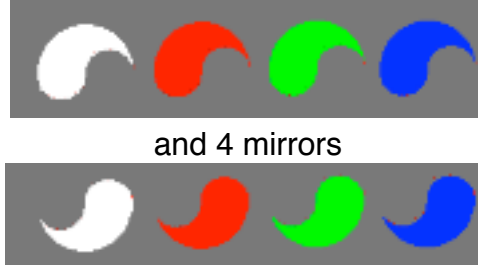
from which emerged $2 = \sqrt{2^2}$ $Cl(2)$ half-spinor fermions



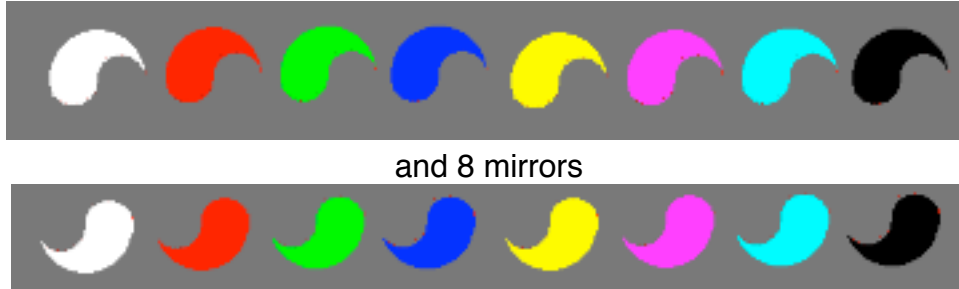
from which emerged $4 = \sqrt{2^4}$ $Cl(4)$ half-spinor fermions



from which emerged $8 = \sqrt{2^6}$ $Cl(6)$ half-spinor fermions



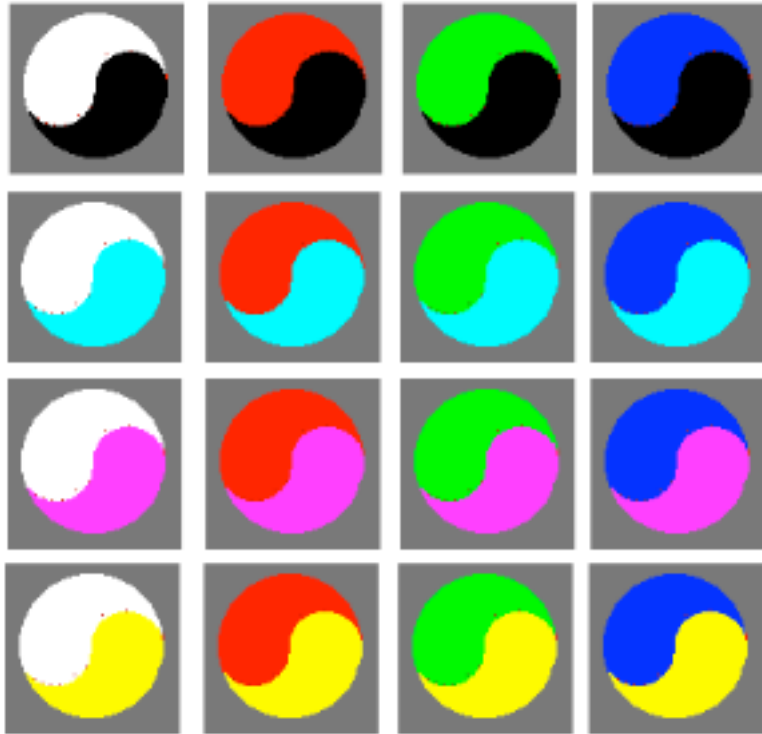
from which emerged $16 = \sqrt{2^8}$ $Cl(8)$ half-spinor fermions



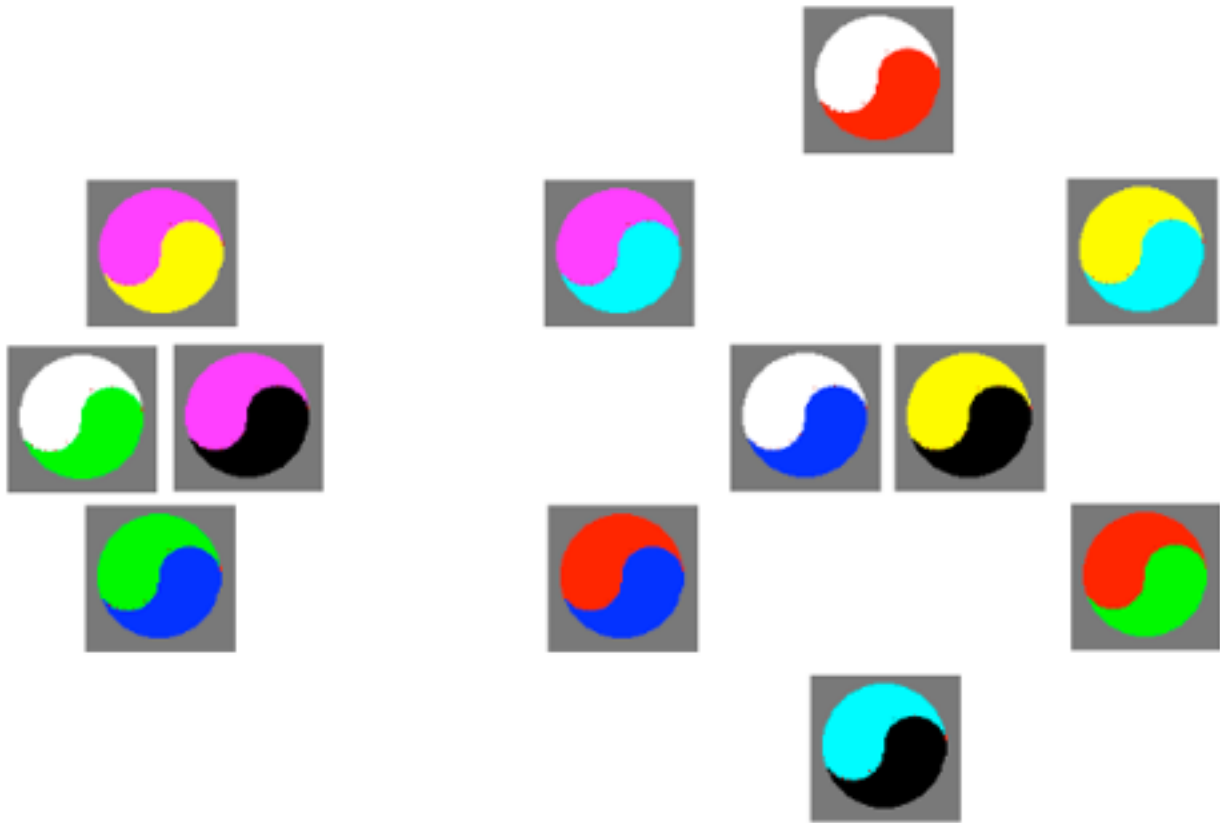
which by $Cl(8)$ Triality are isomorphic with the 8 $Cl(8)$ vectors



so that the 28 antisymmetric pairs of half-spinors and their mirrors are the 28 $Cl(8)$ bivectors of the Lie Algebra of Gauge Groups:



16 of $U(2,2) = U(1) \times SU(2,2) = U(1) \times Spin(2,4)$ for Conformal Gravity



4 of $U(2) = U(1) \times SU(2)$ and 8 of $SU(3)$ for the Standard Model.

As fermion particles the 8 $Cl(8)$ half-spinors



represent

neutrino; red down quark, green down quark, blue down quark;
blue up quark, green up quark, red up quark; electron
(yellow, magenta, cyan, black are used for blue, green, red up quarks and electron)

The 8 mirror $Cl(8)$ half-spinors represent the corresponding fermion antiparticles.

The 8 $Cl(8)$ half-spinor fermions



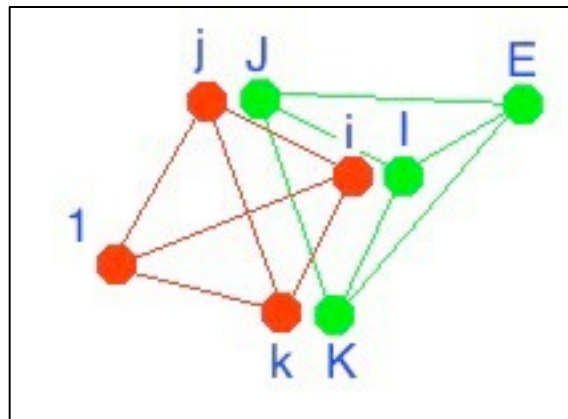
and their 8 mirror Triality equivalents



and their 8 $Cl(8)$ vector Triality equivalents



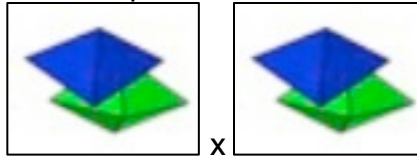
correspond to
the Octonion basis elements $\{1, i, j, k, K, J, I, E\}$
and
can be represented as a pair of tetrahedra



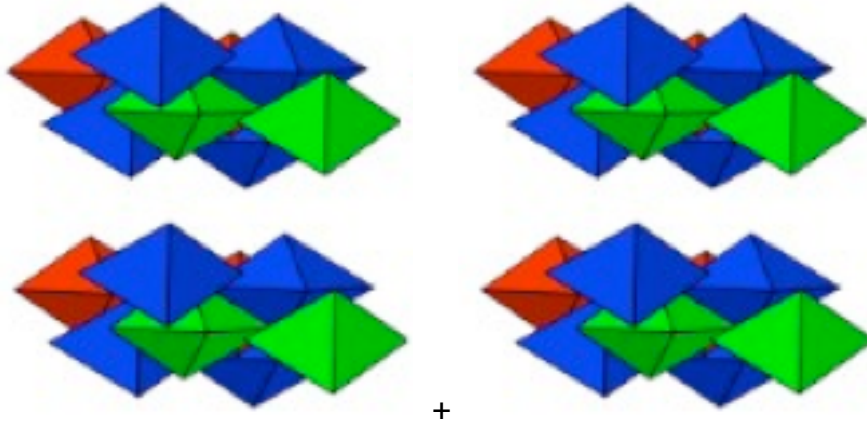
By Real Clifford Algebra 8-periodicity any large spinor space can be embedded in a tensor product of a number copies of the 16-dim full spinors of $Cl(8)$ representable as a pair of a pair of tetrahedra



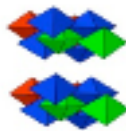
the tensor product of two of which



form the $128+128 = 256$ -dim full spinors of $Cl(8) \times Cl(8) = Cl(16)$

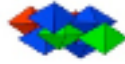


+



One set of 128-dim $Cl(16)$ half-spinors is the spinor/fermion part of the 248-dim Lie algebra $E_8 = 120$ -dim $Spin(16) + 128$ -dim half-spinor of $Spin(16)$ and is also a representation of the 128-dim spinor space denoted as T_2 by Geoffrey Dixon who says in his paper "Matter Universe: Message in the Mathematics":
 "... the 128-dimensional hyperspinor space T_2 ...[is]... the doubling of T ...
 The algebra $T = C \times H \times O$... (complex algebra, quaternions, and octonions) ... is $2 \times 4 \times 8 = 64$ -dimensional ... noncommutative, nonassociative, and nonalternative ...".

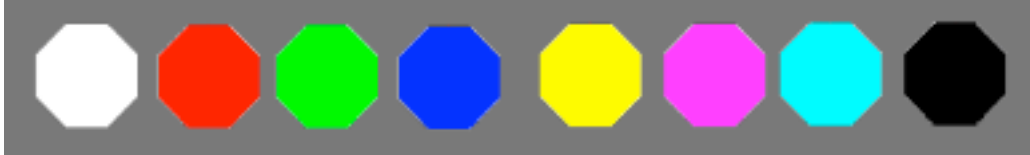
Within 128-dim T2,



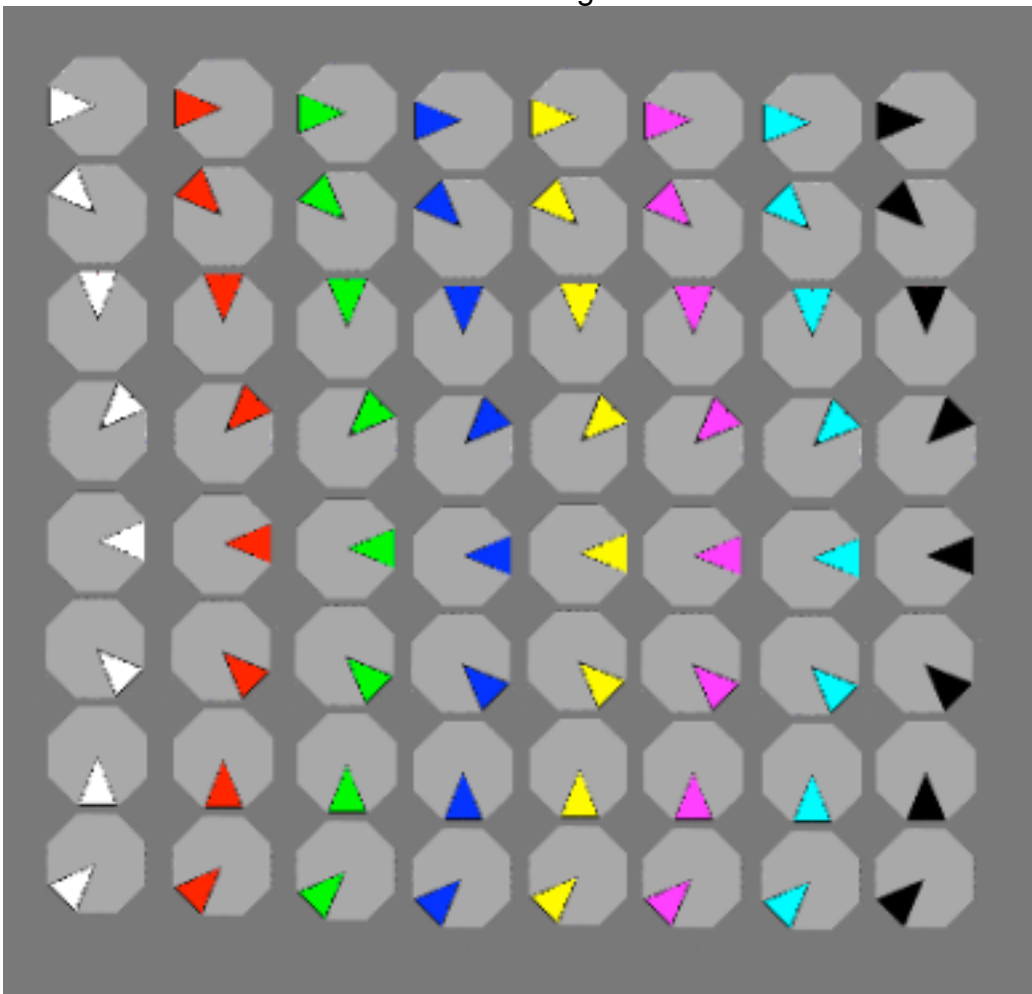
each 64-dim factor T is represented by half of the Spin(16) half-spinor space.

One 64-dim T represents fermion spinor particles while the other T of T2 represents fermion spinor antiparticles.

Let these 8 octagons represent the fermion particle types:



Then these 64 octagon octants



represent the $8 \times 8 = 64$ covariant components of the fermion particles.

With respect to $Cl(16)$ and E_8 the $Cl(8)$ Triality induces

Triality isomorphism between the two 64-dim factors T

that represent fermion particles and antiparticles

and also of both of them

with the 64-dim $D_8 / D_4 \times D_4$ space representing 8-dim position and momentum.

How does T2 represent the first-generation fermions seen in experiments ?

Using basis $\{c_1, c_i\}$ for C and $\{q_1, q_i, q_j, q_k\}$ for H and $\{1, i, j, k, E, I, J, K\}$ for O each T can be decomposed as follows:

$\{q_1, q_i, q_j, q_k\}$ represent { lepton , red quark , green quark , blue quark }

$\{c_1, c_i\}$ represent { neutrino / down quark , electron / up quark }

$\{1, i, j, k, E, I, J, K\}$ represent 8 covariant components of each fermion

with respect to $4+4 = 8$ -dim Kaluza-Klein Spacetime $M_4 \times CP^2$

with $\{1, i, j, k\}$ representing 4-dim M_4 Minkowski Physical Spacetime

and $\{E, I, J, K\}$ representing 4-dim CP^2 Internal Symmetry Space.

How do T2 fermions interact with each other ?

Consider fermionic 128-dim T2 as the spinor part of E8.

Construct a Local Lagrangian using the 120-dim Spin(16) part of E8

which can be decomposed into

two copies of the 28-dim Spin(8) Lie algebra

plus 64-dim of 8-dim spacetime position \times 8-dim spacetime momentum

so that **the Lagrangian density has**

a fermionic term from the T2 spinor space and

gauge boson terms from the two copies of Spin(8)

which are integrated over the 8-dim spacetime as base manifold.

How does the Local Lagrangian Physics extend Globally ?

Since the E8 Lagrangian is Local, it is necessary to patch together Local Lagrangian Regions to form a Global Structure describing a Global E8 Algebraic Quantum Field Theory (AQFT). Each E8 of each region is embedded into $Cl(16)$ and the completion of the union of all tensor products of all the $Cl(16)$ are taken thus producing a generalized **Hyperfinite II₁ von Neumann factor Algebraic Quantum Field Theory.**

What is the Physics of World-Line Histories of Particles/Antiparticles ?

8 + 8 + 8 = 24-dim of fermion particles and antiparticles and of spacetime can be represented by a Leech lattice underlying 26-dim String Theory in which strings represent World-Lines in the E8 Physics model.

The automorphism group of a single 26-dim String Theory cell modulo the Leech lattice is the Monster Group of order about 8×10^{53} .

A fermion particle/antiparticle does not remain a single Planck-scale entity because Tachyons create a cloud of particles/antiparticles.

The cloud is one Planck-scale Fundamental Fermion Valence Particle plus an effectively neutral cloud of particle/antiparticle pairs forming a Kerr-Newman black hole whose structure comes from the 24-dim Leech lattice part of the Monster Group which is $2^{(1+24)}$ times the double cover of Co_1 , for a total order of about 10^{26} .

(Since a Leech lattice is based on copies of an E8 lattice and since there are 7 distinct E8 integral domain lattices there are 7 (or 8 if you include a non-integral domain E8 lattice) distinct Leech lattices, and the physical Leech lattice is a superposition of them, effectively adding a factor of 8 to the order.)

The volume of the Kerr-Newman Cloud should be on the order of 10^{27} x Planck scale, and **the Kerr-Newman Cloud should contain on the order of 10^{27} particle/antiparticle pairs and its size should be somewhat larger than, but roughly similar to, $10^{(27/3)} \times 1.6 \times 10^{(-33)}$ cm = roughly $10^{(-24)}$ cm.**

Kerr-Newman Clouds as Schwinger Sources:

Green's Function Propagators

Schwinger, in Nottingham hep-ph/9310283, said:

"... in the phenomenological **source theory** ...

there are no divergences, and no renormalization ...

the source concept ... is abstracted from the physical possibility of creating or annihilating any particle in a suitable collision. ...

The basic physical act begins with the creation of a particle by a source, followed by the propagation ... of that particle between the neighborhoods of emission and detection, and is closed by the source annihilation of the particle.

Relativistic requirements largely constrain the structure of

the propagation function - Green's function ...".

Wyler/Hua Complex Domain Structure of Schwinger Sources:

Bergman Kernels and Green's functions

Armand Wyler, in "The Complex Light Cone, Symmetric Space of the Conformal Group" (IAS Princeton, June 1972), said:

"... define the Bergman metric, the invariant differential operators and their elementary solutions (Green functions) in the bounded realization D_n of $SO(n,2) / (SO(n) \times SO(2))$ with Silov boundary Q_n ...

the value of the structure constant alpha is obtained as coefficient of the Green function of the Dirac equation in D_5 ...".

E8 Physics:

David Finkelstein's Cl(16) Fundamental Quantum Structure
of Nested Real Clifford Algebras:

Start with Empty Set = \emptyset

Real Dimension of each Clifford Algebra of Precursor Space:

$0 = \text{Cl}(\emptyset) = \{-1,+1\} = \text{Yin and Yang emerge from Tai Chi}$

\

$1 = \text{Cl}(\text{Cl}(\emptyset)) = \text{Real}$

\

$1 + 1 = \text{Cl}(1) = \text{Cl}(\text{Cl}(\text{Cl}(\emptyset))) = \text{Complex}$

\

$1 + 2 + 1 = \text{Cl}(2) = \text{Cl}(\text{Cl}(1)) = \text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\emptyset)))) = \text{Quaternion}$

\

$1 + 4 + 6 + 4 + 1 = \text{Cl}(4) = \text{Cl}(\text{Cl}(2)) = \text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\emptyset))))))$

\

$1 + 16 + 120 + \dots = \text{Cl}(16) = \text{Cl}(\text{Cl}(4)) = \text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\emptyset))))))$

\

$1 + 65,536 + \dots = \text{Cl}(65,536) = \text{Cl}(\text{Cl}(16)) = \text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\text{Cl}(\emptyset))))))$

(by Real Clifford Algebra 8-Periodicity) = $\text{Cl}(16) \times \dots (16 \text{ times}) \dots \times \text{Cl}(16)$

John von Neumann said (“Why John von Neumann did not Like the Hilbert Space Formalism of Quantum Mechanics (and What he Liked Instead)” by Miklos Redei in Studies in the History and Philosophy of Modern Physics 27 (1996) 493-510):

“... if we wish to generalize the lattice of all linear closed subspaces from a Euclidean space to infinitely many dimensions, then one does not obtain Hilbert space ... our “case I_infinity” ... but that configuration, which Murray and I called “case III” ...”.

Completion of the Union of All Finite Tensor Products of Cl(16) with itself gives a generalized Hyperfinite III von Neumann Factor that in turn gives a realistic Algebraic Quantum Field Theory (AQFT).

Since Cl(16) is the Fundamental Building Block of a realistic AQFT with the structure of a generalized Hyperfinite III von Neumann Factor, in order to understand how realistic AQFT works in detail, we must understand the Geometric Structure of Cl(16).

Spinor Growth Sequence

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0 = Integers

1 = Real Numbers (basis = {1})

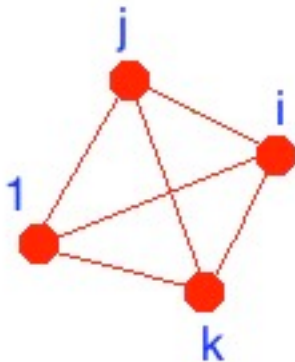


2 = Complex Numbers \mathbb{C} (basis = {1, i}) = $Cl(1)$ = half-spinors of $Cl(4)$ Minkowski



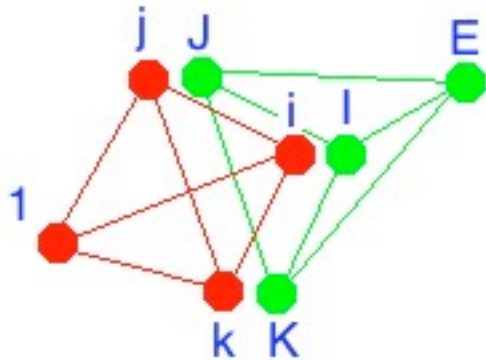
These half-spinors are the basis of the conventional Fermionic Fock Space
Hyperfinitesimal II₁ von Neumann Factor Algebraic Quantum Field Theory (AQFT)

4 = Quaternions \mathbb{Q} (basis = {1, i, j, k}) = $Cl(2)$ = half-spinors of $Cl(6)$ Conformal



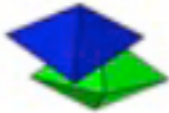
WHICH CORRESPOND TO TETRAHEDRA

8 = Octonions O (basis = {1,i,j,k,l,J,K,E}) = half-spinors of Cl(8)

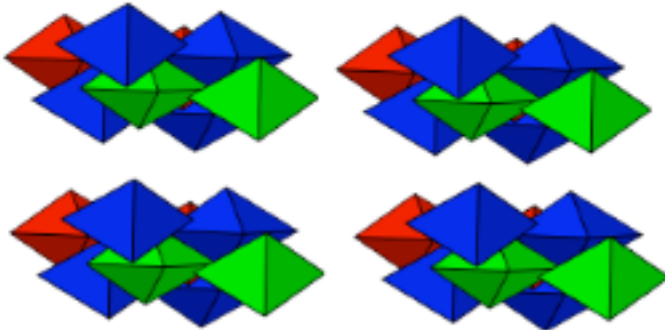


WHICH CORRESPOND TO
Chen-Engel-Glotzer (arXiv 1001.0586) DIMER PAIRS OF TETRAHEDRA

$2^{(8/2)} = 2^4 = 16 =$ full spinors of Cl(8) = vectors of Cl(16)



$2^{(16/2)} = 2^8 = 256 = 4 \times 64 =$ full spinors of Cl(16)



These are the basis of the unconventional generalization of
the Hyperfinite II1 von Neumann Factor
that I use for Algebraic Quantum Field Theory (AQFT)

$2^{(256/2)} = 2^{128} = 3.4 \times 10^{38} =$ full spinors of Cl(256)
Such a large number as 2^{128} is useful in describing
the inflationary expansion of our universe
and the production of the large number of particles that it contains.

Spinor Growth Physics

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Clifford: n grows to 2^n

0

$$2^0 = 1 = \text{Cl}(0)$$

$$2^1 = 2 = \text{Cl}(1)$$

$$2^2 = 4 = \text{Cl}(2)$$

$$2^4 = 16 = \text{Cl}(4)$$

$$2^{16} = 65,536 = \text{Cl}(16) = \text{Cl}(8) \times \text{Cl}(8)$$

$$65,536 + 1 = 65,537 = 2^{2^4} + 1 \text{ is the largest known Fermat Prime}$$

=====

Spinor: n grows to $2^{(n/2)}$ (The Spinor Growth Pattern is due to David Finklestein.)

0 = Integers

$$2^{(0/2)} = 2^0 = 1 = \text{Real Numbers}$$

$$2^{(1/2)} = \sqrt{2}$$

$$2^{(\sqrt{2}/2)} = 2^{0.707} = 1.63$$

$$2^{(1.63/2)} = 1.76$$

$$2^{(1.76/2)} = 1.84$$

... approaches 2 ...

2 = Complex Numbers $C = \text{Cl}(1) = \text{half-spinors of Cl}(4)$ Minkowski

$$2^{(2/2)} = 2 \text{ fixed}$$

4 = Quaternions $Q = \text{Cl}(2) = \text{half-spinors of Cl}(6)$ Conformal

$$2^{(4/2)} = 2^2 = 4 \text{ fixed}$$

Complex and Quaternion Quantum Processes are Unitary
and do not grow

6 = Conformal Physical Space

$$2^{(6/2)} = 2^3 = 8 \text{ Octonions } O$$

$$2^{(8/2)} = 2^4 = 16 = \text{full spinors of Cl}(8)$$

$\text{Cl}(8)$ triality: 8vector = 8+half-spinor = 8-half-spinor

$$F_4 = 28 + 8+8+8$$

$$2^{(16/2)} = 2^8 = 256 = \text{full spinors of Cl}(16)$$

$\text{Cl}(16)$ triality: 64vector = 64++half-half-spinor = 64--half-half-spinor

$$E_8 = (28+28) + 64+64+64$$

$$2^{(256/2)} = 2^{128} = 3.4 \times 10^{38} = \text{full spinors of Cl}(256)$$

$$2^{127} = 1.7 \times 10^{38} = \text{half-spinor of Cl}(256) = (M_{\text{planck}} / M_{\text{proton}})^2$$

$2^{127} - 1$ is a Mersenne Prime

Octonion Quantum Processes are NonUnitary
and can grow during Big Bang Inflation
until the Zizzi Inflation Decoherence Limit of $\sqrt{2^{128}} = 2^{64}$ qubits is reached.

Each qubit at the Decoherence End of Inflation corresponds to a Planck Mass Black Hole which transforms into $2^{64} = 10^{19}$ first-generation fermion particle-antiparticle pairs. The resulting $2^{64} \times 2^{64} = 2^{128} = 10^{19} \times 10^{19} = 10^{38}$ fermion pairs constitutes a Zizzi Quantum Register of order $n_{reh} = 10^{38} = 2^{128}$. Since, as Paola Zizzi says in gr-qc/0007006 :
 "... the quantum register grows with time ... At time $T_n = (n+1) T_{planck}$ the quantum gravity register will consist of $(n+1)^2$ qubits ...", we have the number of qubits at Reheating:
 $N_{reh} = (n_{reh})^2 = (2^{128})^2 = 2^{256} = 10^{77}$
 Since each qubit at Reheating should correspond to fermion particle-antiparticle pairs we have the result that the number of particles in our Universe at Reheating is about 10^{77} nucleons.

=====

64-dim Spinor Structure CxQxO

(The 64-dim spinor structure CxQxO is due to Geoffrey Dixon.)

Cl(16) Triality $64 = 2 \times 4 \times 8 = (CxQ) \times O$

CxQ represents:

1xQ = 4-dim Minkowski M4 Physical Spacetime

ixQ = 4-dim CP2 Internal Symmetry Space

O represents:

8vector = 8 gammas of 8-dim Octonionic Spacetime

8+half-spinor = 8 fermion particles (e, ur, ug, ub ; db, dg, db, nu)

8-half-spinor = 8 fermion antiparticles

CxQxO represents:

64vector = 8 components of each of 8 gammas

64++half-half-spinor = 8 components of each of 8 fermion particles

64--half-half-spinor = 8 components of each of 8 fermion antiparticles

Full spinors of Cl(256)

$2^{128} = 2^{64} \times 2^{64} =$

= all possible states/subsets of 8 components of 8 fermion particles and 8 fermion antiparticles

=====

The Fermat primes, of the form $2^{2^k} + 1$, include:

$2 + 1 = 2^1 + 1 = 2^{2^0} + 1 = 2 + 1 = 3$

$2^2 + 1 = 2^2 + 1 = 2^{2^1} + 1 = 4 + 1 = 5$

$2^{2^2} + 1 = 2^4 + 1 = 2^{2^2} + 1 = 16 + 1 = 17$

$2^{2^2^2} + 1 = 2^{16} + 1 = 2^{2^4} + 1 = 65,536 + 1 = 65,537$

$2^{2^3} + 1 = 2^8 + 1 = 257$ is the only other known Fermat prime.

The Mersenne Primes, of the form $2^k - 1$ for prime k, include:

$2^2 - 1 = 4 - 1 = 3$

$2^3 - 1 = 8 - 1 = 7$

$2^7 - 1 = 128 - 1 = 127$

$2^{127} - 1 =$ approximately 1.7×10^{38}

$2^{(2^{127} - 1)} - 1$ may or may not be prime. Its primality is not now known.

Some other Mersenne Primes are $2^k - 1$

for k = 5, 13, 17, 19, 31, 61, 89, 107, 521, 607, and 1279.

Cl(16) has $2^{16} = 65,536$ elements with graded structure

1
16
120
560
1820
4368
8008
11440
12870
11440
8008
4368
1820
560
120
16
1

The 16-dim grade-1 Vectors of Cl(16) are D8 = Spin(16) Vectors that are acted upon by the 120-dim grade-2 Bivectors of Cl(16) which form the D8 = Spin(16) Lie algebra.

Cl(16) has, in addition to its 16-dim D8 Vector and 120-dim D8 Bivector bosonic commutator structure, a fermionic anticommutator structure related to its $\sqrt{65,536} = 256$ -dim spinors which reduce to 128-dim D8 +half-spinors plus 128-dim D8 -half-spinors.

Pierre Ramond in hep-th/0112261 said:

"... the coset $F4 / SO(9)$... is the sixteen-dimensional Cayley projective plane ... [represented by]... the $SO(9)$ spinor operators [which] satisfy Bose-like commutation relations ... Curiously, if ...[the scalar and spinor 16 of $F4$ are both]... anticommuting, the $F4$ algebra is still satisfied ...".

The same reasoning applies to other exceptional groups that have octonionic structure and spinor component parts, including:

$$E6 = D5 + U(1) + 32\text{-dim full spinor of } D5$$

and

$$\mathbf{248\text{-dim } E8 = 120\text{-dim } D8 + 128\text{-dim half-spinor of } D8.}$$

To study the E8 substructure of Cl(16), note that the 120-dimensional bosonic Cl(16) bivector part of E8 decomposes, with respect to factoring Cl(16) into the tensor product Cl(8) x Cl(8) allowed by 8-periodicity, into $1 \times 28 + 8 \times 8 + 28 \times 1$

				1
				16
				120
				560
				1820
				4368
				8008
				11440
				12870
1	1			1
8	8			16
28	28			120
56	56			560
70	70	x	=	1820
56	56			560
28	28			120
8	8			16
1	1			1
Cl(8)	x Cl(8)	=		Cl(16)

Spinors:

$$\begin{aligned}
 (8s+8c) \times (8s+8c) &= (8s \times 8s + 8c \times 8c) \\
 &+ (8s \times 8c + 8c \times 8s)
 \end{aligned}$$

The 256-dim spinor of $Cl(16)$ decomposes as the direct sum of the two 128-dim half-spinor representations, i.e., as one generation and one anti-generation.

248-dim E_8 contains the 128-dim D_8 $Cl(16)$ half-spinor representation of one generation of Fermion Particles and AntiParticles, but does not contain any of the anti-generation D_8 $Cl(16)$ half-spinor.

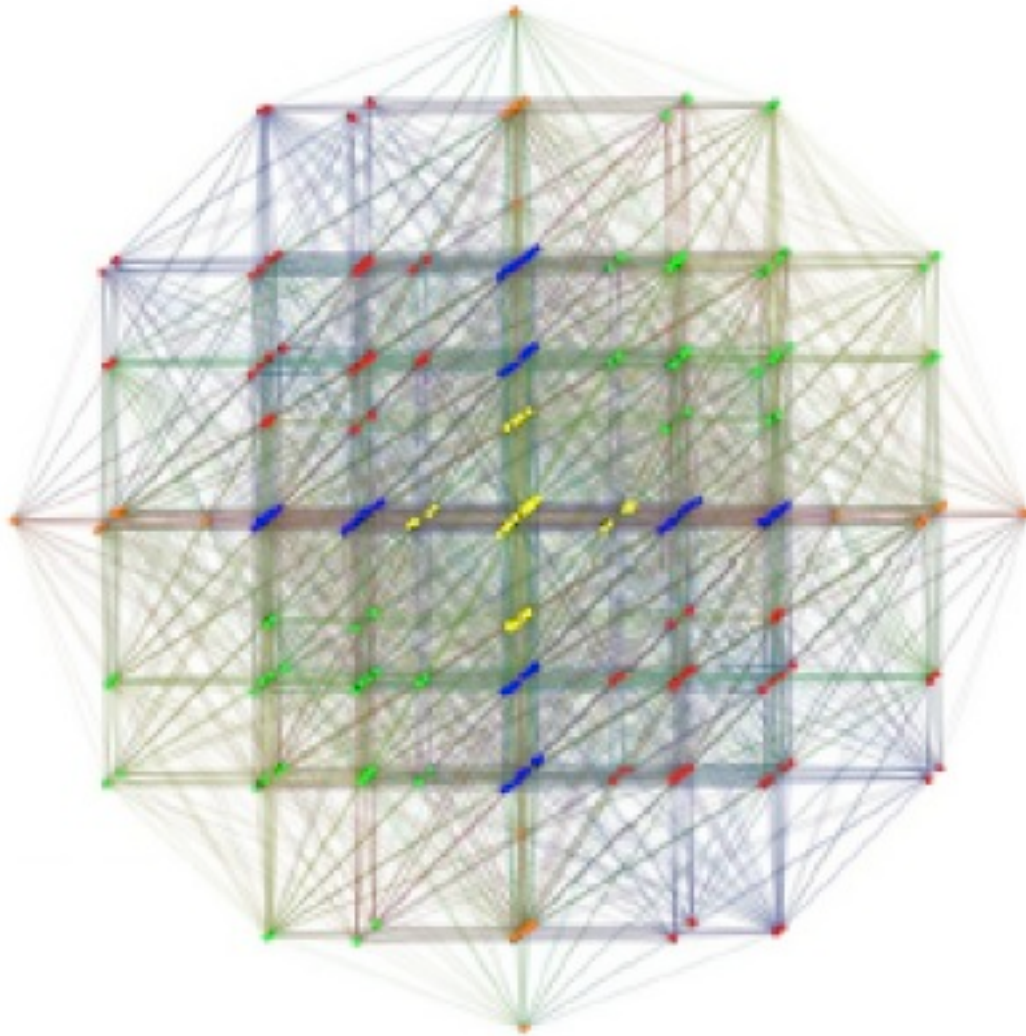
Note that if you tried to build a larger Lie Algebra than E_8 within $Cl(16)$ by using the anti-generation D_8 $Cl(16)$ half-spinor, you would fail because the construction would be mathematically inconsistent, so E_8 is the Maximal Lie Algebra within $Cl(16)$.

Decompose, with respect to factoring $Cl(16)$ into $Cl(8) \times Cl(8)$, the 128-dim fermion one-generation representation into two 64-dim fermion representations in terms of their 8 covariant components with respect to 8-dim spacetime as:

one $64 = 8 \times 8$ representing 8 fundamental left-handed fermion particles in terms of their 8 covariant components with respect to 8-dim spacetime and the other $64 = 8 \times 8$ representing 8 fundamental right-handed fermion antiparticles.

To visualize the E_8 structure, look at the 240 Root Vectors of E_8 :

The 240 root vectors of the 248-dimensional Lie Algebra E8



The 240 Root Vectors are color-keyed as:

24 Yellow

24 Orange

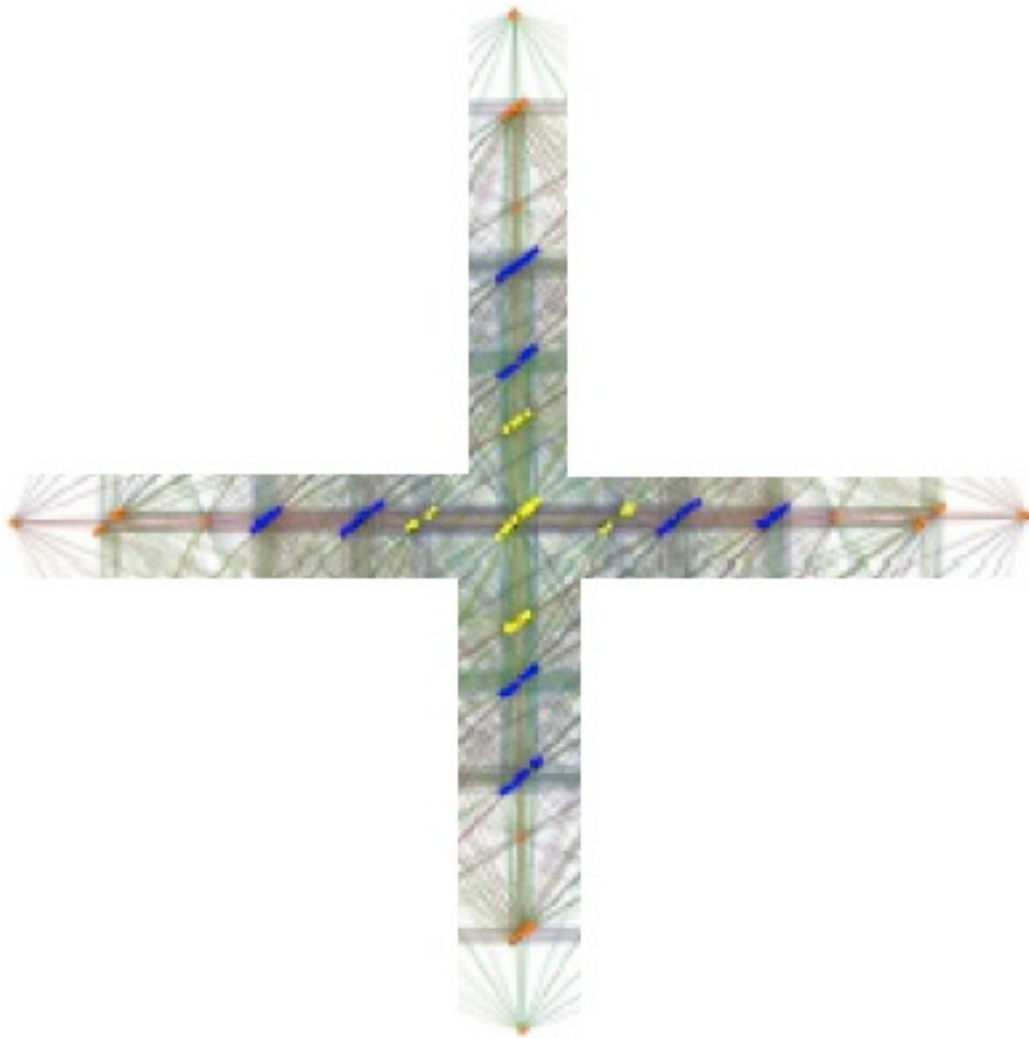
64 Blue

64 Red

64 Green

They are made up of

112 Root Vectors that represent the 112 Root Vectors of the 120-dimensional Lie Algebra D8



These 112 Root Vectors are color-keyed as:

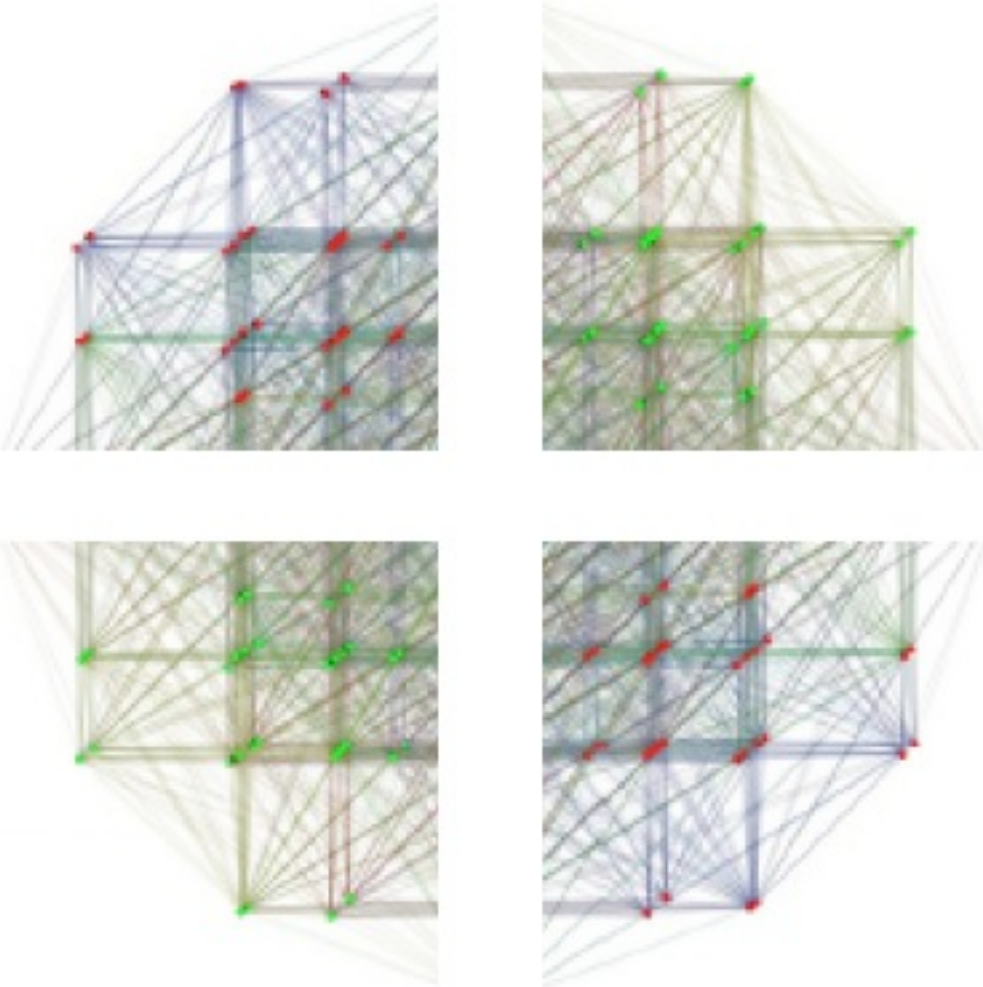
24 Yellow

24 Orange

64 Blue

plus

128 Root Vectors that correspond to one of the 128-dimensional half-spinor representations of the Lie Algebra D8



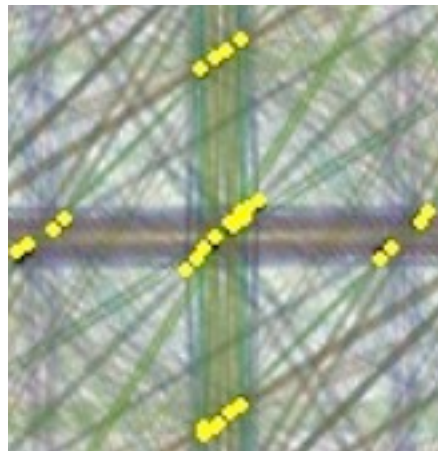
These 128 Root Vectors are color-keyed as:

64 Red

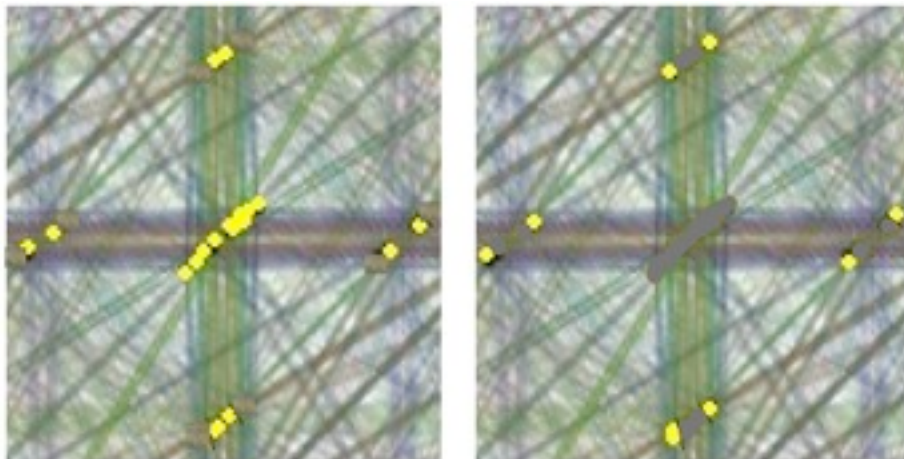
64 Green

**Physical interpretations of the 240 E8 Root Vectors
are given on the following pages:**

The 24 Yellow Root Vectors correspond to the Standard Model Gauge Bosons which act on CP2 Internal Symmetry Space of M4xCP2 Kaluza-Klein Spacetime.

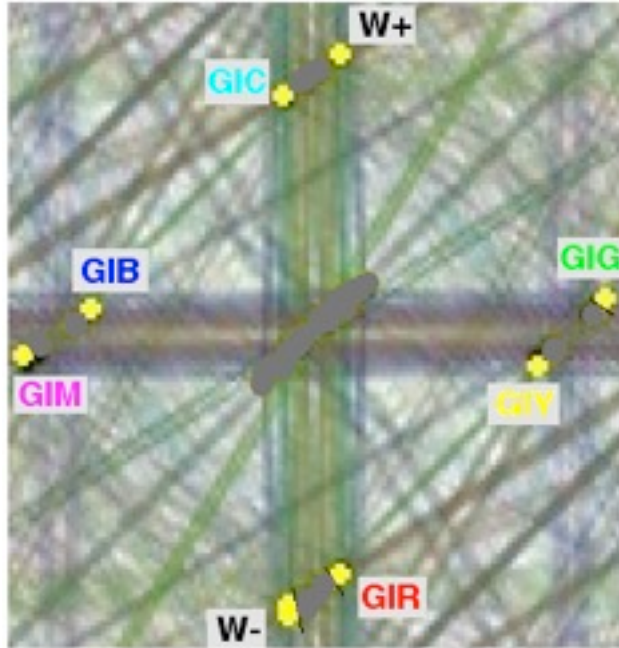


The 16 inner Root Vectors act to coordinate the Standard Model Gauge Bosons with the M4 Minkowski Space of M4xCP2 Kaluza-Klein Spacetime



while the 8 outer Root Vectors form a cube that represents

the W+ and W- Weak Bosons
and
the 6 Gluons that carry Color Charge:



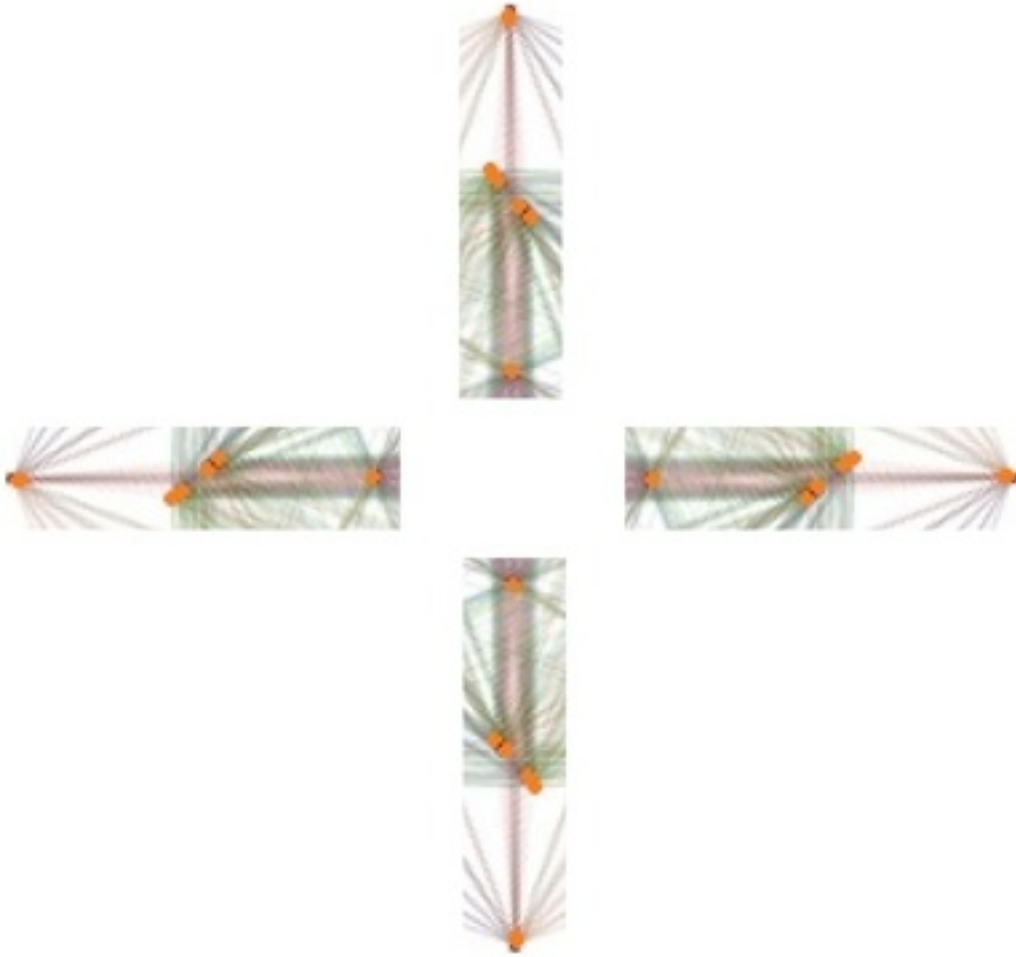
When combined with 4 of the 8 Cartan Subalgebra elements of E_8 (that is, 4 of the 8 elements that are not represented by the 240 Root Vectors) these 8 Root Vectors form the Standard Model Gauge Groups of:

8-dimensional $SU(3)$ Color Force

3-dimensional $SU(2)$ Weak Force

1-dimensional $U(1)$ Electromagnetic Force.

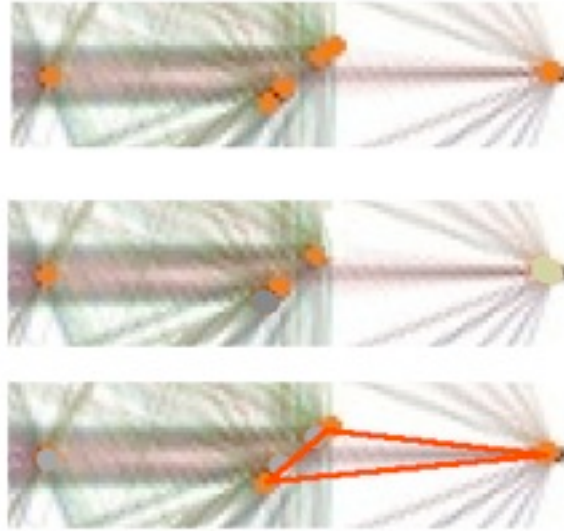
The 24 Orange Root Vectors correspond to the $U(2,2)$ Conformal Group that by a MacDowell-Mansouri mechanism produces Gravity which acts on the M_4 Minkowski space of $M_4 \times CP^2$ Kaluza-Klein Spacetime.



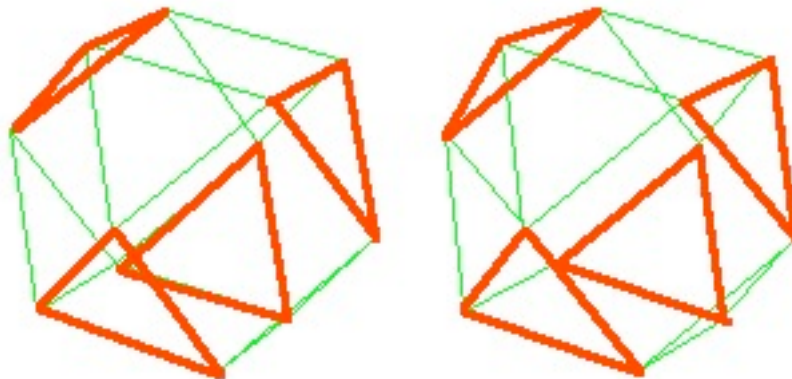
The 24 Orange Root Vectors are composed of 4 sets of 6 as shown above.

Each set of 6 breaks down

into 3 inner Root Vectors plus 3 outer Root Vectors



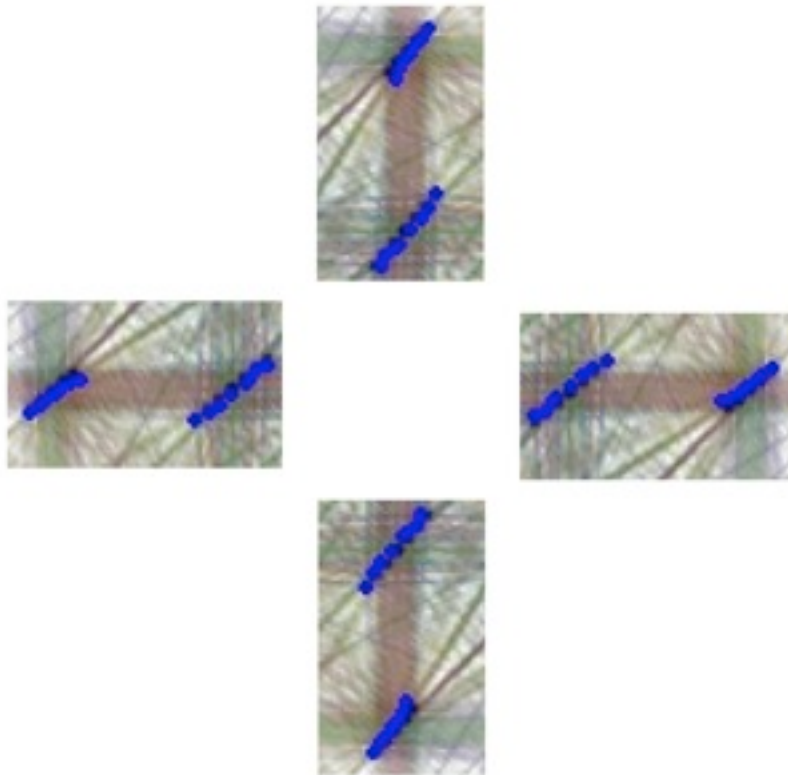
The 3 outer Root Vectors form a triangle,
and
the 12 vertices of the 4 triangles of the outer Root Vectors correspond to
a cuboctahedron



that is the Root Vector Polytope for the $U(2,2)$ Lie Algebra.

The 12 inner Root Vectors act to coordinate the Conformal Group with
the CP^2 Internal Symmetry Space of $M_4 \times CP^2$ Kaluza-Klein Spacetime
while the 12 outer Root Vectors combine with 4 of the 8 Cartan Subalgebra
elements of E_8 (that is, 4 of the 8 elements that are not represented by the 240
Root Vectors) to form the 16-dimensional $U(2,2)$ Conformal Group.

The $8 \times 8 = 64$ Blue Root Vectors correspond to the 8 position dimensions of Kaluza-Klein Spacetime and the corresponding 8 dual momentum dimensions.



63 of the $8 \times 8 = 64$ Blue Root Vectors correspond to the 63 dimensions of the $SL(8)$ Lie Algebra that is the subalgebra of E_8 to which E_8 contracts in its maximal contraction

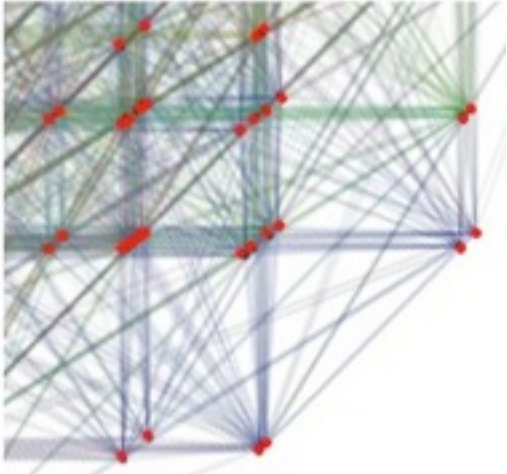
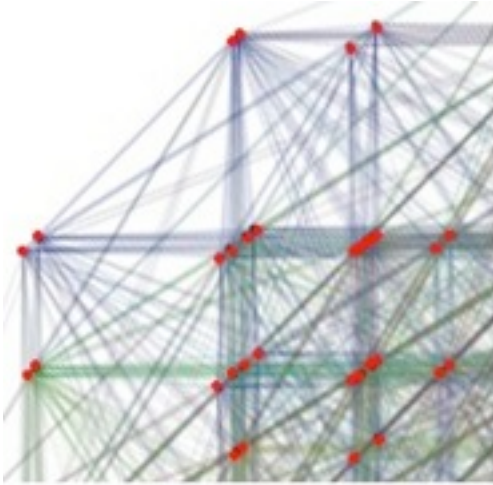
$$E_8 \rightarrow SL(8) + \mathfrak{h}_{92}$$

where \mathfrak{h}_{92} is a 185-dimensional Heisenberg Lie Algebra for 92 sets of creation-annihilation operators:

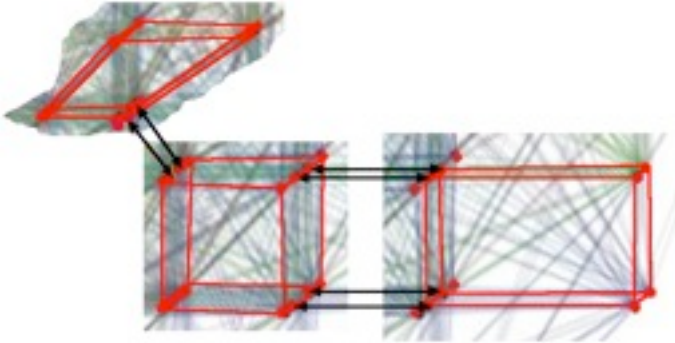
- 64 Fermion Particle Creators + 64 Fermion AntiParticle Creators
- 28 Gravity Boson Creators + 28 Standard Model Boson Creators.

The 64th Blue Root Vector corresponds to the 1 central element of \mathfrak{h}_{92} .

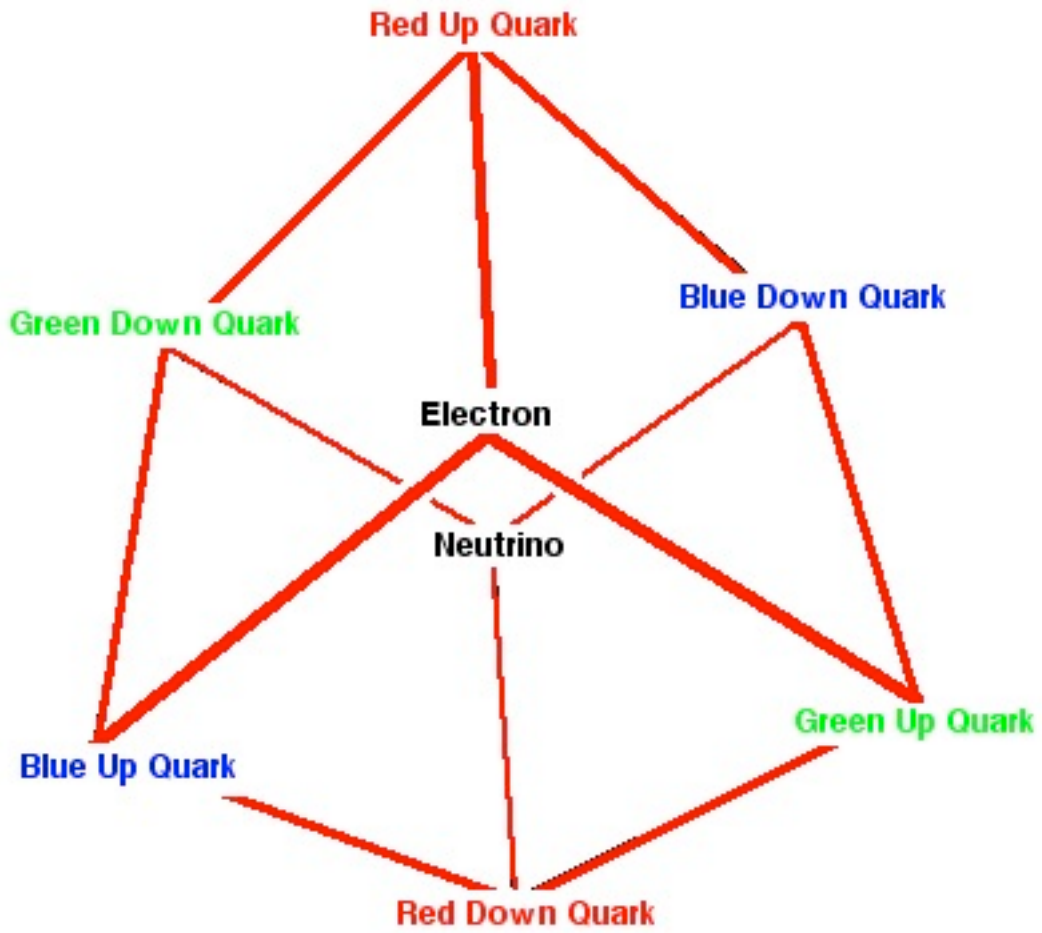
The $8 \times 8 = 64$ Red Root Vectors correspond to the 8 covariant components of the 8 fundamental (First-Generation) Fermion Particles



Each subset of 32 is geometrically equivalent to 4 cubes. Here is a diagram of how some of the cubes fit together:

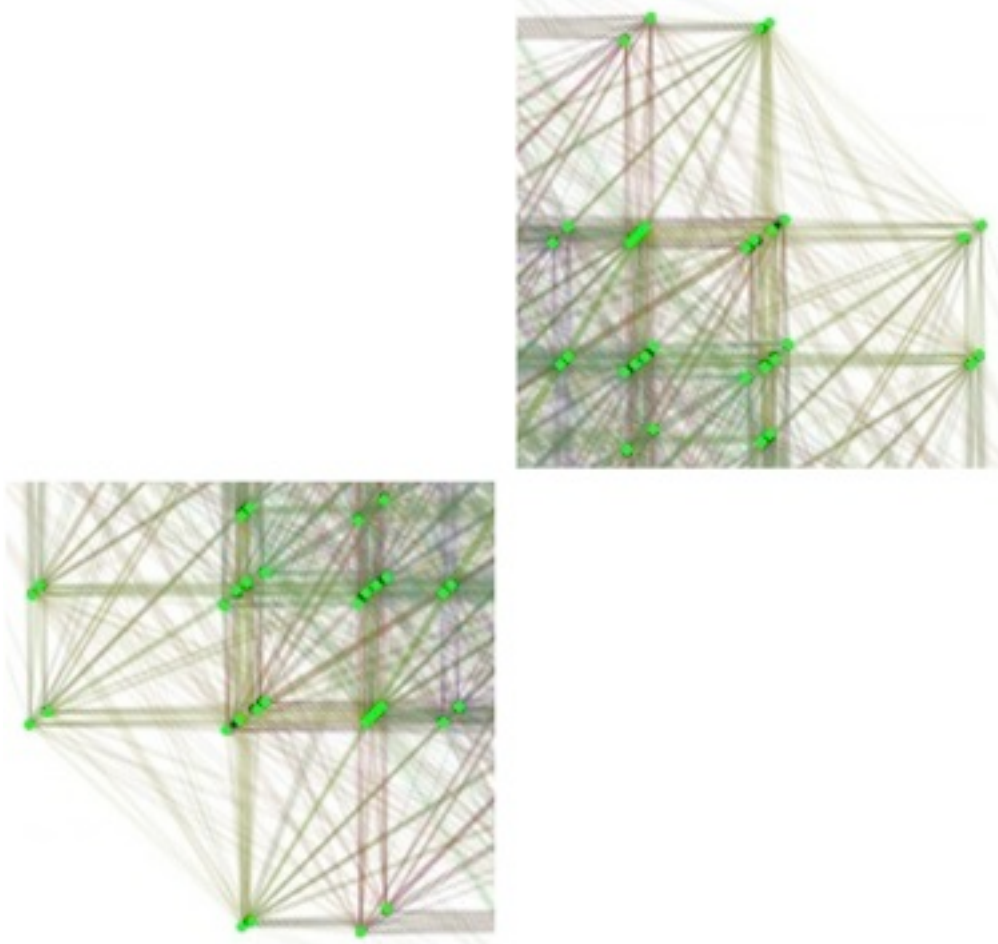


Each cube represents a set of 8 fundamental Fermion Particles:



There are $4+4 = 8$ cubes, so each cube corresponds to one of the 8 covariant components of its set of 8 fundamental Fermion Particles.

The $8 \times 8 = 64$ Green Root Vectors correspond to the 8 covariant components of the 8 fundamental (First-Generation) Fermion AntiParticles



The geometry of the representation of Fermion AntiParticles by the $32+32 = 64$ Root Vectors corresponds to that of Fermion Particles described on the preceding two pages.

You can also visualize the E8 Root Vector structure by writing the Root Vectors in terms of 8-dimensional coordinates of one of the 7 independent E8 lattices. If you use the same color code as above (except that here I use Orange for 48 Root Vectors that are shown above as 24 Yellow and 24 Orange), you can get:

112 = 64 + 48 Root Vectors corresponding to D8:

$$\begin{aligned}
 & \pm 1, \quad \pm i, \quad \pm j, \quad \pm k, \quad \pm e, \quad \pm ie, \quad \pm je, \quad \pm ke, \\
 & (\pm 1 \quad \pm i \quad \quad \quad \quad \quad \pm e \quad \pm ie \quad \quad \quad \quad \quad) / 2 \\
 & (\pm 1 \quad \quad \quad \pm j \quad \quad \quad \pm e \quad \quad \quad \pm je \quad \quad \quad \quad) / 2 \\
 & (\pm 1 \quad \quad \quad \quad \pm k \quad \pm e \quad \quad \quad \quad \pm ke \quad \quad) / 2 \\
 \\
 & (\quad \quad \quad \pm j \quad \pm k \quad \quad \quad \pm je \quad \pm ke \quad \quad) / 2 \\
 & (\quad \quad \pm i \quad \quad \pm k \quad \quad \quad \pm ie \quad \quad \quad \pm ke \quad \quad) / 2 \\
 & (\quad \pm i \quad \pm j \quad \quad \quad \pm ie \quad \pm je \quad \quad \quad \quad) / 2
 \end{aligned}$$

128 = 64 + 64 Root Vectors corresponding to half-spinor of D8:

$$\begin{aligned}
 & (\pm 1 \quad \quad \quad \quad \quad \pm ie \quad \pm je \quad \pm ke \quad \quad) / 2 \\
 & (\pm 1 \quad \quad \quad \pm j \quad \pm k \quad \quad \pm ie \quad \quad \quad \quad) / 2 \\
 & (\pm 1 \quad \pm i \quad \quad \pm k \quad \quad \quad \pm je \quad \quad \quad \quad) / 2 \\
 & (\pm 1 \quad \pm i \quad \pm j \quad \quad \quad \quad \quad \pm ke \quad \quad) / 2 \\
 \\
 & (\quad \pm i \quad \pm j \quad \pm k \quad \pm e \quad \quad \quad \quad \quad) / 2 \\
 & (\quad \pm i \quad \quad \quad \quad \pm e \quad \quad \quad \pm je \quad \pm ke \quad \quad) / 2 \\
 & (\quad \quad \quad \pm j \quad \quad \pm e \quad \pm ie \quad \quad \pm ke \quad \quad) / 2 \\
 & (\quad \quad \quad \pm k \quad \pm e \quad \pm ie \quad \pm je \quad \quad \quad \quad) / 2
 \end{aligned}$$

Use the physical interpretations of the 240 E8 Root Vectors
to construct a **Lagrangian** by
integration over 8-dim Spacetime Base Manifold (64 Root Vectors) of
the Gravity and the Standard Model from the two D4 (48 Root Vectors) and
a Dirac Fermion Particle-AntiParticle term (64+64 Root Vectors).

This Lagrangian differs from conventional Gravity plus Standard Model
in four respects:

- 1 - 8-dimensional spacetime with NonUnitary Octonionic Inflation
- 2 - no Higgs
- 3 - two D4 producing gauge groups
- 4 - 1 generation of fermions

These differences can be reconciled by freezing out at lower-than-Planck energies
a preferred Quaternionic 4-dim subspace of the original (high-energy) 8-dim
spacetime, thus forming an **8-dim Kaluza-Klein spacetime M4xCP2** where

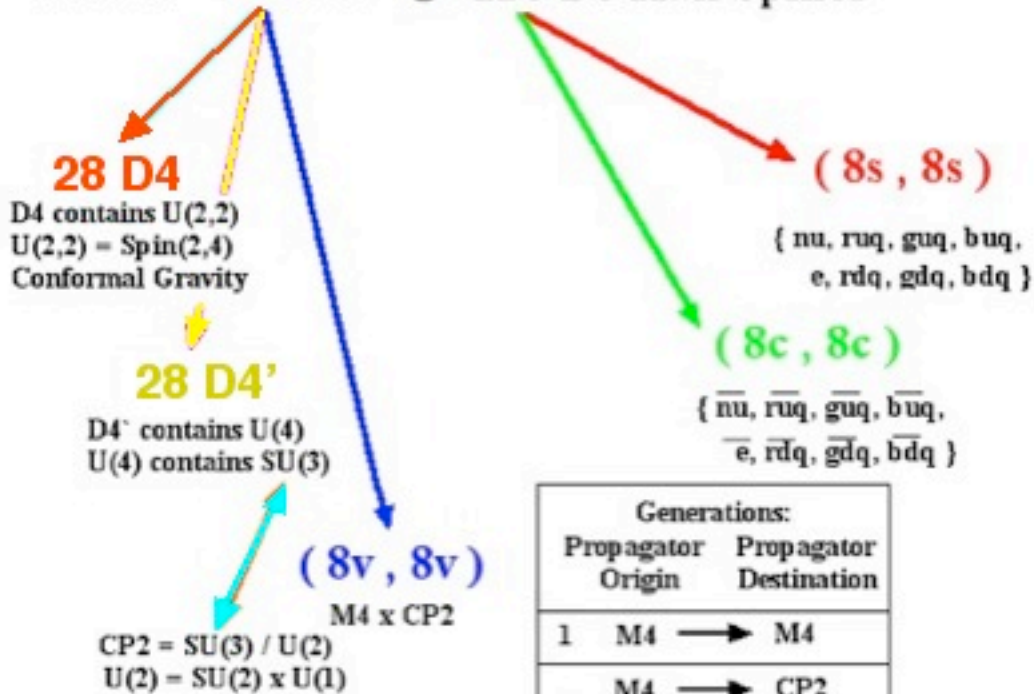
M4 is 4-dim Minkowski Physical Spacetime and
CP2 is a 4-dim Internal Symmetry Space.

This Octonionic to Quaternionic symmetry breaking
makes the Lagrangian consistent with experimental observations:

- 1 and 2 - The Octonionic to Quaternionic symmetry breaking
from 8-dim Spacetime with NonUnitary Octonionic Inflation of our
Universe to Unitary Quaternionic Post-Inflation M4 Minkowski Physical
Spacetime produces the Higgs by a Mayer-Trautman mechanism.
- 3 - The CP2 = SU(3)/U(2) structure of Internal Symmetry Space allows
one D4 to act with respect to M4 as the Conformal Group to produce
Gravity by a MacDowell-Mansouri mechanism and the other D4 to act
as the Standard Model with respect to CP2 by a Batakis mechanism.
- 4 - The 4+4 dimensional structure of M4xCP2 Kaluza-Klein produces
the Second and Third Generations of Fermions and
accurate calculation of the Truth Quark mass for the Middle State of
a 3-State Higgs-Tquark system with Higgs as Tquark Condensate
by a model of Yamawaki et al.

The resulting structure looks like:

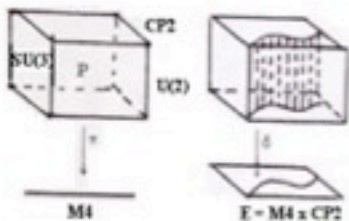
$$248 E_8 = 120 D_8 \oplus 128 D_8 \text{ Half Spinor}$$



Generations:		
	Propagator Origin	Propagator Destination
1	M4	M4
2	M4	CP2
	CP2	M4
3	CP2	CP2

Lagrangian: $\int_{\text{KKspacetime}} \text{gauge term} + \text{fermion term}$

Higgs-Mayer:



Kobayashi-Nomizu:

THEOREM 11.7. Assume in Theorem 11.5 that \mathfrak{t} admits a subspace \mathfrak{m} such that $\mathfrak{t} = \mathfrak{j} + \mathfrak{m}$ (direct sum) and $\text{ad}(J)(\mathfrak{m}) = \mathfrak{m}$, where $\text{ad}(J)$ is the adjoint representation of J in \mathfrak{t} . Then

(1) There is a 1:1 correspondence between the set of K -invariant connections in P and the set of linear mappings $\Lambda_m: \mathfrak{m} \rightarrow \mathfrak{g}$ such that

$$\Lambda_m(\text{ad}(j)(X)) = \text{ad}(j)(\Lambda_m(X)) \quad \text{for } X \in \mathfrak{m} \text{ and } j \in J;$$

the correspondence is given via Theorem 11.5 by

$$\Lambda(X) = \begin{cases} \lambda(X) & \text{if } X \in \mathfrak{j}, \\ \Lambda_m(X) & \text{if } X \in \mathfrak{m}. \end{cases}$$

(2) The curvature form Ω of the K -invariant connection defined by Λ_m satisfies the following condition:

$$2\Omega_m(X, Y) = [\Lambda_m(X), \Lambda_m(Y)] - \Lambda_m([X, Y]_{\mathfrak{m}}) - \lambda([X, Y]_{\mathfrak{j}}) \quad \text{for } X, Y \in \mathfrak{m},$$

The Higgs and the T-quark form a system in which the Higgs is effectively a T-quark condensate.

Here are details on how it all works:

AQFT:

Since the E8 classical Lagrangian is Local, it is necessary to patch together Local Lagrangian Regions to form a Global Structure describing a Global E8 Algebraic Quantum Field Theory (AQFT).

Mathematically, this is done by using Clifford Algebras to embed E8 into Cl(16) and using a copy of Cl(16) to represent each Local Lagrangian Region. A Global Structure is then formed by taking the tensor products of the copies of Cl(16). Due to Real Clifford Algebra 8-periodicity, $Cl(16) = Cl(8) \times Cl(8)$ and any Real Clifford Algebra, no matter how large, can be embedded in a tensor product of factors of Cl(8), and therefore of $Cl(8) \times Cl(8) = Cl(16)$. Just as the completion of the union of all tensor products of 2x2 complex Clifford algebra matrices produces the usual Hyperfinite III von Neumann factor that describes creation and annihilation operators on the fermionic Fock space over $C^{(2n)}$ (see John Baez's Week 175), we can take the completion of the union of all tensor products of $Cl(16) = Cl(8) \times Cl(8)$ to produce a generalized Hyperfinite III von Neumann factor that gives a natural Algebraic Quantum Field Theory structure to the E8 model.

In each tensor product $Cl(16) \times \dots \times Cl(16)$ each of the Cl(16) factors represents a distinct Local Lagrangian Region. Since each Region is distinguishable from any other, each factor of the tensor product is distinguishable so that the AQFT has Maxwell-Boltzmann Statistics.

Within each Local Lagrangian Region Cl(16) lives its own E8. Each 248-dim E8 has indistinguishable boson and fermion particles. The 120-dim bosonic part has commutators and Bose Statistics and the 128-dim fermionic part has anticommutators and Fermi Statistics.

EPR:

For the E8 model AQFT to be realistic, it must be consistent with EPR entanglement relations. Joy Christian in arXiv 0904.4259 “Disproofs of Bell, GHZ, and Hardy Type Theorems and the Illusion of Entanglement” said: “... a [geometrically] correct local-realistic framework ... provides exact, deterministic, and local underpinnings for at least the Bell, GHZ-3, GHZ-4, and Hardy states. ... The alleged non-localities of these states ... result from misidentified [geometries] of the EPR elements of reality. ... The correlations are ... the classical correlations among the points of a 3 or 7-sphere ... S^3 and S^7 ... are ... parallelizable ... The correlations ... can be seen most transparently in the elegant language of Clifford algebra ...”.

To go beyond the interesting but not completely physically realistic Bell, GHZ-3, GHZ-4, and Hardy states, we must consider more complicated spaces than S^3 and S^7 , but still require that they be parallelizable and be related to Clifford algebra structure.

As Martin Cederwall said in hep-th/9310115: “... The only simply connected compact parallelizable manifolds are the Lie groups [including $S^3 = SU(2)$] and S^7 ...”.

We know that $S^3 = SU(2) = Spin(4) / SU(2)$ so that it has global symmetry of $Spin(4)$ transformations and that 6-dimensional $Spin(4)$ is the grade-2 part of the 16-dimensional $Cl(4)$ Clifford algebra with graded structure $16 = 1 + 4 + 6 + 4 + 1$ (where grades are 0,1,2, ...).

We also know that $S^7 = Spin(8) / Spin(7)$ so that it has global symmetry of $Spin(8)$ transformations and that 28-dimensional $Spin(8)$ is the grade-2 part of the 256-dimensional $Cl(8)$ Clifford algebra with graded structure $256 = 1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$.

To get a Clifford algebra related parallelizable Lie group large enough to represent a realistic physics model, take the tensor product $Cl(8) \times Cl(8)$ which by the 8-periodicity property of Real Clifford algebras is $256 \times 256 = 65,536$ -dimensional $Cl(16)$ with graded structure $(1 \times 1) + (1 \times 8 + 8 \times 1) + (1 \times 28 + 28 \times 1 + 8 \times 8) + \dots = 1 + 16 + 120 + \dots$ whose $28 + 28 + 64 = 120$ -dimensional grade-2 part is $Spin(16)$ and whose spinor representation has $256 = 128 + 128$ dimensions.

$Spin(16)$ has $Cl(16)$ Clifford algebra structure and is a Lie group, and therefore parallelizable, but it has grade-2 bivector bosonic structure and so can only represent physical things like gauge bosons and vector spacetime, and cannot represent physical things like fermions with spinor structure.

However, if we add one of the two 128-dimensional $Cl(16)$ half-spinor representations to the bosonic adjoint 120-dimensional representation of $Spin(16)$, we get the $120 + 128 = 248$ -dimensional exceptional Lie group E_8 .

248-dimensional E_8 has a 7-grading (due to Thomas Larsson)
 $8 + 28 + 56 + 64 + 56 + 28 + 8$
 (where grades are $-3, -2, -1, 0, 1, 2, 3$)

If 8 of the 64 central grade-0 elements are assigned to an 8-dimensional Cartan subalgebra of E_8 , the remaining $248 - 8 = 240$ elements are the 240 Root Vectors of E_8 which have a graded structure

$$8 \quad 28 \quad 56 \quad 56 \quad 56 \quad 28 \quad 8$$

that is consistent with the physical interpretations of my E_8 model described earlier in this paper.

Since E_8 is a Lie Group and therefore parallelizable and lives in Clifford Algebra $Cl(16)$ my E_8 Physics model should be consistent with EPR.

Chirality:

Since $E_8 = \text{adjoint } D_8 + \text{half-spinor } D_8$ and D_8 lives in $Cl(16)$
look at these D_8 representations

120-dim adjoint - denoted by $D_8\text{adj}$

128-dim +half-spinor - denoted by D_8s^+

128-dim -half-spinor - denoted by D_8s^-

if you make the physical interpretations:

$D_8\text{adj}$ as gauge bosons plus spacetime

D_8s^+ as one generation of fermion particles and antiparticles

D_8s^- as one antigeneration of fermion particles and antiparticles

then

if you try to form a Lie algebra from

$D_8\text{adj} + D_8s^+ + D_8s^-$

it does not work,

but

if you try to form a Lie algebra from

$D_8\text{adj} + D_8s^+$

you succeed and get E_8

with the $64+64 = 128$ -dim D_8s^+ representing one generation of fermion particles
(one 64 of D_8s^+) and one generation of fermion antiparticles (the other 64 of D_8s^+).

The math structure of Lie algebras is telling you
that there is no physical D_8s^- antigeneration of fermions,
and
that one generation of D_8s^+ fermions lives inside E_8 .

Then you have to deal with the Atiyah-Singer index giving the net number of
generations, which is an issue conventionally formulated
in terms of the Euler index of the compact manifold (6-dim)
used to reduce 10-dim spacetime to physical 4-dim.

If do start with a 10-dim spacetime
you could reduce it using the compact CP^2
leaving an 6-dim conformal spacetime that, by Conformal Group structure,
naturally gives you 4-dim spacetime (compare twistors etc).

For an E8 model,
spacetime is 8-dim reduced to a Kaluza-Klein $M4 \times CP2$

Look at the index structure of the CP2.

CP2 has:

no spin structure

Euler number $2+1 = 3$

no need to have zero Hirzebruch signature as CP2 is 4-dimensional

Atiyah-Singer index $-1/8$ which is not an integer for generation number.

Since CP2 has no spin structure,

you have to give it a generalized spin structure following

Hawking and Pope (Phys. Lett. 73B (1978) 42-44)

and Chakraborty and Parthasarathy (Class. Quantum Grav. 7 (1990) 1217-1224)

to get

(for integral m) for the index $n_R - n_L = (1/2) m (m+1)$

For $m = 1$, $n_R - n_L = (1/2) \times 1 \times 2 = 1$ for 1 generation

For $m = 2$, $n_R - n_L = (1/2) \times 2 \times 3 = 3$ for 3 generations

so

the E8 Physics model with CP2 Internal Symmetry Space

has consistent Chiral Fermions:

for index = 1 for 1 generation as in the E8 prior to dimensional reduction;

for index = 3 for 3 generations as the E8 model after dimensional reduction induces the second and third generations to emerge as effective composites of the first.

F4 and E8

Frank Dodd (Tony) Smith, Jr. - 2012

The Real Clifford Algebra $Cl(8)$ has graded structure

$$1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$$

The 52-dim Exceptional Lie Algebra $F4 = V8 + BV28 + S8+ + S8-$ lives in $Cl(8)$ as

$$\text{Vector } 8 + \text{BiVector } 28 + \text{+Half-Spinor } 8 + \text{-Half-Spinor } 8$$

The Commutator part of $F4$ is $V8 + BV28$

The AntiCommutator part of $F4$ is $S8+ + S8-$

$V8$ and $S8+$ and $S8-$ are related by Triality

$Cl(16) = Cl(8) \times Cl(8)$ by 8-periodicity tensor product.

The $F4 \times F4$ Commutator part of the $Cl(16) = Cl(8) \times Cl(8)$ tensor product is

$$BV28 + V8 \times V8 + BV28 = BV28 + BV64 + BV28 = BV120 = \text{Spin}(16)$$

The $F4 \times F4$ AntiCommutator part of the $Cl(16) = Cl(8) \times Cl(8)$ tensor product is

$$(S8+ + S8-) \times (S8+ + S8-) = (S8+ \times S8+ + S8- \times S8-) + (S8+ \times S8- + S8- \times S8+)$$

Only $(S8+ \times S8+ + S8- \times S8-)$ has two consistent mirror-image helicity components

so the physically relevant $F4 \times F4$ AntiCommutator part of $Cl(16)$ is

$$(S8+ \times S8+ + S8- \times S8-) = S64+ + S64- = \text{Half-Spinor Spin}(16)$$

$BV64$ and $S64+$ and $S64-$ are related by Triality

248-dim $E8$ is the physically relevant part of $F4 \times F4$

$$E8 = \text{Spin}(16) + \text{Half-Spinor Spin}(16) = BV120 + (S64+ + S64-)$$

lives in $Cl(16) = Cl(8) \times Cl(8)$

The Commutator part of $E8$ is $BV120 = BV28 + BV64 + BV28$

The AntiCommutator part of $E8$ is $S64+ + S64-$

$BV64$ and $S64+$ and $S64-$ are related by Triality

Pierre Ramond said in hep-th/0112261: "... exceptional algebras relate tensor and spinor representations of their orthogonal subgroups,

while Spin-Statistics requires them to be treated differently ...

all representations of the exceptional group $F4$ are generated by three sets

of oscillators transforming as 26. We label each copy of 26 oscillators as

$$A_{k_0}, A_{k_i}, i = 1, \dots, 9, B_{k_a}, a = 1, \dots, 16,$$

and their hermitian conjugates, and where $k = 1, 2, 3$.

Under $SO(9)$, the A_{k_i} transform as 9, B_{k_a} transform as 16, and A_{k_0} is a scalar.

They satisfy the commutation relations of ordinary harmonic oscillators ...

Note that the $SO(9)$ spinor operators satisfy Bose-like commutation relations ...

both A_{k_0} and B_{k_a} ... obey Bose commutation relations ...

Curiously,

if both ... A_{k_0} and B_{k_a} ... are anticommuting, the $F4$ algebra is still satisfied ...

One can just as easily use a coordinate representation of the oscillators

by introducing real coordinates

...[for A_{k_i}]... which transform as transverse space vectors,

...[for A_{k_0}]... which transform ... as scalars,

and ...[for B_{k_a}]... which transform ... as space spinors

which satisfy Bose commutation rules ...".

Since the commuting/anticommuting F4 lives in Cl(8) and since Cl(8) by periodicity is the fundamental factor of all large Clifford algebras, the commuting/anticommuting property goes to all large Clifford algebras and in particular goes to the tensor product $Cl(8) \times Cl(8) = Cl(16)$ in which 248-dim E8 lives naturally as 120-dim bivector Spin(16) commutators plus 128-dim half-spinor of Spin(16) anticommutators.

The structure and Maximal Contractions of F4 and E8 are:

52-dim F4 (Real) structure (in red):

$$Cl(8) = 1 + \mathbf{8} + \mathbf{28} + 56 + 70 + 56 + 28 + 8 + 1 = (\mathbf{8} + \mathbf{8}) \times (8 + 8)$$

F4 Maximal Contraction:

21 = Spin(7) where Spin(7) / Spin(6) = S6 for 6-dim Conformal Spacetime with Spin(6) as Conformal Group (if you use Hyperbolic Signature)
- semidirect product with -

15 + 1 + 15 Heisenberg Algebra H15 for 15 Spin(2,4) Conformal Gauge Bosons acting on 6-dim Conformal Spacetime which reduces to our M4 Physical Spacetime

248-dim E8 (Octonion) structure (in red):

$$Cl(16) = 1 + 16 + \mathbf{120} + 560 + 1820 + \dots + 16 + 1 = (\mathbf{64+64}) + (64+64) \times (128 + 128)$$

E8 Maximal Contraction:

63 = SU(8) part of U(8) for 8 position x 8 momentum generators
- semidirect product with -

28 + 64 + 1 + 64 + 28 Heisenberg Algebra H92 for 28 gauge bosons for SU(3)xSU(2)xU(1) plus Spin(2,4) = SU(2,2) Conformal Gravity and 8 components of 8 Fermions

Further: F4 / Spin(9) = OP2

E8 / Spin(16) = (OxO)P2 = 128-dim rank-8 Rosenfeld octo-octonionic projective plane

E6 (Complex) - E7 (Quaternion) - E7.5 (Sextonion)

78-dim E6 structure (in red): $Cl(10) = \mathbf{1} + 10 + \mathbf{45} + 120 + 210 + \dots + 10 + 1 = (\mathbf{16} + \mathbf{16}) \times (16 + 16)$

E6 / F4 = 26-dim traceless part J3(O)o of 27-dim Jordan Algebra J3(O)

E6 Maximal Contraction:

45 = Spin(10) which acts on (2+8) = 10-dim Spacetime part of J3(O)o with 4-dim CP2 Internal Symmetry Space + 6-dim Conformal Spacetime
- semidirect product with -

16 + 1 + 16 Heisenberg Algebra H16 where 16 = (26-10)-dim Fermion part of J3(O)o

E7 (133-dim structure related to Cl(12)) Maximal Contraction:

78 = E6 - semidirect product with - 27 + 1 + 27 Heisenberg Algebra H27 where 27 = Octonionic Jordan Algebra J3(O) = (bijection) = J4(Q)o of (3 Quaternion generators + 8 Spacetime vectors) + (8+ 8 Fermions)

E7.5 Maximal Contraction:

133 = E7 - semidirect product with - 28 + 1 + 28 Heisenberg Algebra H28 where 28 = Quaternionic Jordan Algebra J4(Q) = (bijection) = Spin(8) of Standard Model + Gravity Gauge Bosons

NonUnitary Octonionic Inflation:

In his book Quaternionic Quantum Mechanics and Quantum Fields ((Oxford 1995), Stephen L. Adler says at pages 50-52, 561:

"... If the multiplication is associative, as in the complex and quaternionic cases, we can remove parentheses in ... Schroedinger equation dynamics ... to conclude that ... the inner product $\langle f(t) | g(t) \rangle$... is invariant ... this proof fails in the octonionic case, and hence one cannot follow the standard procedure to get a unitary dynamics. ...[so there is a]... **failure of unitarity in octonionic quantum mechanics...**".

The non-associativity and non-unitarity of octonions might account for particle creation without the need for tapping the energy of an inflaton field.

The non-associative structure of octonions manifests itself in interesting ways:

The 7-sphere S^7 EXPANDS TO $S^7 \times G_2 \times S^7 = D_4$ Lie Algebra.

The 480 Octonion multiplications double-cover the 240 Root Vectors of E_8 .

There are 7 independent E_8 lattices, each corresponding to an integral domain, differing in the configuration of the 240 E_8 Root Vectors that are the innermost shell surrounding the origin of the lattice at unit distance (also sometimes normalized as 2) from the origin. Here is a list of them with points on the line with iE_8, jE_8 notation being common points with the iE_8 and jE_8 lattices):

```

1E8:  ±1,  ±i,  ±j,  ±k,  ±e,  ±ie,  ±je,  ±ke,
      (±1 ±je ±i ±j)/2          (±k ±e ±ie ±ke)/2
      (±1 ±j ±ie ±ke)/2      5E8, 6E8  (±i ±k ±e ±je)/2
      (±1 ±ke ±k ±i)/2          (±j ±e ±ie ±je)/2
      (±1 ±i ±e ±ie)/2      7E8, 3E8  (±j ±k ±je ±ke)/2
      (±1 ±ie ±je ±k)/2      2E8, 4E8  (±i ±j ±e ±ke)/2
      (±1 ±k ±j ±e)/2          (±i ±ie ±je ±ke)/2
      (±1 ±e ±ke ±je)/2          (±i ±j ±k ±ie)/2

```

2E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm i \pm k \pm e)/2$ $(\pm j \pm ie \pm je \pm ke)/2$
 $(\pm 1 \pm e \pm je \pm j)/2$ 7E8, 6E8 $(\pm i \pm k \pm ie \pm ke)/2$
 $(\pm 1 \pm j \pm ke \pm k)/2$ $(\pm i \pm e \pm ie \pm je)/2$
 $(\pm 1 \pm k \pm ie \pm je)/2$ 1E8, 4E8 $(\pm i \pm j \pm e \pm ie)/2$
 $(\pm 1 \pm je \pm i \pm ke)/2$ 3E8, 5E8 $(\pm j \pm k \pm e \pm ie)/2$
 $(\pm 1 \pm ke \pm e \pm ie)/2$ $(\pm i \pm j \pm k \pm je)/2$
 $(\pm 1 \pm ie \pm j \pm i)/2$ $(\pm k \pm e \pm je \pm ke)/2$

3E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm k \pm ke \pm ie)/2$ $(\pm i \pm j \pm e \pm je)/2$
 $(\pm 1 \pm ie \pm i \pm e)/2$ E8, 1E8 $(\pm j \pm k \pm je \pm ke)/2$
 $(\pm 1 \pm e \pm j \pm ke)/2$ $(\pm i \pm k \pm ie \pm je)/2$
 $(\pm 1 \pm ke \pm je \pm i)/2$ 2E8, 5E8 $(\pm j \pm k \pm e \pm ie)/2$
 $(\pm 1 \pm i \pm k \pm j)/2$ 4E8, 6E8 $(\pm e \pm ie \pm je \pm ke)/2$
 $(\pm 1 \pm j \pm ie \pm je)/2$ $(\pm i \pm k \pm e \pm ke)/2$
 $(\pm 1 \pm je \pm e \pm k)/2$ $(\pm i \pm j \pm ie \pm ke)/2$

4E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm ke \pm j \pm je)/2$ $(\pm i \pm k \pm e \pm ie)/2$
 $(\pm 1 \pm je \pm k \pm ie)/2$ 1E8, 2E8 $(\pm i \pm j \pm e \pm ke)/2$
 $(\pm 1 \pm ie \pm e \pm j)/2$ $(\pm i \pm k \pm je \pm ke)/2$
 $(\pm 1 \pm j \pm i \pm k)/2$ 3E8, 6E8 $(\pm e \pm ie \pm je \pm ke)/2$
 $(\pm 1 \pm k \pm ke \pm e)/2$ 7E8, 5E8 $(\pm i \pm j \pm ie \pm je)/2$
 $(\pm 1 \pm e \pm je \pm i)/2$ $(\pm j \pm k \pm ie \pm ke)/2$
 $(\pm 1 \pm i \pm ie \pm ke)/2$ $(\pm j \pm k \pm e \pm je)/2$

5E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm j \pm e \pm i)/2$ $(\pm k \pm ie \pm je \pm ke)/2$
 $(\pm 1 \pm i \pm ke \pm je)/2$ 2E8, 3E8 $(\pm j \pm k \pm e \pm ie)/2$
 $(\pm 1 \pm je \pm ie \pm e)/2$ $(\pm i \pm j \pm k \pm ke)/2$
 $(\pm 1 \pm e \pm k \pm ke)/2$ 7E8, 4E8 $(\pm i \pm j \pm e \pm ie)/2$
 $(\pm 1 \pm ke \pm j \pm ie)/2$ 1E8, 6E8 $(\pm i \pm k \pm e \pm je)/2$
 $(\pm 1 \pm ie \pm i \pm k)/2$ $(\pm j \pm e \pm je \pm ke)/2$
 $(\pm 1 \pm k \pm je \pm j)/2$ $(\pm i \pm e \pm ie \pm ke)/2$

6E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm e \pm ie \pm k)/2$ $(\pm i \pm j \pm je \pm ke)/2$
 $(\pm 1 \pm k \pm j \pm i)/2$ 3E8, 4E8 $(\pm e \pm ie \pm je \pm ke)/2$
 $(\pm 1 \pm i \pm je \pm ie)/2$ $(\pm j \pm k \pm e \pm ke)/2$
 $(\pm 1 \pm ie \pm ke \pm j)/2$ 5E8, 1E8 $(\pm i \pm k \pm e \pm je)/2$
 $(\pm 1 \pm j \pm e \pm je)/2$ 7E8, 2E8 $(\pm i \pm k \pm ie \pm ke)/2$
 $(\pm 1 \pm je \pm k \pm ke)/2$ $(\pm i \pm j \pm e \pm ie)/2$
 $(\pm 1 \pm ke \pm i \pm e)/2$ $(\pm j \pm k \pm ie \pm je)/2$

7E8: $\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$
 $(\pm 1 \pm ie \pm je \pm ke)/2$ $(\pm e \pm i \pm j \pm k)/2$
 $(\pm 1 \pm ke \pm e \pm k)/2$ 5E8, 4E8 $(\pm i \pm j \pm ie \pm je)/2$
 $(\pm 1 \pm k \pm i \pm je)/2$ $(\pm j \pm ie \pm ke \pm e)/2$
 $(\pm 1 \pm je \pm j \pm e)/2$ 6E8, 2E8 $(\pm ie \pm ke \pm k \pm i)/2$
 $(\pm 1 \pm e \pm ie \pm i)/2$ 3E8, 1E8 $(\pm ke \pm k \pm je \pm j)/2$
 $(\pm 1 \pm i \pm ke \pm j)/2$ $(\pm k \pm je \pm e \pm ie)/2$
 $(\pm 1 \pm j \pm k \pm ie)/2$ $(\pm je \pm e \pm i \pm ke)/2$

The vertices that appear in more than one lattice are:

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$	in	all of them;
$(\pm 1 \pm i \pm j \pm k)/2$ and $(\pm e \pm ie \pm je \pm ke)/2$	in	3E8, 4E8, and 6E8 ;
$(\pm 1 \pm i \pm e \pm ie)/2$ and $(\pm j \pm k \pm je \pm ke)/2$	in	7E8, 1E8, and 3E8 ;
$(\pm 1 \pm j \pm e \pm je)/2$ and $(\pm i \pm k \pm ie \pm ke)/2$	in	7E8, 2E8, and 6E8 ;
$(\pm 1 \pm k \pm e \pm ke)/2$ and $(\pm i \pm j \pm ie \pm je)/2$	in	7E8, 4E8, and 5E8 ;
$(\pm 1 \pm i \pm je \pm ke)/2$ and $(\pm j \pm k \pm e \pm ie)/2$	in	2E8, 3E8, and 5E8 ;
$(\pm 1 \pm j \pm ie \pm ke)/2$ and $(\pm i \pm k \pm e \pm je)/2$	in	1E8, 5E8, and 6E8 ;
$(\pm 1 \pm k \pm ie \pm je)/2$ and $(\pm i \pm j \pm e \pm ke)/2$	in	1E8, 2E8, and 4E8 .

The unit vertices in the E8 lattices do not include any of the 256 E8 light cone vertices, of the form $(\pm 1 \pm i \pm j \pm k \pm e \pm ie \pm je \pm ke)/2$.

They appear in the next layer out from the origin, at radius sqrt 2, which layer contains in all 2160 vertices:

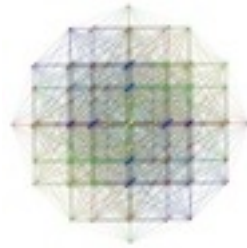
$$2160 = 112 + 256 + 1792 = 112 + (128+128) + 7(128+128)$$

the 112 = root vectors of D8

the (128+128) = 8-cube = two mirror image D8 half-spinors

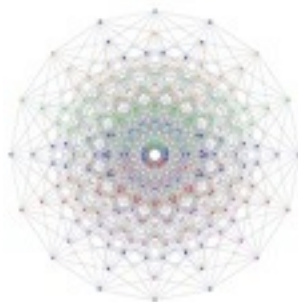
the 7(128+128) = 7 copies of 8-cube for 7 independent E8 lattices, each 8-cube = two mirror image D8 half-spinors related by triality to the 112 and thus to the (128+128) and thus to each other.

All 7 E8 lattices have the same second layer or shell. In the image below,



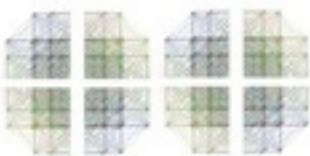
the 240 in the first layer look like

the 112 look like

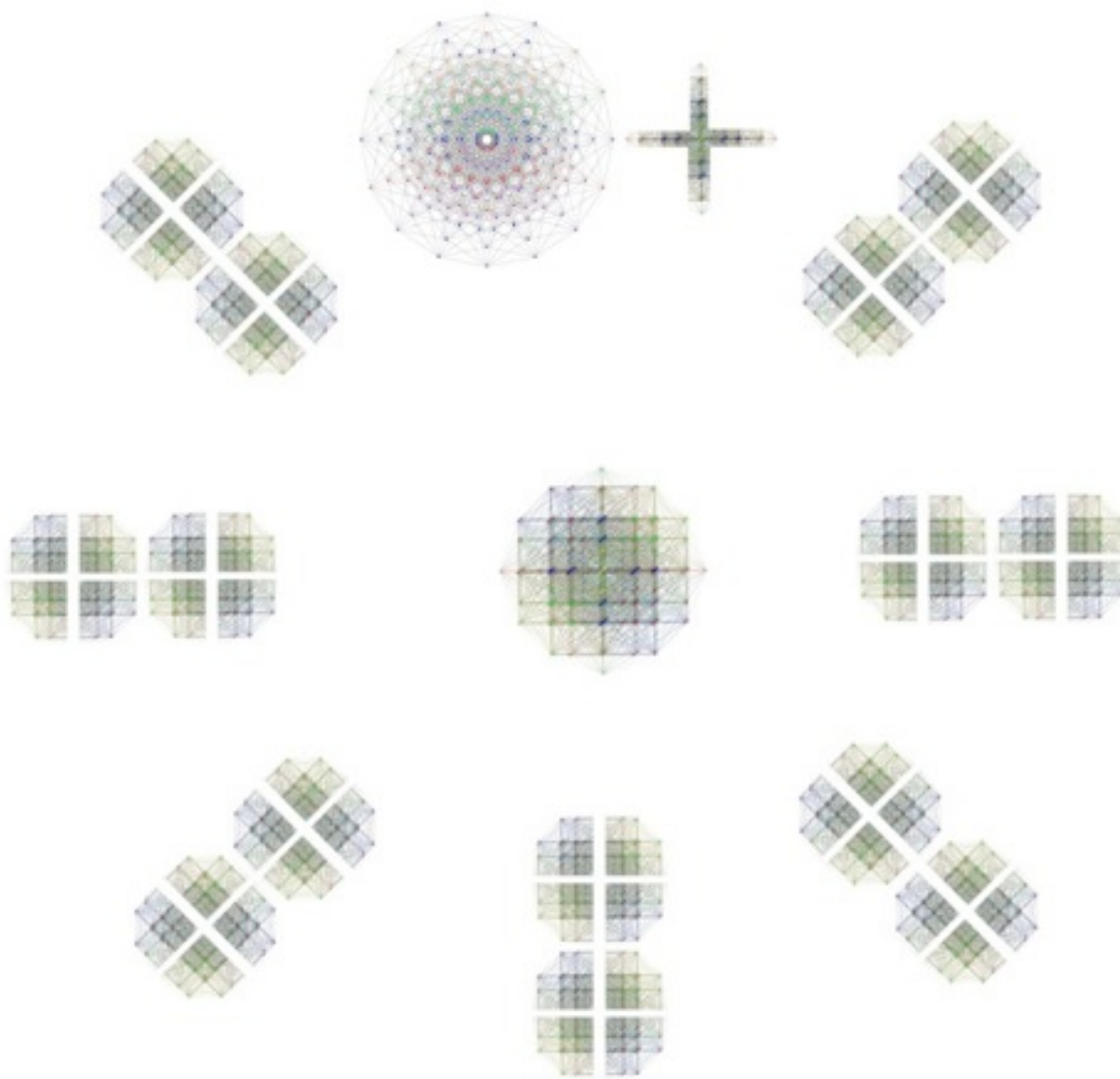


the 256 look like

in the second the 1792 look like



(7 copies of 128+128).



The real 4_{21} Witting polytope of the E_8 lattice in R^8 has
 240 vertices;
 6,720 edges;
 60,480 triangular faces;
 241,920 tetrahedra;
 483,840 4-simplexes;
 483,840 5-simplexes 4_{00} ;
 138,240 + 69,120 6-simplexes 4_{10} and 4_{01} ; and
 17,280 7-simplexes 4_{20} and 2,160 7-cross-polytopes 4_{11} .

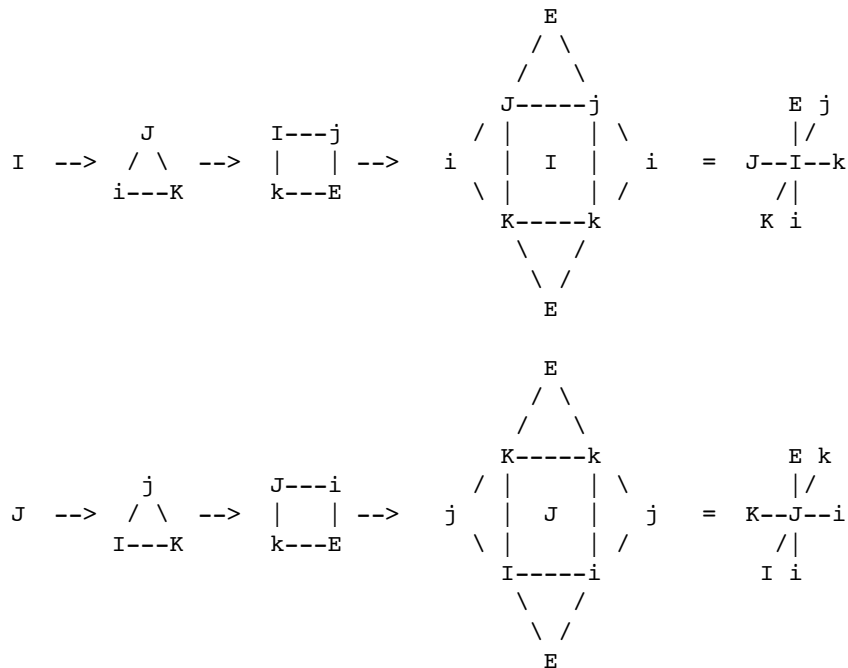
The E8 lattice in R8 has a counterpart in complex C4,
the self-reciprocal honeycomb of Witting polytopes,
a lattice of all points whose 4 coordinates are Eisenstein integers with the
equivalent congruences

$$u_1 + u_2 + u_3 = u_2 - u_3 + u_4 = 0 \pmod{i \sqrt{3}} \text{ and} \\
u_3 - u_2 = u_1 - u_3 = u_2 - u_1 = u_4 \pmod{i \sqrt{3}}.$$

The self-reciprocal Witting polytope in C4 has
240 vertices,
2,160 edges,
2,160 faces, and
240 cells.

It has 27 edges at each vertex.
Its symmetry group has order 155,520 = 3 x 51,840.
It is 6-symmetric, so its central quotient group has order 25,920.
It has 40 diameters orthogonal to which are 40 hyperplanes of symmetry, each
of which contains 72 vertices.
It has a van Oss polygon in C2, its section by a plane joining an edge to the
center, that is the 3{4}3 in C2, with 24 vertices and 24 edges.

The 7 Imaginary Octonions correspond to the 7 independent E8 lattices
and therefore to the 7 Onarhedra/Heptavertons:



$$\begin{array}{c}
K \quad \longrightarrow \quad \begin{array}{c} J \\ / \quad \backslash \\ I \text{---} k \end{array} \quad \longrightarrow \quad \begin{array}{c} K \text{---} i \\ | \quad | \\ j \text{---} E \end{array} \quad \longrightarrow \quad \begin{array}{c} E \\ / \quad \backslash \\ I \text{---} i \\ | \quad | \quad | \\ / \quad K \quad \backslash \\ | \quad | \quad | \\ \backslash \quad J \quad / \\ | \quad | \quad | \\ E \end{array} \quad \longrightarrow \quad \begin{array}{c} E \quad i \\ | \quad / \\ I \text{---} K \text{---} j \\ / \quad | \\ J \quad k \end{array}
\end{array}$$

$$\begin{array}{c}
i \quad \longrightarrow \quad \begin{array}{c} I \\ / \quad \backslash \\ E \text{---} i \end{array} \quad \longrightarrow \quad \begin{array}{c} J \text{---} j \\ | \quad | \\ K \text{---} k \end{array} \quad \longrightarrow \quad \begin{array}{c} k \\ / \quad \backslash \\ I \text{---} J \\ | \quad | \quad | \\ / \quad i \quad \backslash \\ | \quad | \quad | \\ \backslash \quad K \quad / \\ | \quad | \quad | \\ E \end{array} \quad \longrightarrow \quad \begin{array}{c} k \quad J \\ | \quad / \\ I \text{---} i \text{---} E \\ / \quad | \\ K \quad j \end{array}
\end{array}$$

$$\begin{array}{c}
j \quad \longrightarrow \quad \begin{array}{c} J \\ / \quad \backslash \\ E \text{---} j \end{array} \quad \longrightarrow \quad \begin{array}{c} K \text{---} k \\ | \quad | \\ I \text{---} i \end{array} \quad \longrightarrow \quad \begin{array}{c} k \\ / \quad \backslash \\ J \text{---} I \\ | \quad | \quad | \\ / \quad j \quad \backslash \\ | \quad | \quad | \\ \backslash \quad K \quad / \\ | \quad | \quad | \\ E \end{array} \quad \longrightarrow \quad \begin{array}{c} k \quad I \\ | \quad / \\ J \text{---} j \text{---} E \\ / \quad | \\ K \quad i \end{array}
\end{array}$$

$$\begin{array}{c}
k \quad \longrightarrow \quad \begin{array}{c} K \\ / \quad \backslash \\ E \text{---} k \end{array} \quad \longrightarrow \quad \begin{array}{c} I \text{---} i \\ | \quad | \\ J \text{---} j \end{array} \quad \longrightarrow \quad \begin{array}{c} i \\ / \quad \backslash \\ K \text{---} J \\ | \quad | \quad | \\ / \quad k \quad \backslash \\ | \quad | \quad | \\ \backslash \quad I \quad / \\ | \quad | \quad | \\ E \end{array} \quad \longrightarrow \quad \begin{array}{c} i \quad J \\ | \quad / \\ K \text{---} k \text{---} E \\ / \quad | \\ I \quad j \end{array}
\end{array}$$

$$\begin{array}{c}
E \quad \longrightarrow \quad \begin{array}{c} j \\ / \quad \backslash \\ i \text{---} k \end{array} \quad \longrightarrow \quad \begin{array}{c} I \text{---} J \\ | \quad | \\ K \text{---} E \end{array} \quad \longrightarrow \quad \begin{array}{c} i \\ / \quad \backslash \\ J \text{---} k \\ | \quad | \quad | \\ / \quad E \quad \backslash \\ | \quad | \quad | \\ \backslash \quad K \quad / \\ | \quad | \quad | \\ I \end{array} \quad \longrightarrow \quad \begin{array}{c} I \quad k \\ | \quad / \\ J \text{---} E \text{---} j \\ / \quad | \\ K \quad i \end{array}
\end{array}$$

Just as each of the 7 imaginary octonions correspond, in my E8 physics model, to the 7 types of charged fermions (electron; red, blue, green up quarks; red, blue, green down quarks), each Onarhedron/Heptaverton corresponds to a charge-neutral set of all 7 charged fermions. Consider that the initial Big Bang produced a particle-antiparticle pair of the 7 charged fermions, plus the 8th fermion (neutrino) corresponding to the real number 1.

As 8-dimensional Spacetime remains Octonionic throughout Inflation, the paper gr-qc/0007006 by Paola Zizzi shows that

"... during inflation, the universe can be described as a superposed state of quantum ... [qubits]. The self-reduction of the superposed quantum state is ... reached at the end of inflation ...[at]... the decoherence time ... [Tdecoh = 10^9 Tplanck = $10^{(-34)}$ sec] ... and corresponds to a superposed state of ... [$10^{19} = 2^{64}$ qubits]. ... This is also the number of superposed tubulins-qubits in our brain ... leading to a conscious event. ...".

The number of doublings (also known as e-foldings) is estimated in astro-ph/0107459 by Banks and Fischler, who say:

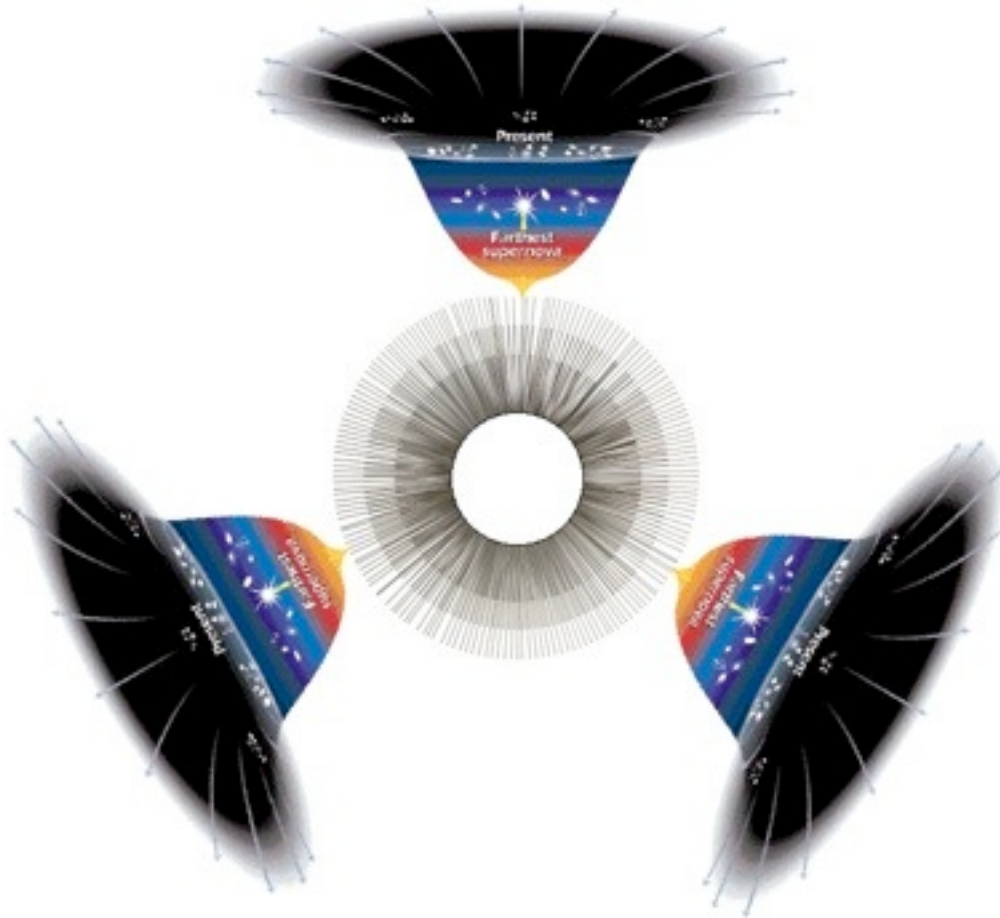
"... If the present acceleration of the universe is due to an asymptotically deSitter universe with small cosmological constant, then the number of e-foldings during inflation is bounded. ... The essential ingredient is that because of the UV-IR connection, entropy requires storage space. The existence of a small cosmological constant restricts the available storage space. ... We obtain the upper bound ... $N_e = 85$... where we took [the cosmological constant] \wedge to be of $O(10^{(-3)} \text{ eV})$. For the sake of comparison, the case $k = 1/3$ [corresponding to the equation of state for a radiation-dominated fluid, such as the cosmic microwave background] yields ... $N_e = 65$... This value for the maximum number of e-foldings is close to the value necessary to solve the "horizon problem".

If at each of the 64 doubling stages of Zizzi inflation the 2 particles of a pair produced $8+8 = 16$ fermions, then at the end of inflation such a non-unitary octonionic process would have produced about $2 \times 16^{64} = 4 \times (2^4)^{64} = 4 \times 2^{256} = 4 \times 10^{77}$ fermion particles. The figure of 4×10^{77} is similar number of particles estimated by considering the initial fluctuation to be a Planck mass Black Hole and the 64 doublings to act on such Black Holes.

Roger Penrose, in his book *The Emperor's New Mind* (Oxford 1989, pages 316-317) said:

"... in our universe ... Entropy ... increases ... Something forced the entropy to be low in the past. ... the low-entropy states in the past are a puzzle. ...".

The Zizzi Inflation phase of our universe ends with decoherence "collapse" of the 2^{64} Superposition Inflated Universe into Many Worlds of the Many-Worlds Quantum Theory, only one of which Worlds is our World.



In this image:
the central white circle is the Inflation Era in which everything is in Superposition;
the boundary of the central circle marks the decoherence/collapse at the End of Inflation;
and each line radiating from the central circle corresponds to one decohered/collapsed Universe World (of course, there are many more lines than actually shown), only three of which are explicitly indicated in the image, and only one of which is Our Universe World. Since our World is only a tiny fraction of all the Worlds, it carries only a tiny fraction of the entropy of the 2^{64} Superposition Inflated Universe, thus solving Penrose's Puzzle.

Paola Zizzi drew **analogy between the Inflation Era of our Universe and the Quantum Consciousness process of human thought formation.** The human brain contains about 10^{18} tubulins in cylindrical microtubules. Each tubulin contains a Dimer that can be in one of two binary states.



The Microtubule

in the illustration (from a Rhett Savage web site), the red dimer has its electron in the down state and the blue dimer has its electron in the up state.

Each tubulin is about $8 \times 4 \times 4$ nanometers in size and contains about 450 molecules (amino acids) each with about 20 atoms.

If about 10% of the brain is involved in a given conscious thought, it involves about 10% of 10^{18} or about 10^{17} tubulins.

Since 10^{17} is about 2^{56} , the mathematics of that thought is described by the Clifford algebra $Cl(56)$ which is (by 8-periodicity) $Cl(56) = Cl(7 \times 8) = Cl(8) \times \dots (7 \text{ times tensor product}) \dots \times Cl(8) = 7 \text{ states of the basic Clifford algebra } Cl(8)$

That may account for

"The Magical Number Seven, Plus or Minus Two:

Some Limits on our Capacity for Processing Information"

by George Miller available on the web at psychclassics.yorku.ca/Miller/

Wikipedia (I am not sure of the accuracy of the article) says
"... the correct number is probably around three or four ...".
which would be the case for thoughts that use a much smaller portion
of human brain capacity.

As to how a thought is formed, the Penrose-Hameroff type model
indicates that all 2^{56} of the tubulins are coherently in phase together,
forming a coherent quantum state containing all possible outcomes of the
thought that is being formed
(all Bohmian possibilities or all possible Worlds of the Many-Worlds)
and
after a time the coherent state decoheres into a single outcome state
that is the thought that is the result of the process
(Some call it collapse of the wave function. Penrose calls it
"Orchestrated Objective Reduction of Quantum Coherence", or Orch OR.)

Penrose proposes that Quantum Gravity causes the Orch OR collapse
that forms each thought after expiration of the time allowed
for that many tubulin states to be held in a coherent superposition.

That time, the time at which decoherence takes place and a thought is formed,
can be calculated using quantum gravity ideas
(see tony5m17h.net/QuantumMind2003.html and related pages)
and
the calculation results are consistent with the data of the human brain
(such as number of tubulins etc).

Another aspect of human consciousness is psychic connections which are readily
explained in terms of resonances between brains (or other things) holding patterns
of states that resonate with a state of a given human brain (some humans are better
than others at getting into such states and holding them, which accounts for some
people like curanderos being more talented than others, and also accounts for the
erratic nature of experimental results about psychic phenomena).

The book "Collective Electrodynamics" by Carver Mead is the best reference
that I know of about quantum theory and resonance.

E8 Physics Model and 26D String Theory with Monster Group Symmetry

viXra 1210.0072

Frank Dodd (Tony) Smith, Jr. - 2012

A physically realistic Lattice Bosonic String Theory with
Strings = World-Lines and Monster Group Symmetry
containing gravity and the Standard Model
can be constructed consistently with the E8 physics model
248-dim E8 = 120-dim adjoint D8 + 128-dim half-spinor D8
= (28 + 28 + 64) + (64 + 64)

Joseph Polchinski, in his books String Theory vols. I and II(Cambridge 1998), says:
"... the **closed ... unoriented ... bosonic string ... theory** has the maximal 26-
dimensional Poincare invariance ... It is possible to have a consistent theory ...
[with]... the **dilaton** ... the [**string-]graviton** ...[and]... the **tachyon** ...[whose]...
negative mass-squared means that the no-string 'vacuum' is actually unstable ... ".
The **dilaton** of E8 Physics sets the Planck scale as the scale for
the 16 dimensions that are orbifolded fermion particles and anti-particles
and the 4 dimensions of the CP2 Internal Symmetry Space of M4xCP2 spacetime.
The remaining 26-16-4 = 6 dimensions are the Conformal Physical Spacetime with
Spin(2,4) = SU(2,2) symmetry that produces M4 Physical Spacetime.
The **string-graviton** of E8 Physics is a spin-2 interaction among strings.
If Strings = World Lines and World Lines are past and future histories of particles,
then string-graviton interactions determine a Cramer Transaction Quantum Theory
discussed in quantum-ph/0408109. Roger Penrose in "Road to Reality" (Knopf
2004) says: "... **quantum** mechanics ... alternates between ... **unitary** evolution U ...
and state reduction R ... quantum state **reduction** ... is ... **objective** ... **OR** ...
it is always a gravitational phenomenon ... [A] conscious event ... would be ...
orchestrated **OR** ... of ... large-scale quantum coherence ... of ... microtubules ...".
String-Gravity produces Sarfatti-Bohm Quantum Potential with Back-Reaction.
It is distinct from the MacDowell-Mansouri Gravity of stars and planets.
The **tachyon** produces the instability of a truly empty vacuum state with no strings.
It is natural, because if our Universe were ever to be in a state with no strings,
then tachyons would create strings = World Lines thus filling our Universe with the
particles and World-Lines = strings that we see. Something like this is necessary for
particle creation in the Inflationary Era of non-unitary Octonionic processes.

Our construction of a 26D String Theory consistent with E8 Physics uses a structure that is not well-known, so I will mention it here before we start:

There are 7 independent E8 lattices, each corresponding to one of the 7 imaginary octonions denoted by $iE8$, $jE8$, $kE8$, $EE8$, $IE8$, $JE8$, and $KE8$ and related to both D8 adjoint and half-spinor parts of E8 and with 240 first-shell vertices. An 8th E8 lattice $1E8$ with 240 first-shell vertices related to the D8 adjoint part of E8 is related to the 7 octonion imaginary lattices (viXra 1301.0150v2).

It can act as an effectively independent lattice as part of the basis subsets $\{1E8, EE8\}$ or $\{1E8, iE8, jE8, kE8\}$.

With that in mind, here is the construction:

Step 1:

Consider the 26 Dimensions of Bosonic String Theory as the 26-dimensional traceless part $J3(O)_o$

$$a \quad O^+ \quad O_v$$

$$O^{+*} \quad b \quad O^-$$

$$O_v^* \quad O^{-*} \quad -a-b$$

(where O_v , O^+ , and O^- are in Octonion space with basis $\{1, i, j, k, E, I, J, K\}$ and a and b are real numbers with basis $\{1\}$)

of the 27-dimensional Jordan algebra $J3(O)$ of 3×3 Hermitian Octonion matrices.

Step 2:

Take a D3 brane to correspond to the Imaginary Quaternionic associative subspace spanned by $\{i, j, k\}$ in the 8-dimensional Octonionic O_v space.

Step 3:

Compactify the 4-dimensional co-associative subspace spanned by $\{E,I,J,K\}$ in the Octonionic O_v space as a $CP^2 = SU(3)/U(2)$, with its 4 world-brane scalars corresponding to the 4 covariant components of a Higgs scalar.

Add this subspace to $D3$, to get $D7$.

Step 4:

Orbifold the 1-dimensional Real subspace spanned by $\{1\}$ in the Octonionic O_v space by the discrete multiplicative group $Z_2 = \{-1,+1\}$, with its fixed points $\{-1,+1\}$ corresponding to past and future time. This discretizes time steps and gets rid of the world-brane scalar corresponding to the subspace spanned by $\{1\}$ in O_v . It also gives our brane a 2-level timelike structure, so that its past can connect to the future of a preceding brane and its future can connect to the past of a succeeding brane.

Add this subspace to $D7$, to get $D8$.

$D8$, our basic Brane, looks like two layers (past and future) of $D7$ s.

Beyond $D8$ our String Theory has $26 - 8 = 18$ dimensions, of which $25 - 8$ have corresponding world-brane scalars:

- 8 world-brane scalars for Octonionic O^+ space;
- 8 world-brane scalars for Octonionic O^- space;
- 1 world-brane scalars for real a space; and
- 1 dimension, for real b space, in which the $D8$ branes containing spacelike $D3$ s are stacked in timelike order.

Step 5:

To get rid of the world-brane scalars corresponding to the Octonionic O^+ space, orbifold it by the 16-element discrete multiplicative group $Oct16 = \{+/-1, +/-i, +/-j, +/-k, +/-E, +/-I, +/-J, +/-K\}$ to reduce O^+ to 16 singular points $\{-1, -i, -j, -k, -E, -I, -J, -K, +1, +i, +j, +k, +E, +I, +J, +K\}$.

- Let the 8 O^+ singular points $\{-1, -i, -j, -k, -E, -I, -J, -K\}$ correspond to the fundamental fermion particles {neutrino, red up quark, green up quark, blue up quark, electron, red down quark, green down quark, blue down quark} located on the past D7 layer of D8.
- Let the 8 O^+ singular points $\{+1, +i, +j, +k, +E, +I, +J, +K\}$ correspond to the fundamental fermion particles {neutrino, red up quark, green up quark, blue up quark, electron, red down quark, green down quark, blue down quark} located on the future D7 layer of D8.

The 8 components of the 8 fundamental first-generation fermion particles = $8 \times 8 = 64$ correspond to the **64** of the 128-dim half-spinor D8 part of E8.

This gets rid of the 8 world-brane scalars corresponding to O^+ , and leaves:

- 8 world-brane scalars for Octonionic O^- space;
- 1 world-brane scalars for real a space; and
- 1 dimension, for real b space, in which the D8 branes containing spacelike D3s are stacked in timelike order.

Step 6:

To get rid of the world-brane scalars corresponding to the Octonionic O^- space, orbifold it by the 16-element discrete multiplicative group $Oct_{16} = \{+/-1, +/-i, +/-j, +/-k, +/-E, +/-I, +/-J, +/-K\}$ to reduce O^- to 16 singular points $\{-1, -i, -j, -k, -E, -I, -J, -K, +1, +i, +j, +k, +E, +I, +J, +K\}$.

- Let the 8 O^- singular points $\{-1, -i, -j, -k, -E, -I, -J, -K\}$ correspond to the fundamental fermion anti-particles {anti-neutrino, red up anti-quark, green up anti-quark, blue up anti-quark, positron, red down anti-quark, green down anti-quark, blue down anti-quark} located on the past D7 layer of D8.
- Let the 8 O^- singular points $\{+1, +i, +j, +k, +E, +I, +J, +K\}$ correspond to the fundamental fermion anti-particles {anti-neutrino, red up anti-quark, green up anti-quark, blue up anti-quark, positron, red down anti-quark, green down anti-quark, blue down anti-quark} located on the future D7 layer of D8.

The 8 components of the 8 fundamental first-generation fermion anti-particles = $8 \times 8 = 64$ correspond to the 64 of the 128-dim half-spinor D8 part of E8.

This gets rid of the 8 world-brane scalars corresponding to O^- , and leaves:

- 1 world-brane scalars for real a space; and
- 1 dimension, for real b space, in which the D8 branes containing spacelike D3s are stacked in timelike order.

Step 7:

Let the 1 world-brane scalar for real a space correspond to a Bohm-type Quantum Potential acting on strings in the stack of D8 branes.

Interpret strings as world-lines in the Many-Worlds, short strings representing virtual particles and loops.

Step 8:

Fundamentally, physics is described on HyperDiamond Lattice structures.

There are 7 independent E8 lattices, each corresponding to one of the 7 imaginary octonions denoted by $iE8$, $jE8$, $kE8$, $EE8$, $IE8$, $JE8$, and $KE8$ and related to both D8 adjoint and half-spinor parts of E8 and with 240 first-shell vertices.

An 8th E8 lattice $1E8$ with 240 first-shell vertices related to the D8 adjoint part of E8 is related to the 7 octonion imaginary lattices.

Give each D8 brane structure based on Planck-scale E8 lattices so that each D8 brane is a superposition/intersection/coincidence of the eight E8 lattices.
(see viXra 1301.0150v2)

Step 9:

Since Polchinski says "... If r D-branes coincide ... there are r^2 vectors, forming the adjoint of a $U(r)$ gauge group ...", make the following assignments:

- a gauge boson emanating from D8 from its $1E8$ and $EE8$ lattices is a $U(2)$ ElectroWeak boson thus accounting for the photon and W^+ , W^- and Z^0 bosons.
- a gauge boson emanating from D8 from its $IE8$, $JE8$, and $KE8$ lattices is a $U(3)$ Color Gluon boson thus accounting for the 8 Color Force Gluon bosons.

The $4+8 = 12$ bosons of the Standard Model Electroweak and Color forces correspond to 12 of the 28 dimensions of 28-dim $Spin(8)$ that corresponds to the 28 of the 120-dim adjoint D8 part of E8.

- a gauge boson emanating from D8 from its $1E8$, $iE8$, $jE8$, and $kE8$ lattices is a $U(2,2)$ boson for conformal $U(2,2) = Spin(2,4) \times U(1)$ MacDowell-Mansouri gravity plus conformal structures consistent with the Higgs mechanism and with observed Dark Energy, Dark Matter, and Ordinary matter.

The 16-dim $U(2,2)$ is a subgroup of 28-dim $Spin(2,6)$ that corresponds to the 28 of the 120-dim adjoint D8 part of E8.

Step 10:

Since Polchinski says "... there will also be r^2 massless scalars from the components normal to the D-brane. ... the collective coordinates ... X^u ... for the embedding of n D-branes in spacetime are now enlarged to $n \times n$ matrices. This 'noncommutative geometry' ...[may be]... an important hint about the nature of spacetime. ...", make the following assignment:

The 8×8 matrices for the collective coordinates linking a D8 brane to the next D8 brane in the stack are needed to connect the eight E8 lattices of the D8 brane to the eight E8 lattices of the next D8 brane in the stack.

The $8 \times 8 = 64$ correspond to the 64 of the 120 adjoint D8 part of E8.

We have now accounted for all the scalars
and

have shown that the model has the physics content of the realistic E8 Physics model with Lagrangian structure based on $E8 = (28 + 28 + 64) + (64 + 64)$ and AQFT structure based on $Cl(16)$ with real Clifford Algebra periodicity and generalized Hyperfinite II₁ von Neumann factor algebra.

Bosonic String: Monster Gnome Fake Monster

Compactification: Leech Torus Longitudinal Torus Transversal

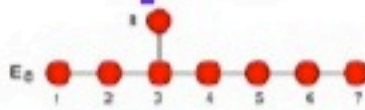
K27



E11 = E8+++



E8



Cl(16)

Contains E8 = Adjoint D8 + Conjugate Spinor D8

Cl(16) x ... (N times tensor product) ... x Cl(16)
by 8-periodicity is Cl(16N)

hyperfinite factor AQFT

Completion of Union of All Cl(16) Tensor Products

A Single Cell of E8 26-dimensional Bosonic String Theory,
in which Strings are physically interpreted as World-Lines,
can be described by taking the quotient of its 24-dimensional O+, O-, Ov
subspace modulo the 24-dimensional Leech lattice.
Its automorphism group is the largest finite sporadic group, the Monster Group,
whose order is
8080, 17424, 79451, 28758, 86459, 90496, 17107, 57005, 75436, 80000, 00000
=
2⁴⁶ .3²⁰ .5⁹ .7⁶ .11² .13³ .17.19.23.29.31.41.47.59.71
or about 8 x 10⁵³.

A Leech lattice construction is described by Robert A. Wilson in his 2009 paper "Octonions and the Leech lattice":

"... The (real) octonion algebra is an 8-dimensional (non-division) algebra with an orthonormal basis { 1=i00 , i0 , i1 , i2 , i3 , i4 , i5 , i6 } labeled by the projective line PL(7) = { oo } u F7

...

The E8 root system embeds in this algebra ... take the 240 roots to be ...
112 octonions ... +/- it +/- iu for any distinct t,u

... and ...

128 octonions (1/2)(+/- 1 +/- i0 +/- ... +/- i6) which have an odd number of minus signs.

Denote by L the lattice spanned by these 240 octonions

...

Let s = (1/2)(- 1 + i0 + ... + i6) so s is in L ... write R for Lbar ...

...

(1/2) (1 + i0) L = (1/2) R (1 + i0) is closed under multiplication ... Denote this ...by A
 ... Writing B = (1/2) (1 + i0) A (1 + i0) ...from ... Moufang laws ... we have
 L R = 2 B , and ... B L = L and R B = R ...[also]... 2 B = L sbar

...

the roots of B are

[16 octonions]... +/- it for t in PL(7)

... together with

[112 octonions]... (1/2) (+/- 1 +/- it +/- i(t+1) +/- i(t+3)) ...for t in F7

... and ...

[112 octonions]... (1/2) (+/- i(t+2) +/- i(t+4) +/- i(t+5) +/- i(t+6)) ...for t in F7

...

the octonionic Leech lattice ... contains the following 196560 vectors of norm 4 ,
 where M is a root of L and j,k are in J = { +/- it | t in PL(7) },
 and all permutations of the three coordinates are allowed:

(2 M, 0 , 0)

Number: 3x240 = 720

(M sbar, +/- (M sbar) j , 0)

Number: 3x240 x 16 = 11520

((M s) j , +/- M k , +/- (M j) k)

Number: 3x240 x 16 x 16 = 184320

...

The key to the simple proofs above is the observation that $LR = 2B$ and $BL = L$: these remarkable facts appear not to have been noticed before ... some work ... by Geoffrey Dixon ...". Geoffrey Dixon says in his book "Division Algebras, Lattices, Physics, Windmill Tilting" using notation $\{e_0, e_1, e_2, e_3, e_4, e_5, e_6, e_7\}$ for the Octonion basis elements that Robert A. Wilson denotes by $\{1=i_0, i_1, i_2, i_3, i_4, i_5, i_6\}$ and I often denote by $\{1, i, j, k, E, I, J, K\}$: "...

$$\begin{aligned} \Xi_0 &= \{\pm e_a\}, \\ \Xi_2 &= \{(\pm e_a \pm e_b \pm e_c \pm e_d)/2 : a, b, c, d \text{ distinct}, \\ &\quad e_a(e_b(e_c e_d)) = \pm 1\}, \end{aligned}$$

$$\begin{aligned} \Xi^{\text{even}} &= \Xi_0 \cup \Xi_2, \\ \mathcal{E}_8^{\text{even}} &= \text{span}\{\Xi^{\text{even}}\}, \end{aligned}$$

$$\begin{aligned} \Xi_1 &= \{(\pm e_a \pm e_b)/\sqrt{2} : a, b \text{ distinct}\}, \\ \Xi_3 &= \{(\sum_{a=0}^7 \pm e_a)/\sqrt{8} : \text{even number of '+'s}\}, \end{aligned}$$

$$\begin{aligned} \Xi^{\text{odd}} &= \Xi_1 \cup \Xi_3, \\ \mathcal{E}_8^{\text{odd}} &= \text{span}\{\Xi^{\text{odd}}\} \end{aligned}$$

(spans over integers) ...

Ξ^{even} has $16+224 = 240$ elements ... Ξ^{odd} has $112+128 = 240$ elements ...

$\mathcal{E}_8^{\text{even}}$ does not close with respect to our given octonion multiplication ...[but]...

the set $\Xi^{\text{even}}[0-a]$, derived from Ξ^{even} by replacing each occurrence of e_0 ... with e_a , and vice versa, is multiplicatively closed. ...".

Geoffrey Dixon's Ξ^{even} corresponds to B

Geoffrey Dixon's $\Xi^{\text{even}}[0-a]$ corresponds to the seven At

Geoffrey Dixon's Ξ^{odd} corresponds to L

Ignoring factors like 2, j, k, and +/-1 the Leech lattice structure is:

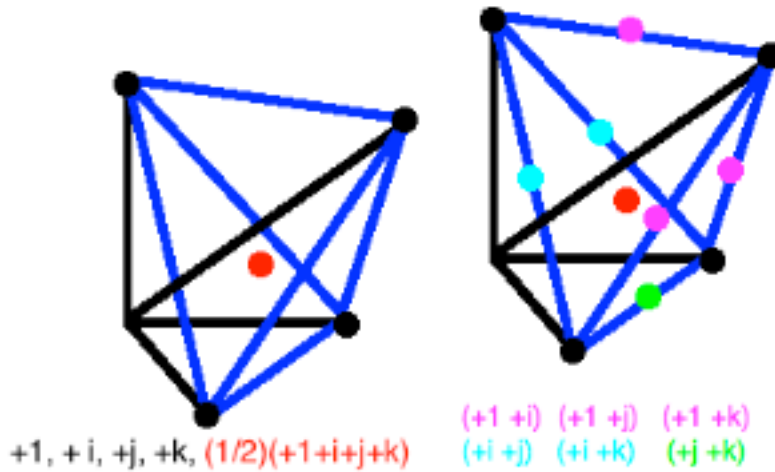
(L , 0 , 0)	Number: $3 \times 240 = 720$
(B , B , 0)	Number: $3 \times 240 \times 16 = 11520$
(L s , L , L)	Number: $3 \times 240 \times 16 \times 16 = 184320$

(Ξ^{odd} , 0 , 0)	Number: $3 \times 240 = 720$
(Ξ^{even} , Ξ^{even} , 0)	Number: $3 \times 240 \times 16 = 11520$
(Ξ^{odd} s , Ξ^{odd} , Ξ^{odd})	Number: $3 \times 240 \times 16 \times 16 = 184320$

My view is that **the E8 domain B is fundamental** and the E8 domains L and L s are derived from it.

That view is based on analogy with the 4-dimensional 24-cell and its dual 24-cell. Using Quaternionic coordinates $\{1, i, j, k\}$ the 24-cell of 4-space has one Superposition Vertex for each 16-region of 4-space.

A Dual 24-cell gives a new Superposition Vertex at each edge of the region.



The Initial 24-cell Quantum Operators act with respect to 4-dim Physical Spacetime. $\{1, i, j, k\}$ represent time and 3 space coordinates.

$(1/2)(+1+i+j+k)$ represents a fundamental first-generation Fermion particle/antiparticle (there is one for for each of the 16-regions).

The Dual 24-cell Quantum Operators act with respect to 4-dim CP2 Internal Symmetry Space. Since $CP^2 = SU(3)/SU(2) \times U(1)$,

$(+1 +i)$ $(+1 +j)$ $(+1 +k)$ are permuted by S_3 to form the Weyl Group of Color Force $SU(3)$,

$(+i +j)$ $(+i +k)$ are permuted by S_2 to form the Weyl Group of Weak Force $SU(2)$,

$(+j +k)$ is permuted by S_1 to form the Weyl Group of Electromagnetic Force $U(1)$.

The B-type 24-cell is fundamental because it gives Fundamental Fermions.

The L-type dual 24-cell is derivative because it gives Standard Model Gauge Bosons.

Robert A. Wilson in "Octonions and the Leech lattice" also said

"... **B is not closed under multiplication** ... Kirmse's mistake ... [but] ... as Coxeter ... pointed out ...

... there are seven non-associative rings $A_t = (1/2) (1 + it) B (1 + it)$, obtained from B by swapping 1 with it ... for t in F7 ...".

H. S. M. Coxeter in "Integral Cayley Numbers" (Duke Math. J. 13 (1946) 561-578) said "... Kirmse ... defines ... an integral domain ... which he calls J1 [Wilson's B] ... [but] ...

J1 itself is not closed under multiplication ... Bruck sent ... a revised description ... [of a] ... domain J ... derived from J1 by transposing two of the i's [imaginary Octonions] ...

It is closed under multiplication ... there are ... seven such domains, since the $(7 \text{ choose } 2) = 21$ possible transpositions fall into 7 sets of 3, each set having the same effect. In each of the seven domains, one of the ... seven i's ... plays a special role, viz., that one which is not affected by any of the three transpositions. ...

J contains ... 240 units ... ". J is one of Wilson's seven A_t and, in Octonionic coordinates $\{1, i, j, k, e, ie, je, ke\}$, is shown below with physical interpretation color-coded as

8-dim Spacetime Coordinates x 8-dim Momentum Dirac Gammas

Gravity $SU(2,2) = Spin(2,4)$ in a D4 + Standard Model $SU(3) \times U(2)$ in a D4

8 First-Generation Fermion Particles x 8 Coordinate Components

8 First-Generation Fermion AntiParticles x 8 Coordinate Components

112 = (16+48=64) + (24+24=48) Root Vectors corresponding to D8:

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke,$

$(\pm 1 \pm i \quad \quad \quad \pm e \pm ie \quad \quad \quad)/2$
 $(\pm 1 \quad \quad \pm j \quad \quad \quad \pm e \quad \quad \quad \pm je \quad \quad \quad)/2$
 $(\pm 1 \quad \quad \quad \pm k \pm e \quad \quad \quad \pm ke)/2$

$(\quad \quad \quad \pm j \pm k \quad \quad \quad \pm je \pm ke)/2$
 $(\quad \pm i \quad \quad \quad \pm k \quad \quad \quad \pm ie \quad \quad \quad \pm ke)/2$
 $(\quad \pm i \pm j \quad \quad \quad \pm ie \pm je \quad \quad \quad)/2$

128 = 64 + 64 Root Vectors corresponding to half-spinor of D8:

$(\pm 1 \quad \quad \quad \quad \quad \quad \pm ie \pm je \pm ke)/2$
 $(\pm 1 \quad \quad \quad \pm j \pm k \quad \quad \quad \pm ie \quad \quad \quad)/2$
 $(\pm 1 \pm i \quad \quad \quad \pm k \quad \quad \quad \pm je \quad \quad \quad)/2$
 $(\pm 1 \pm i \pm j \quad \quad \quad \quad \quad \quad \pm ke)/2$

$(\quad \pm i \pm j \pm k \pm e \quad \quad \quad \quad \quad \quad)/2$
 $(\quad \pm i \quad \quad \quad \pm e \quad \quad \quad \pm je \pm ke)/2$
 $(\quad \quad \quad \pm j \pm e \pm ie \quad \quad \quad \pm ke)/2$
 $(\quad \quad \quad \pm k \pm e \pm ie \pm je \quad \quad \quad)/2$

The above Coxeter-Bruck J is, in the notation I usually use, denoted 7E8 .
 It is one of Coxeter's seven domains (Wilson's seven {A0,A1,A2,A3,A4,A5,A6})
 that I usually denote as { 1E8 , 2E8 , 3E8 , 4E8 , 5E8 , 6E8 , 7E8 } .

Since the Leech lattice structure is

$(L , 0 , 0)$ **Number: 3x240 = 720**
 $(B , B , 0)$ **Number: 3x240 x 16 = 11520**
 $(L s , L , L)$ **Number: 3x240 x 16 x 16 = 184320**

if you replace the structural B with 7E8 and the **Leech lattice structure** becomes

$(L , 0 , 0)$ **Number: 3x240 = 720**
 $(7E8 , 7E8 , 0)$ **Number: 3x240 x 16 = 11520**
 $(L s , L , L)$ **Number: 3x240 x 16 x 16 = 184320**

and the **Leech lattice of E8 26-dim String Theory is the Superposition of 8 Leech lattices based on each of { B , 1E8 , 2E8 , 3E8 , 4E8 , 5E8 , 6E8 , 7E8 }**
 just as the D8 branes of E8 26-dim String Theory are each the Superposition of
 the 8 domains { B , 1E8 , 2E8 , 3E8 , 4E8 , 5E8 , 6E8 , 7E8 } .

What happens to a Fundamental Fermion Particle whose World-Line string intersects a Single Cell ?

The Fundamental Fermion Particle does not remain a single Planck-scale entity. **Tachyons create clouds of particles/antiparticles** as described by Bert Schroer in hep-th/9908021: "... any compactly localized operator applied to the vacuum generates clouds of pairs of particle/antiparticles ... More specifically it leads to the impossibility of having a local generation of pure one-particle vectors unless the system is interaction-free ...".

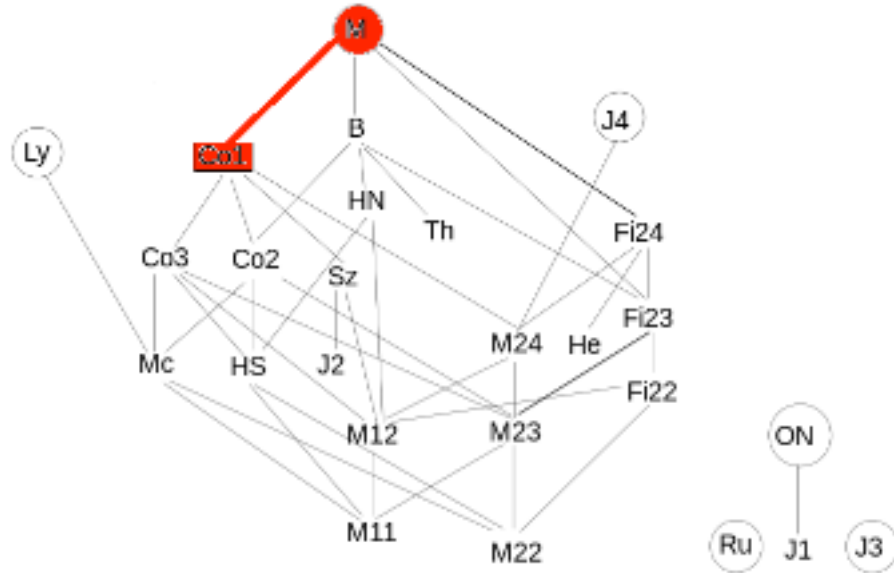
What is the structural form of the Fundamental Fermion Cloud ?

In "**Kerr-Newman [Black Hole] solution as a Dirac particle**", hep-th/0210103, H. I. Arcos and J. G. Pereira say: "... For $m^2 < a^2 + q^2$, with m , a , and q respectively the source mass, angular momentum per unit mass, and electric charge, the Kerr-Newman (KN) solution of Einstein's equation reduces to a naked singularity of circular shape, enclosing a disk across which the metric components fail to be smooth ... due to its topological structure, the extended KN spacetime does admit states with half-integral angular momentum. ... The state vector ... evolution is ... governed by the Dirac equation. ... for symmetry reasons, the electric dipole moment of the KN solution vanishes identically, a result that is within the limits of experimental data ... a and m are thought of as parameters of the KN solution, which only asymptotically correspond respectively to angular momentum per unit mass and mass. Near the singularity, a represents the radius of the singular ring ... With ... renormalization ... for the usual scattering energies, the resulting radius is below the experimental limit for the extendedness of the electron ...".

What is the size of the Fundamental Fermion Kerr-Newman Cloud ?

The FFKN Cloud is one Planck-scale Fundamental Fermion Valence Particle plus an effectively neutral cloud of particle/antiparticle pairs. The symmetry of the cloud is governed by the 24-dimensional Leech lattice by which the Single Cell was formed.

Here (adapted from Wikipedia) is a chart of the Monster M and its relation to other Sporadic Finite Groups and some basic facts and commentary:



The largest such subgroups of M are B, Fi24, and Co1.

B, the Baby Monster, is sort of like a downsized version of M, as B contains Co2 and Fi23 while M contains Co1 and Fi24.

Fi24 (more conventionally denoted Fi_{24}') is of order $1255205709190661721292800 = 1.2 \times 10^{24}$. It is the centralizer of an element of order 3 in the monster group M and is a triple cover of a 3-transposition group. It may be that Fi_{24}' symmetry has its origin in the Triality of E8 26-dim String Theory.

The order of Co1 is $2^{21} \cdot 3^9 \cdot 5^4 \cdot 7^2 \cdot 11 \cdot 13 \cdot 23$ or about 4×10^{18} .

$\text{Aut}(\text{Leech Lattice}) = \text{double cover of Co1}$.

The order of the double cover $2 \cdot \text{Co1}$ is $2^{22} \cdot 3^9 \cdot 5^4 \cdot 7^2 \cdot 11 \cdot 13 \cdot 23$ or about 0.8×10^{19} .

Taking into account the non-sporadic part of the Leech Lattice symmetry

according to the ATLAS at brauer.maths.qmul.ac.uk/Atlas/v3/spor/M/

the maximal subgroup of M involving Co1 is $2^{(1+24)} \cdot \text{Co1}$ of order

$139511839126336328171520000 = 1.4 \times 10^{26}$

As $2 \cdot \text{Co1}$ is the Automorphism group of the Leech Lattice modulo to which the Single Cell was formed, and as

the E8 26-dim String Theory Leech Lattice is a superposition of 8 Leech Lattices, $8 \times 2^{(1+24)} \cdot \text{Co1}$ describes the structure of the FFKN Cloud. Therefore,

the volume of the FFKN Cloud should be on the order of $10^{27} \times \text{Planck scale}$, and

the FFKN Cloud should contain on the order of 10^{27} particle/antiparticle pairs

and **its size should be somewhat larger than, but roughly similar to,**

$10^{(27/3)} \times 1.6 \times 10^{(-33)} \text{ cm} = \text{roughly } 10^{(-24)} \text{ cm}$.

The full 26-dimensional Lattice Bosonic String Theory can be regarded as an infinite-dimensional Affinization of the Theory of c Single Cell.

James Lepowsky said in math.QA/0706.4072:

"... the Fischer-Griess Monster M ... was constructed by Griess as a symmetry group (of order about 10^{54}) of a remarkable new commutative but very, very highly nonassociative, seemingly ad-hoc, algebra B of dimension 196,883. The "structure constants" of the Griess algebra B were "forced" by expected properties of the conjectured-to-exist Monster. It was proved by J. Tits that M is actually the full symmetry group of B

There should exist a (natural) infinite-dimensional Z -graded module for M (i.e., representation of M)

$$V = \text{DIRSUM}(n=-1,0,1,2,3,\dots) V_n \dots$$

such that

$$\dots \text{ the graded dimension of the graded vector space } V \dots = \dots \text{SUM}(n=-1,0,1,2,3,\dots) (\dim V_n) q^n$$

where

$J(q) = q^{-1} + 0 + 196884q + \text{higher-order terms}$,
the classical modular function with its constant term set to 0. $J(q)$ is the suitably normalized generator of the field of $SL(2, Z)$ -modular invariant functions on the upper half-plane, with $q = \exp(2\pi i \tau)$, τ in the upper half-plane ...

Conway and Norton conjectured ... for every g in M (not just $g = 1$), the the generating function

$$\dots \text{ the graded trace of the action of } g \text{ on the graded space } V \dots = \dots \text{SUM}(n=-1,0,1,2,3,\dots) (\text{tr } g | V_n) q^n$$

should be the analogous "Hauptmodul" for a suitable discrete subgroup of $SL(2, R)$, a subgroup having a fundamental "genus-zero property," so that its associated field of modular-invariant functions has a single generator (a Hauptmodul) ... (... the graded dimension is of course the graded trace of the identity element $g = 1$.) The Conway-Norton conjecture subsumed a remarkable coincidence that had been noticed earlier

- that **the 15 primes giving rise to the genus-zero property ... are precisely the primes dividing the order of the ... Monster ...**

the McKay-Thompson conjecture ... that there should exist a natural ... infinite-dimensional \mathbb{Z} -graded M -module V whose graded dimension is $J(q)$... was (constructively) proved The graded traces of some, but not all, of the elements of the Monster - the elements of an important subgroup of M , namely, a certain involution centralizer involving the largest Conway sporadic group Co_1 - were consequences of the construction, and these graded traces were indeed (suitably) modular functions ... We called this V "**the moonshine module $V[\text{flat}]$ "** ...

The construction ... needed ... a natural infinite-dimensional "affinization" of the Griess algebra B acting on $V[\text{flat}]$

This "affinization," which was part of the new algebra of vertex operators, is analogous to, but more subtle than, the notion of affine Lie algebra More precisely, the vertex operators were needed for a "commutative affinization" of a certain natural 196884-dimensional enlargement B' of B , with an identity element (rather than a "zero" element) adjoined to B . This enlargement B' naturally incorporated the Virasoro algebra - the central extension of the Lie algebra of formal vector fields on the circle - acting on $V[\text{flat}]$...

The vertex operators were also needed for a natural "lifting" of Griess's action of M from the finite-dimensional space B to the infinite-dimensional structure $V[\text{flat}]$, including its algebra of vertex operators and its copy of the affinization of B' .

Thus the Monster was now realized as the symmetry group of a certain explicit "algebra of vertex operators" based on an infinite-dimensional \mathbb{Z} -graded structure whose graded dimension is the modular function $J(q)$.

Griess's construction of B and of M acting on B was a crucial guide for us, although we did not start by using his construction; rather, we recovered it, as a finite-dimensional "slice" of a new infinite-dimensional construction using vertex operator considerations. ...

The initially strange-seeming finite-dimensional Griess algebra was now embedded in a natural new infinite-dimensional space on which a certain algebra of vertex operators acts ... At the same time, the Monster, a finite group, took on a new appearance by now being understood in terms of a natural infinite-dimensional

structure. ... the largest sporadic finite simple group, the Monster, was "really" infinite-dimensional ...

The very-highly-nonassociative Griess algebra, or rather, from our viewpoint, the natural modification of the Griess algebra, with an identity element adjoined, coming from a "forced" copy the Virasoro algebra, became simply the conformal-weight-two subspace of an algebra of vertex operators of a certain "shape." ...

the constant term of $J(q)$ is zero, and this choice of constant term, which is not uniquely determined by number-theoretic principles, is not traditional in number theory. It turned out that the vanishing of the constant term ... was canonically "forced" by the requirement that the Monster should act naturally on $V[\text{flat}]$ and on an associated algebra of vertex operators.

This vanishing of the degree-zero subspace of $V[\text{flat}]$ is actually analogous in a certain strong sense to the absence of vectors in the Leech lattice of square-length two; the Leech lattice is a distinguished rank-24 even unimodular (self-dual) lattice with no vectors of square-length two.

In addition, this vanishing of the degree-zero subspace of $V[\text{flat}]$ and the absence of square-length-two elements of the Leech lattice are in turn analogous to the absence of code-words of weight 4 in the Golay error-correcting code, a distinguished self-dual binary linear code on a 24-element set, with the lengths of all code-words divisible by 4. In fact, the Golay code was used in the original construction of the Leech lattice, and the Leech lattice was used in the construction of $V[\text{flat}]$

This was actually to be expected ... because it was well known that the automorphism groups of both the Golay code and the Leech lattice are (essentially) sporadic finite simple groups; the automorphism group of the Golay code is the Mathieu group M_{24} and the automorphism group of the Leech lattice is a double cover of the Conway group Co_1 mentioned above, and both of these sporadic groups were well known to be involved in the Monster ... in a fundamental way...

The Golay code is actually unique subject to its distinguishing properties mentioned above ... and **the Leech lattice is unique** subject to its distinguishing properties mentioned above ... **Is $V[\text{flat}]$ unique? If so, unique subject to what? ... this uniqueness is an unsolved problem ...**

$V[\text{flat}]$ came to be viewed in retrospect by string theorists as an inherently string-theoretic structure: the "chiral algebra" underlying the Z_2 -orbifold conformal field theory based on the Leech lattice.

The string-theoretic geometry is this: One takes the torus that is the quotient of 24-dimensional Euclidean space modulo the Leech lattice, and then one takes the quotient of this manifold by the "negation" involution $x \rightarrow -x$, giving rise to an orbit space called an "orbifold"—a manifold with, in this case, a "conical" singularity. Then one takes the "conformal field theory" (presuming that it exists mathematically) based on this orbifold, and from this one forms a "string theory" in two-dimensional space-time by compactifying a 26-dimensional "bosonic string" on this 24-dimensional orbifold. The string vibrates in a 26-dimensional space, 24 dimensions of which are curled into this 24-dimensional orbifold ...

Borcherds used ... ideas, including his results on generalized Kac-Moody algebras, also called Borcherds algebras, together with certain ideas from string theory, including the "physical space" of a bosonic string along with the "no-ghost theorem" ... to prove the remaining Conway-Norton conjectures for the structure $V[\text{flat}]$... What had remained to prove was ... that ... the conjugacy classes outside the involution centralizer - were indeed the desired Hauptmoduls ... He accomplished this by constructing a copy of his "Monster Lie algebra" from the "physical space" associated with $V[\text{flat}]$ enlarged to a central-charge-26 vertex algebra closely related to the 26-dimensional bosonic-string structure mentioned above. He transported the known action of the Monster from $V[\text{flat}]$ to this copy of the Monster Lie algebra, and ... he proved certain recursion formulas ... he succeeded in concluding that all the graded traces for $V[\text{flat}]$ must coincide with the formal series for the Hauptmoduls ...

this vertex operator algebra $V[\text{flat}]$ has the following three simply-stated properties ...

- (1) $V[\text{flat}]$, which is an irreducible module for itself ... , is its only irreducible module, up to equivalence ... every module for the vertex operator algebra $V[\text{flat}]$ is completely reducible and is in particular a direct sum of copies of itself. Thus the vertex operator algebra $V[\text{flat}]$ has no more representation theory than does a field! (I mean a field in the sense of mathematics, not physics. Given a field, every one of its modules - called vector spaces, of course - is completely reducible and is a direct sum of copies of itself.)
- (2) $\dim V[\text{flat}]_0 = 0$. This corresponds to the zero constant term of $J(q)$; while the constant term of the classical modular function is essentially

arbitrary, and is chosen to have certain values for certain classical number-theoretic purposes, the constant term must be chosen to be zero for the purposes of moonshine and the moonshine module vertex operator algebra.

- (3) The central charge of the canonical Virasoro algebra in $V[\text{flat}]$ is 24. "24" is the "same 24" so basic in number theory, modular function theory, etc. As mentioned above, this occurrence of 24 is also natural from the point of view of string theory.

These three properties are actually "smallness" properties in the sense of conformal field theory and string theory. These properties allow one to say that $V[\text{flat}]$ essentially defines the smallest possible nontrivial string theory ... (These "smallness" properties essentially amount to: "no nontrivial representation theory," "no nontrivial gauge group," i.e., "no continuous symmetry," and "no nontrivial monodromy"; this last condition actually refers to both the first and third "smallness" properties.)

Conversely, conjecturally ... $V[\text{flat}]$ is the unique vertex operator algebra with these three "smallness" properties (up to isomorphism). This conjecture ... remains unproved. It would be the conformal-field-theoretic analogue of the uniqueness of the Leech lattice in sphere-packing theory and of the uniqueness of the Golay code in error-correcting code theory ...

Proving this uniqueness conjecture can be thought of as the "zeroth step" in the program of classification of (reasonable classes of) conformal field theories. M. Tuite has related this conjecture to the genus-zero property in the formulation of monstrous moonshine.

Up to this conjecture, then, we have the following remarkable characterization of the largest sporadic finite simple group: **The Monster is the automorphism group of the smallest nontrivial string theory that nature allows ... Bosonic 26-dimensional space-time ... "compactified" on 24 dimensions, using the orbifold construction $V[\text{flat}]$...** or more precisely, the automorphism group of the vertex operator algebra with the canonical "smallness" properties. ...

This definition of the Monster in terms of "smallness" properties of a vertex operator algebra provides a remarkable motivation for the definition of the precise notion of vertex (operator) algebra. The discovery of string theory (as a mathematical, even if not necessarily physical) structure sooner or later must lead naturally to the question of whether this "smallest" possible nontrivial vertex operator algebra V exists, and the question of what its symmetry group (which turns out to be the largest sporadic finite simple group) is.

And on the other hand, the classification of the the finite simple groups - a mathematical problem of the absolutely purest possible sort - leads naturally to the question of what natural structure the largest sporadic group is the symmetry group of; the answer entails the development of string theory and vertex operator algebra theory (and involves modular function theory and monstrous moonshine as well).

The Monster, a singularly exceptional structure - in the same spirit that the Lie algebra E_8 is "exceptional," though M is far more "exceptional" than E_8 - helped lead to, and helps shape, the very general theory of vertex operator algebras. (The exceptional nature of structures such as E_8 , the Golay code and the Leech lattice in fact played crucial roles in the construction of $V[\text{flat}]$...

$V[\text{flat}]$ is defined over the field of real numbers, and in fact over the field of rational numbers, in such a way that the Monster preserves the real and in fact rational structure, and that the Monster preserves a rational-valued positive-definite symmetric bilinear form on this rational structure. ...

the "orbifold" construction of $V[\text{flat}]$...[has been]... interpreted in terms of algebraic quantum field theory, specifically, in terms of local conformal nets of von Neumann algebras on the circle ...

the notion of vertex operator algebra is actually the "one-complex-dimensional analogue" of the notion of Lie algebra. But at the same time that it is the "one-complex-dimensional analogue" of the notion of Lie algebra, the notion of vertex operator algebra is also the "one-complex-dimensional analogue" of the notion of commutative associative algebra (which again is the corresponding "one-real-dimensional" notion). ... This analogy with the notion of commutative associative algebra comes from the "commutativity" and "associativity" properties of the vertex operators ... in a vertex operator algebra ...

The remarkable and paradoxical-sounding fact that the notion of vertex operator algebra can be, and is, the "one-complex-dimensional analogue" of BOTH the notion of Lie algebra AND the notion of commutative associative algebra lies behind much of the richness of the whole theory, and of string theory and conformal field theory.

When mathematicians realized a long time ago that complex analysis was qualitatively entirely different from real analysis (because of the uniqueness of analytic continuation, etc., etc.), a whole new point of view became possible. In vertex operator algebra theory and string theory, there is again a fundamental passage from "real" to "complex," this time leading from the concepts of both Lie

algebra and commutative associative algebra to the concept of vertex operator algebra and to its theory, and also leading from point particle theory to string theory. ...

While a string sweeps out a two-dimensional (or, as we've been mentioning, one-complex-dimensional) "worldsheet" in space-time, **a point particle of course sweeps out a one-real-dimensional "world-line"** in space-time, with time playing the role of the "one real dimension," and this "one real dimension" is related in spirit to the "one real dimension" of the classical operads that I've briefly referred to - the classical operads "mediating" the notion of associative algebra and also the notion of Lie algebra (and indeed, any "classical" algebraic notion), and in addition "mediating" the classical notion of braided tensor category. The "sequence of operations performed one after the other" is related (not perfectly, but at least in spirit) to the ordering ("time-ordering") of the real line.

But as we have emphasized, the "algebra" of vertex operator algebra theory and also of its representation theory (vertex tensor categories, etc.) is "mediated" by an (essentially) one-complex-dimensional (analytic partial) operad (or more precisely, as we have mentioned, the infinite-dimensional analytic structure built on this). When one needs to compose vertex operators, or more generally, intertwining operators, after the formal variables are specialized to complex variables, one must choose not merely a (time-)ordered sequencing of them, but instead, a suitable complex number, or more generally, an analytic local coordinate as well, for each of the vertex operators.

This process, very familiar in string theory and conformal field theory, is a reflection of how the one-complex-dimensional operadic structure "mediates" the algebraic operations in vertex operator algebra theory.

Correspondingly, "algebraic" operations in this theory are not intrinsically "time-ordered"; they are instead controlled intrinsically by the one-complex-dimensional operadic structure. The "algebra" becomes intrinsically geometric.

"Time," or more precisely, as we discussed above, the one-real-dimensional world-line, is being replaced by a one-complex-dimensional world-sheet.

This is the case, too, for the vertex tensor category structure on suitable module categories. In vertex operator algebra theory, "algebra" is more concerned with one-complex-dimensional geometry than with one-real-dimensional time. ...".

Coleman-Mandula:

Steven Weinberg said at pages 382-384 of his book
The Quantum Theory of Fields, Vol. III (Cambridge 2000):
"... The proof of the Coleman-Mandula theorem ... makes it clear
that the list of possible bosonic symmetry generators is essentially the same
in d greater than 2 spacetime dimensions as in four spacetime dimensions:

...

there are only the momentum d -vector P_u , a Lorentz generator $J_{uv} = -J_{vu}$
(with u and v here running over the values $1, 2, \dots, d-1, 0$), and various
Lorentz scalar 'charges' ...

the fermionic symmetry generators furnish a representation of the
homogeneous Lorentz group ... or, strictly speaking, of its covering group
 $\text{Spin}(d-1,1)$

The anticommutators of the fermionic symmetry generators with each other
are bosonic symmetry generators, and therefore must be a linear
combination of the P_u , J_{uv} , and various conserved scalars. ...

the general fermionic symmetry generator must transform according to the
fundamental spinor representations of the Lorentz group ...

and not in higher spinor representations,
such as those obtained by adding vector indices to a spinor. ...".

In short, the important thing about Coleman-Mandula is that fermions in a unified
model must "... transform according to the fundamental spinor representations of
the Lorentz group ... or, strictly speaking, of its covering group $\text{Spin}(d-1,1)$"
where d is the dimension of spacetime in the model.

In my E8 Physics model, E8 is the sum of
the adjoint representation and a half-spinor representation of $\text{Spin}(16)$,
and

the $\text{Spin}(16)$ structure (since $\text{Cl}(16) = \text{Cl}(8) \times \text{Cl}(8)$) leads
to $\text{Spin}(8)$ or $\text{Spin}(1,7)$ structure with Triality automorphisms among
8-dim spacetime vectors and the two 8-dim half-spinors

and

the fermionic fundamental spinor representations of the E8 model are
therefore built with respect to Lorentz, spinor, etc representations based on
 $\text{Spin}(1,7)$ spacetime consistently with Weinberg's work,

so

the E8 model is consistent with Coleman-Mandula.

Mayer-Trautman Mechanism:

The objective is to reduce the integral over the 8-dim Kaluza-Klein $M_4 \times CP^2$ to an integral over the 4-dim M_4 .

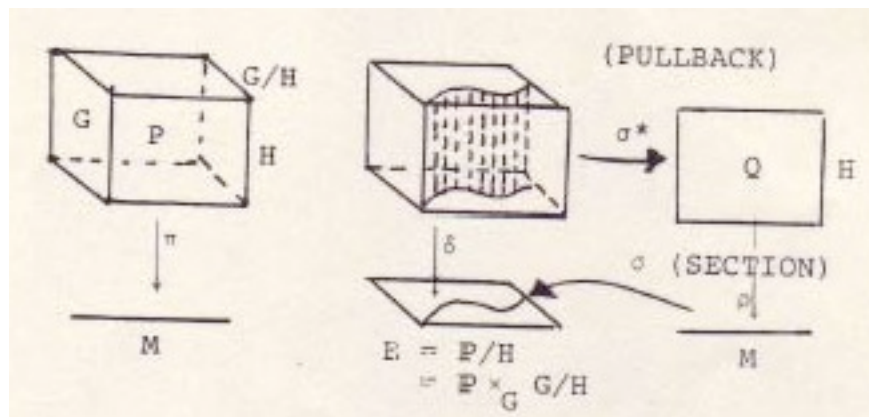
Since the $D_4 = U(2,2)$ acts on the M_4 , there is no problem with it.
 Since the $CP^2 = SU(3) / U(2)$ has global $SU(3)$ action, the $SU(3)$ can be considered as a local gauge group acting on the M_4 , so there is no problem with it.

However, the $U(2)$ acts on the $CP^2 = SU(3) / U(2)$ as little group, and so has local action on CP^2 and then on M_4 , so the local action of $U(2)$ on CP^2 must be integrated out to get the desired $U(2)$ local action directly on M_4 .

Since the $U(1)$ part of $U(2) = U(1) \times SU(2)$ is Abelian, its local action on CP^2 and then M_4 can be composed to produce a single $U(1)$ local action on M_4 , so there is no problem with it.

That leaves non-Abelian $SU(2)$ with local action on CP^2 and then on M_4 , and the necessity to integrate out the local CP^2 action to get something acting locally directly on M_4 .

This is done by a mechanism due to Meinhard Mayer and A. Trautman in “A Brief Introduction to the Geometry of Gauge Fields” and “The Geometry of Symmetry Breaking in Gauge Theories”, Acta Physica Austriaca, Suppl. XXIII (1981) where they say:
 "...



... We start out from ... four-dimensional M [M_4] ...[and]... R ...[that is]... obtained from ... G/H [$CP^2 = SU(3) / U(2)$] ... the physical surviving components of A and F , which we will denote by A and F , respectively, are a one-form and two form on

M [M4] with values in H [SU(2)] ... the remaining components will be subjected to symmetry and gauge transformations, thus reducing the Yang-Mills action ... [on M4 x CP2]... to a Yang-Mills-Ginzburg-Landau action on M [M4] ... Consider the Yang-Mills action on R ...

$$S_{YM} = \text{Integral Tr} (F \wedge *F)$$

... We can ... split the curvature F into components along M [M4] (spacetime) and those along directions tangent to G/H [CP2] .

We denote the former components by $F_{\mu\nu}$ and the latter by F_{ab} , whereas the mixed components (one along M, the other along G/H) will be denoted by $F_{\mu a}$... Then the integrand ... becomes

$$\text{Tr} (F_{\mu\nu} F^{\mu\nu} + 2 F_{\mu a} F^{a\mu} + F_{ab} F^{ab})$$

...

The first term .. becomes the [SU(2)] Yang-Mills action for the reduced [SU(2)] Yang-Mills theory

...

the middle term .. becomes, symbolically,

$$\text{Tr} \text{Sum} D_{\mu} \text{PHI}(?) D^{\mu} \text{PHI}(?)$$

where $\text{PHI}(?)$ is the Lie-algebra-valued 0-form corresponding to the invariance of A with respect to the vector field ξ , in the G/H [CP2] direction

...

the third term ... involves the contraction $F_{\mu\nu}$ of F with two vector fields lying along G/H [CP2] ... we make use of the equation [from Mayer-Trautman, Acta Physica Austriaca, Suppl. XXIII (1981) 433-476, equation 6.18]

$$2 F_{\mu\nu} = [\text{PHI}(?) , \text{PHI}(?)] - \text{PHI}([\xi, \xi])$$

... Thus,

the third term ... reduces to what is essentially a Ginzburg-Landau potential in the components of PHI :

$$\text{Tr} F_{\mu\nu} F^{\mu\nu} = (1/4) \text{Tr} ([\text{PHI} , \text{PHI}] - \text{PHI})^2$$

... special cases which were considered show that ... [the equation immediately above]... has indeed the properties required of a Ginzburg-Landau-Higgs potential, and moreover the relative signs of the quartic and quadratic terms are correct, and only one overall normalization constant ... is needed. ...".

See S. Kobayashi and K. Nomizu, Foundations of Differential Geometry, Volume I, Wiley (1963), especially section II.11:

“ ...

THEOREM 11.7. *Assume in Theorem 11.5 that \mathfrak{k} admits a subspace \mathfrak{m} such that $\mathfrak{k} = \mathfrak{j} + \mathfrak{m}$ (direct sum) and $\text{ad}(J)(\mathfrak{m}) = \mathfrak{m}$, where $\text{ad}(J)$ is the adjoint representation of J in \mathfrak{k} . Then ...*

The curvature form Ω of the K -invariant connection defined by $\Lambda_{\mathfrak{m}}$ satisfies the following condition:

$$2\Omega_{u_0}(\tilde{X}, \tilde{Y}) = [\Lambda_{\mathfrak{m}}(X), \Lambda_{\mathfrak{m}}(Y)] - \Lambda_{\mathfrak{m}}([X, Y]_{\mathfrak{m}}) - \lambda([X, Y]_{\mathfrak{j}})$$

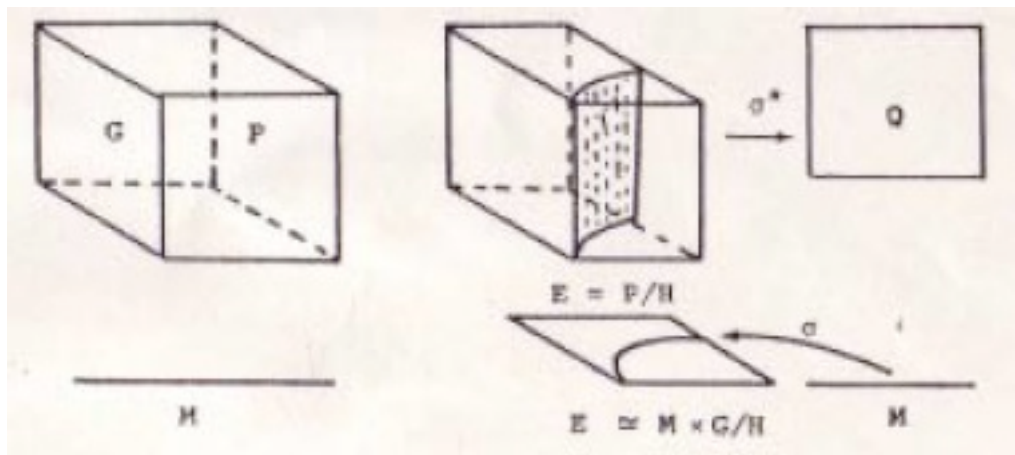
for $X, Y \in \mathfrak{m}$,

...”

Along the same lines,

Meinhard E. Mayer said (Hadronic Journal 4 (1981) 108-152):

“ ...



... each point of ... the ... fibre bundle ... E consists of a four-dimensional spacetime point x [in M_4] to which is attached the homogeneous space G/H [$SU(3)/U(2) = CP^2$] ... the components of the curvature lying in the homogeneous space G/H [$= SU(3)/U(2)$] could be reinterpreted as Higgs scalars (with respect to spacetime [M_4]) ...

the Yang-Mills action reduces to a Yang-Mills action for the h -components [$U(2)$ components] of the curvature over M [M_4] and a quartic functional for the “Higgs scalars”, which not only reproduces the Ginzburg-Landau potential, but also gives the correct relative sign of the constants, required for the BEHK ... Brout-Englert-Higgs-Kibble ... mechanism to work. ...”.

MacDowell-Mansouri Mechanism:

Rabindra Mohapatra (in section 14.6 of Unification and Supersymmetry, 2nd edition, Springer-Verlag 1992) says:

§14.6. Local Conformal Symmetry and Gravity

Before we study supergravity, with the new algebraic approach developed, we would like to discuss how gravitational theory can emerge from the gauging of conformal symmetry. For this purpose we briefly present the general notation for constructing gauge covariant fields. The general procedure is to start with the Lie algebra of generators X_A of a group

$$[X_A, X_B] = f_{AB}^C X_C, \quad (14.6.1)$$

where f_{AB}^C are structure constants of the group. We can then introduce a gauge field connection h_μ^A as follows:

$$h_\mu = h_\mu^A X_A. \quad (14.6.2)$$

Let us denote the parameter associated with X_A by ε^A . The gauge transformations on the fields h_μ^A are given as follows:

$$\delta h_\mu^A = \partial_\mu \varepsilon^A + h_\mu^B \varepsilon^C f_{CB}^A = (D_\mu \varepsilon)^A. \quad (14.6.3)$$

We can then define a covariant curvature

$$R_{\mu\nu}^A = \partial_\nu h_\mu^A - \partial_\mu h_\nu^A + h_\nu^B h_\mu^C f_{CB}^A. \quad (14.6.4)$$

Under a gauge transformation

$$\delta_{\text{gauge}} R_{\mu\nu}^A = R_{\mu\nu}^B \varepsilon^C f_{CB}^A. \quad (14.6.5)$$

We can then write the general gauge invariant action as follows:

$$I = \int d^4x Q_{\mu\nu}^{\alpha\beta\gamma} R_{\mu\nu}^A R_{\alpha\beta}^B R_{\gamma\sigma}^C. \quad (14.6.6)$$

Let us now apply this formalism to conformal gravity. In this case

$$h_\mu = P_\mu e_\nu^\alpha + M_{\alpha\beta} \omega_\mu^{\alpha\beta} + K_\alpha f_\mu^\alpha + D b_\mu. \quad (14.6.7)$$

The various $R_{\mu\nu}$ are

$$R_{\mu\nu}(P) = \partial_\nu e_\mu^\alpha - \partial_\mu e_\nu^\alpha + \omega_\mu^{\alpha\beta} e_\nu^\beta - \omega_\nu^{\alpha\beta} e_\mu^\beta - b_\mu e_\nu^\alpha + b_\nu e_\mu^\alpha, \quad (14.6.8)$$

$$R_{\mu\nu}(M) = \partial_\nu \omega_\mu^{\alpha\beta} - \partial_\mu \omega_\nu^{\alpha\beta} - \omega_\nu^{\alpha\gamma} \omega_\mu^\beta{}_\gamma + \omega_\mu^{\alpha\gamma} \omega_\nu^\beta{}_\gamma - 4(e_\mu^\alpha f_\nu^\beta - e_\nu^\alpha f_\mu^\beta), \quad (14.6.9)$$

$$R_{\mu\nu}(K) = \partial_\nu f_\mu^\alpha - \partial_\mu f_\nu^\alpha - b_\mu f_\nu^\alpha + b_\nu f_\mu^\alpha + \omega_\mu^{\alpha\beta} f_\nu^\beta - \omega_\nu^{\alpha\beta} f_\mu^\beta, \quad (14.6.10)$$

$$R_{\mu\nu}(D) = \partial_\nu b_\mu - \partial_\mu b_\nu + 2e_\mu^\alpha f_\nu^\alpha - 2e_\nu^\alpha f_\mu^\alpha. \quad (14.6.11)$$

The gauge invariant Lagrangian for the gravitational field can now be written down, using eqn. (14.6.6), as

$$S = \int d^4x \varepsilon_{\alpha\beta\gamma\delta} e^{\alpha\mu\nu} R_{\mu\nu}^{\alpha\beta}(M) R_{\mu\nu}^{\gamma\delta}(M). \quad (14.6.12)$$

We also impose the constraint that

$$R_{\mu\nu}(P) = 0, \quad (14.6.13)$$

which expresses ω_a^{mn} as a function of (e, b) . The reason for imposing this constraint has to do with the fact that P_a transformations must be eventually identified with coordinate transformation. To see this point more explicitly let us consider the vierbein e_a^μ . Under coordinate transformations

$$\delta_{GC}(\xi^\nu)e_a^\mu = \partial_\nu \xi^\lambda e_\lambda^\mu + \xi^\lambda \partial_\lambda e_a^\mu. \quad (14.6.14)$$

Using eqn. (14.6.8) we can rewrite

$$\delta_{GC}(\xi^\nu)e_a^\mu = \delta_P(\xi^\nu)e_a^\mu + \delta_M(\xi^\nu\omega^{mn})e_a^\mu + \delta_D(\xi^\nu b) e_a^\mu + \xi^\nu R_{\nu a}^\mu(P),$$

where

$$\delta_P(\xi^\nu)e_a^\mu = \partial_\nu \xi^\mu + \xi^\nu \omega_a^{\mu\nu} + \xi^{\mu\nu} b_\nu. \quad (14.6.15)$$

If $R^{\mu\nu}(P) = 0$, the general coordinate transformation becomes related to a set of gauge transformations via eqn. (14.6.15).

At this point we also wish to point out how we can define the covariant derivative. In the case of internal symmetries $D_\mu = \partial_\mu - iX_A h_\mu^A$; now since momentum is treated as an internal symmetry we have to give a rule. This follows from eqn. (14.6.15) by writing a redefined translation generator \tilde{P} such that

$$\delta_{\tilde{P}}(\xi) = \delta_{GC}(\xi^\nu) - \sum_{A'} \delta_{A'}(\xi^{\mu\nu} h_\mu^A), \quad (14.6.16)$$

where A' goes over all gauge transformations excluding translation. The rule is

$$\delta_{\tilde{P}}(\xi^{\mu\nu})\phi = \xi^{\mu\nu} D_\mu^C \phi. \quad (14.6.17)$$

We also wish to point out that for fields which carry spin or conformal charge, only the intrinsic parts contribute to D_μ^C and the orbital parts do not play any role.

Coming back to the constraints we can then vary the action with respect to f_a^μ to get an expression for it, i.e.,

$$e_a^\mu f_{a\mu} = -\frac{1}{4}[e_a^\lambda e_{\lambda a} R_{\lambda\lambda}^{\mu\mu} - \frac{1}{2}g_{\mu\nu} R], \quad (14.6.18)$$

where f_a^μ has been set to zero in R written in the right-hand side.

This eliminates (from the theory the degrees of freedom) ω_a^{mn} and f_a^μ and we are left with e_a^μ and b_μ . Furthermore, these constraints will change the transformation laws for the dependent fields so that the constraints do not change.

Let us now look at the matter coupling to see how the familiar gravity theory emerges from this version. Consider a scalar field ϕ . It has conformal weight $\lambda = 1$. So we can write a covariant derivative for it, eqn. (14.6.17)

$$D_\mu^C \phi = \partial_\mu \phi - \phi b_\mu. \quad (14.6.19)$$

We note that the conformal charge of ϕ can be assumed to be zero since $K_\mu = x^2 \partial$ and is the dimension of inverse mass. In order to calculate $\square^C \phi$ we

start with the expression for d'Alembertian in general relativity

$$\frac{1}{e} \partial_\nu (g^{\mu\nu} e D_\mu^c \phi). \quad (14.6.20)$$

The only transformations we have to compensate for are the conformal transformations and the scale transformations. Since

$$\delta b_\alpha = -2\xi_k^\alpha e_{\mu\alpha}, \quad \delta(\phi b_\alpha) = \phi \delta b_\alpha = -2\phi f_\mu^\alpha e_\alpha^\mu = +\frac{\lambda}{12} \phi R, \quad (14.6.21)$$

where, in the last step, we have used the constraint equation (14.6.18). Putting all these together we find

$$\square^c \phi = \frac{1}{e} \partial_\nu (g^{\mu\nu} e D_\mu^c \phi) + b_\alpha D_\alpha^c \phi + \frac{\lambda}{12} \phi R. \quad (14.6.22)$$

Thus, the Lagrangian for conformal gravity coupled to matter fields can be written as

$$S = \int e d^4x \frac{1}{2} \phi \square^c \phi. \quad (14.6.23)$$

Now we can use conformal transformation to gauge $b_\alpha = 0$ and local scale transformation to set $\phi = \kappa^{-1}$ leading to the usual Hilbert action for gravity. To summarize, we start with a Lagrangian invariant under full local conformal symmetry and fix conformal and scale gauge to obtain the usual action for gravity. We will adopt the same procedure for supergravity. An important technical point to remember is that, \square^c , the conformal d'Alembertian contains R , which for constant ϕ , leads to gravity. We may call ϕ the auxiliary field.

After the scale and conformal gauges have been fixed, the conformal Lagrangian becomes a de Sitter Lagrangian. Einstein-Hilbert gravity can be derived from the de Sitter Lagrangian, as was first shown by **MacDowell and Mansouri (Phys. Rev. Lett. 38 (1977) 739)**. (Note that Frank Wilczek, in [hep-th/9801184](https://arxiv.org/abs/hep-th/9801184), says that the MacDowell-Mansouri "... approach to casting gravity as a gauge theory was initiated by MacDowell and Mansouri ... S. MacDowell and F. Mansouri, Phys. Rev. Lett. 38 739 (1977) ... , and independently Chamseddine and West ... A. Chamseddine and P. West Nucl. Phys. B 129, 39 (1977); also quite relevant is A. Chamseddine, Ann. Phys. 113, 219 (1978). ...".

The minimal group required to produce Gravity, and therefore the group that is used in calculating Force Strengths, is the de Sitter group, as is described by Freund in chapter 21 of his book Supersymmetry (Cambridge 1986) (Note that chapter 21 is a Non-Supersymmetry chapter leading up to a Supergravity description in the following chapter 22):

"... Einstein gravity as a gauge theory ... we expect a set of gauge fields w^{ab}_u for the Lorentz group and a further set e^a_u for the translations, ...

Everybody knows though, that Einstein's theory contains but one spin two field, originally chosen by Einstein as $g_{uv} = e^a_u e^b_v \eta_{ab}$

(n_{ab} = Minkowski metric).

What happened to the w^{ab}_u ?

The field equations obtained from the Hilbert-Einstein action by varying the w^{ab}_u are algebraic in the w^{ab}_u ... permitting us to express the w^{ab}_u in terms of the e^a_u

...

The w do not propagate ...

We start from the four-dimensional de-Sitter algebra ... $so(3,2)$.

Technically this is the anti-de-Sitter algebra ...

We envision space-time as a four-dimensional manifold M .

At each point of M we have a copy of $SO(3,2)$ (a fibre ...) ...

and we introduce the gauge potentials (the connection) $h^A_\mu(x)$

$A = 1, \dots, 10$, $\mu = 1, \dots, 4$. Here x are local coordinates on M .

From these potentials h^A_μ we calculate the field-strengths

(curvature components) [let $@$ denote partial derivative]

$R^A_{\mu\nu} = @_\mu h^A_\nu - @_\nu h^A_\mu + f^A_{BC} h^B_\mu h^C_\nu$

...[where]...

the structure constants f^C_{AB} ...[are for]... the anti-de-Sitter algebra

We now wish to write down the action S as an integral over

the four-manifold M ... $S(Q) = \text{INTEGRAL}_M R^A \wedge R^B Q_{AB}$

where Q_{AB} are constants ... to be chosen ... we require

... the invariance of $S(Q)$ under local Lorentz transformations

... the invariance of $S(Q)$ under space inversions ...

...[AFTER A LOT OF ALGEBRA THAT I WON'T TYPE HERE]...

we shall see ...[that]... the action becomes invariant under all local [anti]de-Sitter transformations ...[and]... we recognize ... the familiar

Hilbert-Einstein action with cosmological term in vierbein notation ...

Variation of the vierbein leads to the Einstein equations with cosmological term.

Variation of the spin-connection ... in turn ... yield the torsionless Christoffel connection ... the torsion components ... now vanish.

So at this level full $sp(4)$ invariance has been checked.

... Were it not for the assumed space-inversion invariance ...

we could have had a parity violating gravity. ...

Unlike Einstein's theory ...[MacDowell-Mansouri].... does not require Riemannian invertibility of the metric. ... the solution has torsion ... produced by an interference between parity violating and parity conserving amplitudes.

Parity violation and torsion go hand-in-hand.

Independently of any more realistic parity violating solution of the gravity equations this raises the cosmological question whether the universe as a whole is in a space-inversion symmetric configuration. ...".

At this stage, we have reconciled the first 3 of the 4 differences between our E8 Physics Model and conventional Gravity plus the Standard Model. Now we turn attention to

Second and Third Fermion Generations:

As to the existence of 3 Generations of Fermions, note that the 8 First Generation Fermion Particles and the 8 First Generation Fermion AntiParticles can each be represented by the 8 basis elements of the Octonions O, and that the **Second and Third Generations** can be represented by **Pairs of Octonions OxO** and **Triples of Octonions $OxOxO$** respectively.

When the non-unitary Octonionic 8-dim spacetime is reduced to the Kaluza-Klein $M4 \times CP2$ at the End of Inflation, there are 3 possibilities for a fermion propagator from point A to point B:

- 1 - A and B are both in $M4$, so its path can be represented by the single O;
- 2 - Either A or B, but not both, is in $CP2$, so its path must be augmented by one projection from $CP2$ to $M4$, which projection can be represented by a second O, giving a second generation OxO ;
- 3 - Both A and B are in $CP2$, so its path must be augmented by two projections from $CP2$ to $M4$, which projections can be represented by a second O and a third O, giving a third generation $OxOxO$.

E8 Physics Fermions: 3 Conformal Generations

Frank Dodd (Tony) Smith, Jr. - 2012

viXra 1212.0046

The E8 Lie Algebra of the E8 Physics Model contains two D4 Lie subalgebras:

248-dim E8 = 120-dim D8 + 128-dim half-spinor of D8

120-dim D8 = 28-dim D4 + 28-dim D4 + 64-dim D8 / D4xD4

One of the D4 contains an A2 = SU(3) Lie subalgebra that represents the Color Force of the Standard Model.

The Weak and Electromagnetic Forces are produced by a Batakis mechanism

(see Class. Quantum Grav. 3 (1986) L99-L105 by N. A. Batakis) in which spacetime is 8-dimensional Kaluza-Klein M4 x CP2.

Color Force SU(3) acts globally on CP2 = SU(3) / SU(2)xU(1) and,

due to Kaluza-Klein structure, acts as local gauge group on M4 Minkowski spacetime.

Local gauge group action of Weak SU(2) and Electromagnetic U(1) Forces comes from their being local isotropy groups of the symmetric space CP2.

Casimir Operators describe some physical properties of the Standard Model Forces:

A0 Lie algebra U(1) has trivial Weyl Group 1

and trivial Casimir of degree 1

so that the Photon carries no charge.

A1 Lie algebra SU(2) has Weyl Group S2 of order 2! = 2

and quadratic Casimir of degree 2 representing isospin

so that SU(2) Weak Bosons can carry Electromagnetic Charge.

A2 Lie algebra SU(3) has Weyl Group S3 of order 3! = 6

and two Casimir Operators of degrees 2 and 3:

a quadratic Casimir representing 2 { + , - } isospin charge states and

a cubic Casimir representing 3 { red, green, blue } colors

so that SU(3) Gluons can carry Electromagnetic Charge and Color Charge.

The other D4 contains an A3 = D3 Conformal Lie subalgebra that represents

Gravity by a generalized MacDowell-Mansouri mechanism (see section 14.6 of Rabintra Mohapatra's book "Unification and Supersymmetry", 2nd edition, Springer-Verlag 1992).

The Conformal Group in the form SU(2,2) = Spin(2,4) is described by

Robert Gilmore in his books "Lie Groups, Lie Algebras, and Some of Their Applications", Wiley 1974, and "Lie Groups, Physics, and Geometry", Cambridge 2008.

The Conformal Group has a Weyl Group of 2^2 x 3! = 24 elements

and has 3 Casimir Operators of degrees 2 and 4 and 6/2 = 3.

The Conformal degree 3 Casimir represents the 3 Generations of Fermions

(instead of the 3 colors as in the case of the Standard Model D4 of E8).

In its D3 Spin(2,4) form the Conformal Lie algebra can be represented as a 6x6 antisymmetric real matrix:

$$\begin{array}{cccccc}
 0 & J_1 & J_2 & M_1 & A_1 & G_1 \\
 -J_1 & 0 & J_3 & M_2 & A_2 & G_2 \\
 -J_2 & -J_3 & 0 & M_3 & A_3 & G_3 \\
 -M_1 & -M_2 & -M_3 & 0 & A_4 & G_4 \\
 -A_1 & -A_2 & -A_3 & -A_4 & 0 & G_5 \\
 -G_1 & -G_2 & -G_3 & -G_4 & -G_5 & 0
 \end{array}$$

$\{J_1, J_2, J_3\}$ form a Spin(0,3) subalgebra of Spin(2,4) and produce a quadratic Casimir Operator that represents an Angular Momentum Operator.

Adding $\{M_1, M_2, M_3\}$ forms a Spin(1,3) subalgebra of Spin(2,4) and produces a second quadratic Casimir Operator that represents a Laplace-Runge-Lenz Operator.

Adding $\{A_1, A_2, A_3\}$ and $\{A_4\}$ forms a Spin(2,3) AntiDeSitter subalgebra of Spin(2,4) with a quartic Casimir Operator that is a combination of $\{M_1, M_2, M_3\}$ and $\{A_1, A_2, A_3\}$. $\{A_1, A_2, A_3\}$ represent Momentum and $\{A_4\}$ represents Energy/Mass of Poincare Gravity and its Dark Matter Primordial Black Holes.

Adding $\{G_1, G_2, G_3\}$ and $\{G_4\}$ and $\{G_5\}$ forms the full Spin(2,4) and produces a cubic Casimir Operator for representation of 3 Generations of Fermions. The $\{G_1, G_2, G_3\}$ represent 3 Higgs components giving mass to 3 Weak Bosons. and $\{G_4\}$ represents massive Higgs Scalar as Fermion Condensate. As Special Conformal and Scale degrees of freedom they also represent the Momentum of Expansion of the Universe and its Dark Energy.

Adding $\{G_5\}$ represents Higgs/Fermion mass of Ordinary Matter.

The Higgs as a Fermionic Condensate gives mass to Fermions. The fundamental Fermion Particles are those of the First Generation:

{neutrino, red down quark, green down quark, blue down quark;
electron, red up quark, green up quark, blue up quark}

They can be represented as basis elements $\{1, i, j, k, E, I, J, K\}$ of Octonions O.

Each of $\{A_4\}$ and $\{G_4\}$ and $\{G_5\}$ can represent the mass of Fundamental Fermions.

The {A4} Conformal substructure

$$\begin{array}{cc} 0 & A4 \\ -A4 & 0 \end{array}$$

represents First Generation Fermion Particles as Octonion basis elements O.

The {A4} plus {G5} Conformal substructure

$$\begin{array}{ccc} 0 & A4 & \\ -A4 & 0 & G5 \\ & -G5 & 0 \end{array}$$

represents Second Generation Fermion Particles as Octonion Pairs OxO.

The {A4} and {G5} plus {G4} Conformal substructure

$$\begin{array}{ccc} 0 & A4 & G4 \\ -A4 & 0 & G5 \\ -G4 & -G5 & 0 \end{array}$$

represents Third Generation Fermion Particles as Octonion Triples OxOxO.

Fermion AntiParticles are represented in a similar way.

Combinatorics of O and OxO and OxOxO produce realistic Fermion masses, as calculated in detail in viXra 1108.0027

The Third Generation Truth Quark (Tquark) is by far the most massive Fermion so the Higgs as a Fermionic Condensate is effectively a Tquark Condensate.

Note:

E8 has 8 Casimir Operators of degrees 2, 8, 12, 14, 18, 20, 24, 30

The Conformal quadratic 2 is in E8, the Conformal quartic 4 is in the 8 of E8, and the Conformal cubic $6/2 = 3$ is in the 12 of E8.

D8 has 8 Casimir Operators of degrees 2, 4, 6, 8, 10, 12, 14, 8

The Conformal quadratic 2 and quartic 4 are in D8 and the Conformal cubic $6/2 = 3$ is in the 6 of D8.

D4 has 4 Casimir Operators of degrees 2, 4, 6, 4

The Conformal quadratic 2 and quartic 4 are in D4 and the Conformal cubic $6/2 = 3$ is in the 6 of D4.

SUMMARY:

The Conformal Group in the form $SU(2,2) = Spin(2,4)$ is described by Robert Gilmore in his book "Lie Groups, Physics, and Geometry", Cambridge 2008: "... 8x8 matrices acting on the four coordinates and the four momenta ... satisfy an antisymmetric ... symplectic metric ... preserve[d by the] ... group ... $Sp(8;\mathbb{R})$... [and a]... symmetric metric ... with signature (+4,-4) ... preserve[d by the] ... group ... $SO(4,4)$...

$$Sp(8; \mathbb{R}) \cap SO(4, 4) = SU(2, 2) \simeq SO(4, 2)$$

... The fifteen-dimensional Lie algebra for the Dirac equation is ... summarized by the 6x6 matrix

$$\begin{bmatrix} 0 & J_3 & -J_2 & M_1 & A_1 & \Gamma_1 & + \\ -J_3 & 0 & J_1 & M_2 & A_2 & \Gamma_2 & + \\ J_2 & -J_1 & 0 & M_3 & A_3 & \Gamma_3 & + \\ -M_1 & -M_2 & -M_3 & 0 & A_4 & \Gamma_4 & + \\ \hline A_1 & A_2 & A_3 & A_4 & 0 & \Gamma_5 & - \\ \Gamma_1 & \Gamma_2 & \Gamma_3 & \Gamma_4 & -\Gamma_5 & 0 & - \end{bmatrix}$$

... three ... operators A_4 , G_4 , G_5 close under commutation and span ... $so(2,1)$... The Casimir operator for this [sub]algebra is $C^2 = G_5^2 - G_4^2 - A_4^2$... [It can be]... used to determine eigenstates and energy eigenvalues ...".

- $\{J_1, J_2, J_3\}$ represent Angular Momentum. $\{M_1, M_2, M_3\}$ represent Laplace-Runge-Lenz.
- $\{A_1, A_2, A_3\}$ represent Momentum.
- $\{G_1, G_2, G_3\}$ represent Higgs for W-Bosons and Momentum of Universe Expansion.
- $\{A_4\}$ and $\{G_4\}$ and $\{G_5\}$ represent Energy/Mass including Higgs mass for Fermions.

The $\{A_4\}$ Conformal substructure

$$\begin{bmatrix} 0 & A_4 \\ -A_4 & 0 \end{bmatrix}$$

represents First Generation Fermion Particles as Octonion basis elements O.

The $\{A_4\}$ plus $\{G_5\}$ Conformal substructure

$$\begin{bmatrix} 0 & A_4 & \\ -A_4 & 0 & G_5 \\ & -G_5 & 0 \end{bmatrix}$$

represents Second Generation Fermion Particles as Octonion Pairs OxO .

The $\{A_4\}$ plus $\{G_5\}$ plus $\{G_4\}$ Conformal substructure

$$\begin{bmatrix} 0 & A_4 & G_4 \\ -A_4 & 0 & G_5 \\ -G_4 & -G_5 & 0 \end{bmatrix}$$

represents Third Generation Fermion Particles as Octonion Triples $OxOxO$.

Dark Energy - Dark Matter - Ordinary Matter:

The Lorentz Group is represented by 6 generators

$$\begin{array}{cccc}
 0 & J1 & J2 & M1 \\
 -J1 & 0 & J3 & M2 \\
 -J2 & -J3 & 0 & M3 \\
 -M1 & -M2 & -M3 & 0
 \end{array}$$

There are two ways to extend the Lorentz Group
(see arXiv gr-qc/9809061 by Aldrovandi and Peireira):

To the **Poincare Group with No Cosmological Constant** by adding 4 generators

$$\begin{array}{ccccc}
 0 & J1 & J2 & M1 & A1 \\
 -J1 & 0 & J3 & M2 & A2 \\
 -J2 & -J3 & 0 & M3 & A3 \\
 -M1 & -M2 & -M3 & 0 & A4 \\
 -A1 & -A2 & -A3 & -A4 & 0
 \end{array}$$

{A1,A2,A3} represent Momentum and {A4} represents Energy/Mass of Poincare Gravity and its Dark Matter Primordial Black Holes.

and to the semidirect product of Lorentz and 4 Special Conformal generators to get a **Non-Zero Cosmological Constant for Universe Expansion**

$$\begin{array}{cccccc}
 0 & J1 & J2 & M1 & & G1 \\
 -J1 & 0 & J3 & M2 & & G2 \\
 -J2 & -J3 & 0 & M3 & & G3 \\
 -M1 & -M2 & -M3 & 0 & & G4 \\
 \\
 -G1 & -G2 & -G3 & -G4 & & 0
 \end{array}$$

so that {G1,G2,G3} represent 3 Higgs components giving mass to 3 Weak Bosons and {G4} represents massive Higgs Scalar as Fermion Condensate. As Special Conformal and Scale Conformal degrees of freedom they also represent the Momentum of Expansion of the Universe and its Dark Energy.

One additional generator {G5} represents Higgs/Fermion mass of Ordinary Matter.

All 15 generators combine to make the full Conformal Lie Algebra $SU(2,2) = Spin(2,4)$

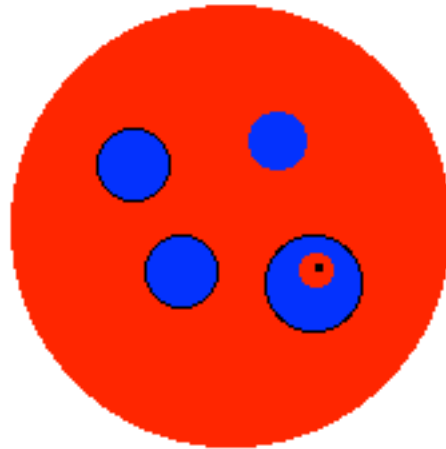
$$\begin{array}{cccccc}
 0 & J1 & J2 & M1 & A1 & G1 \\
 -J1 & 0 & J3 & M2 & A2 & G2 \\
 -J2 & -J3 & 0 & M3 & A3 & G3 \\
 -M1 & -M2 & -M3 & 0 & A4 & G4 \\
 -A1 & -A2 & -A3 & -A4 & 0 & G5 \\
 -G1 & -G2 & -G3 & -G4 & -G5 & 0
 \end{array}$$

Dark Energy - Dark Matter - Ordinary Matter:

In E8 Physics, our 4-dimensional Physical SpaceTime **Universe** begins as a relatively small spatial volume in which all 15 generators of Conformal $SU(2,2) = Spin(2,4)$ including all 4 Special Conformal and Scale Conformal generators are fully effective.



Rabindra Mohapatra (in section 14.6 of "Unification and Supersymmetry," 2nd edition, Springer-Verlag 1992) said: "... we start with a Lagrangian invariant under full local conformal symmetry and fix its conformal and scale gauge to obtain the usual action for gravity ... the conformal d'Alembertian contains ... curvature ... R , which for constant ... scalar field ... Φ , leads to gravity. We may call Φ the auxiliary field ...". I view Φ as corresponding to the Higgs 3 Special Conformal generators $\{G1, G2, G3\}$ that are frozen fixed during expansion in some regions of our **Universe** to become **Gravitationally Bound Domains** (such as **Galaxies**) like icebergs in an ocean of water.



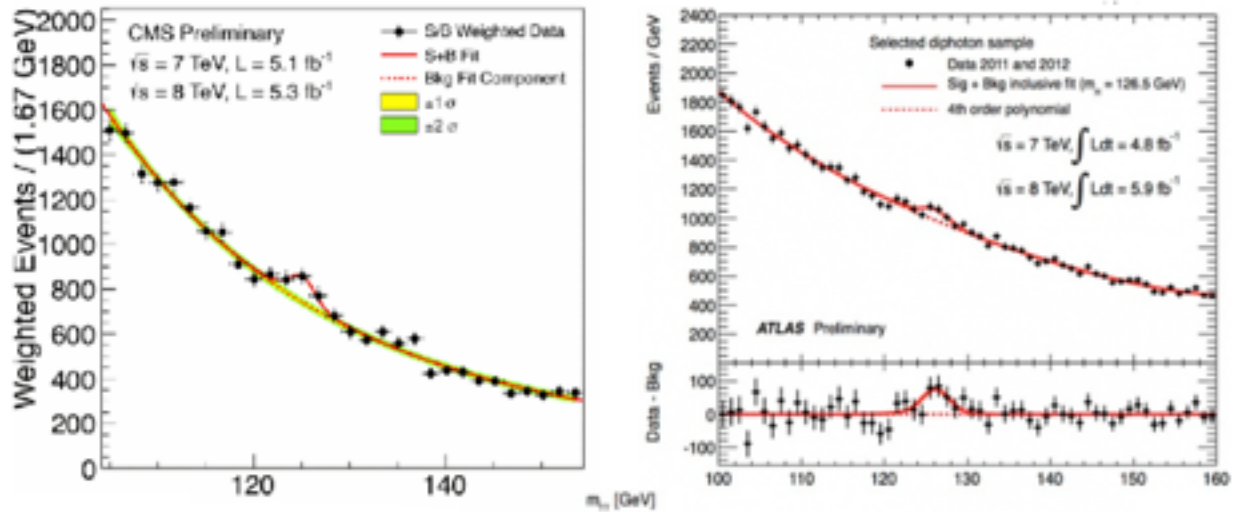
Since the **Gravitationally Bound Domains** (such as our Inner Solar System) have no Expansion Momentum we only see there the Poincare Part of Conformal Gravity plus the Higgs effects of $\{G4\}$ and $\{G5\}$ and the ElectroWeak Broken Symmetry caused by freezing-out fixing $\{G1, G2, G3\}$:

0	J1	J2	M1	A1	-
-J1	0	J3	M2	A2	-
-J2	-J3	0	M3	A3	-
-M1	-M2	-M3	0	A4	G4
-A1	-A2	-A3	-A4	0	G5
-	-	-	-G4	-G5	0

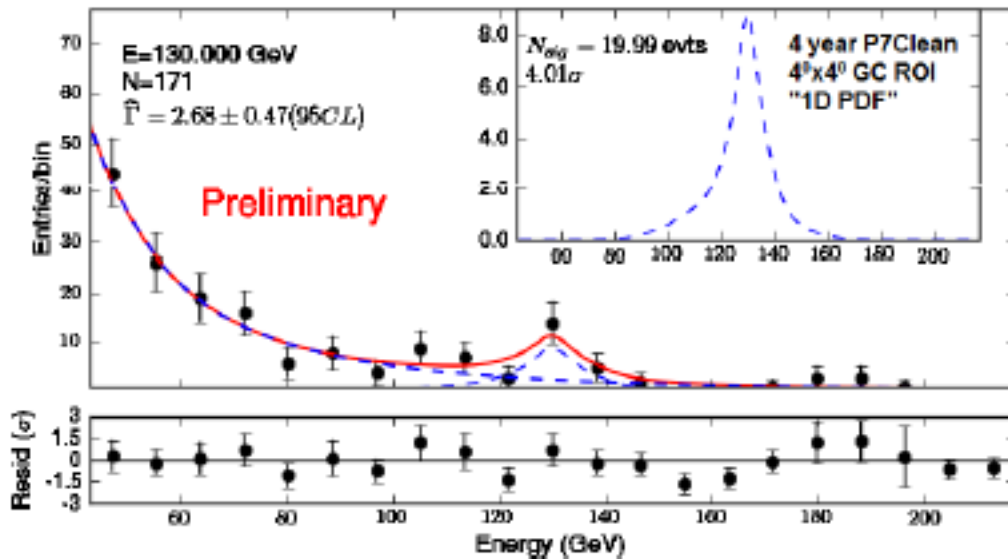
Sgr A* and Higgs = Tquark-Tantiquark Condensate:

Sagittarius A* (Sgr A*) is a very massive black hole in the center of our Galaxy into which large amounts of Hydrogen fall. As the Hydrogen approaches Sgr A* it increases in energy, ionizing into protons and electrons, and eventually producing a fairly dense cloud of infalling energetic protons whose collisions with ambient protons are at energies similar to the proton-proton collisions at the LHC.

LHC diphoton histograms for ATLAS and CMS as of mid-2012 clearly show a peak that probably is evidence of a Higgs boson with mass around 125 GeV.



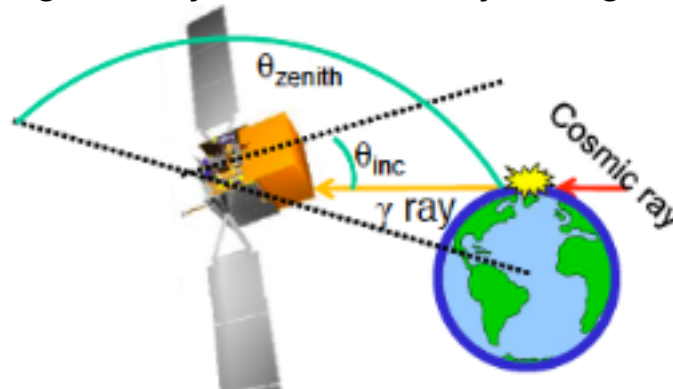
Andrea Albert at The Fermi Symposium 11/2/2012 said: "... gamma rays detectable by the Fermi Large Area Telescope [FLAT] ...



... Line-like Feature near 135 GeV ... localized in the galactic center ...".

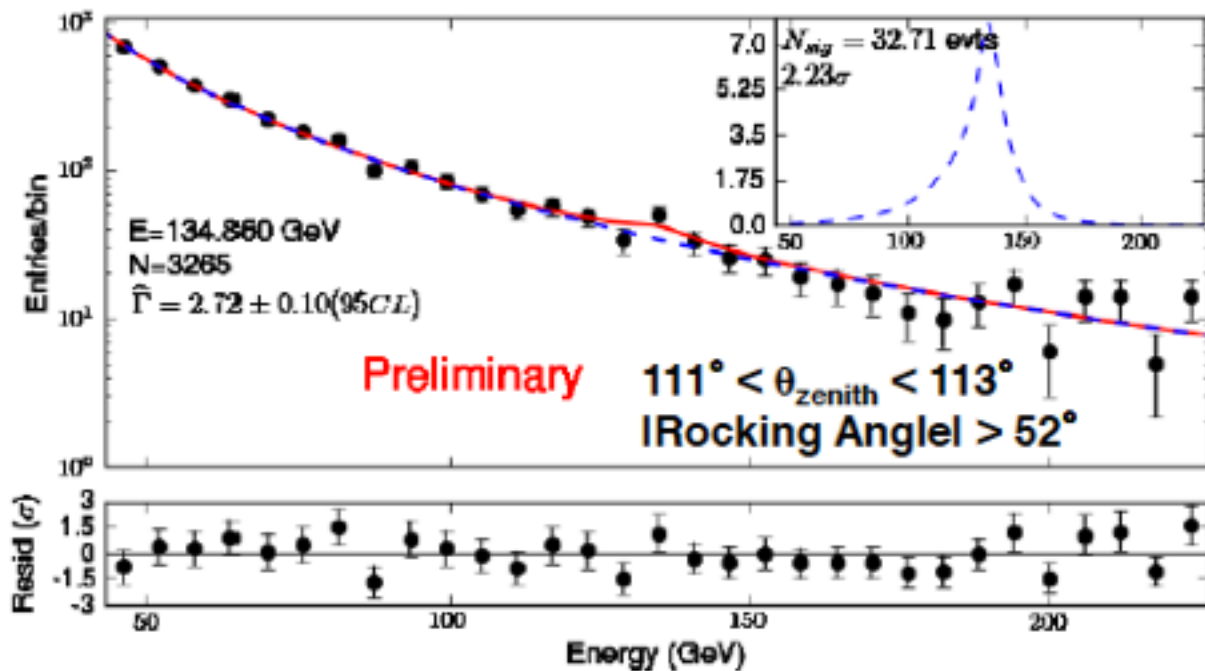
Sgr A* and Higgs = Tquark-Tantiquark Condensate:

In addition to the Galactic Center observations,
Fermi LAT looked at gamma rays from Cosmic Rays hitting Earth's atmosphere



by looking at the Earth Limb.

Andrea Albert at The Fermi Symposium 11/2/2012 also said: "... Earth Limb is a bright gamma-ray source ... From cosmic-ray interactions in the atmosphere ...



Fermi LAT Spectral Line Search

11/02/2012

... Line-like feature ... at 135 GeV .. Appears when LAT is pointing at the Limb ...".

Since 90% of high-energy Cosmic Rays are Protons and since their collisions with Protons and other nuclei in Earth's atmosphere produce gamma rays, the 135 GeV Earth Limb Line seen by Fermi LAT is also likely to be the Higgs produced by collisions analogous to those at the LHC.

Sgr A* and Higgs = Tquark-Tantiquark Condensate:

Olivier K. in a comment in Jester's blog on 10 November 2012 said:

"... Could the 135GeV bump be related ... to current Higgs ... properties ? ...

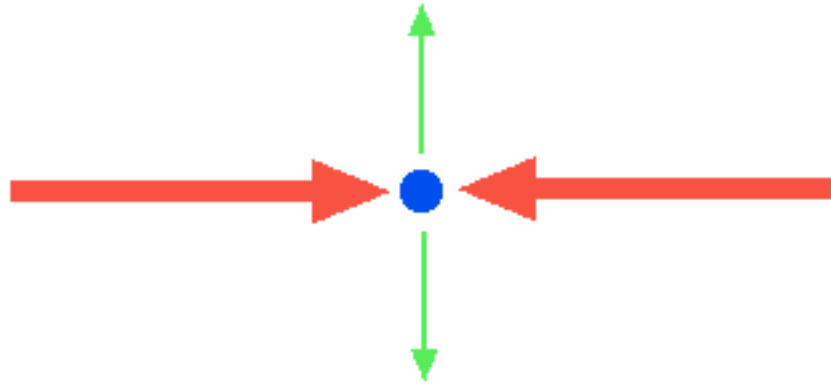
The coincidence between GeV figures ...[for LHC] Higgs mass and this [Fermi LAT] bump is thrilling for an amateur like me..."

Jester in his resonances blog on 17 April 2012 said, about Fermi LAT:

"... the plot shows the energy of *single* photons as measured by Fermi, not the invariant mass of photon pairs ...".

Since the LHC 125 GeV peak is for "invariant mass of photon pairs" and the Fermi LAT 135 GeV peak is for ""single" photons" how could both correspond to a Higgs mass state around 130 GeV ?

The LHC sees collisions of high-energy protons (red arrows) forming Higgs (blue dot)



with the Higgs at rest decaying into a photon pair (green arrows) giving the observed Higgs peak (around 130 GeV) as **invariant mass of photon pairs**.

Fermi LAT at Galactic Center and Earth Limb sees

collisions of one high-energy proton with a low-energy (relatively at rest) proton forming Higgs



with Higgs moving fast from momentum inherited from the high-energy proton decaying into two photons: one with low energy not observed by Fermi LAT and the other being observed by Fermi LAT as a high-energy gamma ray carrying almost all of the Higgs decay energy (around 130 GeV) as a **"single" photon**.

Therefore, **the coincidence noted by Olivier K. is probably a realistic phenomenon.**

Sgr A* and Higgs = Tquark-Tantiquark Condensate:

Jester, replying to the comment by Olivier K., dismissed the proposal that Fermi LAT may have seen the Higgs, saying on 11 November 2012:

"Afaik,
there's no model connecting the 130(5)GeV Fermi line to the 125 GeV Higgs."

so

I hereby propose a model:

Protons from Hydrogen infalling into Sgr A* acquire enough energy and density to produce proton-proton collisions similar to those at the LHC, as could Cosmic Ray Protons hitting the Earth's atmosphere,

and

the 135 GeV Line observed by Fermi LAT is due to proton-proton collisions producing Higgs in the diphoton channel

and

the 125 GeV Higgs-like evidence observed by ATLAS and CMS is also due to proton-proton collisions producing Higgs in the diphoton channel

and

the difference between 135 GeV at Fermi LAT and 125 GeV at LHC can be accounted for by comparing details of experimental setup and analysis-related assumptions.

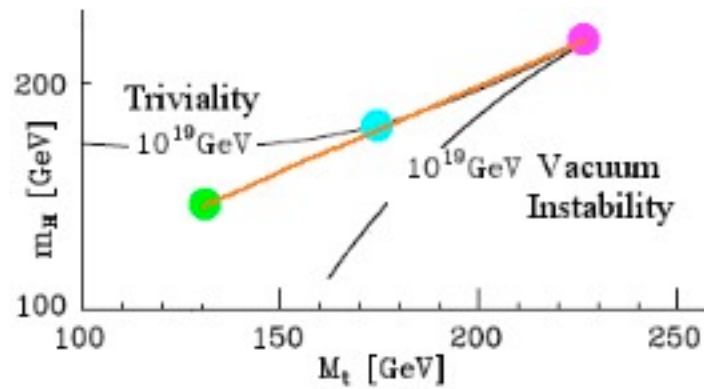
Given that model,

I propose that Olivier K. be given credit for stating the possibility that both Fermi LAT and the LHC have indeed seen the Higgs, which is an interesting example of mutual confirmation of Collider Physics and Astrophysics observations.

The {G4} conformal generator that represents both Dark Energy of Universe Expansion and the Massive Higgs Scalar as Fermionic Condensate (dominated by third-generation Tquark-Tantiquark Condensate) may be involved in the Sgr A* Galactic Center Process.

Sgr A* and Higgs = Tquark-Tantiquark Condensate:

Due to its relationship with the Higgs as Tquark-Tantiquark Condensate,
the Truth Quark might be related by $\{G_4\}$ to Dark Energy of Universe Expansion
as well as
by a 3-state mass system due to its interaction with the Higgs as Condensate to



a Strong Coupling / Composite-Higgs Regime (known as Triviality)
and
a Vacuum Instability Regime.

At this point, all four differences have been reconciled, and our classical Lagrangian E8 Physics Model describes Gravity as well as the Standard Model with a BEHK Higgs mechanism, but we must now show how to calculate Force Strengths, Particle Masses, KM Parameters, and the ratio Dark Energy : Dark Matter : Ordinary Matter and then compare those calculations with Experimental Observations.

Here is a summary of E8 model calculation results. Since ratios are calculated, values for one particle mass and one force strength are assumed. Quark masses are constituent masses. Some higher-order results are listed.

Dark Energy : Dark Matter : Ordinary Matter = 0.75 : 0.21 : 0.04

Particle/Force	Tree-Level	Higher-Order	
e-neutrino	0	0 for nu_1	
mu-neutrino	0	9×10^{-3} eV for nu_2	
tau-neutrino	0	5.4×10^{-2} eV for nu_3	
electron	0.5110 MeV		
down	312.8 MeV	charged pion = 139 MeV	
up	312.8 MeV	proton = 938.25 MeV neutron - proton = 1.1 MeV	
muon	104.8 MeV	106.2 MeV	
strange	625 MeV		
charm	2090 MeV		
tauon	1.88 GeV		
beauty	5.63 GeV		
truth(low state)	130 GeV		
truth(middle state)	174 GeV		
truth(high state)	218 GeV		
W+	80.326 GeV		
W-	80.326 GeV		
W0	98.379 GeV	Z0 = 91.862 GeV	
Higgs VEV	252.5 GeV (assumed)	Mplanck=1.217x10 ¹⁹ GeV	
Higgs(low state)	145.8 GeV		
Higgs(middle state)	182 GeV		
Higgs(high state)	239 GeV		
Gravity Gg	1(assumed)		
(Gg)(Mproton ² / Mplanck ²)		5×10^{-39}	
EM fine structure	1/137.03608		
Weak Gw	0.2535		
Gw(Mproton ² / (Mw+ ² + Mw- ² + Mz0 ²))		1.05×10^{-5}	
color force at 0.245 GeV	0.6286	0.106 at 91 GeV	
Kobayashi-Maskawa parameters for W+ and W- processes are:			
	d	s	b
u	0.975	0.222	0.00249 -0.00388i
c	-0.222 -0.000161i	0.974 -0.0000365i	0.0423
t	0.00698 -0.00378i	-0.0418 -0.00086i	0.999
The phase angle d13 is taken to be 1 radian.			


```

neutrino mixing matrix:
      nu_1      nu_2      nu_3
nu_e   0.87      0.50      0
nu_m  -0.35      0.61      0.71
nu_t   0.35     -0.61      0.71

```

As to some higher-order and nonperturbative calculations, one motivation for my value of 245 MeV for the basic Λ_{QCD} of the color force is the paper of Shifman at hep-ph/9501222 in which Shifman said:

"... a set of data ("high-energy data") yield values of $\alpha_s(M_Z)$ in the $\overline{\text{MS}}$ scheme which cluster around 0.125 ... with the error bars 0.005 ...

The corresponding value of Λ_{QCD} is about 500 MeV ... These numbers, accepted as the most exact results for the strong coupling constant existing at present, propagate further into a stream of papers ... devoted to various aspects of QCD. The question arises whether Quantum Chromodynamics can tolerate these numbers. I will argue below that the answer is negative.

... I believe that $\alpha_s(M_Z)$ must be close to 0.11 and the corresponding value of Λ_{QCD} close to 200 MeV (or even smaller). ...

The value of $\alpha_s(M_Z)$ emerging from the so called global fits based mainly on the data at the Z peak (and assuming the standard model) is three standard deviations higher than the one stemming from the low-energy phenomenology. ...".

Patrascioiu and Seiler in hep-ph/9609292 said:

"... the running of α_s predicted by perturbation (PT) theory is not correctly describing the accelerator experiments at the highest energies. A natural explanation is provided by the authors' 1992 proposal that in fact the true running predicted by the nonperturbatively defined lattice QCD is different ...".

The Patrascioiu and Seiler paper indicates that my crude use of simple perturbative QCD running may not be correct. If you look at Figure 2 of their paper, you see that their "possible modified running of α_s " curve is at 100 GeV close to the 0.12 range, while their 2-loop PT curve is close to the 0.10 range of my crude perturbative calculation.

So, it may be that nonperturbative effects might bring calculations of my model closer to observations.

Further, it may be difficult to do very accurate nonperturbative QCD calculations, based in part on what Morozov and Niemi say in hep-th/0304178 :

"... The field theoretical renormalization group equations have many common features with the equations of dynamical systems. ... we propose that besides isolated fixed points, the couplings in a renormalizable field theory may also flow towards more general, even fractal attractors. This could lead to Big Mess scenarios ...".

I am not contending that my tree-level calculations are in exact agreement with currently accepted observations.

I am contending that the overall approximate agreement of my calculations with observations of many parameters does indicate that the fundamental structure of my E8 physics model is sound.

My view of constituent quark masses is that they can be (and are in my model) meaningful, particularly in nonrelativistic quark models of light-quark hadrons (for heavier quarks, the percentage difference between current and constituent masses can be relatively small). For example, Guidry, in his book Gauge Field Theories, John Wiley (1991), says:

"... the current masses of the quarks ... are considerably smaller than the constituent masses for the lightest quarks $M_u = 300 \text{ MeV}$ $M_d = 300 \text{ MeV}$...
... the masses of the constituent quarks presumably reflect a dressing by the confinement mechanism ... understanding of the relationship between current masses and constituent masses awaits a first-principles solution of the QCD bound-state problem. ... Nevertheless, nonrelativistic models of quark structure for hadrons have been found to work surprisingly well, even for light hadrons. ...".

As I said in quant-ph/9806023 :

"... The effectiveness of the NonRelativistic Quark Model of hadrons can be explained by Bohm's quantum theory applied to a fermion confined in a box, in which the fermion is at rest because its kinetic energy is transformed into PSI-field potential energy. ...".

Further, Georgi, in his book Weak Interactions and Modern Particle Theory, Benjamin-Cummings (1984), says:

"... Successes of the Nonrelativistic Quark Model ...

... The first striking success is that the baryon masses are given correctly by this picture ... The leading contribution to the baryon mass in the nonrelativistic limit is just the sum of the constituent quark masses. ... A good picture of the baryon masses is obtained if we take ... $\mu = m_d = \dots = 360 \text{ MeV}$... $m_s = 540 \text{ MeV}$...
... With these masses, the octet baryon magnetic moments are ...[in]... excellent ... agreement ... with the data ... The success ... in giving not only the ratios of the baryon magnetic moments, but even their overall scale, seems ... to be very significant. ... The mystery of the connection between QCD and the quark model remains ...".

My view is that the structure of my E8 model, in which constituent quark masses are calculated from volumes of bounded complex domains and their Shilov boundaries, may shed some light on the connection between QCD current masses and constituent masses. In particular, those geometric volumes may be related to effective summation over a lot of QCD states to produce a bound-state constituent result.

Two other higher-order calculations in my E8 model are:

1 - For the muon, my tree-level calculation is 104.8 MeV and the accepted observational value is about 105.6 MeV. All I have done is to note that the difference seems to me to be well within the range of radiative corrections. For example, following Bailin and Love, in their book Introduction to Gauge Field Theory, IOP (rev ed 1993):

Radiative corrections to order α for the muon decay rate using Sirlin's on-mass-shell renormalization scheme give a 7% increase³⁵ in the muon decay rate compared to the tree graph prediction:

$$\Gamma(\mu) = \frac{G_F^2 m_\mu^5}{192\pi^3} \left(1 - 8 \frac{m_e^2}{m_\mu^2} + 8 \left(\frac{m_e^2}{m_\mu^2} \right)^3 - \left(\frac{m_e^2}{m_\mu^2} \right)^4 - 12 \left(\frac{m_e^2}{m_\mu^2} \right)^2 \ln \left(\frac{m_e^2}{m_\mu^2} \right) \right)$$

Since the decay rate is directly proportional to $m\mu^5$, the increase can be considered to be an increase in the muon mass of about 1.36%, from the uncorrected theoretical value of 104.8 MeV to 106.2 MeV.

The experimental value is 105.7 MeV.

2 - For the proton-neutron mass difference (which is zero in my E8 model at tree level) further calculation involving connections between down valence quarks and virtual sea strange quarks gives a value of 1.1 MeV for the neutron mass excess over the proton mass, which is close to the accepted value of about 1.3 MeV.

Force Strengths:

The primary postulate for my E8 physics model is:

0 - I start with the emergence from the void of a binary choice, like Yin-Yang, which naturally gives a real Clifford algebra, so that physics is described by a very large real Clifford algebra (a generalized hyperfinite III von Neumann factor) that can be seen as a tensor product of a lot of $Cl(16)$ Clifford Algebras, each of which contains an E8 Lie Algebra.

Then:

1 - Since $Cl(16) = Cl(8) \times Cl(8)$ it is clear that $Cl(8)$ describes physics locally and it is also clear that 248-dim E8 in $Cl(16)$ can be described in terms of 256-dim $Cl(8)$ which has an Octonionic 8-dim Vector Space.

2 - At low (after Inflation) energies a specific quaternionic submanifold freezes out, splitting the 8-dim spacetime into a $4+4 = 8$ -dim $M4 \times CP2$ Kaluza-Klein.

3 - $Cl(8)$ bivector $Spin(8)$ is the D4 Lie algebra two copies of which are in the E8 Physics Lagrangian that is integrated over a base manifold that is 8-dim $M4 \times CP2$ Kaluza-Klein. This shows that the **Force Strength is made up of two parts:**
the relevant spacetime manifold of gauge group global action
and
the relevant symmetric space manifold of gauge group local action.

4 -Roughly, the 4-dim spacetime Lagrangian gauge boson term is:
the integral over spacetime as seen by gauge boson acting globally of the gauge force term of the gauge boson acting locally for the gauge bosons of each of the four forces:

U(1) for electromagnetism

SU(2) for weak force

SU(3) for color force

Spin(5) - compact version of antiDeSitter Spin(2,3) for gravity by
the MacDowell-Mansouri mechanism.

Look at the basic Lagrangian of a gauge theory model:

Integral over Spacetime of
Gauge Boson Force Term

In the conventional picture,
for each gauge force the gauge boson force term contains the force strength,
which in Feynman's picture is the amplitude to emit a gauge boson,
and can also be thought of as the probability = square of amplitude,
in an explicit (like $g |F|^2$) or an implicit (incorporated into the $|F|^2$) form.
Either way,
the conventional picture is that the force strength g is an ad hoc inclusion.

My E8 Physics model does not put in force strength g ad hoc,
but
constructs the integral such that the force strength emerges naturally from the
geometry of each gauge force.

To do that, for each gauge force:

1 - make the spacetime over which the integral is taken be spacetime as it is seen
by that gauge boson, that is, in terms of the symmetric space with global
symmetry of the gauge boson:

the U(1) photon sees 4-dim spacetime as $T^4 = S^1 \times S^1 \times S^1 \times S^1$
the SU(2) weak boson sees 4-dim spacetime as $S^2 \times S^2$
the SU(3) weak boson sees 4-dim spacetime as CP^2
the Spin(5) of gravity sees 4-dim spacetime as S^4 .

2 - make the gauge boson force term have the volume of the Shilov boundary
corresponding to the symmetric space with local symmetry of the gauge boson.
The nontrivial Shilov boundaries are:

for SU(2) Shilov = $RP^1 \times S^2$
for SU(3) Shilov = S^5
for Spin(5) Shilov = $RP^1 \times S^4$

The result is (ignoring technicalities for exposition) the geometric factor for force
strength calculation.

Each force is related to a gauge group:

U(1) for electromagnetism

SU(2) for weak force

SU(3) for color force

Spin(5) - compact version of antiDeSitter Spin(2,3) for gravity by the MacDowell-Mansouri mechanism

Global:

Each gauge group is the global symmetry of a symmetric space

S¹ for U(1)

S² = SU(2)/U(1) = Spin(3)/Spin(2) for SU(2)

CP² = SU(3)/SU(2) × U(1) for SU(3)

S⁴ = Spin(5)/Spin(4) for Spin(5)

Local:

Each gauge group is the local symmetry of a symmetric space

U(1) for itself

SU(2) for Spin(5) / SU(2) × U(1)

SU(3) for SU(4) / SU(3) × U(1)

Spin(5) for Spin(7) / Spin(5) × U(1)

The nontrivial local symmetry symmetric spaces correspond to bounded complex domains

SU(2) for Spin(5) / SU(2) × U(1) corresponds to IV₃

SU(3) for SU(4) / SU(3) × U(1) corresponds to B⁶ (ball)

Spin(5) for Spin(7) / Spin(5) × U(1) corresponds to IV₅

The nontrivial bounded complex domains have Shilov boundaries

SU(2) for Spin(5) / SU(2) × U(1) corresponds to IV₃ Shilov = RP¹ × S²

SU(3) for SU(4) / SU(3) × U(1) corresponds to B⁶ (ball) Shilov = S⁵

Spin(5) for Spin(7) / Spin(5) × U(1) corresponds to IV₅ Shilov = RP¹ × S⁴

Global and Local Together:

Very roughly (see my web site tony5m17h.net and papers for details), think of the force strength as
the integral over the global symmetry space of
the physical (ie Shilov Boundary) volume=strength of the force.

That is (again very roughly and intuitively):

the geometric strength of the force is given by the product of
the volume of a 4-dim thing with global symmetry of the force and
the volume of the Shilov Boundary for the local symmetry of the force.

When you calculate the product volumes (using some tricky normalization stuff), you see that roughly:

Volume product for gravity is the largest volume
so since (as Feynman says) force strength = probability to emit a gauge boson means that the highest force strength or probability should be 1
I normalize the gravity Volume product to be 1, and so roughly get:

Volume product for gravity = 1
Volume product for color = 2/3
Volume product for weak = 1/4
Volume product for electromagnetism = 1/137

There are two further main components of a force strength:

- 1 - for massive gauge bosons, a suppression by a factor of $1 / M^2$
- 2 - renormalization running (important for color force).

Consider Massive Gauge Bosons:

I consider gravity to be carried by virtual Planck-mass black holes, so that the geometric strength of gravity should be reduced by $1/M_p^2$

I consider the weak force to be carried by weak bosons, so that the geometric strength of gravity should be reduced by $1/M_W^2$

That gives the result:

gravity strength = G (Newton's G)

color strength = $2/3$

weak strength = G_F (Fermi's weak force G)

electromagnetism = $1/137$

Consider Renormalization Running for the Color Force::

That gives the result:

gravity strength = G (Newton's G)

color strength = $1/10$ at weak boson mass scale

weak strength = G_F (Fermi's weak force G)

electromagnetism = $1/137$

The use of compact volumes is itself a calculational device, because it would be more nearly correct, instead of

the integral over the compact global symmetry space of
the compact physical (ie Shilov Boundary) volume=strength of the force
to use

the integral over the hyperbolic spacetime global symmetry space of
the noncompact invariant measure of the gauge force term.

However, since the strongest (gravitation) geometric force strength is to be normalized to 1, the only thing that matters is ratios, and the compact volumes (finite and easy to look up in the book by Hua) have the same ratios as the noncompact invariant measures.

In fact, I should go on to say that continuous spacetime and gauge force geometric objects are themselves also calculational devices, and that it would be even more nearly correct to do the calculations with respect to a discrete generalized hyperdiamond Feynman checkerboard.

Here are more details about the force strength calculations:

The force strength of a given force is

$$\text{alphaforce} = \frac{1}{M\text{force}^2} \left(\frac{\text{Vol}(\text{MISforce})}{\text{Vol}(\text{Qforce}) / \text{Vol}(\text{Dforce})^{1/m\text{force}}} \right)$$

where:

alphaforce represents the force strength;

Mforce represents the effective mass;

MISforce represents the part of the target Internal Symmetry Space that is available for the gauge boson to go to;

Vol(MISforce) stands for volume of MISforce, and is sometimes also denoted by the shorter notation Vol(M);

Qforce represents the link from the origin to the target that is available for the gauge boson to go through;

Vol(Qforce) stands for volume of Qforce;

Dforce represents the complex bounded homogeneous domain of which Qforce is the Shilov boundary;

mforce is the dimensionality of Qforce, which is 4 for Gravity and the Color force, 2 for the Weak force (which therefore is considered to have two copies of QW for each spacetime HyperDiamond link), and 1 for Electromagnetism (which therefore is considered to have four copies of QE for each spacetime HyperDiamond link)

Vol(Dforce)^(1 / mforce) stands for a dimensional normalization factor (to reconcile the dimensionality of the Internal Symmetry Space of the target vertex with the dimensionality of the link from the origin to the target vertex).

The Qforce, Hermitian symmetric space,
and Dforce manifolds for the four forces are:

Gauge Group	Hermitian Symmetric Space	Type of Dforce	mforce	Qforce
Spin(5)	Spin(7) / Spin(5)xU(1)	IV5	4	RP ¹ xS ⁴
SU(3)	SU(4) / SU(3)xU(1)	B ⁶ (ball)	4	S ⁵
SU(2)	Spin(5) / SU(2)xU(1)	IV3	2	RP ¹ xS ²
U(1)	-	-	1	-

The geometric volumes needed for the calculations are mostly taken from the book Harmonic Analysis of Functions of Several Complex Variables in the Classical Domains (AMS 1963, Moskva 1959, Science Press Peking 1958) by L. K. Hua [with unit radius scale].

Note that

Force	M	Vol(M)
gravity	S ⁴	8pi ² /3 - S ⁴ is 4-dimensional
color	CP ²	8pi ² /3 - CP ² is 4-dimensional
weak	S ² x S ²	2 x 4pi - S ² is a 2-dim boundary of 3-dim ball 4-dim S ² x S ² = = topological boundary of 6-dim 2-polyball Shilov Boundary of 6-dim 2-polyball = S ² + S ² = = 2-dim surface frame of 4-dim S ² x S ²
e-mag	T ⁴	4 x 2pi - S ¹ is 1-dim boundary of 2-dim disk 4-dim T ⁴ = S ¹ x S ¹ x S ¹ x S ¹ = = topological boundary of 8-dim 4-polydisk Shilov Boundary of 8-dim 4-polydisk = = S ¹ + S ¹ + S ¹ + S ¹ = = 1-dim wire frame of 4-dim T ⁴

Note (thanks to Carlos Castro for noticing this) that the volume listed for S5 is for a squashed S5, a Shilov boundary of the complex domain corresponding to the symmetric space $SU(4) / SU(3) \times U(1)$.

Note (thanks again to Carlos Castro for noticing this) also that the volume listed for CP2 is unconventional, but physically justified by noting that S4 and CP2 can be seen as having the same physical volume, with the only difference being structure at infinity.

Also note that for U(1) electromagnetism, whose photon carries no charge, the factors Vol(Q) and Vol(D) do not apply and are set equal to 1, and from another point of view, the link manifold to the target vertex is trivial for the abelian neutral U(1) photons of Electromagnetism, so we take QE and DE to be equal to unity.

Force	M	Vol(M)	Q	Vol(Q)	D	Vol(D)
gravity	S^4	$8\pi^2/3$	$RP^1 \times S^4$	$8\pi^3/3$	$IV5$	$\pi^{5/2} 4^5!$
color	CP^2	$8\pi^2/3$	S^5	$4\pi^3$	$B^6(\text{ball})$	$\pi^3/6$
weak	$S^2 \times S^2$	$2 \times 4\pi$	$RP^1 \times S^2$	$4\pi^2$	$IV3$	$\pi^3/24$
e-mag	T^4	$4 \times 2\pi$	-	-	-	-

Using these numbers, the results of the calculations are the relative force strengths at the characteristic energy level of the generalized Bohr radius of each force:

Gauge Group	Force	Characteristic Energy	Geometric Force Strength	Total Force Strength
Spin(5)	gravity	approx 10^{19} GeV	1	$G G m_{\text{proton}}^2$ approx 5×10^{-39}
SU(3)	color	approx 245 MeV	0.6286	0.6286
SU(2)	weak	approx 100 GeV	0.2535	$G W m_{\text{proton}}^2$ approx 1.05×10^{-5}
U(1)	e-mag	approx 4 KeV	1/137.03608	1/137.03608

The force strengths are given at the characteristic energy levels of their forces, because the force strengths run with changing energy levels.

The effect is particularly pronounced with the color force.

The color force strength was calculated using a simple perturbative QCD renormalization group equation at various energies, with the following results:

Energy Level	Color Force Strength
245 MeV	0.6286
5.3 GeV	0.166
34 GeV	0.121
91 GeV	0.106

Taking other effects, such as Nonperturbative QCD, into account, should give a Color Force Strength of about 0.125 at about 91 GeV

Fermion Masses:

The primary postulate for my E8 physics model is:

0 - I start with the emergence from the void of a binary choice, like Yin-Yang, which naturally gives a real Clifford algebra, so that physics is described by a very large real Clifford algebra (a generalized hyperfinite III von Neumann factor) that can be seen as a tensor product of a lot of Cl(16) Clifford Algebras, each of which contains an E8 Lie Algebra.

Then:

1 - Since $Cl(16) = Cl(8) \times Cl(8)$ it is clear that Cl(8) describes physics locally and it is also clear that 248-dim E8 in Cl(16) can be described in terms of 256-dim Cl(8) which has two Octonionic 8-dim half-spinor spaces with physical interpretation by which first-generation fermion particles correspond to octonion basis of Spin(8) +half-spinors

l to e-neutrino
i to red down quark
j to green down quark
k to blue down quark
E to electron
I to red up quark
J to green up quark
K to blue up quark

and first-generation fermion antiparticles correspond to octonion basis of Spin(8) -half-spinors

l to e-antineutrino
i to red down antiquark
j to green down antiquark
k to blue down antiquark
E to positron
I to red up antiquark
J to green up antiquark
K to blue up antiquark

2 - The two Spin(8) 8-dim half-spinors and the Spin(8) 8-dim vectors are all related to each other by Triality. Modifying Steven Weinberg's description of physics Lagrangians in his book "Elementary Particles and the Laws of Physics: The 1986 Dirac Memorial Lectures" to apply to 8-dim spacetime gives this quote

All terms in the Lagrangian density must have units [mass]⁸, because length and time have units of inverse mass and the Lagrangian density integrated over spacetime must have no units. From the $m\psi\psi$ term, we see that the electron field must have units [mass]^{7/2}, because $\frac{7}{2} + \frac{7}{2} + 1 = 8$

from which it is clear that at high (UltraViolet) energies in the E8 physics model gauge boson terms have dimension 1 in the Lagrangian and fermion terms have dimension 7/2 in the Lagrangian, so that the Triality gives a Subtle Supersymmetry whereby

$$\text{Total Boson Lagrangian Dimensionality} = 28 \times 1 = 28$$

is exactly balanced by

$$\text{Total Fermion Lagrangian Dimensionality} = 8 \times 7 / 2 = 28$$

thus

the Triality Subtle Supersymmetry shows UltraViolet Finiteness of the E8 model

3 - At low (after Inflation) energies a specific quaternionic submanifold freezes out, splitting the 8-dim spacetime into a 4+4 = 8-dim M4xCP2 Kaluza-Klein and creating second and third generation fermions that can live in the 4-dim internal symmetry space and correspond respectively to pairs and triples of octonion basis elements,

4 - Cl(8) bivector Spin(8) is the D4 Lie algebra two copies of which are in the E8 Physics Lagrangian that is integrated over a base manifold that is 8-dim M4xCP2 Kaluza-Klein.

5 - Roughly, the 4-dim spacetime Lagrangian fermion term is integral over spacetime of spinor fermion term

In the conventional picture, the spinor fermion term is of the form $m S S^*$ where m is the fermion mass and S and S^* represent the given fermion.

Although the mass m is derived from the Higgs mechanism, the Higgs coupling constants are, in the conventional picture, ad hoc parameters, so that effectively the mass term is, in the conventional picture, an ad hoc inclusion.

My E8 model does not put in the mass m as an ad hoc Higgs coupling value, but

constructs the Lagrangian integral such that the mass m emerges naturally from the geometry of the spinor fermions.

To do that,

make the spinor fermion mass term have the volume of the Shilov boundary corresponding to

the symmetric space with LOCAL symmetry of the Spin(8) gauge group with respect to which the first generation spinor fermions are seen as +half-spinor and -half-spinor spaces.

Note that due to Triality,

Spin(8) can act on those 8-dimensional half-spinor spaces similarly to the way it acts on 8-dimensional vector spacetime prior to dimensional reduction.

Then, take the the spinor fermion volume to be the Shilov boundary corresponding to the same symmetric space on which Spin(8) acts as a local gauge group that is used to construct 8-dimensional vector spacetime:

the symmetric space $\text{Spin}(10) / \text{Spin}(8) \times U(1)$
corresponds to a bounded domain of type IV8
whose Shilov boundary is $\mathbb{R}P^1 \times S^7$

Since all the first generation fermions see the spacetime over which the integral is taken in the same way (unlike what happens for the force strength calculation), the only geometric volume factor relevant for calculating first generation fermion mass ratios is in the spinor fermion volume term.

Since fermions in this model correspond to Kerr-Newman Black Holes, the quark mass in this model is a constituent mass.

Consider a first-generation massive lepton (or antilepton, i.e., electron or positron). For definiteness, consider an electron E (a similar line of reasoning applies to the positron).

Gluon interactions do not affect the colorless electron (E)

By weak boson interactions or decay, an electron (E) can only be taken into itself or a massless (at tree level) neutrino.

As the lightest massive first-generation fermion, the electron cannot decay into a quark.

Since the electron cannot be related to any other massive Dirac fermion, its volume $V(\text{electron})$ is taken to be 1.

Consider a first-generation quark (or antiquark).

For definiteness, consider a red down quark I (a similar line of reasoning applies to the others of the first generation).

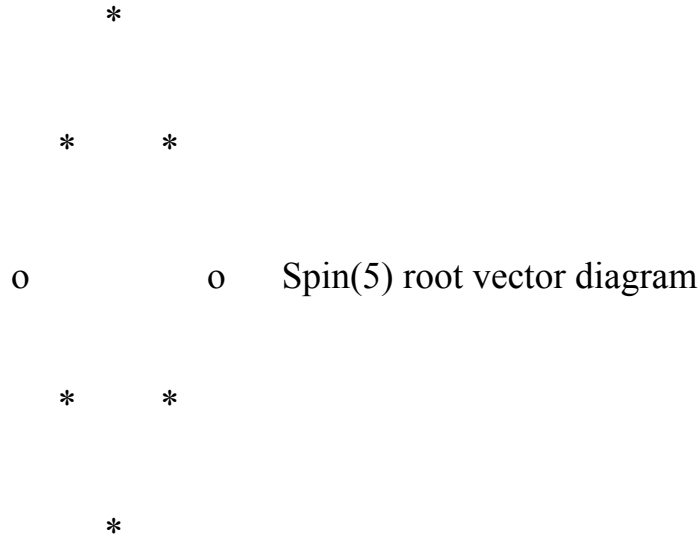
By gluon interactions, the red quark (I) can be interchanged with the blue and green down quarks (J and K).

By weak boson interactions, it can be taken into the red, blue, and green up quarks (i , j , and k).

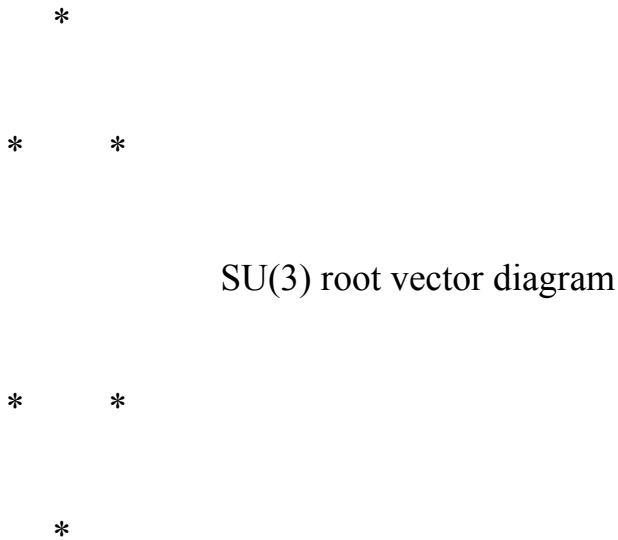
Given the up and down quarks, pions can be formed from quark-antiquark pairs, and the pions can decay to produce electrons (E) and neutrinos (ν).

Therefore first-generation quarks or antiquarks can by gluons, weak bosons, or decay occupy the entire volume of the Shilov boundary $RP^1 \times S^7$, which volume is $\pi^5 / 3$, so its volume $V(\text{quark})$ is taken to be $\pi^5 / 3$.

Consider graviton interactions with first-generation fermions.
 Since MacDowell-Mansouri gravitation comes from 10 Spin(5) gauge bosons,
 8 of which are charged (carrying color or electric charge)
 as shown in the root Spin(5) root vector diagram



in which the 6 root vectors * correspond to color carrying gauge bosons act
 similarly to the action of the 6 color-charged SU(3) gluons shown in the SU(3) root
 vector diagram



The 2 charged Spin(5) gravitons denoted by o carry electric charge.

However, even though the electron carries electric charge,
the electric charge carrying Spin(5) gravitons can only change the electron into a
(tree-level) massless neutrino,
so the Spin(5) gravitons do not enhance the electron volume factor,
which remains electron volume (taking gravitons into account) = $V(\text{electron}) = 1$

Since the quark carries color charge,
Spin(5) graviton action on its color charge multiplies its volume $V(\text{quark})$ by 6,
giving
quark gravity-enhanced volume = $6 \times V(\text{quark}) = 6 \pi^5 / 3 = 2 \pi^5$
The 2 Spin(5) gravitons carrying electric charge only cannot change quarks into
leptons, so they do not enhance the quark volume factor, so we have (where m_d is
down quark mass, m_u is up quark mass, and m_e is electron mass)
 $m_d / m_e = m_u / m_e = 2 \pi^5 / 1 = 2 \pi^5 = 612.03937$

The proton mass is calculated as the sum of the constituent masses of its
constituent quarks
 $m_{\text{proton}} = m_u + m_u + m_d = 938.25 \text{ MeV}$
which is close to the experimental value of 938.27 MeV.

In the first generation,
each quark corresponds to a single octonion basis element
and the up and down quark constituent masses are the same:
First Generation - 8 singletons - $m_u / m_d = 1$
Down - corresponds to 1 singleton - constituent mass 312 MeV
Up - corresponds to 1 singleton - constituent mass 312 MeV

Second and third generation calculations are generally more complicated.
Combinatorics indicates that in higher generations the up-type quarks are heavier
than the down-type quarks.

The third generation case,
in which the fermions correspond to triples of octonions,
is simple enough to be used here as an illustration of the combinatoric effect:

Third Generation
 $8^3 = 512$ triples
 $m_t / m_b = 483 / 21 = 161 / 7 = 23$
down-type (Beauty) - corresponds to 21 triples - constituent mass 5.65 GeV
up-type (Truth) - corresponds to 483 triples - constituent mass 130 GeV

Here are more details about the fermion mass calculations:

Fermion masses are calculated as a product of four factors:

$$V(\text{Qfermion}) \times N(\text{Graviton}) \times N(\text{octonion}) \times \text{Sym}$$

$V(\text{Qfermion})$ is the volume of the part of the half-spinor fermion particle manifold $S^7 \times \mathbb{R}P^1$ that is related to the fermion particle by photon, weak boson, and gluon interactions.

$N(\text{Graviton})$ is the number of types of $\text{Spin}(0,5)$ graviton related to the fermion. The 10 gravitons correspond to the 10 infinitesimal generators of $\text{Spin}(0,5) = \text{Sp}(2)$. 2 of them are in the Cartan subalgebra. 6 of them carry color charge, and may therefore be considered as corresponding to quarks. The remaining 2 carry no color charge, but may carry electric charge and so may be considered as corresponding to electrons. One graviton takes the electron into itself, and the other can only take the first-generation electron into the massless electron neutrino. Therefore only one graviton should correspond to the mass of the first-generation electron. The graviton number ratio of the down quark to the first-generation electron is therefore $6/1 = 6$.

$N(\text{octonion})$ is an octonion number factor relating up-type quark masses to down-type quark masses in each generation.

Sym is an internal symmetry factor, relating 2nd and 3rd generation massive leptons to first generation fermions. It is not used in first-generation calculations.

The ratio of the down quark constituent mass to the electron mass is then calculated as follows:

Consider the electron, E.

By photon, weak boson, and gluon interactions, E can only be taken into 1, the massless neutrino. The electron and neutrino, or their antiparticles, cannot be combined to produce any of the massive up or down quarks. The neutrino, being massless at tree level, does not add anything to the mass formula for the electron. Since the electron cannot be related to any other massive Dirac fermion, its volume $V(Q_{\text{electron}})$ is taken to be 1.

Next consider a red down quark ie. By gluon interactions, ie can be taken into je and ke, the blue and green down quarks. By also using weak boson interactions, it can be taken into i, j, and k, the red, blue, and green up quarks. Given the up and down quarks, pions can be formed from quark-antiquark pairs, and the pions can decay to produce electrons and neutrinos. Therefore the red down quark (similarly, any down quark) is related to any part of $S^7 \times RP^1$, the compact manifold corresponding to $\{ 1, i, j, k, ie, ie, ke, e \}$ and therefore a down quark should have a spinor manifold volume factor $V(Q_{\text{down quark}})$ of the volume of $S^7 \times RP^1$. The ratio of the down quark spinor manifold volume factor to the electron spinor manifold volume factor is just

$$V(Q_{\text{down quark}}) / V(Q_{\text{electron}}) = V(S^7 \times RP^1) / 1 = \pi^5 / 3.$$

Since the first generation graviton factor is 6,

$$m_d / m_e = 6V(S^7 \times RP^1) = 2\pi^5 = 612.03937$$

As the up quarks correspond to i, j, and k, which are the octonion transforms under e of ie, je, and ke of the down quarks, the up quarks and down quarks have the same constituent mass

$$m_u = m_d.$$

Antiparticles have the same mass as the corresponding particles.

Since the model only gives ratios of masses, the mass scale is fixed so that the electron mass $m_e = 0.5110 \text{ MeV}$.

Then, the constituent mass of the down quark is $m_d = 312.75 \text{ MeV}$, and the constituent mass for the up quark is $m_u = 312.75 \text{ MeV}$.

These results when added up give a total mass of first generation fermion particles: $\Sigma m_f = 1.877 \text{ GeV}$

As the proton mass is taken to be the sum of the constituent masses of its constituent quarks

$$m_{\text{proton}} = m_u + m_u + m_d = 938.25 \text{ MeV}$$

The theoretical calculation is close to the experimental value of 938.27 MeV.

The third generation fermion particles correspond to triples of octonions. There are $8^3 = 512$ such triples.

The triple $\{ 1, 1, 1 \}$ corresponds to the tau-neutrino.

The other 7 triples involving only 1 and E correspond to the tauon:

$$\begin{aligned} & \{ e, e, e \} \\ & \{ e, e, 1 \} \\ & \{ e, 1, e \} \\ & \{ 1, e, e \} \\ & \{ 1, 1, e \} \\ & \{ 1, e, 1 \} \\ & \{ e, 1, 1 \} \end{aligned}$$

The symmetry of the 7 tauon triples is the same as the symmetry of the 3 down quarks, the 3 up quarks, and the electron, so the tauon mass should be the same as the sum of the masses of the first generation massive fermion particles. Therefore the tauon mass is calculated at tree level as 1.877 GeV.

The calculated Tauon mass of 1.88 GeV is a sum of first generation fermion masses, all of which are valid at the energy level of about 1 GeV.

However, as the Tauon mass is about 2 GeV, the effective Tauon mass should be renormalized from the energy level of 1 GeV (where the mass is 1.88 GeV) to the energy level of 2 GeV.

Such a renormalization should reduce the mass. If the renormalization reduction were about 5 percent, the effective Tauon mass at 2 GeV would be about 1.78 GeV.

The 1996 Particle Data Group Review of Particle Physics gives a Tauon mass of 1.777 GeV.

Note that all triples corresponding to the tau and the tau-neutrino are colorless.

The beauty quark corresponds to 21 triples.

They are triples of the same form as the 7 tauon triples, but for 1 and ie, 1 and je, and 1 and ke, which correspond to the red, green, and blue beauty quarks, respectively.

The seven triples of the red beauty quark correspond to the seven triples of the tauon, except that the beauty quark interacts with 6 Spin(0,5) gravitons while the tauon interacts with only two.

The beauty quark constituent mass should be the tauon mass times the third generation graviton factor $6/2 = 3$, so the B-quark mass is $m_b = 5.63111 \text{ GeV}$.

The calculated Beauty Quark mass of 5.63 GeV is a constituent mass, that is, it corresponds to the conventional pole mass plus 312.8 MeV.

Therefore, the calculated Beauty Quark mass of 5.63 GeV corresponds to a conventional pole mass of 5.32 GeV.

The 1996 Particle Data Group Review of Particle Physics gives a lattice gauge theory Beauty Quark pole mass as 5.0 GeV.

The pole mass can be converted to an MSbar mass if the color force strength constant α_s is known. The conventional value of α_s at about 5 GeV is about 0.22.

Using $\alpha_s(5 \text{ GeV}) = 0.22$, a pole mass of 5.0 GeV gives an MSbar 1-loop Beauty Quark mass of 4.6 GeV, and an MSbar 1,2-loop Beauty Quark mass of 4.3, evaluated at about 5 GeV.

If the MSbar mass is run from 5 GeV up to 90 GeV, the MSbar mass decreases by about 1.3 GeV, giving an expected MSbar mass of about 3.0 GeV at 90 GeV. DELPHI at LEP has observed the Beauty Quark and found a 90 GeV MSbar Beauty Quark mass of about 2.67 GeV, with error bars ± 0.25 (stat) ± 0.34 (frag) ± 0.27 (theo).

Note that the theoretical model calculated Beauty Quark mass of 5.63 GeV corresponds to a pole mass of 5.32 GeV, which is somewhat higher than the conventional value of 5.0 GeV.

However,

the theoretical model calculated value of the color force strength constant α_s at about 5 GeV is about 0.166,

while the conventional value of the color force strength constant α_s at about 5 GeV is about 0.216,

and the theoretical model calculated value of the color force strength constant α_s at about 90 GeV is about 0.106,

while the conventional value of the color force strength constant α_s at about 90 GeV is about 0.118.

The theoretical model calculations gives a Beauty Quark pole mass (5.3 GeV) that is about 6 percent higher than the conventional Beauty Quark pole mass (5.0 GeV),

and a color force strength α_s at 5 GeV (0.166)

such that $1 + \alpha_s = 1.166$ is about 4 percent lower

than the conventional value of $1 + \alpha_s = 1.216$ at 5 GeV.

Note particularly that triples of the type $\{ 1, ie, je \}$, $\{ ie, je, ke \}$, etc., do not correspond to the beauty quark, but to the truth quark.

The truth quark corresponds to the remaining 483 triples,

so the constituent mass of the red truth quark

is $161/7 = 23$ times the red beauty quark mass,

and the red T-quark mass is

$m_t = 129.5155$ GeV

The blue and green truth quarks are defined similarly.

All other masses than the electron mass

(which is the basis of the assumption of the value of the Higgs scalar field vacuum expectation value $v = 252.514$ GeV),

including the Higgs scalar mass and Truth quark mass,

are calculated (not assumed) masses in the E8 model.

These results when added up give a total mass of third generation fermion particles:

$\Sigma m_f = 1,629$ GeV

The second generation fermion particles correspond to pairs of octonions.

There are $8^2 = 64$ such pairs. The pair $\{ 1, 1 \}$ corresponds to the mu-neutrino.

The pairs $\{ 1, e \}$, $\{ e, 1 \}$, and $\{ e, e \}$ correspond to the muon.

Compare the symmetries of the muon pairs to the symmetries of the first generation fermion particles.

The pair $\{ e, e \}$ should correspond to the e electron.

The other two muon pairs have a symmetry group S_2 , which is $1/3$ the size of the color symmetry group S_3 which gives the up and down quarks their mass of 312.75 MeV.

Therefore the mass of the muon should be the sum of the $\{ e, e \}$ electron mass and

the $\{ 1, e \}$, $\{ e, 1 \}$ symmetry mass, which is $1/3$ of the up or down quark mass.

Therefore, $m_{\mu} = 104.76 \text{ MeV}$.

According to the 1998 Review of Particle Physics of the Particle Data Group, the experimental muon mass is about 105.66 MeV.

Note that all pairs corresponding to the muon and the mu-neutrino are colorless.

The red, blue and green strange quark each corresponds to the 3 pairs involving 1 and ie, je, or ke.

The red strange quark is defined as the three pairs 1 and i, because i is the red down quark.

Its mass should be the sum of two parts:

the $\{ i, i \}$ red down quark mass, 312.75 MeV, and

the product of the symmetry part of the muon mass, 104.25 MeV, times the graviton factor.

Unlike the first generation situation,

massive second and third generation leptons can be taken,

by both of the colorless gravitons that may carry electric charge, into massive particles.

Therefore the graviton factor for the second and third generations is $6/2 = 3$.

Therefore the symmetry part of the muon mass times the graviton factor 3 is 312.75 MeV,

and the red strange quark constituent mass is

$m_s = 312.75 \text{ MeV} + 312.75 \text{ MeV} = 625.5 \text{ MeV}$

The blue strange quarks correspond to the three pairs involving j, the green strange quarks correspond to the three pairs involving k, and their masses are determined similarly.

The charm quark corresponds to the other 51 pairs. Therefore, the mass of the red charm quark should be the sum of two parts: the { i, i }, red up quark mass, 312.75 MeV; and the product of the symmetry part of the strange quark mass, 312.75 MeV, and the charm to strange octonion number factor 51/9, which product is 1,772.25 MeV. Therefore the red charm quark constituent mass is $m_c = 312.75 \text{ MeV} + 1,772.25 \text{ MeV} = 2.085 \text{ GeV}$

The blue and green charm quarks are defined similarly, and their masses are calculated similarly.

The calculated Charm Quark mass of 2.09 GeV is a constituent mass, that is, it corresponds to the conventional pole mass plus 312.8 MeV.

Therefore, the calculated Charm Quark mass of 2.09 GeV corresponds to a conventional pole mass of 1.78 GeV.

The 1996 Particle Data Group Review of Particle Physics gives a range for the Charm Quark pole mass from 1.2 to 1.9 GeV.

The pole mass can be converted to an MSbar mass if the color force strength constant α_s is known. The conventional value of α_s at about 2 GeV is about 0.39, which is somewhat lower than the theoretical model value. Using $\alpha_s(2 \text{ GeV}) = 0.39$, a pole mass of 1.9 GeV gives an MSbar 1-loop mass of 1.6 GeV, evaluated at about 2 GeV.

These results when added up give a total mass of second generation fermion particles:

$$\Sigma_{\text{2nd}} = 32.9 \text{ GeV}$$

Higgs and W-boson Masses:

As with forces strengths, the calculations produce ratios of masses, so that only one mass need be chosen to set the mass scale.

In the E8 model, the value of the fundamental mass scale vacuum expectation value $v = \langle \text{PHI} \rangle$ of the Higgs scalar field is set to be the sum of the physical masses of the weak bosons, W^+ , W^- , and Z^0 , whose tree-level masses will then be shown by ratio calculations to be 80.326 GeV, 80.326 GeV, and 91.862 GeV, respectively, and so that the electron mass will then be 0.5110 MeV.

The relationship between the Higgs mass and v is given by the Ginzburg-Landau term from the Mayer Mechanism as

$$(1/4) \text{Tr} ([\text{PHI} , \text{PHI}] - \text{PHI})^2$$

or, in the notation of hep-ph/9806009 by Guang-jiong Ni

$$(1/4!) \lambda \text{PHI}^4 - (1/2) \sigma \text{PHI}^2$$

where the Higgs mass $M_H = \sqrt{2 \sigma}$

Ni says:

"... the invariant meaning of the constant λ in the Lagrangian is not the coupling constant, the latter will change after quantization ... The invariant meaning of λ is nothing but the ratio of two mass scales:

$$\lambda = 3 (M_H / \text{PHI})^2$$

which remains unchanged irrespective of the order ...".

Since $\langle \text{PHI} \rangle^2 = v^2$, and assuming at tree-level that $\lambda = 1$ (a value consistent with the Higgs-Tquark condensate model of Michio Hashimoto, Masaharu Tanabashi, and Koichi Yamawaki in their paper at hep-ph/0311165, we have, at tree-level

$$M_H^2 / v^2 = 1 / 3$$

In the E8 model, the fundamental mass scale vacuum expectation value v of the Higgs scalar field is the fundamental mass parameter that is to be set to define all other masses by the mass ratio formulas of the model and

$$v \text{ is set to be } 252.514 \text{ GeV}$$

so that

$$M_H = v / \sqrt{3} = 145.789 \text{ GeV}$$

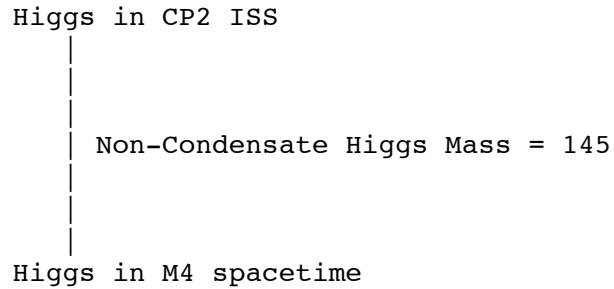
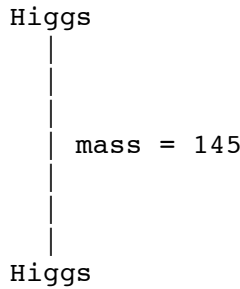
As described above, in the E8 model

$$v \text{ is set to be } 252.514 \text{ GeV } M_H = v / \sqrt{3} = 145.789 \text{ GeV}$$

This is a tree-level calculation in (4+4)-dim Kaluza-Klein with a 4-dim M4 Minkowski Physical Spacetime at each point of which there lives a 4-dim CP2 Internal Symmetry Space (ISS).

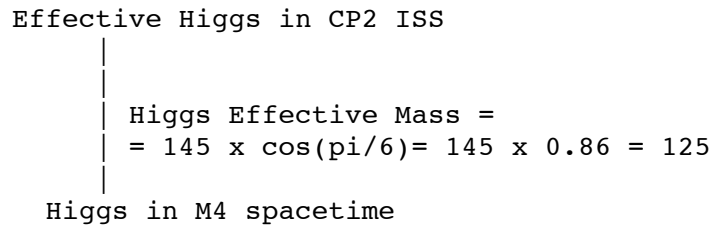
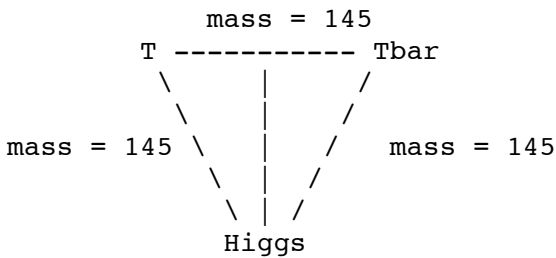
A Non-Condensate Higgs is represented by a Higgs at a point in M4

that is connected to a Higgs representation in CP2 ISS by a line whose length represents the Higgs mass



of the tree-level calculation set out above.

However, in my E8 Physics model, the Higgs has beyond-tree-level structure due to a Tquark condensate



in which the Higgs at a point in M4 is connected to a T and Tbar in CP2 ISS

so that the vertices of the Higgs-T-Tbar system are connected by lines forming an equilateral triangle whose line lengths represent the tree-level calculated mass. Therefore:

The effective length from the Higgs in M4 to the Effective Higgs in CP2 ISS (the mass observed by LHC) is the altitude of the equilateral triangle: $145 \times \cos(\pi/6) = 125 \text{ GeV}$.

To get W-boson masses,
denote the 3 SU(2) high-energy weak bosons
(massless at energies higher than the electroweak unification)
by W^+ , W^- , and W_0 ,
corresponding to the massive physical weak bosons W^+ , W^- , and Z_0 .

The triplet $\{ W^+, W^-, W_0 \}$ couples directly with the $T - Tbar$ quark-antiquark pair,
so that the total mass of the triplet $\{ W^+, W^-, W_0 \}$ at the electroweak unification
is equal to the total mass of a $T - Tbar$ pair, 259.031 GeV.

The triplet $\{ W^+, W^-, Z_0 \}$ couples directly with the Higgs scalar,
which carries the Higgs mechanism by which the W_0 becomes the physical Z_0 ,
so that the total mass of the triplet $\{ W^+, W^-, Z_0 \}$
is equal to the vacuum expectation value v of the Higgs scalar field,
 $v = 252.514$ GeV.

What are individual masses of members of the triplet $\{ W^+, W^-, Z_0 \}$?

First, look at the triplet $\{ W^+, W^-, W_0 \}$
which can be represented by the 3-sphere S^3 .
The Hopf fibration of S^3 as
 $S^1 \rightarrow S^3 \rightarrow S^2$
gives a decomposition of the W bosons
into the neutral W_0 corresponding to S^1
and the charged pair W^+ and W^- corresponding to S^2 .

The mass ratio of the sum of the masses of W^+ and W^- to the mass of W_0
should be the volume ratio of the S^2 in S^3 to the S^1 in S^3 .
The unit sphere S^3 in R^4 is normalized by $1 / 2$.
The unit sphere S^2 in R^3 is normalized by $1 / \sqrt{3}$.
The unit sphere S^1 in R^2 is normalized by $1 / \sqrt{2}$.
The ratio of the sum of the W^+ and W^- masses to the W_0 mass should then be
 $(2 / \sqrt{3}) V(S^2) / (2 / \sqrt{2}) V(S^1) = 1.632993$

Since the total mass of the triplet $\{ W^+, W^-, W_0 \}$ is 259.031 GeV, the total mass
of a $T - Tbar$ pair, and the charged weak bosons have equal mass, we have
 $M_{W^+} = M_{W^-} = 80.326$ GeV and $M_{W_0} = 98.379$ GeV.

The charged $W^{+/-}$ neutrino-electron interchange must be symmetric with the electron-neutrino interchange, so that the absence of right-handed neutrino particles requires that the charged $W^{+/-}$ SU(2) weak bosons act only on left-handed electrons.

Each gauge boson must act consistently on the entire Dirac fermion particle sector, so that the charged $W^{+/-}$ SU(2) weak bosons act only on left-handed fermion particles of all types.

The neutral W_0 weak boson does not interchange Weyl neutrinos with Dirac fermions, and so is not restricted to left-handed fermions, but also has a component that acts on both types of fermions, both left-handed and right-handed, conserving parity.

However, the neutral W_0 weak bosons are related to the charged $W^{+/-}$ weak bosons by custodial SU(2) symmetry, so that the left-handed component of the neutral W_0 must be equal to the left-handed (entire) component of the charged $W^{+/-}$.

Since the mass of the W_0 is greater than the mass of the $W^{+/-}$, there remains for the W_0 a component acting on both types of fermions.

Therefore the full W_0 neutral weak boson interaction is proportional to $(M_{W^{+/-}}^2 / M_{W_0}^2)$ acting on left-handed fermions and $(1 - (M_{W^{+/-}}^2 / M_{W_0}^2))$ acting on both types of fermions.

If $(1 - (M_{W^{+/-}}^2 / M_{W_0}^2))$ is defined to be $\sin(\theta_w)^2$ and denoted by K , and if the strength of the $W^{+/-}$ charged weak force (and of the custodial SU(2) symmetry) is denoted by T , then the W_0 neutral weak interaction can be written as $W_0L = T + K$ and $W_0R = K$.

Since the W_0 acts as W_0L with respect to the parity violating SU(2) weak force and as W_0R with respect to the parity conserving U(1) electromagnetic force of the U(1) subgroup of SU(2), the W_0 mass m_{W_0} has two components: the parity violating SU(2) part m_{W_0L} that is equal to $M_{W^{+/-}}$ and the parity conserving part M_{W_0R} that acts like a heavy photon.

As $M_{W0} = 98.379 \text{ GeV} = M_{W0L} + M_{W0LR}$, and as $M_{W0L} = M_{W\pm} = 80.326 \text{ GeV}$, we have $M_{W0LR} = 18.053 \text{ GeV}$.

Denote by $*\alpha_E = *e^2$ the force strength of the weak parity conserving U(1) electromagnetic type force that acts through the U(1) subgroup of SU(2).

The electromagnetic force strength $\alpha_E = e^2 = 1 / 137.03608$ was calculated above using the volume $V(S^1)$ of an S^1 in R^2 , normalized by $1 / \sqrt{2}$.

The $*\alpha_E$ force is part of the SU(2) weak force whose strength $\alpha_W = w^2$ was calculated above using the volume $V(S^2)$ of an $S^2 \subset R^3$, normalized by $1 / \sqrt{3}$.

Also, the electromagnetic force strength $\alpha_E = e^2$ was calculated above using a 4-dimensional spacetime with global structure of the 4-torus T^4 made up of four S^1 1-spheres, while the SU(2) weak force strength $\alpha_W = w^2$ was calculated above using two 2-spheres $S^2 \times S^2$, each of which contains one 1-sphere of the $*\alpha_E$ force.

Therefore

$$*\alpha_E = \alpha_E (\sqrt{2} / \sqrt{3}) (2 / 4) = \alpha_E / \sqrt{6},$$

$$*e = e / (\text{4th root of } 6) = e / 1.565,$$

and the mass m_{W0LR} must be reduced to an effective value

$$M_{W0LR\text{eff}} = M_{W0LR} / 1.565 = 18.053 / 1.565 = 11.536 \text{ GeV}$$

for the $*\alpha_E$ force to act like an electromagnetic force in the E8 model:

$$*e M_{W0LR} = e (1/1.565) M_{W0LR} = e M_{Z0},$$

where the physical effective neutral weak boson is denoted by $Z0$.

Therefore, the correct E8 model values for weak boson masses and the Weinberg angle θ_w are:

$$M_{W+} = M_{W-} = 80.326 \text{ GeV};$$

$$M_{Z0} = 80.326 + 11.536 = 91.862 \text{ GeV};$$

$$\sin(\theta_w)^2 = 1 - (M_{W\pm} / M_{Z0})^2 = 1 - (80.326 / 91.862)^2 = 0.235.$$

Radiative corrections are not taken into account here, and may change these tree-level values somewhat.

Kobayashi-Maskawa Parameters:

The Kobayashi-Maskawa parameters are determined in terms of the sum of the masses of the 30 first-generation fermion particles and antiparticles, denoted by $S_{mf1} = 7.508 \text{ GeV}$, and the similar sums for second-generation and third-generation fermions, denoted by $S_{mf2} = 32.94504 \text{ GeV}$ and $S_{mf3} = 1,629.2675 \text{ GeV}$.

The reason for using sums of all fermion masses (rather than sums of quark masses only) is that all fermions are in the same spinor representation of Spin(8), and the Spin(8) representations are considered to be fundamental.

The following formulas use the above masses to calculate Kobayashi-Maskawa parameters:

phase angle $d_{13} = 70.529 \text{ degrees}$

$$\sin(\alpha) = s_{12} = \frac{[m_e + 3m_d + 3m_u]}{\sqrt{[m_e^2 + 3m_d^2 + 3m_u^2] + [3m_\mu^2 + 3m_s^2 + 3m_c^2]}} = 0.222198$$

$$\sin(\beta) = s_{13} = \frac{[m_e + 3m_d + 3m_u]}{\sqrt{[m_e^2 + 3m_d^2 + 3m_u^2] + [3m_\tau^2 + 3m_b^2 + 3m_t^2]}} = 0.004608$$

$$\sin(*\gamma) = \frac{[3m_\mu + 3m_s + 3m_c]}{\sqrt{[3m_\tau^2 + 3m_b^2 + 3m_t^2] + [3m_\mu^2 + 3m_s^2 + 3m_c^2]}}$$

$$\sin(\gamma) = s_{23} = \sin(*\gamma) \sqrt{S_{mf2} / S_{mf1}} = 0.04234886$$

The factor $\sqrt{S_{mf2} / S_{mf1}}$ appears in s_{23} because an s_{23} transition is to the second generation and not all the way to the first generation, so that the end product of an s_{23} transition has a greater available energy than s_{12} or s_{13} transitions by a factor of S_{mf2} / S_{mf1} .

Since the width of a transition is proportional to the square of the modulus of the relevant KM entry and the width of an s_{23} transition has greater available energy than the s_{12} or s_{13} transitions by a factor of S_{mf2} / S_{mf1} the effective magnitude of the s_{23} terms in the KM entries is increased by the factor $\sqrt{S_{mf2} / S_{mf1}}$.

The Chau-Keung parameterization is used, as it allows the K-M matrix to be represented as the product of the following three 3x3 matrices:

$$\begin{matrix} 1 & 0 & 0 \\ 0 & \cos(\gamma) & \sin(\gamma) \\ 0 & -\sin(\gamma) & \cos(\gamma) \end{matrix}$$

$$\begin{matrix} \cos(\beta) & 0 & \sin(\beta)\exp(-i d_{13}) \\ 0 & 1 & 0 \\ -\sin(\beta)\exp(i d_{13}) & 0 & \cos(\beta) \end{matrix}$$

$$\begin{matrix} \cos(\alpha) & \sin(\alpha) & 0 \\ -\sin(\alpha) & \cos(\alpha) & 0 \\ 0 & 0 & 1 \end{matrix}$$

The resulting Kobayashi-Maskawa parameters for W^+ and W^- charged weak boson processes, are:

	d	s	b
u	0.975	0.222	0.00249 -0.00388i
c	-0.222 -0.000161i	0.974 -0.0000365i	0.0423
t	0.00698 -0.00378i	-0.0418 -0.00086i	0.999

The matrix is labelled by either (u c t) input and (d s b) output, or, as above, (d s b) input and (u c t) output.

For Z^0 neutral weak boson processes, which are suppressed by the GIM mechanism of cancellation of virtual subprocesses, the matrix is labelled by either (u c t) input and (u'c't') output, or, as below, (d s b) input and (d's'b') output:

	d	s	b
d'	0.975	0.222	0.00249 -0.00388i
s'	-0.222 -0.000161i	0.974 -0.0000365i	0.0423
b'	0.00698 -0.00378i	-0.0418 -0.00086i	0.999

Since neutrinos of all three generations are massless at tree level, the lepton sector has no tree-level K-M mixing.

According to a Review on the KM mixing matrix by Gilman, Kleinknecht, and Renk in the 2002 Review of Particle Physics: "... Using the eight tree-level constraints discussed below together with unitarity, and assuming only three generations, the 90% confidence limits on the magnitude of the elements of the complete matrix are

	d	s	b
u	0.9741 to 0.9756	0.219 to 0.226	0.00425 to 0.0048
c	0.219 to 0.226	0.9732 to 0.9748	0.038 to 0.044
t	0.004 to 0.014	0.037 to 0.044	0.9990 to 0.9993

... The constraints of unitarity connect different elements, so choosing a specific value for one element restricts the range of others. ... The phase δ_{13} lies in the range $0 < \delta_{13} < 2\pi$, with non-zero values generally breaking CP invariance for the weak interactions. ... Using tree-level processes as constraints only, the matrix elements ... [of the 90% confidence limit shown above] ... correspond to values of the sines of the angles of $s_{12} = 0.2229 \pm 0.0022$, $s_{23} = 0.0412 \pm 0.0020$, and $s_{13} = 0.0036 \pm 0.0007$. If we use the loop-level processes discussed below as additional constraints, the sines of the angles remain unaffected, and the CKM phase, sometimes referred to as the angle $\gamma = \phi_3$ of the unitarity triangle ... is restricted to $\delta_{13} = (1.02 \pm 0.22)$ radians = 59 ± 13 degrees. ... CP-violating amplitudes or differences of rates are all proportional to the product of CKM factors ... $s_{12} s_{13} s_{23} c_{12} c_{13}^2 c_{23} \sin\delta_{13}$. This is just twice the area of the unitarity triangle. ... All processes can be quantitatively understood by one value of the CKM phase $\delta_{13} = 59 \pm 13$ degrees. The value of $\beta = 24 \pm 4$ degrees from the overall fit is consistent with the value from the CP-asymmetry measurements of 26 ± 4 degrees. The invariant measure of CP violation is $J = (3.0 \pm 0.3) \times 10^{-5}$ From a combined fit using the direct measurements, B mixing, ϵ , and $\sin 2\beta$, we obtain: $\text{Re } V_{td} = 0.0071 \pm 0.0008$, $\text{Im } V_{td} = -0.0032 \pm 0.0004$... Constraints... on the position of the apex of the unitarity triangle following from $|V_{ub}|$, B mixing, ϵ , and $\sin 2\beta$".

In hep-ph/0208080, Yosef Nir says: "... Within the Standard Model, the only source of CP violation is the Kobayashi-Maskawa (KM) phase ... The study of CP violation is, at last, experiment driven. ... The CKM matrix provides a consistent picture of all the measured flavor and CP violating processes. ... There is no signal of new flavor physics. ... Very likely, the KM mechanism is the dominant source of CP violation in flavor changing processes. ... The result is consistent with the SM predictions. ...".

Neutrino Mixing

Consider the three generations of neutrinos:
nu_e (electron neutrino); nu_m (muon neutrino); nu_t
and three neutrino mass states: nu_1 ; nu_2 : nu_3
and
the division of 8-dimensional spacetime into
4-dimensional physical Minkowski spacetime
plus
4-dimensional CP2 internal symmetry space.

The heaviest mass state nu_3 corresponds to a neutrino
whose propagation begins and ends in CP2 internal symmetry space,
lying entirely therein. According to the D4-D5-E6-E7-E8 VoDou
Physics Model the mass of nu_3 is zero at tree-level
but it picks up a first-order correction propagating
entirely through internal symmetry space by
merging with an electron through the weak and electromagnetic forces,
effectively acting not merely as a point
but
as a point plus an electron loop at both beginning and ending points
so

the first-order corrected mass of nu_3 is given by
 $M_{\nu_3} \times (1/\sqrt{2}) = M_e \times GW(m_{\text{proton}}^2) \times \alpha_E$
where the factor $(1/\sqrt{2})$ comes from the Ut3 component
of the neutrino mixing matrix
so that

$$\begin{aligned} M_{\nu_3} &= \sqrt{2} \times M_e \times GW(m_{\text{proton}}^2) \times \alpha_E = \\ &= 1.4 \times 5 \times 10^5 \times 1.05 \times 10^{(-5)} \times (1/137) \text{ eV} = \\ &= 7.35 / 137 = 5.4 \times 10^{(-2)} \text{ eV}. \end{aligned}$$

Note that the neutrino-plus-electron loop can be anchored
by weak force action through any of the 6 first-generation quarks
at each of the beginning and ending points, and that the
anchor quark at the beginning point can be different from
the anchor quark at the ending point,
so that there are $6 \times 6 = 36$ different possible anchorings.

The intermediate mass state nu_2 corresponds to a neutrino
whose propagation begins or ends in CP2 internal symmetry space
and ends or begins in physical Minkowski spacetime,
thus having only one point (either beginning or ending) lying
in CP2 internal symmetry space where it can act not merely
as a point but as a point plus an electron loop.
According to the D4-D5-E6-E7-E8 VoDou Physics Model the mass

of ν_2 is zero at tree-level
but it picks up a first-order correction at only one (but not both)
of the beginning or ending points
so that so that there are 6 different possible anchorings
for ν_2 first-order corrections, as opposed to the 36 different
possible anchorings for ν_3 first-order corrections,
so that
the first-order corrected mass of ν_2 is less than
the first-order corrected mass of ν_3 by a factor of 6,
so
the first-order corrected mass of ν_2 is

$$M_{\nu_2} = M_{\nu_3} / \text{Vol}(\text{CP}2) = 5.4 \times 10^{(-2)} / 6$$

$$= 9 \times 10^{(-3)} \text{eV}.$$

The low mass state ν_1 corresponds to a neutrino
whose propagation begins and ends in physical Minkowski spacetime.
thus having only one anchoring to CP2 interna symmetry space.
According to E8 Physics the mass of ν_1 is zero at tree-level
but it has only 1 possible anchoring to CP2
as opposed to the 36 different possible anchorings for ν_3 first-order corrections
or the 6 different possible anchorings for ν_2 first-order corrections
so that
the first-order corrected mass of ν_1 is less than
the first-order corrected mass of ν_2 by a factor of 6,
so
the first-order corrected mass of ν_1 is

$$M_{\nu_1} = M_{\nu_2} / \text{Vol}(\text{CP}2) = 9 \times 10^{(-3)} / 6$$

$$= 1.5 \times 10^{(-3)} \text{eV}.$$

Therefore:

$$\begin{aligned} \text{the mass-squared difference } D(M_{23}^2) &= M_{\nu_3}^2 - M_{\nu_2}^2 = \\ &= (2916 - 81) \times 10^{(-6)} \text{ eV}^2 = \\ &= 2.8 \times 10^{(-3)} \text{ eV}^2 \end{aligned}$$

and

$$\begin{aligned} \text{the mass-squared difference } D(M_{12}^2) &= M_{\nu_2}^2 - M_{\nu_1}^2 = \\ &= (81 - 2) \times 10^{(-6)} \text{ eV}^2 = \\ &= 7.9 \times 10^{(-5)} \text{ eV}^2 \end{aligned}$$

The 3×3 unitary neutrino mixing matrix neutrino mixing matrix U

	ν_1	ν_2	ν_3
ν_e	Ue1	Ue2	Ue3
ν_m	Um1	Um2	Um3
ν_t	Ut1	Ut2	Ut3

can be parameterized (based on the 2010 Particle Data Book)
by 3 angles and 1 Dirac CP violation phase

$$U = \begin{pmatrix} c_{12} c_{13} & s_{12} c_{13} & s_{13} e^{-i\delta} \\ -s_{12} c_{23} - c_{12} s_{23} s_{13} e^{i\delta} & c_{12} c_{23} - s_{12} s_{23} s_{13} e^{i\delta} & s_{23} c_{13} \\ s_{12} s_{23} - c_{12} c_{23} s_{13} e^{i\delta} & -c_{12} s_{23} - s_{12} c_{23} s_{13} e^{i\delta} & c_{23} c_{13} \end{pmatrix}$$

where $c_{ij} = \cos(\theta_{ij})$, $s_{ij} = \sin(\theta_{ij})$

The angles are

$$\theta_{23} = \pi/4 = 45 \text{ degrees}$$

because

ν_3 has equal components of ν_m and ν_t so

that $U_{m3} = U_{t3} = 1/\sqrt{2}$ or, in conventional

notation, mixing angle $\theta_{23} = \pi/4$

so that $\cos(\theta_{23}) = 0.707 = \sqrt{2}/2 = \sin(\theta_{23})$

$$\theta_{13} = 9.594 \text{ degrees} = \arcsin(1/6)$$

and $\cos(\theta_{13}) = 0.986$

because $\sin(\theta_{13}) = 1/6 = 0.167 = |U_{e3}| = \text{fraction of } \nu_3 \text{ that is } \nu_e$

$$\theta_{12} = \pi/6 = 30 \text{ degrees}$$

because

$\sin(\theta_{12}) = 0.5 = 1/2 = U_{e2} = \text{fraction of } \nu_2 \text{ begin/end points}$

that are in the physical spacetime where massless ν_e lives

so that $\cos(\theta_{12}) = 0.866 = \sqrt{3}/2$

$\delta = 70.529$ degrees is the Dirac CP violation phase

$$e^{i\delta} = \cos(70.529) + i \sin(70.529) = 0.333 + 0.943 i$$

This is because the neutrino mixing matrix has 3-generation structure

and so has the same phase structure as the KM quark mixing matrix

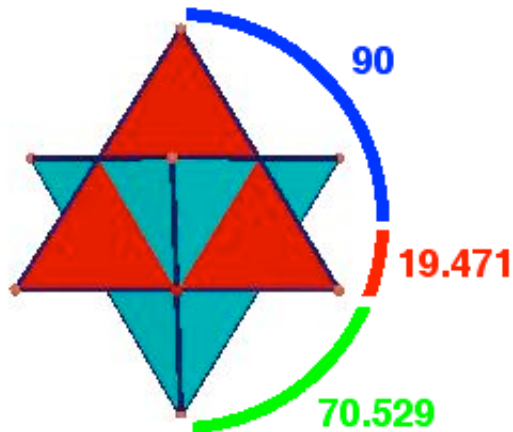
in which the Unitarity Triangle angles are:

$$\beta = \angle V_3 V_1 V_4 = \arccos(2/\sqrt{3}) \cong 19.471 \text{ degrees so } \sin 2\beta = 0.6285$$

$$\alpha = \angle V_1 V_3 V_4 = 90 \text{ degrees}$$

$$\gamma = \angle V_1 V_4 V_3 = \arcsin(2/\sqrt{3}) \cong 70.528 \text{ degrees}$$

The constructed Unitarity Triangle angles can be seen on the Stella Octangula configuration of two dual tetrahedra (image from gauss.math.nthu.edu.tw):



Then we have for the neutrino mixing matrix:

	nu_1	nu_2	nu_3
nu_e	0.866 x 0.986	0.50 x 0.986	0.167 x e-id
nu_m	-0.5 x 0.707 -0.866 x 0.707 x 0.167 x eid	0.866 x 0.707 -0.5 x 0.707 x 0.167 x eid	0.707 x 0.986
nu_t	0.5 x 0.707 -0.866 x 0.707 x 0.167 x eid	-0.866 x 0.707 -0.5 x 0.707 x 0.167 x eid	0.707 x 0.986

	nu_1	nu_2	nu_3
nu_e	0.853	0.493	0.167 e-id
nu_m	-0.354 -0.102 eid	0.612 -0.059 eid	0.697
nu_t	0.354 -0.102 eid	-0.612 -0.059 eid	0.697

Since $e^{i(70.529)} = \cos(70.529) + i \sin(70.529) = 0.333 + 0.943 i$
and $.333e^{-i(70.529)} = \cos(70.529) - i \sin(70.529) = 0.333 - 0.943 i$

	nu_1	nu_2	nu_3
nu_e	0.853	0.493	0.056 - 0.157 i
nu_m	-0.354 -0.034 - 0.096 i	0.612 -0.020 - 0.056 i	0.697
nu_t	0.354 -0.034 - 0.096 i	-0.612 -0.020 - 0.056 i	0.697

for a result of

	nu_1	nu_2	nu_3
nu_e	0.853	0.493	0.056 - 0.157 i
nu_m	-0.388 - 0.096 i	0.592 - 0.056 i	0.697
nu_t	0.320 - 0.096 i	0.632 - 0.056 i	0.697

which is consistent with the approximate experimental values of mixing angles shown in the Michaelmas Term 2010 Particle Physics handout of Prof Mark Thomson if the matrix is modified by taking into account the March 2012 results from Daya Bay observing non-zero $\theta_{13} = 9.54$ degrees.

Proton-Neutron Mass Difference:

According to the 1986 CODATA Bulletin No. 63, the experimental value of the neutron mass is 939.56563(28) Mev, and the experimental value of the proton is 938.27231(28) Mev.

The neutron-proton mass difference 1.3 Mev is due to the fact that the proton consists of two up quarks and one down quark, while the neutron consists of one up quark and two down quarks.

The magnitude of the electromagnetic energy difference $m_N - m_P$ is about 1 Mev, but the sign is wrong: $m_N - m_P = -1$ Mev, and the proton's electromagnetic mass is greater than the neutron's.

The difference in energy between the bound states, neutron and proton, is not due to a difference between the Pre-Quantum constituent masses of the up quark and the down quark, which are calculated in the E8 model to be equal.

It is due to the difference between the Quantum color force interactions of the up and down constituent valence quarks with the gluons and virtual sea quarks in the neutron and the proton.

An up valence quark, constituent mass 313 Mev, does not often swap places with a 2.09 Gev charm sea quark, but a 313 Mev down valence quark can more often swap places with a 625 Mev strange sea quark.

Therefore the Quantum color force constituent mass of the down valence quark is heavier by about

$$(m_s - m_d) (m_d/m_s)^2 a(w) |V_{ds}| = 312 \times 0.25 \times 0.253 \times 0.22 \text{ Mev} = 4.3 \text{ Mev},$$

(where $a(w) = 0.253$ is the geometric part of the weak force strength and $|V_{ds}| = 0.22$ is the magnitude of the K-M parameter mixing first generation down and second generation strange)

so that the Quantum color force constituent mass Q_{md} of the down quark is

$$Q_{md} = 312.75 + 4.3 = 317.05 \text{ MeV}.$$

Similarly, the up quark Quantum color force mass increase is about
 $(m_c - m_u) (m_u/m_c)^2 a(w) |V_{uc}| = 1777 \times 0.022 \times 0.253 \times 0.22 \text{ MeV} = 2.2 \text{ MeV},$

(where $|V_{uc}| = 0.22$ is the magnitude of the K-M parameter mixing first generation up and second generation charm)

so that the Quantum color force constituent mass Q_{mu} of the up quark is

$$Q_{mu} = 312.75 + 2.2 = 314.95 \text{ MeV}.$$

Therefore, the Quantum color force Neutron-Proton mass difference is

$$m_N - m_P = Q_{md} - Q_{mu} = 317.05 \text{ MeV} - 314.95 \text{ MeV} = 2.1 \text{ MeV}.$$

Since the electromagnetic Neutron-Proton mass difference is roughly

$$m_N - m_P = -1 \text{ MeV}$$

the total theoretical Neutron-Proton mass difference is

$$m_N - m_P = 2.1 \text{ MeV} - 1 \text{ MeV} = 1.1 \text{ MeV},$$

an estimate that is fairly close to the experimental value of 1.3 MeV.

Note that in the equation $(m_s - m_d) (m_d/m_s)^2 a(w) |V_{ds}| = 4.3 \text{ MeV} ,$

V_{ds} is a mixing of down and strange by a neutral Z_0 ,

compared to the more conventional V_{us} mixing by charged W .

Although real neutral Z_0 processes are suppressed by the GIM mechanism, which is a cancellation of virtual processes,

the process of the equation is strictly a virtual process.

Note also that the K-M mixing parameter $|V_{ds}|$ is linear.

Mixing (such as between a down quark and a strange quark) is a two-step process, that goes approximately as the square of $|V_{ds}|$:

First the down quark changes to a virtual strange quark, producing one factor of $|V_{ds}|$.

Then, second, the virtual strange quark changes back to a down quark, producing a second factor of $|V_{ds}|$, which is approximately equal to $|V_{ds}|$.

Only the first step (one factor of $|V_{ds}|$) appears in the Quantum mass formula used to determine the neutron mass.

Measurement of a neutron mass includes a sum over histories of the valence quarks inside the neutron in some of which you will "see" some of the two valence down quarks in a virtual transition state or change from down to strange before the second action, or change back. Therefore, you should take into account those histories in the sum in which you see a strange valence quark, and you get the linear factor $|V_{ds}|$ in the above equation.

Pion Mass:

The quark content of a charged pion is a quark - antiquark pair: either Up plus antiDown or Down plus antiUp. Experimentally, its mass is about 139.57 MeV.

The quark is a Naked Singularity Kerr-Newman Black Hole, with electromagnetic charge e and spin angular momentum J and constituent mass M 312 MeV, such that $e^2 + a^2$ is greater than M^2 (where $a = J / M$).

The antiquark is also a Naked Singularity Kerr-Newman Black Hole, with electromagnetic charge e and spin angular momentum J and constituent mass M 312 MeV, such that $e^2 + a^2$ is greater than M^2 (where $a = J / M$).

According to General Relativity, by Robert M. Wald (Chicago 1984) page 338 [Problems] ... 4. ...:

"... Suppose two widely separated Kerr black holes with parameters (M_1, J_1) and (M_2, J_2) initially are at rest in an axisymmetric configuration, i.e., their rotation axes are aligned along the direction of their separation.

Assume that these black holes fall together and coalesce into a single black hole.

Since angular momentum cannot be radiated away in an axisymmetric spacetime, the final black hole will have momentum $J = J_1 + J_2$".

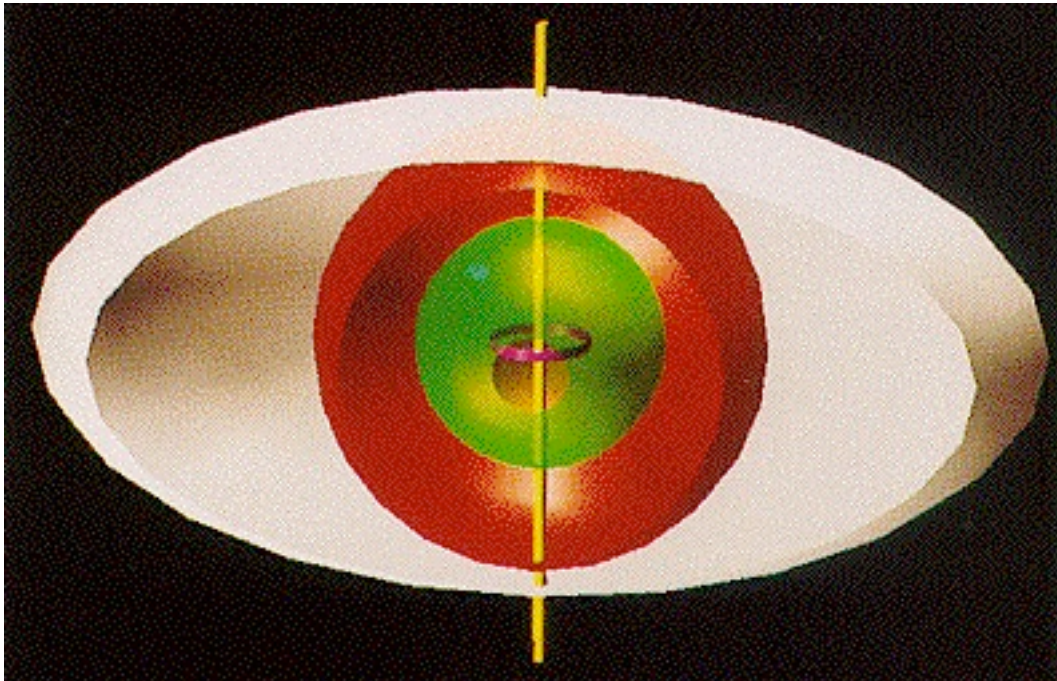
The neutral pion produced by the quark - antiquark pair would have zero angular momentum, thus reducing the value of $e^2 + a^2$ to e^2 .

For fermion electrons with spin $1/2$, $1/2 = e / M$ (see for example Misner, Thorne, and Wheeler, Gravitation (Freeman 1972), page 883) so that $M^2 = 4 e^2$ is greater than e^2 for the electron. In other words, the angular momentum term a^2 is necessary to make $e^2 + a^2$ greater than M^2 so that the electron can be seen as a Kerr-Newman naked singularity.

Since the magnitude of electromagnetic charge of each quark or antiquark is less than that of an electron, and since the mass of each quark or antiquark (as well as the pion mass) is greater than that of an electron, and since the quark - antiquark pair (as well as the pion) has angular momentum zero, the quark - antiquark pion has M^2 greater than $e^2 + a^2 = e^2$.

(Note that color charge, which is nonzero for the quark and the antiquark and is involved in the relation M^2 less than sum of spin-squared and charges-squared by which quarks and antiquarks can be seen as Kerr-Newman naked singularities, is not relevant for the color-neutral pion.)

Therefore, the pion itself is a normal Kerr-Newman Black Hole with Outer Event Horizon = Ergosphere at $r = 2M$ (the Inner Event Horizon is only the origin at $r = 0$) as shown in this image



from *Black Holes - A Traveller's Guide*, by Clifford Pickover (Wiley 1996) in which the Ergosphere is white, the Outer Event Horizon is red, the Inner Event Horizon is green, and the Ring Singularity is purple. In the case of the pion, the white and red surfaces coincide, and the green surface is only a point at the origin.

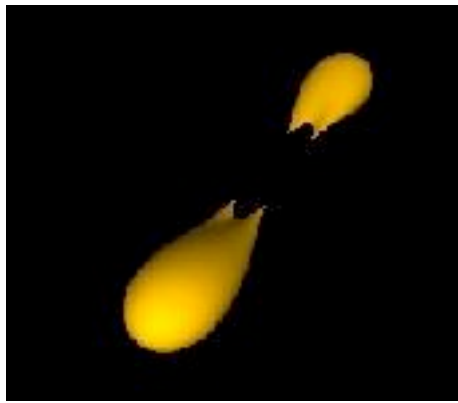
According to section 3.6 of Jeffrey Winicour's 2001 Living Review of the Development of Numerical Evolution Codes for General Relativity (see also a 2005 update):

"... The black hole event horizon associated with ... slightly broken ... degeneracy [of the axisymmetric configuration]... reveals new features not seen in the degenerate case of the head-on collision ... If the degeneracy is slightly broken, the individual black holes form with spherical topology but as they approach, tidal distortion produces two sharp pincers on each black hole just prior to merger.

... Tidal distortion of approaching black holes ...



... Formation of sharp pincers just prior to merger ..



... toroidal stage just after merger ...



At merger, the two pincers join to form a single ... toroidal black hole.

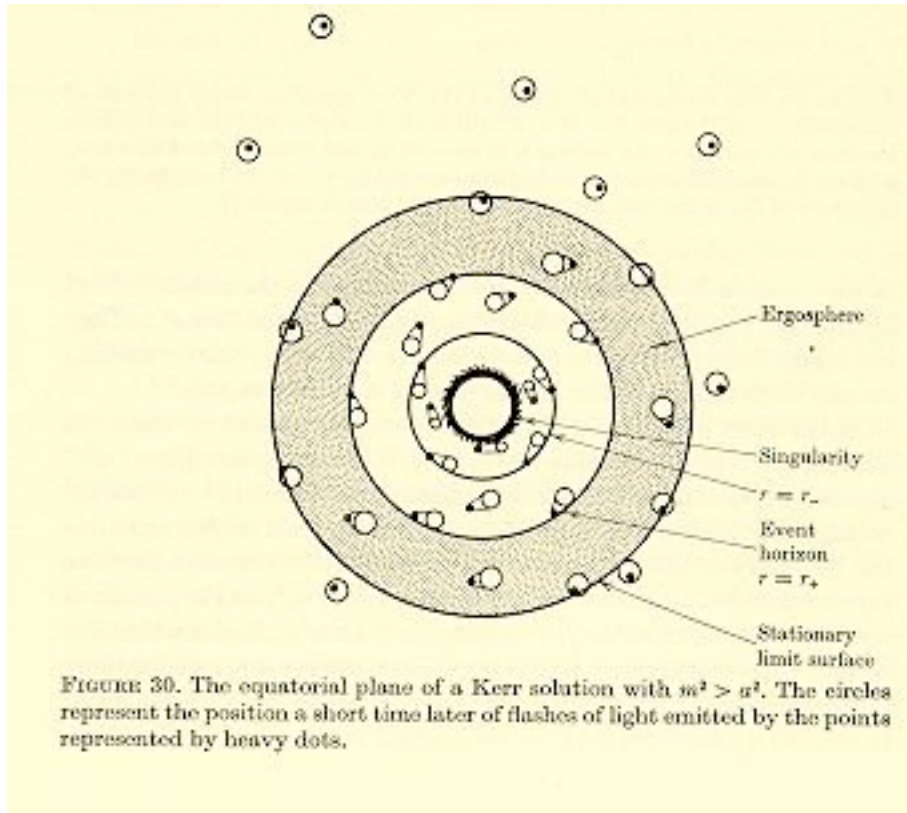
The inner hole of the torus subsequently [begins to] close... up (superluminally) ... [If the closing proceeds to completion, it]... produce[s] first a peanut shaped black hole and finally a spherical black hole. ...".

In the physical case of quark and antiquark forming a pion, the toroidal black hole remains a torus. The torus is an event horizon and therefore is not a 2-spacelike dimensional torus, but is a (1+1)-dimensional torus with a timelike dimension.

The effect is described in detail in Robert Wald's book *General Relativity* (Chicago 1984). It can be said to be due to extreme frame dragging, or to timelike translations becoming spacelike as though they had been Wick rotated in Complex SpaceTime.

As Hawking and Ellis say in *The LargeScale Structure of Space-Time* (Cambridge 1973):

"... The surface $r = r_+$ is ... the event horizon ... and is a null surface ...



... On the surface $r = r_+$ the wavefront corresponding to a point on this surface lies entirely within the surface. ...".

A (1+1)-dimensional torus with a timelike dimension can carry a Sine-Gordon Breather, and the soliton and antisoliton of a Sine-Gordon Breather correspond to the quark and antiquark that make up the pion.

Sine-Gordon Breathers are described by Sidney Coleman in his Erica lecture paper Classical Lumps and their Quantum Descendants (1975), reprinted in his book Aspects of Symmetry (Cambridge 1985), where Coleman writes the Lagrangian for the Sine-Gordon equation as (Coleman's eq. 4.3):

$$L = (1 / B^2) ((1/2) (df)^2 + A (\cos(f) - 1))$$

and Coleman says:

"... We see that, in classical physics, B is an irrelevant parameter: if we can solve the sine-Gordon equation for any non-zero B, we can solve it for any other B. The only effect of changing B is the trivial one of changing the energy and momentum assigned to a given solution of the equation. This is not true in quantum physics, because the relevant object for quantum physics is not L but [eq. 4.4]

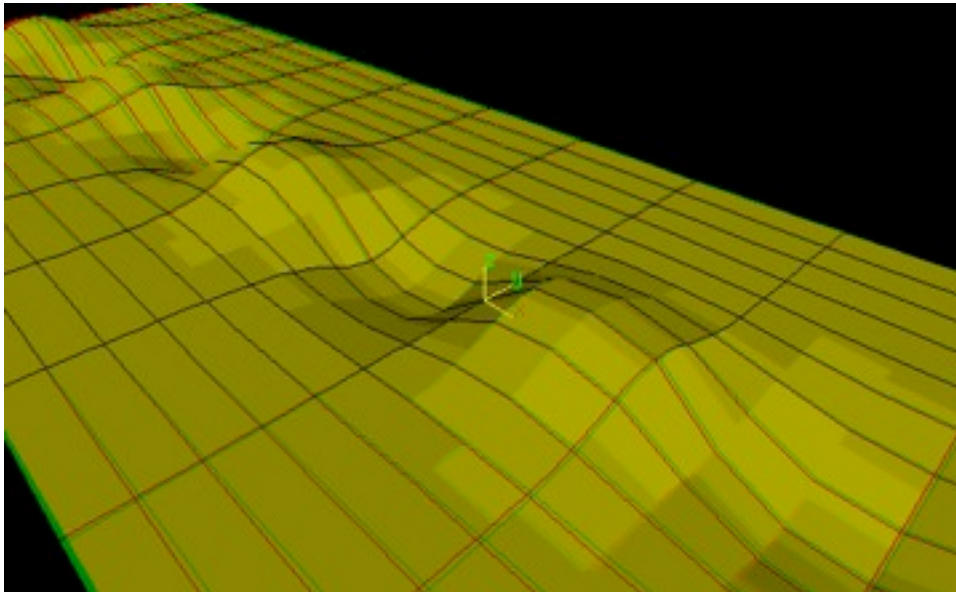
$$L / \hbar = (1 / (B^2 \hbar)) ((1/2) (df)^2 + A (\cos(f) - 1))$$

An other way of saying the same thing is to say that in quantum physics we have one more dimensional constant of nature, Planck's constant, than in classical physics. ... the classical limit, vanishing \hbar , is exactly the same as the small-coupling limit, vanishing B ... from now on I will ... set \hbar equal to one. ...

... the sine-Gordon equation ... [has]... an exact periodic solution ... [eq. 4.59]...

$$f(x, t) = (4 / B) \arctan((n \sin(w t) / \cosh(n w x))$$

where [eq. 4.60] $n = \sqrt{ A - w^2 } / w$ and w ranges from 0 to A . This solution has a simple physical interpretation ... a soliton far to the left ... [and]... an antisoliton far to the right. As $\sin(w t)$ increases, the soliton and antisoliton mover farther apart from each other. When $\sin(w t)$ passes through one, they turn around and begin to approach one another. As $\sin(w t)$ comes down to zero ... the soliton and antisoliton are on top of each other ... when $\sin(w t)$ becomes negative .. the soliton and antisoliton have passed each other. ... [



This stereo image of a Sine-Gordon Breather was generated by the program 3D-Filmstrip for Macintosh by Richard Palais. You can see the stereo with red-green or red-cyan 3D glasses. The program is on the WWW at <http://rsp.math.brandeis.edu/3D-Filmstrip>. The Sine-Gordon Breather is confined in space (y-axis) but periodic in time (x-axis), and therefore naturally lives on the (1+1)-dimensional torus with a timelike dimension of the Event Horizon of the pion. ...]

... Thus, Eq. (4.59) can be thought of as a soliton and an antisoliton oscillation about their common center-of-mass. For this reason, it is called 'the doublet [or Breather] solution'. ... the energy of the doublet ... [eq. 4.64]

$$E = 2 M \sqrt{1 - (w^2 / A)}$$

where [eq. 4.65] $M = 8 \sqrt{A} / B^2$ is the soliton mass. Note that the mass of the doublet is always less than twice the soliton mass, as we would expect from a soliton-antisoliton pair. ... Dashen, Hasslacher, and Neveu ... Phys. Rev. D10, 4114; 4130; 4138 (1974). A pedagogical review of these methods has been written by R. Rajaraman (Phys. Reports 21, 227 (1975 ... Phys. Rev. D11, 3424 (1975) ... [Dashen, Hasslacher, and Neveu found that]... there is only a single series of bound states, labeled by the integer N ... The energies ... are ... [eq. 4.82]

$$E_N = 2 M \sin(B'^2 N / 16)$$

where $N = 0, 1, 2 \dots < 8 \pi / B'^2$, [eq. 4.83]

$$B'^2 = B^2 / (1 - (B^2 / 8 \pi))$$

and M is the soliton mass. M is not given by Eq. (4.675), but is the soliton mass corrected by the DHN formula, or, equivalently, by the first-order weak coupling expansion. ... I have written the equation in this form .. to eliminate A, and thus avoid worries about renormalization conventions. Note that the DHN formula is identical to the Bohr-Sommerfeld formula, except that B is replaced by B'. ... Bohr and Sommerfeld[s] ... quantization formula says that if we have a one-parameter family of periodic motions, labeled by the period, T, then an energy eigenstate occurs whenever [eq. 4.66]

$$[\text{Integral from } 0 \text{ to } T](dt \dot{p} = 2 \pi N,$$

where N is an integer. ... Eq.(4.66) is cruder than the WKB formula, but it is much more general; it is always the leading approximation for any dynamical system ... Dashen et al speculate that Eq. (4.82) is exact. ...

the sine-Gordon equation is equivalent ... to the massive Thirring model. This is surprising, because the massive Thirring model is a canonical field theory whose Hamiltonian is expressed in terms of fundamental Fermi fields only. Even more surprising, when $B^2 = 4 \pi$, that sine-Gordon equation is equivalent to a free massive Dirac theory, in one spatial dimension. ... Furthermore, we can identify the

mass term in the Thirring model with the sine-Gordon interaction,
[eq. 5.13]

$$M = - (A / B^2) N_m \cos(B f)$$

.. to do this consistently ... we must say [eq. 5.14]

$$B^2 / (4 \pi) = 1 / (1 + g / \pi)$$

....[where]... g is a free parameter, the coupling constant [for the Thirring model]... Note that if $B^2 = 4 \pi$, $g = 0$, and the sine-Gordon equation is the theory of a free massive Dirac field. ... It is a bit surprising to see a fermion appearing as a coherent state of a Bose field. Certainly this could not happen in three dimensions, where it would be forbidden by the spin-statistics theorem. However, there is no spin-statistics theorem in one dimension, for the excellent reason that there is no spin. ... the lowest fermion-antifermion bound state of the massive Thirring model is an obvious candidate for the fundamental meson of sine-Gordon theory. ... equation (4.82) predicts that all the doublet bound states disappear when B^2 exceeds 4π . This is precisely the point where the Thirring model interaction switches from attractive to repulsive. ... these two theories ... the massive Thirring model .. and ... the sine-Gordon equation ... define identical physics. ... I have computed the predictions of ...[various]... approximation methods for the ration of the soliton mass to the meson mass for three values of B^2 : 4π (where the qualitative picture of the soliton as a lump totally breaks down), 2π , and π . At 4π we know the exact answer

... I happen to know the exact answer for 2π , so I have included this in the table. ...

Method	$B^2 = \pi$	$B^2 = 2\pi$	$B^2 = 4\pi$
Zeroth-order weak coupling expansion eq2.13b	2.55	1.27	0.64
Coherent-state variation	2.55	1.27	0.64
First-order weak coupling expansion	2.23	0.95	0.32
Bohr-Sommerfeld eq4.64	2.56	1.31	0.71
DHN formula eq4.82	2.25	1.00	0.50
Exact	?	1.00	0.50

...[eq. 2.13b] $E = 8 \sqrt{A} / B^2$...[is the]... energy of the lump ... of sine-Gordon theory ... frequently called 'soliton...' in the literature ... [Zeroth-order is the classical case, or classical limit.] ...

... Coherent-state variation always gives the same result as the ... Zeroth-order weak coupling expansion

The ... First-order weak-coupling expansion ... explicit formula ... is $(8 / B^2) - (1 / \pi)$".

Note that, using the VoDou Physics constituent mass of the Up and Down quarks and antiquarks, about 312.75 MeV, as the soliton and antisoliton masses, and setting $B^2 = \pi$ and using the DHN formula, the mass of the charged pion is calculated to be

$$(312.75 / 2.25) \text{ MeV} = 139 \text{ MeV}$$

which is in pretty good agreement with the experimental value of about 139.57 MeV.

Why is the value $B^2 = \pi$ (or, using Coleman's eq. (5.14), the Thirring coupling constant $g = 3\pi$) the special value that gives the pion mass ?

Because $B^2 = \pi$ is where the First-order weak coupling expansion substantially coincides with the (probably exact) DHN formula.

In other words, the physical quark - antiquark pion lives where the first-order weak coupling expansion is exact.

Near the end of his article, Coleman expressed "Some opinions":

"... This has been a long series of physics lectures with no reference whatsoever to experiment. This is embarrassing.

... Is there any chance that the lump will be more than a theoretical toy in our field? I can think of two possibilities.

One is that there will appear a theory of strong-interaction dynamics in which hadrons are thought of as lumps, or, ... as systems of quarks bound into lumps. ... I am pessimistic about the success of such a theory. ... However, I stand ready to be converted in a moment by a convincing computation.

The other possibility is that a lump will appear in a realistic theory ... of weak and electromagnetic interactions ... the theory would have to imbed the $U(1) \times SU(2)$ group ... in a larger group without $U(1)$ factors ... it would be a magnetic monopole. ...".

This description of the hadronic pion as a quark - antiquark system governed by the sine-Gordon - massive Thirring model should dispel Coleman's pessimism about his first stated possibility and relieve his embarrassment about lack of contact with experiment.

As to his second stated possibility, very massive monopoles related to $SU(5)$ GUT are still within the realm of possible future experimental discoveries.

Further material about the sine-Gordon doublet Breather and the massive Thirring equation can be found in the book Solitons and Instantons (North-Holland 1982,1987) by R. Rajaraman, who writes:

"... the doublet or breather solutions ... can be used as input into the WKB method. ... the system is ... equivalent to the massive Thirring model, with the SG soliton state identifiable as a fermion. ... Mass of the quantum soliton ... will consist of a classical term followed by quantum corrections. The energy of the classical soliton ... is ... [eq. 7.3]

$$E_{cl}[f_{sol}] = 8 m^3 / L$$

The quantum corrections ... to the 'soliton mass' ... is finite as the momentum cut-off goes to infinity and equals $(- m / \pi)$. Hence the quantum soliton's mass is [eq. 7.10]

$$M_{sol} = (8 m^3 / L) - (m / \pi) + O(L).$$

The mass of the quantum antisoliton will be, by ... symmetry, the same as M_{sol}

The doublet solutions ... may be quantised by the WKB method. ... we see that the coupling constant (L / m^2) has been replaced by a 'renormalised' coupling constant G ... [eq. 7.24]

$$G = (L / m^2) / (1 - (L / 8 \pi m^2))$$

... as a result of quantum corrections. ... the same thing had happened to the soliton mass in eq. (7.10). To leading order, we can write [eq. 7.25]

$$M_{\text{sol}} = (8 m^3 / L) - (m / \pi) = 8 m / G$$

... The doublet masses ... bound-state energy levels ... $E = M_N$, where ... [eq. 7.28]

$$M_N = (16 m / G) \sin(N G / 16) ; N = 1, 2, \dots < 8 \pi / G$$

Formally, the quantisation condition permits all integers N from 1 to ∞ , but we run out of classical doublet solutions on which these bound states are based when $N > 8 \pi / G$ The classical solutions ... bear the same relation to the bound-state wavefunctionals ... that Bohr orbits bear to hydrogen atom wavefunctions. ...

Coleman ... show[ed] explicitly ... the SG theory equivalent to the charge-zero sector of the MT model, provided ... $L / 4 \pi m^2 = 1 / (1 + g / \pi)$

...[where in Coleman's work set out above such as his eq. (5.14), $B^2 = L / m^2$]...

Coleman ... resurrected Skyrme's conjecture that the quantum soliton of the SG model may be identified with the fermion of the MT model. ... "

What about the Neutral Pion?

The quark content of the charged pion is $u\bar{d}$ or $d\bar{u}$, both of which are consistent with the sine-Gordon picture. Experimentally, its mass is 139.57 Mev.

The neutral pion has quark content $(u\bar{u} + d\bar{d})/\sqrt{2}$ with two components, somewhat different from the sine-Gordon picture, and a mass of 134.96 Mev.

The effective constituent mass of a down valence quark increases (by swapping places with a strange sea quark) by about

$$\begin{aligned} DcMdquark &= (M_s - M_d) (M_d/M_s)^2 \text{ aw } V_{12} = \\ &= 312 \times 0.25 \times 0.253 \times 0.22 \text{ Mev} = 4.3 \text{ Mev.} \end{aligned}$$

Similarly, the up quark color force mass increase is about

$$\begin{aligned} DcMuquark &= (M_c - M_u) (M_u/M_c)^2 \text{ aw } V_{12} = \\ &= 1777 \times 0.022 \times 0.253 \times 0.22 \text{ Mev} = 2.2 \text{ Mev.} \end{aligned}$$

The color force increase for the charged pion $DcMpion\pm = 6.5 \text{ Mev}$.

Since the mass $M_{pion\pm} = 139.57 \text{ Mev}$ is calculated from a color force sine-Gordon soliton state, the mass 139.57 Mev already takes $DcMpion\pm$ into account.

For $pion_0 = (u\bar{u} + d\bar{d})/\sqrt{2}$, the d and \bar{d} of the $d\bar{d}$ pair do not swap places with strange sea quarks very often because it is energetically preferential for them both to become a $u\bar{u}$ pair.

Therefore, from the point of view of calculating $DcMpion_0$, the $pion_0$ should be considered to be only $u\bar{u}$, and $DcMpion_0 = 2.2 + 2.2 = 4.4 \text{ Mev}$.

If, as in the nucleon, $DeM(pion_0 - pion\pm) = -1 \text{ Mev}$, the theoretical estimate is

$$\begin{aligned} DM(pion_0 - pion\pm) &= DcM(pion_0 - pion\pm) + DeM(pion_0 - pion\pm) = \\ &= 4.4 - 6.5 - 1 = -3.1 \text{ Mev,} \end{aligned}$$

roughly consistent with the experimental value of -4.6 Mev.

Planck Mass:

In the E8 model, a Planck-mass black hole is not a tree-level classical particle such as an electron or a quark, but a quantum entity resulting from the Many-Worlds quantum sum over histories at a single point in spacetime.

Consider an isolated single point, or vertex in the lattice picture of spacetime. In the E8 model, fermions live on vertices, and only first-generation fermions can live on a single vertex. (The second-generation fermions live on two vertices that act at our energy levels very much like one, and the third-generation fermions live on three vertices that act at our energy levels very much like one.)

At a single spacetime vertex, a Planck-mass black hole is the Many-Worlds quantum sum of all possible virtual first-generation particle-antiparticle fermion pairs permitted by the Pauli exclusion principle to live on that vertex.

Once a Planck-mass black hole is formed, it is stable in the E8 model. Less mass would not be gravitationally bound at the vertex. More mass at the vertex would decay by Hawking radiation.

In the E8 model, a Planck-mass black hole can be formed:
as the end product of Hawking radiation decay of a larger black hole;
by vacuum fluctuation;
or perhaps by using a pion laser.

Since Dirac fermions in 4-dimensional spacetime can be massive (and are massive at low enough energies for the Higgs mechanism to act), the Planck mass in 4-dimensional spacetime is the sum of masses of all possible virtual first-generation particle-antiparticle fermion pairs permitted by the Pauli exclusion principle.

There are 8 fermion particles and 8 fermion antiparticles for a total of 64 particle-antiparticle pairs.

A typical combination should have several quarks, several antiquarks, a few colorless quark-antiquark pairs that would be equivalent to pions, and some leptons and antileptons.

Due to the Pauli exclusion principle, no fermion lepton or quark could be present at the vertex more than twice unless they are in the form of boson pions, colorless first-generation quark-antiquark pairs not subject to the Pauli exclusion principle. Of the 64 particle-antiparticle pairs, 12 are pions.

A typical combination should have about 6 pions.

If all the pions are independent,
the typical combination should have a mass of about $.14 \times 6 \text{ GeV} = 0.84 \text{ GeV}$.

However, just as the pion mass of $.14 \text{ GeV}$ is less than
the sum of the masses of a quark and an antiquark,
pairs of oppositely charged pions may form a bound state of less mass
than the sum of two pion masses.

If such a bound state of oppositely charged pions has a mass as small as $.1 \text{ GeV}$,
and
if the typical combination has one such pair and 4 other pions, then the typical
combination could have a mass in the range of 0.66 GeV .

Summing over all 2^{64} combinations,
the total mass of a one-vertex universe should give a Planck mass roughly around
 $0.66 \times 2^{64} = 1.217 \times 10^{19} \text{ GeV}$.

Since each fermion particle has a corresponding antiparticle,
a Planck-mass Black Hole is neutral with respect to electric and color charges.

The value for the Planck mass given in the Particle Data Group's 1998 review is
 $1.221 \times 10^{19} \text{ GeV}$.

Dark Energy : Dark Matter : Ordinary Matter:

Gravity and the Cosmological Constant come from the MacDowell-Mansouri Mechanism and the 15-dimensional $\text{Spin}(2,4) = \text{SU}(2,2)$ Conformal Group, which is made up of:

3 Rotations;
3 Boosts;
4 Translations;
4 Special Conformal transformations; and
1 Dilatation.

According to gr-qc/9809061 by R. Aldrovandi and J. G. Peireira:

"... If the fundamental spacetime symmetry of the laws of Physics is that given by the de Sitter instead of the Poincare group, the P-symmetry of the weak cosmological-constant limit and the Q-symmetry of the strong cosmological-constant limit can be considered as limiting cases of the fundamental symmetry. ...
... N ...[is the space]... whose geometry is gravitationally related to an infinite cosmological constant ...[and]... is a 4-dimensional cone-space in which $ds = 0$, and whose group of motion is Q. Analogously to the Minkowski case, N is also a homogeneous space, but now under the kinematical group Q, that is, $N = Q/L$ [where L is the Lorentz Group of Rotations and Boosts]. In other words, the point-set of N is the point-set of the special conformal transformations.
Furthermore, the manifold of Q is a principal bundle $P(Q/L, L)$, with $Q/L = N$ as base space and L as the typical fiber. The kinematical group Q, like the Poincare group, has the Lorentz group L as the subgroup accounting for both the isotropy and the equivalence of inertial frames in this space. However, the special conformal transformations introduce a new kind of homogeneity. Instead of ordinary translations, all the points of N are equivalent through special conformal transformations. ...

... Minkowski and the cone-space can be considered as dual to each other, in the sense that their geometries are determined respectively by a vanishing and an infinite cosmological constants. The same can be said of their kinematical group of motions: P is associated to a vanishing cosmological constant and Q to an infinite cosmological constant.

The dual transformation connecting these two geometries is the spacetime inversion $x^\mu \rightarrow x^\mu / \sigma^2$. Under such a transformation, the Poincare group P is transformed into the group Q, and the Minkowski space M becomes the cone-space N. The points at infinity of M are concentrated in the vertex of the cone-space N, and those on the light-cone of M becomes the infinity of N. It is

interesting to notice that, despite presenting an infinite scalar curvature, the concepts of space isotropy and equivalence between inertial frames in the cone-space N are those of special relativity. The difference lies in the concept of uniformity as it is the special conformal transformations, and not ordinary translations, which act transitively on N"

Since the Cosmological Constant comes from the 10 Rotation, Boost, and Special Conformal generators of the Conformal Group $\text{Spin}(2,4) = \text{SU}(2,2)$, the fractional part of our Universe of the Cosmological Constant should be about $10 / 15 = 67\%$.

Since Black Holes, including Dark Matter Primordial Black Holes, are curvature singularities in our 4-dimensional physical spacetime, and since Einstein-Hilbert curvature comes from the 4 Translations of the 15-dimensional Conformal Group $\text{Spin}(2,4) = \text{SU}(2,2)$ through the MacDowell-Mansouri Mechanism (in which the generators corresponding to the 3 Rotations and 3 Boosts do not propagate), the fractional part of our Universe of Dark Matter Primordial Black Holes should be about $4 / 15 = 27\%$.

Since Ordinary Matter gets mass from the Higgs mechanism which is related to the 1 Scale Dilatation of the 15-dimensional Conformal Group $\text{Spin}(2,4) = \text{SU}(2,2)$, the fractional part of our universe of Ordinary Matter should be about $1 / 15 = 6\%$.

Therefore, our Flat Expanding Universe should, according to the cosmology of the model, have (without taking into account any evolutionary changes with time) roughly:

67% Cosmological Constant

27% Dark Matter - possibly primordial stable Planck mass black holes

6% Ordinary Matter

As Dennis Marks pointed out to me,
since density ρ is proportional to $(1+z)^3(1+w)$ for red-shift factor z
and a constant equation of state w :

$w = -1$ for Λ and the average overall density of Λ Dark Energy remains constant
with time and the expansion of our Universe;

and

$w = 0$ for nonrelativistic matter so that the overall average density of Ordinary
Matter declines as $1 / R^3$ as our Universe expands;

and

$w = 0$ for primordial black hole dark matter - stable Planck mass black holes - so
that Dark Matter also has density that declines as $1 / R^3$ as our Universe expands;
so that the ratio of their overall average densities must vary with time, or scale
factor R of our Universe, as it expands.

Therefore, the above calculated ratio $0.67 : 0.27 : 0.06$ is valid
only for a particular time, or scale factor, of our Universe.

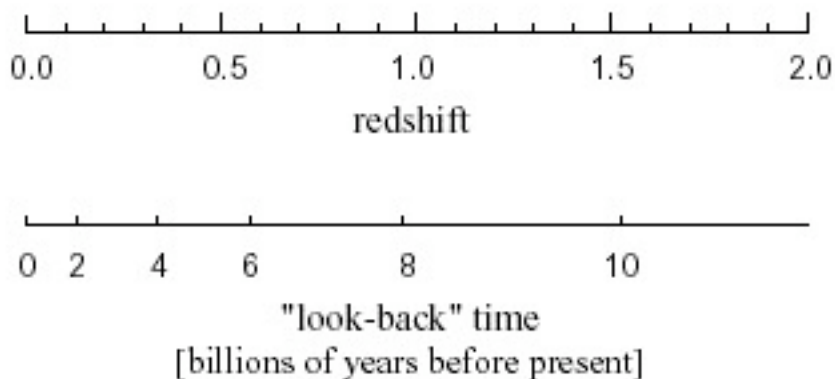
When is that time ? Further, what is the value of the ratio now ?

Since WMAP observes Ordinary Matter at 4% NOW,
the time when Ordinary Matter was 6% would be
at redshift z such that

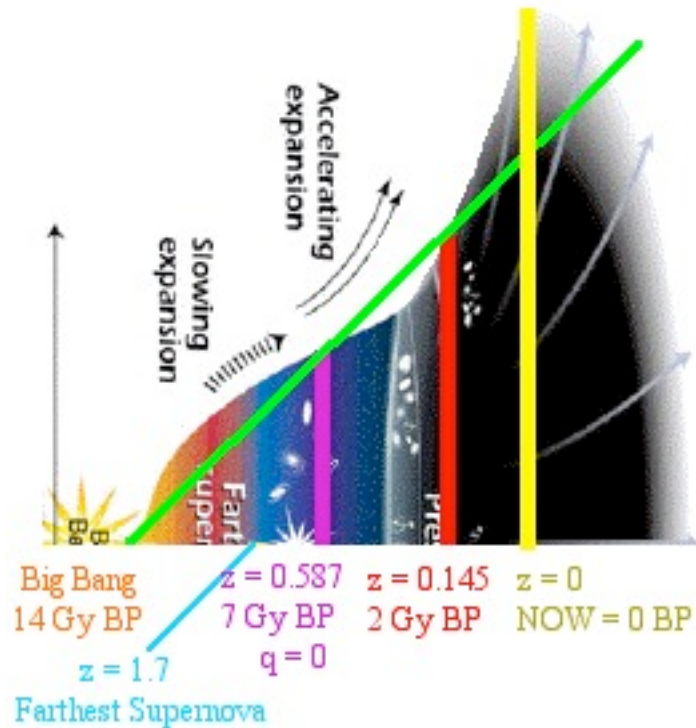
$$1 / (1+z)^3 = 0.04 / 0.06 = 2/3, \text{ or } (1+z)^3 = 1.5, \text{ or } 1+z = 1.145, \text{ or } z = 0.145.$$

To translate redshift into time,

in billions of years before present, or Gy BP, use this chart



from a www.supernova.lbl.gov file SNAPoverview.pdf to see that
the time when Ordinary Matter was 6%
would have been a bit over 2 billion years ago, or 2 Gy BP.



In the diagram, there are four Special Times in the history of our Universe:
the Big Bang Beginning of Inflation (about 13.7 Gy BP);

1 - the End of Inflation = Beginning of Decelerating Expansion
(beginning of green line also about 13.7 Gy BP);

2 - the End of Deceleration ($q=0$) = Inflection Point =
= Beginning of Accelerating Expansion
(purple vertical line at about $z = 0.587$ and about 7 Gy BP).

According to a hubblesite web page credited to Ann Feild, the above diagram "... reveals changes in the rate of expansion since the universe's birth 15 billion years ago. The more shallow the curve, the faster the rate of expansion. The curve changes noticeably about 7.5 billion years ago, when objects in the universe began flying apart as a faster rate. ...".

According to a CERN Courier web page: "... Saul Perlmutter, who is head of the Supernova Cosmology Project ... and his team have studied altogether some 80 high red-shift type Ia supernovae. Their results imply that the universe was decelerating for the first half of its existence, and then began accelerating approximately 7 billion years ago. ...".

According to astro-ph/0106051 by Michael S. Turner and Adam G. Riess: "... current supernova data ... favor deceleration at $z > 0.5$... SN 1997ff at $z = 1.7$

provides direct evidence for an early phase of slowing expansion if the dark energy is a cosmological constant ...".

3 - the Last Intersection of the Accelerating Expansion of our Universe of Linear Expansion (green line) with the Third Intersection (at red vertical line at $z = 0.145$ and about 2 Gy BP), which is also around the times of the beginning of the Proterozoic Era and Eukaryotic Life, Fe₂O₃ Hematite ferric iron Red Bed formations, a Snowball Earth, and the start of the Oklo fission reactor. 2 Gy is also about 10 Galactic Years for our Milky Way Galaxy and is on the order of the time for the process of a collision of galaxies.

4 - Now.

Those four Special Times define four Special Epochs:

The Inflation Epoch, beginning with the Big Bang and ending with the End of Inflation. The Inflation Epoch is described by Zizzi Quantum Inflation ending with Self-Decoherence of our Universe (see gr-qc/0007006).

The Decelerating Expansion Epoch, beginning with the Self-Decoherence of our Universe at the End of Inflation. During the Decelerating Expansion Epoch, the Radiation Era is succeeded by the Matter Era, and the Matter Components (Dark and Ordinary) remain more prominent than they would be under the "standard norm" conditions of Linear Expansion.

The Early Accelerating Expansion Epoch, beginning with the End of Deceleration and ending with the Last Intersection of Accelerating Expansion with Linear Expansion. During Accelerating Expansion, the prominence of Matter Components (Dark and Ordinary) declines, reaching the "standard norm" condition of Linear Expansion at the end of the Early Accelerating Expansion Epoch at the Last Intersection with the Line of Linear Expansion.

The Late Accelerating Expansion Epoch, beginning with the Last Intersection of Accelerating Expansion and continuing forever, with New Universe creation happening many times at Many Times. During the Late Accelerating Expansion Epoch, the Cosmological Constant Λ is more prominent than it would be under the "standard norm" conditions of Linear Expansion.

Now happens to be about 2 billion years into the Late Accelerating Expansion Epoch.

What about Dark Energy : Dark Matter : Ordinary Matter now ?

As to how the Dark Energy Λ and Cold Dark Matter terms have evolved during the past 2 Gy, a rough estimate analysis would be:

Λ and CDM would be effectively created during expansion in their natural ratio $67 : 27 = 2.48 = 5 / 2$, each having proportionate fraction $5 / 7$ and $2 / 7$, respectively;

CDM Black Hole decay would be ignored; and

pre-existing CDM Black Hole density would decline by the same $1 / R^3$ factor as Ordinary Matter, from 0.27 to $0.27 / 1.5 = 0.18$.

The Ordinary Matter excess $0.06 - 0.04 = 0.02$ plus the first-order CDM excess $0.27 - 0.18 = 0.09$ should be summed to get a total first-order excess of 0.11, which in turn should be distributed to the Λ and CDM factors in their natural ratio $67 : 27$, producing, for NOW after 2 Gy of expansion:

$$\text{CDM Black Hole factor} = 0.18 + 0.11 \times 2/7 = 0.18 + 0.03 = 0.21$$

for a total calculated Dark Energy : Dark Matter : Ordinary Matter ratio for now of

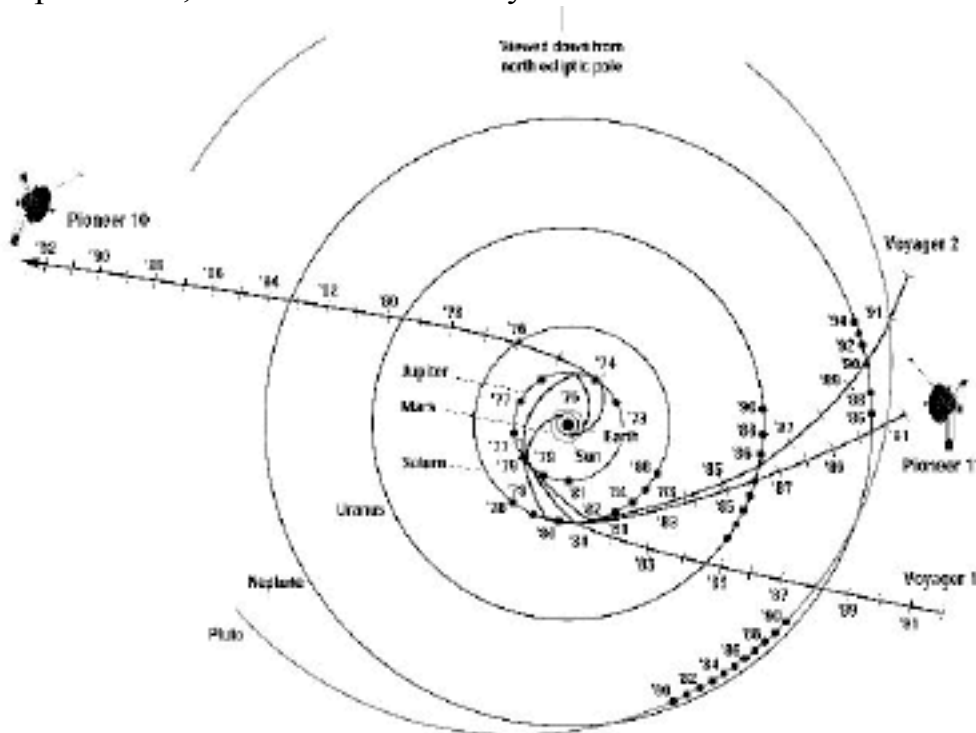
$$0.75 : 0.21 : 0.04$$

so that the present ratio of $0.73 : 0.23 : 0.04$ observed by WMAP seems to me to be substantially consistent with the cosmology of the E8 model.

Pioneer Anomaly:

After the Inflation Era and our Universe began its current phase of expansion, some regions of our Universe become Gravitationally Bound Domains (such as, for example, Galaxies) in which the 4 Conformal GraviPhoton generators are frozen out, forming domains within our Universe like IceBergs in an Ocean of Water.

On the scale of our Earth-Sun Solar System, the region of our Earth, where we do our local experiments, is in a Gravitationally Bound Domain.



Pioneer spacecraft are not bound to our Solar System and are experiments beyond the Gravitationally Bound Domain of our Earth-Sun Solar System.

In their Study of the anomalous acceleration of Pioneer 10 and 11 gr-qc/0104064 John D. Anderson, Philip A. Laing, Eunice L. Lau, Anthony S. Liu, Michael Martin Nieto, and Slava G. Turyshev say: "... The latest successful precession maneuver to point ...[Pioneer 10]... to Earth was accomplished on 11 February 2000, when Pioneer 10 was at a distance from the Sun of 75 AU. [The distance from the Earth was [about] 76 AU with a corresponding round-trip light time of about 21 hour.] ... The next attempt at a maneuver, on 8 July 2000, was unsuccessful ... conditions will again be favorable for an attempt around July, 2001. ... At a now nearly constant velocity relative to the Sun of 12.24 km/s, Pioneer 10 will continue its motion into interstellar space, heading generally for the red star Aldebaran ... about

68 light years away ... it should take Pioneer 10 over 2 million years to reach its neighborhood...

[the above image is] Ecliptic pole view of Pioneer 10, Pioneer 11, and Voyager trajectories. Digital artwork by T. Esposito. NASA ARC Image # AC97-0036-3. ... on 1 October 1990 ... Pioneer 11 ... was [about] 30 AU away from the Sun ... The last communication from Pioneer 11 was received in November 1995, when the spacecraft was at distance of [about] 40 AU from the Sun. ... Pioneer 11 should pass close to the nearest star in the constellation Aquila in about 4 million years Calculations of the motion of a spacecraft are made on the basis of the range time-delay and/or the Doppler shift in the signals. This type of data was used to determine the positions, the velocities, and the magnitudes of the orientation maneuvers for the Pioneer, Galileo, and Ulysses spacecraft considered in this study. ... The Pioneer spacecraft only have two- and three-way S-band Doppler. ... analyses of radio Doppler ... data ... indicated that an apparent anomalous acceleration is acting on Pioneer 10 and 11 ... The data implied an **anomalous, constant acceleration with a magnitude $a_P = 8 \times 10^{-8}$ cm/cm/s², directed towards the Sun** ...

... the size of the anomalous acceleration is of the order $c H$, where H is the Hubble constant ...

... Without using the apparent acceleration, CHASMP shows a steady frequency drift of about -6×10^{-9} Hz / s, or 1.5 Hz over 8 years (one-way only). ... This equates to a clock acceleration, $-a_t$, of -2.8×10^{-18} s / s² . The identity with the apparent Pioneer acceleration is $a_P = a_t c$...

... Having noted the relationships

$$a_P = c a_t$$

and that of ...

$$a_H = c H \rightarrow 8 \times 10^{-8} \text{ cm} / \text{s}^2$$

if $H = 82 \text{ km} / \text{s} / \text{Mpc}$...

we were motivated to try to think of any ... "time" distortions that might ... fit the CHASMP Pioneer results ... In other words ...

Is there any evidence that some kind of "time acceleration" is being seen?

... In particular we considered ... Quadratic Time Augmentation. This model adds a quadratic-in-time augmentation to the TAI-ET (International Atomic Time - Ephemeris Time) time transformation, as follows

$$ET \rightarrow ET + (1/2) a_{ET} ET^2$$

The model fits Doppler fairly well ...

... There was one [other] model of the ...[time acceleration]... type that was especially fascinating. This model adds a quadratic in time term to the light time as seen by the DSN station:

$$\begin{aligned} \text{delta_TAI} &= \text{TAI_received} - \text{TAI_sent} \rightarrow \\ \rightarrow \text{delta_TAI} &+ (1/2) a_quad (\text{TAI_received}^2 - \text{TAI_sent}^2) \end{aligned}$$

It mimics a line of sight acceleration of the spacecraft, and could be thought of as an expanding space model.

Note that a_quad affects only the data. This is in contrast to the a_t ... that affects both the data and the trajectory. ... This model fit both Doppler and range very well. Pioneers 10 and 11 ... the numerical relationship between the Hubble constant and a_P ... remains an interesting conjecture. ...".

In his book *Mathematical Cosmology and Extragalactic Astronomy* (Academic Press 1976) (pages 61-62 and 72), Segal says:

"... Temporal evolution in ... Minkowski space ... is

$$H \rightarrow H + s I$$

... unispace temporal evolution ... is ...

$$H \rightarrow (H + 2 \tan(a/2)) / (1 - (1/2) H \tan(a/2)) = H + a I + (1/4) a H^2 + O(s^2)$$

..."

Therefore,

the Pioneer Doppler anomalous acceleration is an experimental observation of a system that is not gravitationally bound in the Earth-Sun Solar System, and its results are consistent with Segal's Conformal Theory.

Rosales and Sanchez-Gomez say, at gr-qc/9810085:

"... the recently reported anomalous acceleration acting on the Pioneers spacecrafts should be a consequence of the existence of some local curvature in light geodesics when using the coordinate speed of light in an expanding spacetime. This suggests that the Pioneer effect is nothing else but the detection of cosmological expansion in the solar system. ... the ... problem of the detected misfit between the calculated and the measured position in the spacecrafts ... this quantity differs from the expected ... just in a systematic "bias" consisting on an effective residual acceleration directed toward the center of coordinates; its constant value is ... $H c$...

This is the acceleration observed in Pioneer 10/11 spacecrafts. ... a periodic orbit does not experience the systematic bias but only a very small correction ... which is not detectable ... in the old Foucault pendulum experiment ... the motion of the

pendulum experiences the effect of the Earth based reference system being not an inertial frame relatively to the "distant stars". ... Pioneer effect is a kind of a new cosmological Foucault experiment, the solar system based coordinates, being not the true inertial frame with respect to the expansion of the universe, mimics the role that the rotating Earth plays in Foucault's experiment ...".

The Rosales and Sanchez-Gomez idea of a 2-phase system in which objects bound to the solar system (in a "periodic orbit") are in one phase (non-expanding pennies-on-a-balloon) while unbound (escape velocity) objects are in another phase (expanding balloon) that "feels" expansion of our universe is very similar to my view of such things as described on this page.

The Rosales and Sanchez-Gomez paper very nicely unites:
the physical 2-phase (bounded and unbounded orbits) view;
the Foucault pendulum idea; and the cosmological value H_0 .

My view, which is consistent with that of Rosales and Sanchez-Gomez, can be summarized as a 2-phase model based on Segal's work which has two phases with different metrics:

a metric for outside the inner solar system, a dark energy phase in which gravity is described in which all 15 generators of the conformal group are effective, some of which are related to the dark energy by which our universe expands;
and

a metric for where we are, in regions dominated by ordinary matter, in which the 4 special conformal and 1 dilation degrees of freedom of the conformal group are suppressed and the remaining 10 generators (antideSitter or Poincare, etc) are effective, thus describing ordinary matter phenomena.

If you look closely at the difference between the metrics in those two regions, you see that the full conformal dark energy region gives an "extra acceleration" that acts as a "quadratic in time term" that has been considered as an explanation of the Pioneer effect by John D. Anderson, Philip A. Laing, Eunice L. Lau, Anthony S. Liu, Michael Martin Nieto, and Slava G. Turyshev in their paper at gr-qc/0104064.

Jack Sarfatti has a 2-phase dark energy / dark matter model that can give a similar anomalous acceleration in regions where $c^2 \wedge$ dark energy / dark matter is effectively present. If there is a phase transition (around Uranus at 20 AU) whereby ordinary matter dominates inside that distance from the sun and exotic dark energy / dark matter appears at greater distances, then Jack's model could also explain the Pioneer anomaly and it may be that Jack's model with ordinary and exotic phases and my model with deSitter/Poincare and Conformal phases may be two ways of looking at the same thing.

As to what might be the physical mechanism of the phase transition, Jack says "... Rest masses of [ordinary matter] particles ... require the smooth non-random Higgs Ocean ... which soaks up the choppy random troublesome zero point energy ...".

In other words in a region in which ordinary matter is dominant, such as the Sun and our solar system, the mass-giving action of the Higgs mechanism "soaks up" the Dark Energy zero point conformal degrees of freedom that are dominant in low-ordinary mass regions of our universe (which are roughly the intergalactic voids that occupy most of the volume of our universe). That physical interpretation is consistent with my view.

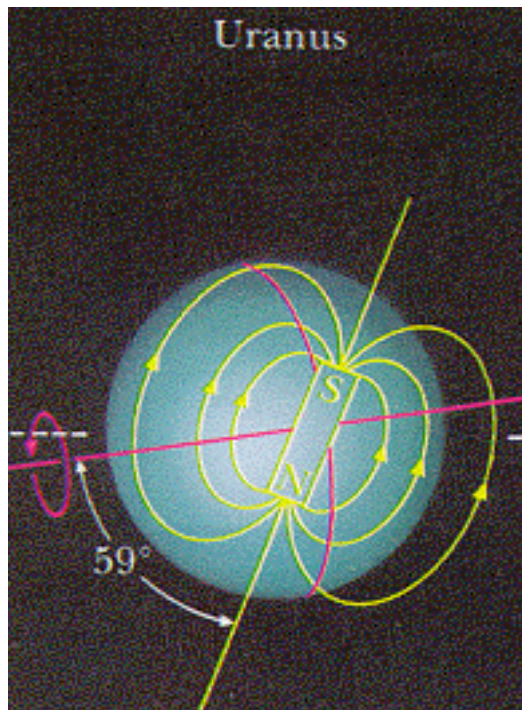
Transition at Orbit of Uranus:

It may be that the observation of the Pioneer phase transition at Uranus from ordinary to anomalous acceleration is an experimental result that gives us a first look at dark energy / dark matter phenomena that could lead to energy sources that could be even more important than the nuclear energy discovered during the past century.

In gr-qc/0104064 Anderson et al say:

"... Beginning in 1980 ... at a distance of 20 astronomical units (AU) from the Sun ... we found that the largest systematic error in the acceleration residuals was a constant bias, a_P , directed toward the Sun. Such anomalous data have been continuously received ever since. ...",

so that the transition from inner solar system Minkowski acceleration to outer Segal Conformal acceleration occurs at about 20 AU, which is about the radius of the orbit of Uranus. That phase transition may account for the unique rotational axis of Uranus,



which lies almost in its orbital plane.

The most stable state of Uranus may be with its rotational axis pointed toward the Sun, so that the Solar hemisphere would be entirely in the inner solar system Minkowski acceleration phase and the anti-Solar hemisphere would be in entirely in the outer Segal Conformal acceleration phase.

Then the rotation of Uranus would not take any material from one phase to the other, and there would be no drag on the rotation due to material going from phase to phase.

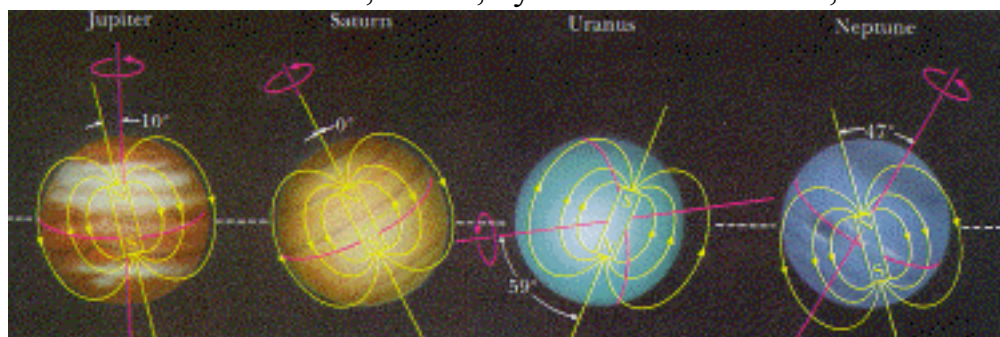
Of course, as Uranus orbits the Sun, it will only be in that most stable configuration twice in each orbit, but an orbit in the ecliptic containing that most stable configuration twice (such as its present orbit) would be in the set of the most stable ground states, although such an effect would be very small now.

However, such an effect may have been more significant on the large gas/dust cloud that was condensing into Uranus and therefore it may have caused Uranus to form initially with its rotational axis pointed toward the Sun.

In the pre-Uranus gas/dust cloud, any component of rotation that carried material from one phase to another would be suppressed by the drag of undergoing phase transition, so that, after Uranus condensed out of the gas/dust cloud, the only remaining component of Uranus rotation would be on an axis pointing close to the Sun, which is what we now observe.

In the pre-Uranus gas/dust cloud, any component of rotation that carried material from one phase to another would be suppressed by the drag of undergoing phase transition, so that, after Uranus condensed out of the gas/dust cloud, the only remaining component of Uranus rotation would be on an axis pointing close to the Sun, which is what we now observe.

Much of the perpendicular (to Uranus orbital plane) angular momentum from the original gas/dust cloud may have been transferred (via particles "bouncing" off the phase boundary) to the clouds forming Saturn (inside the phase boundary) or Neptune (outside the phase boundary, thus accounting for the substantial (relative to Jupiter) deviation of their rotation axes from exact perpendicularity (see images above and below from Universe, 4th ed, by William Kaufmann, Freeman 1994).



According to Utilizing Minor Planets to Assess the Gravitational Field in the Outer Solar System, astro-ph/0504367, by Gary L. Page, David S. Dixon, and John F. Wallin:

"... the great distances of the outer planets from the Sun and the nearly circular orbits of Uranus and Neptune makes it very difficult to use them to detect the

Pioneer Effect. ... The ratio of the Pioneer acceleration to that produced by the Sun at a distance equal to the semimajor axis of the planets is 0.005, 0.013, and 0.023 percent for Uranus, Neptune, and Pluto, respectively. ... Uranus' period shortens by 5.8 days and Neptune's by 24.1, while Pluto's period drops by 79.7 days. ... an equivalent change in aphelion distance of 3.8×10^{10} , 1.2×10^{11} , and 4.3×10^{11} cm for Uranus, Neptune, and Pluto. In the first two cases, this is less than the accepted uncertainty in range of 2×10^6 km [or 2×10^{11} cm] (Seidelmann 1992). ... Pluto[s] ... orbit is even less well-determined ... than the other outer planets. ... [C]ometes ... suffer ... from outgassing ... [and their nuclei are hard to locate precisely] ...".

According to a google cache of an Independent UK 23 September 2002 article by Marcus Chown:

"... The Pioneers are "spin-stabilised", making them a particularly simple platform to understand. Later probes ... such as the Voyagers and the Cassini probe ... were stabilised about three axes by intermittent rocket boosts. The unpredictable accelerations caused by these are at least 10 times bigger than a small effect like the Pioneer acceleration, so they completely cloak it. ...".

Can we use Laboratory Experiments on Earth to get access to the energy of all 15 generators of Conformal Spin(2,4)?

In astro-ph/0512327 Christian Beck says: "... if dark energy is produced by vacuum fluctuations then there is a chance to probe some of its properties by simple laboratory tests based on Josephson junctions. These electronic devices can be used to perform 'vacuum fluctuation spectroscopy', by directly measuring a noise spectrum induced by vacuum fluctuations. One would expect to see a cutoff near 1.7 THz in the measured power spectrum, provided the new physics underlying dark energy couples to electric charge.

The effect exploited by the Josephson junction is a subtle nonlinear mixing effect and has nothing to do with the Casimir effect or other effects based on van der Waals forces. A Josephson experiment of the suggested type will now be built, and we should know the result within the next 3 years. ...".

That Josephson experiment is by P A Warburton of University College London. It is EPSRC Grant Reference: EP/D029783/1, "Externally-Shunted High-Gap Josephson Junctions: Design, Fabrication and Noise Measurements", starting 1 February 2006 and ending 31 January 2009 with £ Value: 242,348. Its abstract states:

"... In the late 1990's measurements of the cosmic microwave background radiation and distant supernovae confirmed that around 70% of the energy in the universe is in the form of gravitationally-repulsive dark energy. This dark energy is not only responsible for the accelerating expansion of the universe but also was the driving force for the big bang. A possible source of this dark energy is vacuum fluctuations which arise from the finite zero-point energy of a quantum mechanical oscillator, $hf/2$ (where f is the oscillator frequency). ... dark energy may be measured in the laboratory using resistively-shunted Josephson junctions (RS-JJ's). Vacuum fluctuations in the resistive shunt at low temperatures can be measured by non-linear mixing within the Josephson junction. If vacuum fluctuations are responsible for dark energy, the finite value of the dark energy density in the universe (as measured by astronomical observations) sets an upper frequency limit on the spectrum of the quantum fluctuations in this resistive shunt. Beck and Mackey calculated an upper bound on this cut-off frequency of 1.69 THz. ... We therefore propose to perform measurements of the quantum noise in RS-JJ's fabricated using superconductors with sufficiently large gap energies that the full noise spectrum up to and beyond 1.69 THz can be measured. ... Nitride junctions have cut-off frequencies of around 2.5 THz, which should give sufficiently low quasiparticle current noise around 1.69 THz at accessible measurement temperatures. Cuprate superconductors have an energy gap an order of magnitude higher than the nitrides, but here there is finite quasiparticle tunnelling at voltages less than the gap voltage, due to the d-wave pairing symmetry. By performing experiments on both the nitrides and the cuprates we will have two independent measurements of the possible cut-off frequency in two very different materials systems. This would give irrefutable confirmation (or indeed refutation) of the vacuum fluctuations hypothesis. ...".

Beck and Mackey in astro-ph/0406504 say: "... the zero-point term has proved important in explaining X-ray scattering in solids ... ; understanding of the Lamb shift ... in hydrogen ... ; predicting the Casimir effect ... ; understanding the origin of Van der Waals forces ... ; interpretation of the Aharonov-Bohm effect ... ; explaining Compton scattering ... ; and predicting the spectrum of noise in electrical circuits

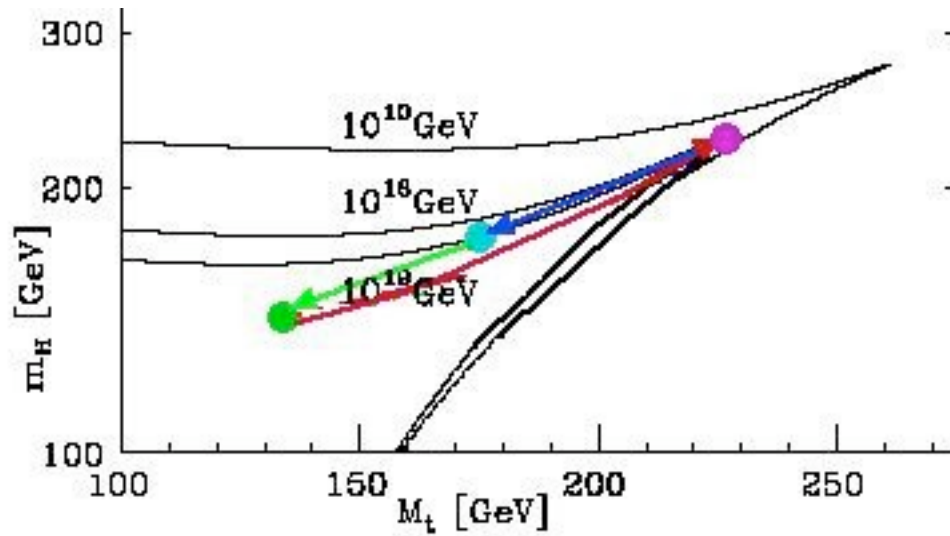
It is this latter effect that concerns us here. ... We predict that the measured spectrum in Josephson junction experiments must exhibit a cutoff at the critical frequency ν_c ... [corresponding to the currently observed Dark Energy density $0.73 \times \text{critical density} = 0.73 \times 5.3 \text{ GeV/m}^3 = 3.9 \text{ GeV/m}^3$]... If not, the corresponding vacuum energy density would exceed the currently measured dark energy density of the universe. ... The energy associated with the computed cutoff frequency ν_c ... [about $1.7 \times 10^{12} \text{ Hz}$]...

$$E_c = h \nu_c = (7.00 \pm 0.17) \times 10^{-3} \text{ eV} \dots$$

coincides with current experimental estimates of neutrino masses. .. It is likely that the Josephson junction experiment only measures the photonic part of the vacuum fluctuations, since this experiment is purely based on electromagnetic interaction. ... If the frequency cutoff is observed, it could be used to determine the fraction ... of dark energy density that is produced by electromagnetic processes ... Finally, we conjecture that it will be interesting to re-analyze experimentally observed $1/f$ noise in electrical circuits under the hypothesis that it could be a possible manifestation of suppressed zero-point fluctuations. ... Our simple theoretical considerations show that $1/f$ noise arises naturally if bosonic vacuum fluctuations are suppressed by fermionic ones. ...".

Truth Quark - Higgs 3-State System:

My physics model has 3 states (green, cyan, magenta) for the Higgs-Tquark system:



The low state (green) is in the usual stable-vacuum no-triviality space-time region.

The middle state (cyan) is on the Triviality boundary where the Higgs is composite T-Tbar condensate in 8-dim Kaluza-Klein spacetime with high-energy cut-off scale at the Planck energy 10^{19} GeV which is the lowest of the three Triviality boundary upper bound curves.

The high state (magenta) is at the critical point where the Triviality boundary (upper bound curves) intersects the vacuum stability boundary (right-side bound curves).

As to composite Higgs and the Triviality boundary, Pierre Ramond says in his book *Journeys Beyond the Standard Model* (Perseus Books 1999) at pages 175-176:

"... The Higgs quartic coupling has a complicated scale dependence. It evolves according to

$$d \lambda / d t = (1 / 16 \pi^2) \beta_{\lambda}$$

where the one loop contribution is given by

$$\beta_{\lambda} = 12 \lambda^2 - \dots - 4 H \dots$$

The value of λ at low energies is related [to] the physical value of the Higgs mass according to the tree level formula \

$$m_H = v \sqrt{ 2 \lambda }$$

while the vacuum value is determined by the Fermi constant

...

for a fixed vacuum value v , let us assume that the Higgs mass and therefore λ is large. In that case, β_{λ} is dominated by the λ^2 term, which drives the coupling towards its Landau pole at higher energies.

Hence the higher the Higgs mass, the higher λ is and the closer [r] the Landau pole to experimentally accessible regions.

This means that for a given (large) Higgs mass,

we expect the standard model to enter a strong coupling regime

at relatively low energies, losing in the process our ability to calculate.

This does not necessarily mean that the theory is incomplete,

only that we can no longer handle it ...

it is natural to think that this effect is caused by new strong interactions,

and that the Higgs actually is a composite ...

The resulting bound on λ is sometimes called the **triviality bound**.

The reason for this unfortunate name (the theory is anything but trivial)

stems from lattice studies where the coupling is assumed to be finite everywhere;

in that case the coupling is driven to zero, yielding in fact a trivial theory.

In the standard model λ is certainly not zero. ...".

Composite Higgs as Tquark condensate studies by Yamawaki et al have produced realistic models that are consistent with my E8 model with a 3-State System:

1 - My basic E8 Physic model state

with Tquark mass = 130 GeV and Higgs mass = 146 GeV

2 - Triviality boundary 8-dim Kaluza-Klein state described by Hashimoto, Tanabashi, and Yamawaki in hep-ph/0311165 where they say:

"... "..." We perform the most attractive channel (MAC) analysis in the top mode standard model with TeV-scale extra dimensions, where the standard model gauge bosons and the third generation of quarks and leptons are put in $D(=6,8,10,\dots)$ dimensions. In such a model, bulk gauge couplings rapidly grow in the ultraviolet region. In order to make the scenario viable, only the attractive force of the top condensate should exceed the critical coupling, while other channels such as the bottom and tau condensates should not. We then find that the top condensate can be the MAC for $D=8$... We predict masses of the top (m_t) and the Higgs (m_H) ... based on the renormalization group for the top Yukawa and Higgs quartic couplings with the compositeness conditions at the scale where the bulk top condenses ... for ... [Kaluza-Klein type] ... dimension... $D=8$... $m_t = 172-175$ GeV and $m_H = 176-188$ GeV ...".

3 - Critical point BHL state

with Tquark mass = 218 ± 3 GeV and Higgs mass = 239 ± 3 GeV

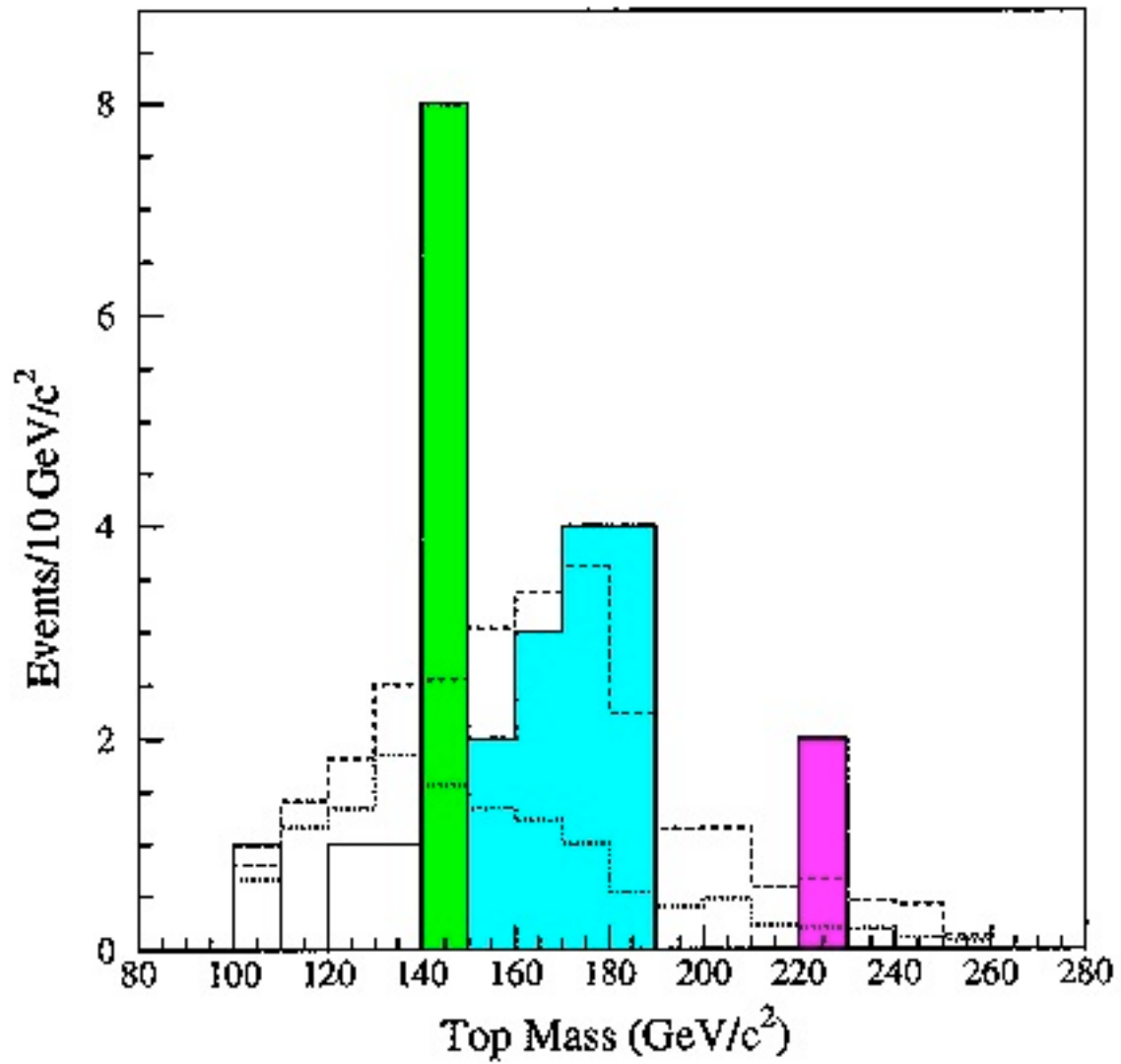
As Yamawaki said in hep-ph/9603293: "... **the BHL formulation of the top quark condensate ... is based on the RG equation combined with the compositeness condition ... start[s] with the SM Lagrangian which includes explicit Higgs field at the Lagrangian level ... BHL is crucially based on the perturbative picture ... [which] ... breaks down at high energy near the compositeness scale / \ ... [10^{19} GeV] ... there must be a certain matching scale $\Lambda_{\text{Matching}}$ such that the perturbative picture (BHL) is valid for $\mu < \Lambda_{\text{Matching}}$, while only the nonperturbative picture (MTY) becomes consistent for $\mu > \Lambda_{\text{Matching}}$... However, **thanks to the presence of a quasi-infrared fixed point, BHL prediction is numerically quite stable against ambiguity at high energy region, namely, rather independent of whether this high energy region is replaced by MTY or something else.** ... Then we expect $m_t = m_t(\text{BHL}) = \dots = 1/(\text{sqrt}(2)) y_{\text{bart}} v$ within 1-2%, where y_{bart} is the quasi-infrared fixed point given by $\text{Beta}(y_{\text{bart}}) = 0$ in ... the one-loop RG equation ... The composite Higgs loop changes y_{bart}^2 by roughly the factor $N_c/(N_c + 3/2) = 2/3$ compared with the MTY value, i.e., 250 GeV $\rightarrow 250 \times \text{sqrt}(2/3) = 204$ GeV, while the electroweak gauge boson loop with opposite sign pulls it back a little bit to a higher value. **The BHL value is then****

given by $m_t = 218 \pm 3 \text{ GeV}$, at $\Lambda = 10^{19} \text{ GeV}$. The Higgs boson was predicted as a $t\bar{t}$ bound state with a mass $M_H = 2m_t$ based on the pure NJL model calculation¹. Its mass was also calculated by BHL through the full RG equation ... the result being ... $M_H / m_t = 1.1$) at $\Lambda = 10^{19} \text{ GeV}$...".

... the top quark condensate proposed by Miransky, Tanabashi and Yamawaki (MTY) and by Nambu independently ... **entirely replaces the standard Higgs doublet by a composite one formed by a strongly coupled short range dynamics (four-fermion interaction) which triggers the top quark condensate.** The Higgs boson emerges as a $t\bar{t}$ bound state and hence is deeply connected with the top quark itself. ... MTY introduced explicit four-fermion interactions responsible for the top quark condensate in addition to the standard gauge couplings. Based on the explicit solution of the ladder SD equation, MTY found that even if all the dimensionless four-fermion couplings are of $O(1)$, only the coupling larger than the critical coupling yields non-zero (large) mass ... The model was further formulated in an elegant fashion by Bardeen, Hill and Lindner (BHL) in the SM language, based on the RG equation and the compositeness condition. BHL essentially incorporates $1/N_c$ sub-leading effects such as those of the composite Higgs loops and ... gauge boson loops which were disregarded by the MTY formulation. We can explicitly see that **BHL is in fact equivalent to MTY at $1/N_c$ -leading order**. Such effects turned out to reduce the above MTY value 250 GeV down to 220 GeV ...".

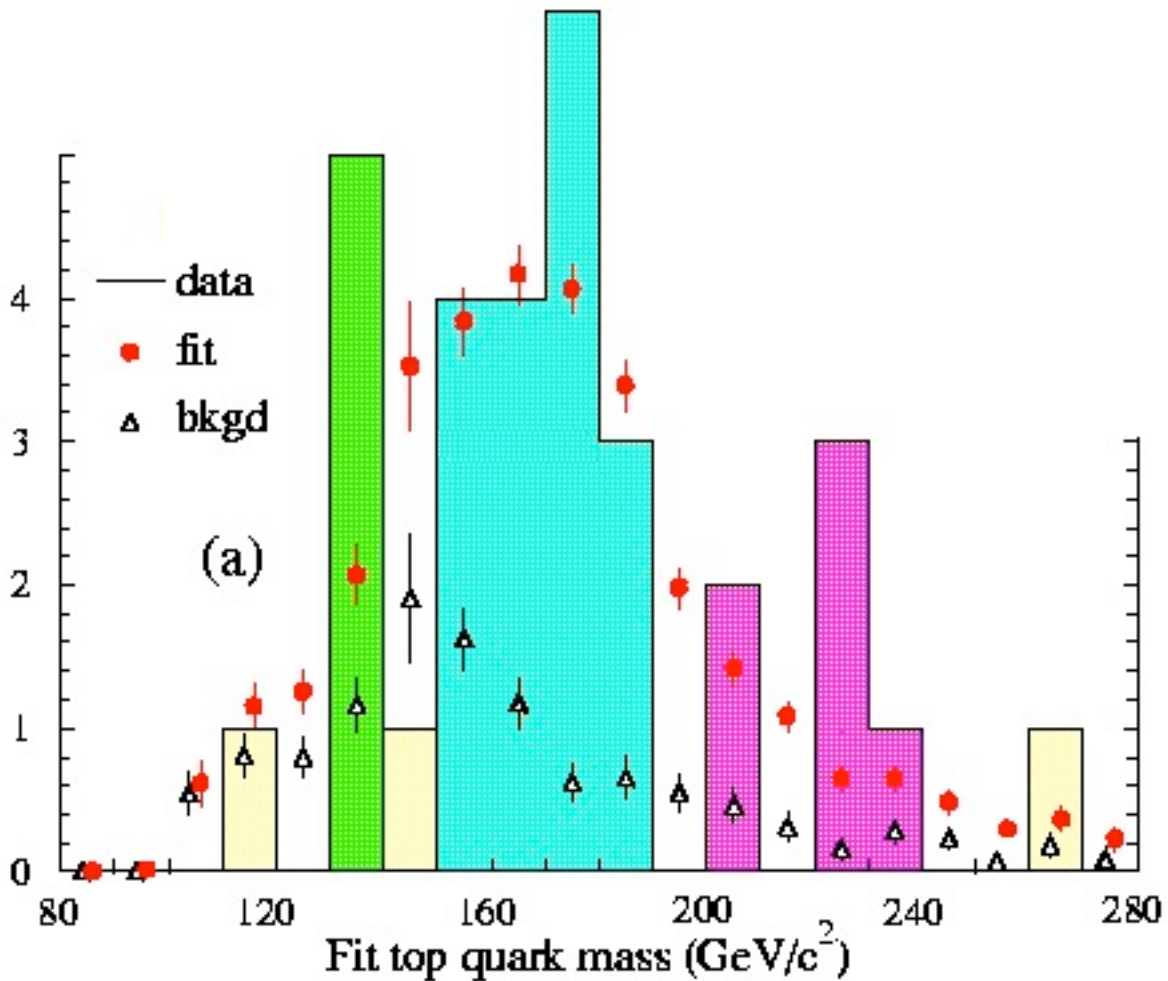
8-dim Kaluza-Klein spacetime physics as required by Hashimoto, Tanabashi, and Yamawaki for the Middle State of the 3-State System was described by N. A. Batakis in Class. Quantum Grav. 3 (1986) L99-L105 in terms a $M_4 \times CP_2$ structure similar to that of my E8 Physics model. Although spacetime and Standard Model gauge bosons worked well for Batakis, he became discouraged by difficulties with fermions, perhaps because he did not use Clifford Algebras with natural spinor structures for fermions.

In 1994 a semileptonic histogram from CDF



seems to me to show all three states of the T-quark.

In 1997 a semileptonic histogram from D0



also seems to me to show all three states of the T-quark.

The fact that the low (green) state showed up in both independent detectors indicates a significance of 4 sigma.

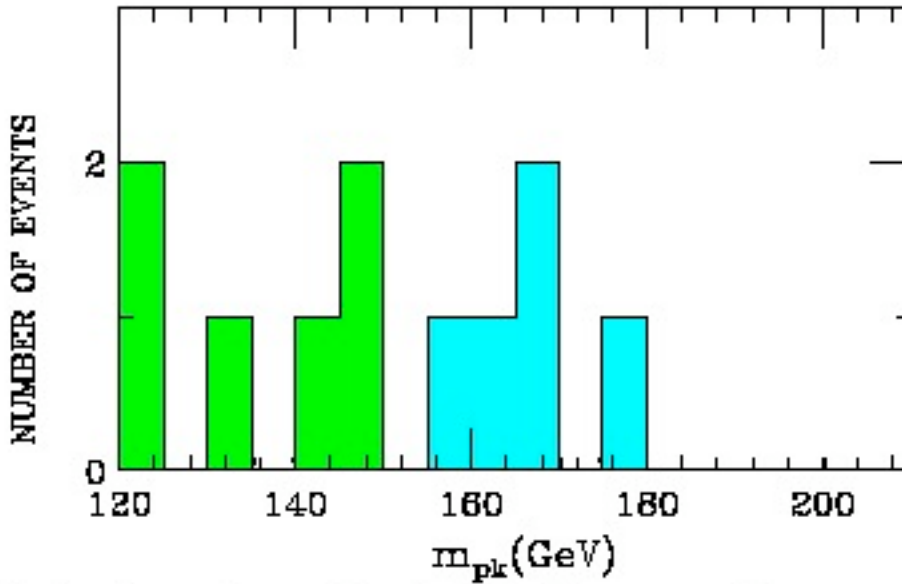
Some object that the low (green) state peak should be as wide as the peak for the middle (cyan) state,

but

my opinion is that the middle (cyan) state should be wide because it is on the Triviality boundary where the composite nature of the Higgs as T-Tbar condensate becomes manifest and

the low (cyan) state should be narrow because it is in the usual non-trivial region where the T-quark acts more nearly as a single individual particle.

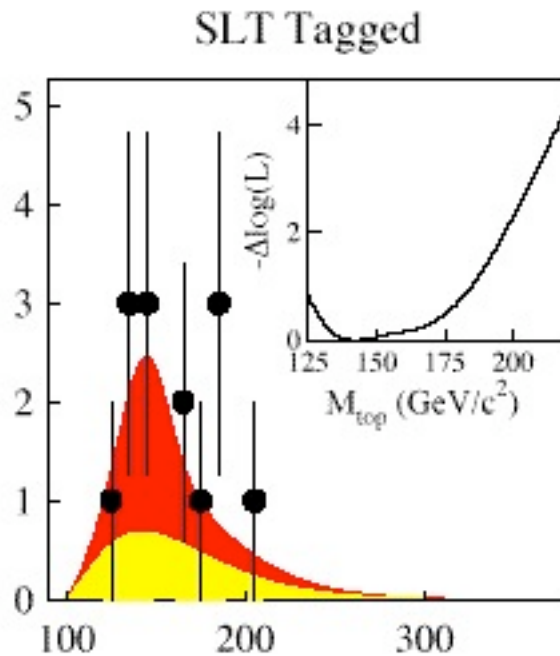
In 1998 a dilepton histogram from CDF



The distribution of $m_{p\ell}$ values determined from 11 CDF dilepton events available empirically.

seems to me to show both the low (green) state and the middle (cyan) state of the T-quark.

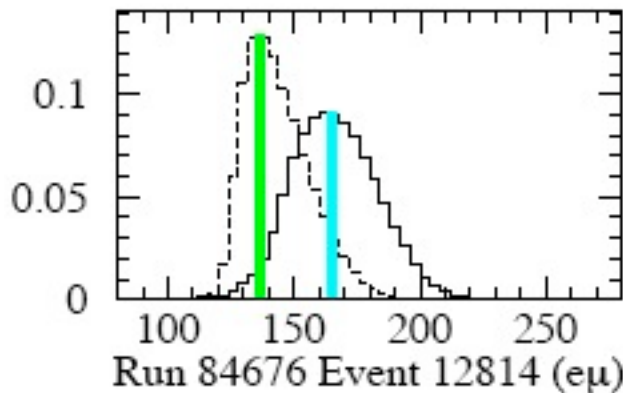
In 1998 an analysis of 14 SLT tagged lepton + 4 jet events by CDF



showed a T-quark mass of 142 GeV (+33,-14) that seems to me to be consistent with the low (green) state of the T-quark.

In 1997 the Ph.D. thesis of Erich Ward Varnes (Varnes-fermilab-thesis-1997-28) at page 159 said:

"... distributions for the dilepton candidates. For events with more than two jets, the dashed curves show the results of considering only the two highest ET jets in the reconstruction ...



..." (colored bars added by me)

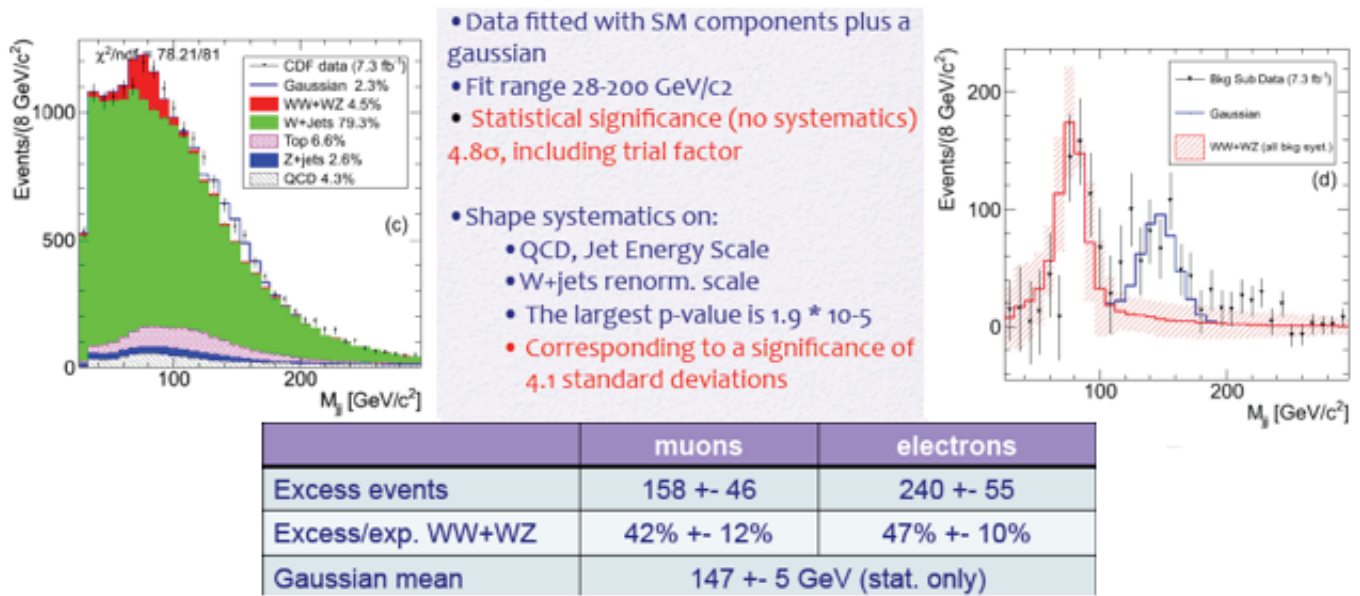
The event for all 3 jets (solid curve) seems to me to correspond to decay of a middle (cyan) T-quark state with one of the 3 jets corresponding to decay from the Triviality boundary down to the low (green) T-quark state, whose immediately subsequent decay is corresponds to the 2-jet (dashed curve) event at the low (green) energy level.

After 1998 until very recently Fermilab focussed its attention on detailed analysis of the middle (cyan) T-quark state, getting much valuable detailed information about it but **not producing much information about the low or high states.**

Although the 2-jet dilepton event is roughly at the same energy as the 125 GeV Higgs observed by the LHC in 2012, such a dijet T quark event has substantially different characteristics from a Higgs event. As Matt Strassler said in his blog on 27 July 2012: "... The dilepton T quark candidate has a lepton, an anti-lepton, a bottom quark jet and an anti-bottom quark jet (though the two can't be distinguished experimentally), and something undetected, presumably neutrinos. A Higgs candidate event would have two bottom quark jets and either no leptons, or one lepton and something undetected, or a lepton-anti-lepton pair forming a Z particle candidate with nothing undetected. Furthermore, the ... mass obtained for a potential top quark is formed by combining a lepton, a bottom quark jet and a guess about a neutrino, whereas a mass for a Higgs particle comes from combining the bottom quark and antiquark jets. ...".

In 2010 the thesis of Viviana Cavaliere (FERMILAB-THESIS-2010-51) said: "... We present the measurement of the WW and WZ production cross section in p pbar collisions at $\sqrt{s} = 1.96$ TeV, in a final state consisting of an electron or muon, neutrino and jets. ... **for the [120 , 160] GeV/c² mass range ... an excess is observed ... corresponding to a significance of 3.3 sigma ...**".

At EPS HEP 2011 (21 July) Viviana Cavaliere of CDF described a Wjj bump in slides showing



CDF vs Do comparison
 Evaluated xsec using Do procedure
 • 3.1 +- 0.8 pb (with 4.3 fb⁻¹ data)
 • 3.0 +- 0.7 pb (with 7.3 fb⁻¹ data)
 To be compared with Do fit of:
 • 0.82 +- 0.83 pb
 results are only ~2σ apart

The D0 results were also presented at EPS HEP 2011 (21 July), claiming consistency with the minimal Standard Model and refutation of a narrow interpretation (a 4 pb cross section with no error bars) of the CDF results.

LHC results presented at EPS HEP 2011 (21 July) by Tetiana Berger-Hrynova who said that ATLAS saw "... No significant excess over Standard Model processes seen in 1.02 fb⁻¹ of data ...[but]... This channel is not optimal at LHC with W+jet bkg 20 times higher ...".

The CDF Gaussian Peak is located at 147 GeV which is within about 10% of the 130 GeV value of the E8Physics tree-level calculation. The 130 GeV value is well inside the 120-160 GeV range described for the Wjj bump in the CDF paper at arxiv 1104.0699 which said "... we estimate a cross section times the particle branching ratio into dijets of the order of 4 pb. ...".

My view of all the cross section results taken together is that they are roughly consistent with a single T cross section of 2.90 pb (see arxiv 1104.4087 by Plehn and Takeuchi).

An objection to Tquark as cause of the excess was raised by Giovanni Punzi in slides 31 and 33 of his 2011 Blois Rencontres presentation where he said said: "... could this be top background [arXiv: 1104.4087, arXiv: 1104.3790] ... the answer is NO - this cannot possibly be top background - there is no significant tagged component ...".

However,

As to b-tagging, the CDF update on the W_{jj} bump said:

"... b-tagging in the excess region ... No significant enhancement of b-tagged events is observed in the "excess" region compared to the sideband regions. ... This highlights that ... the excess is not due to an under-estimated t-tbar content since in these events at least one of the jets should give rise to a b-quark in the "excess" region" ...",

so
while lack of tagging might be an argument against t-tbar causing the excess,
my position is that singleT might cause the excess.

As to b-tagging for singleT, Sullivan and Menon in arxiv 1104.3790 said:

"... one may wonder whether there is a large excess in the 2 b-tag CDF dijet invariant mass. CDF has measured that signal in an analysis to search for Higgs production in WH to $Wbb\bar{b}$. There are two reasons we do not expect to see a large excess in that study. First, the deficit in Wbb from t-channel single-top is almost perfectly cancelled by the excess in the s-channel single-top contribution. The basic cuts in the Higgs analysis are almost identical to the single-top-quark analysis, and so there is no contamination from processes with additional jets. Furthermore, in the CDF Higgs analysis, they normalize their background subtraction to data. Hence, any residual excess should be removed. ...".

What about T-Tbar Events ?

My view is that most of the T-Tbar events were included in the Tquark background in the analysis processes used by CDF and D0 and LHC.

Further:

Eichten, Lane, Martin, and Pilon, in arXiv 1206.0186, discuss "the CDF Dijet Excess at the 8-TeV LHC".

Although the context of their article is Technicolor, some of their observations are relevant to my model:

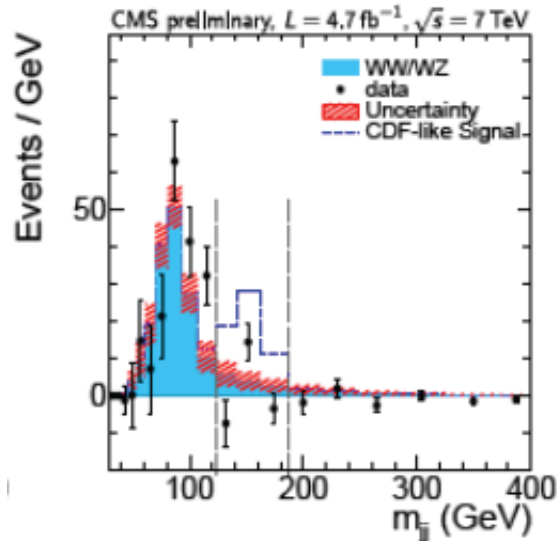
"... we study ... observability in LHC detectors for 8 TeV and 20/fb ... [of]... the dijet excess seen by the CDF Collaboration near 150 GeV in W_{jj} production ... We show that cuts similar to those employed by CDF, and recently by ATLAS, cannot confirm the dijet signal ...

the ATLAS Collaboration published dijet spectra for 1.02/fb of W_{jj} data with exactly two jets and with two or more jets passing selection criteria ... There is no evidence of CDF's dijet excess near 150 GeV nor even of the standard model $WW=WZ$ signal near 80 GeV. This is what we anticipated ... because of the great increase in W_{jj} backgrounds at the LHC relative to the Tevatron. ... our simulation shows that the CDF/ATLAS cuts can neither reveal nor exclude ... the CDF signal at the LHC for any reasonable luminosity.

...

the CMS Collaboration studied the dijet-mass spectrum in $W \rightarrow l \nu$ plus jets production with 4.7/fb at 7TeV ...

No significant enhancement near 150 GeV was observed ... CMS reported a 95% upper limit on the production cross section times $B(W \rightarrow l \nu)$ of 1.3 pb. ... Our prediction for the cross section was ... 1.7 pb, 25% higher than CMS's limit ... Cuts ... typically caused the background to peak very near the dijet resonance. To get the signal off the peak (and more like the original CDF M_{jj} excess), we used the following ...[cuts]... the resulting M_{jj} distribution is ...

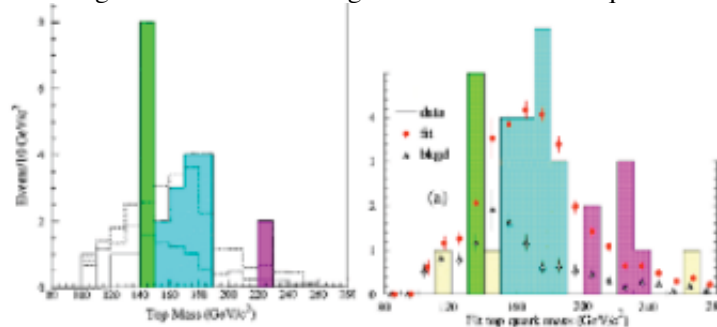


... Notwithstanding the CMS result, we believe that a better understanding of the backgrounds than CMS demonstrated is required to observe or exclude the ... signal in this channel. ...".

Note that there is a CMS data point of about 15 events at the CDF-like Signal. Although it is not quite as high as the CDF-like Signal, it looks to me like the same thing with a somewhat lower cross-section than the 4 pb of the original CDF Wjj excess, and therefore consistent with my model.

I disagree with Tommaso Dorigo who said (on a slide at ICFP 2012 and by email) "... No signal is observed ... 95 percent CL upper limits exclude the CDF effect ... there is one bin high and two bins low ... a signal will never appear in just one bin ... you should add the bins anyway for any meaningful result ... Nobody in their right mind in HEP nowadays looks at single bins fluctuating up if the signal is known to affect at least three or four of them ...".

First, Tommaso and Fermilab reject the single-bin CDF and D0 signals for a low-mass Tquark state (green bars)

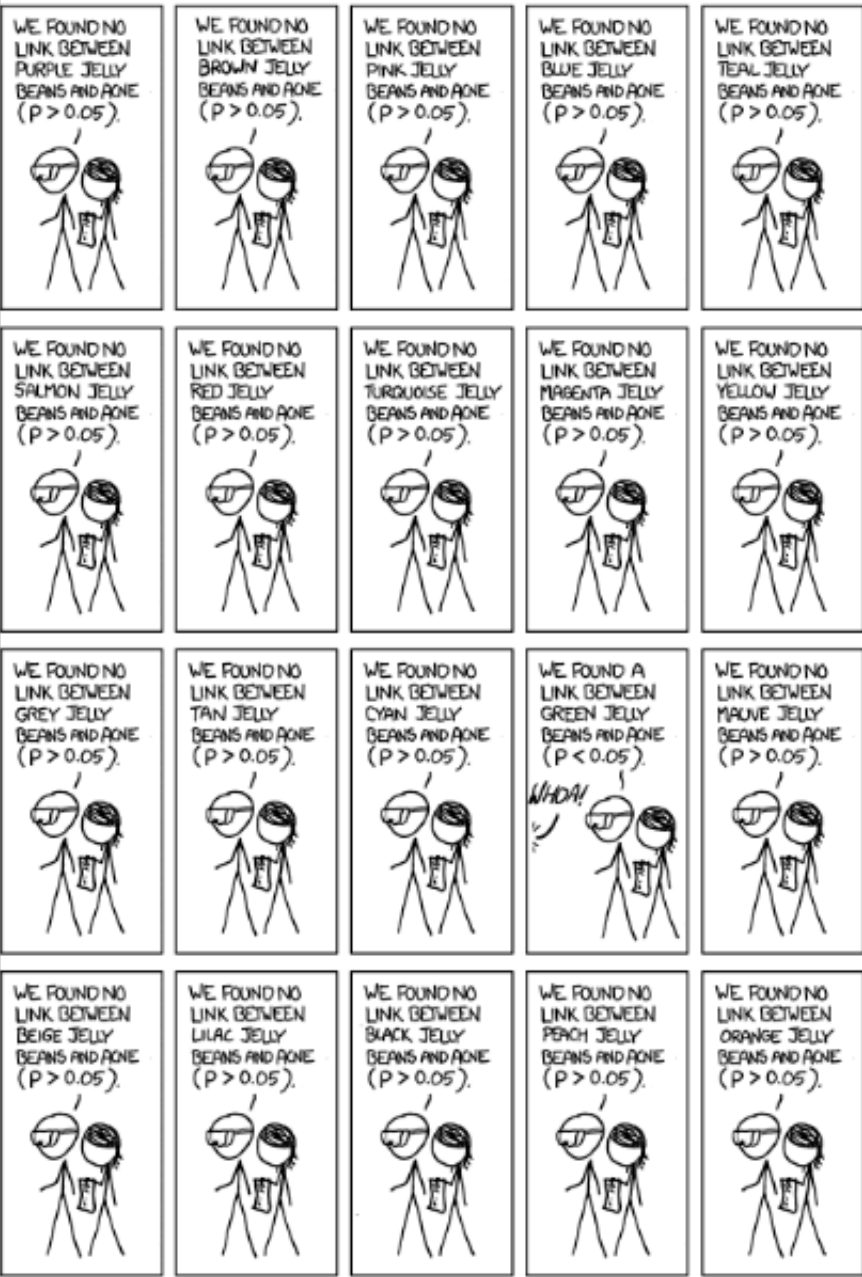
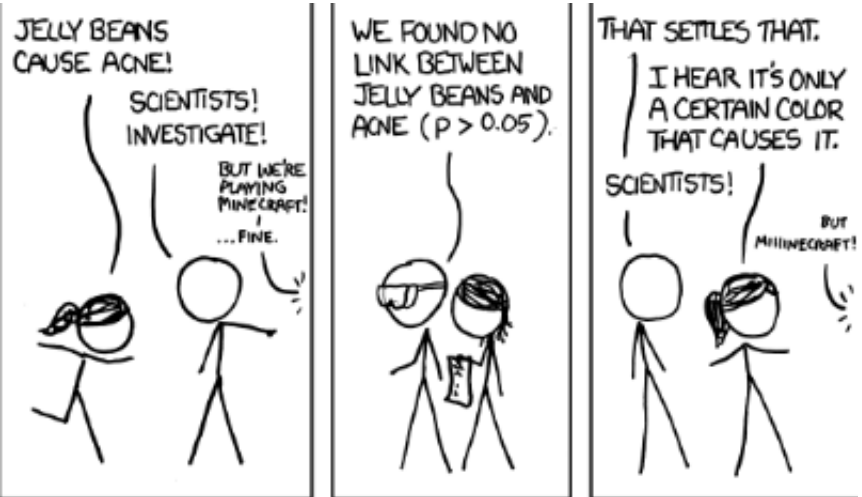


even though Tommaso has characterized them together as 4 sigma and (in my view) they are supported by much subsequent experimental data.

Second, Tommaso had no reason to believe that "the signal is known to affect at least three or four" bins because the nature of the particle causing the CDF Wjj bump is unknown to him (my view is that it is a single-Tquark phenomenon due to a meson with a low-mass-state Tquark which could have a very narrow peak as in the CDF and D0 histograms shown immediately above)

and it is possible that CDF saw a broad peak while CMS saw a narrow peak because CMS had better resolution than CDF.

Third, 95 percent CL is not a high enough standard to exclude anything - consider this from xkcd:



== NEWS ==

GREEN JELLY BEANS LINKED TO ACNE!

95% CONFIDENCE



ONLY 5% CHANCE OF COINCIDENCE!

SCIENTISTS...

Wavy lines representing illegible text in the article body.

125 GeV Standard Model Higgs

by Frank Dodd (Tony) Smith Jr.

Abstract:

In July 2012 the LHC announced observation of a 125 GeV state of the Standard Model Higgs boson.

Therefore, I lost a bet to Tommaso Dorigo and had to revise my E8 Physics model:

Now it has no Tquark mesons (I was wrong about having a quantum protectorate that extended Tquark lifetime enough to permit meson formation)

and

my calculated low mass state Higgs mass of 145 GeV is now seen to be only a tree level value that goes to $0.86 \times 145 = 125$ GeV effective mass seen by the LHC.

In view of the detailed LHC histograms for the Higgs to ZZ to 4l Golden Channel,

I remain in favor of a Standard Model Higgs with 3 Mass States:

125 GeV (effective mass) ; around 200 GeV ; around 250 GeV.

(References are included in the body of the paper and in linked material.)

125 GeV Standard Model Higgs (low mass state)

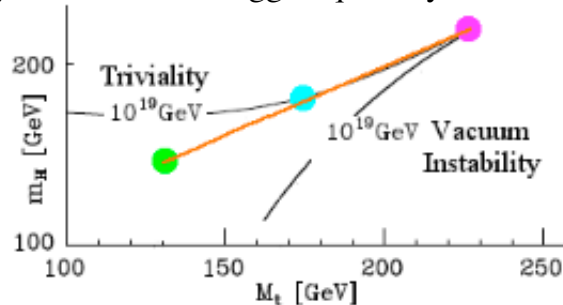
200 GeV midHiggs and 240 GeV highHiggs

Frank Dodd (Tony) Smith, Jr. - July 2012

This paper is about LHC results announced through 4 July 2012 (it supercedes my [earlier papers](#)).

The LHC has observed a 125 GeV (about 133 proton masses) state of the Standard Model Higgs boson.

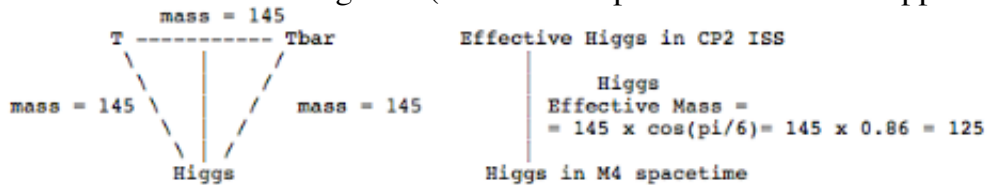
In my E8 Physics model the Higgs/Tquark system has 3 mass states



with the low-mass Higgs state calculated in my E8 Physics model at tree level to be near 145 GeV.

The 125 GeV observed peak is at about 0.86 times the 145 GeV tree-level calculation.

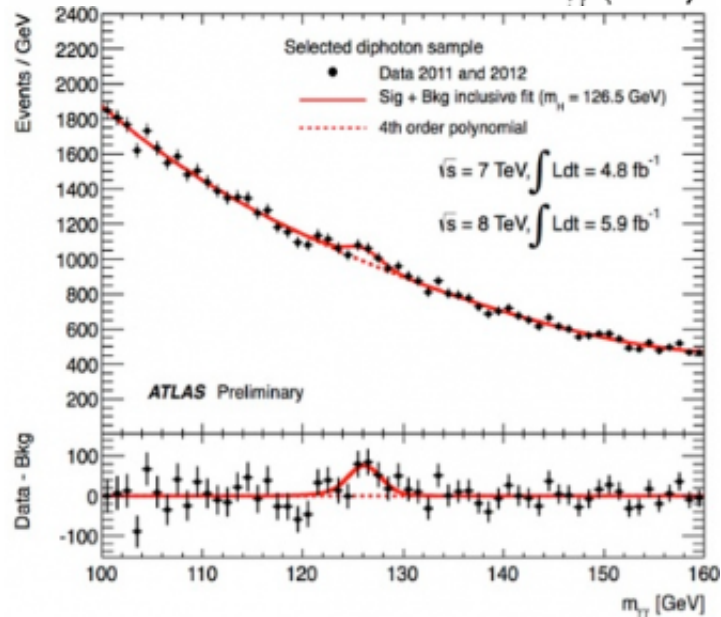
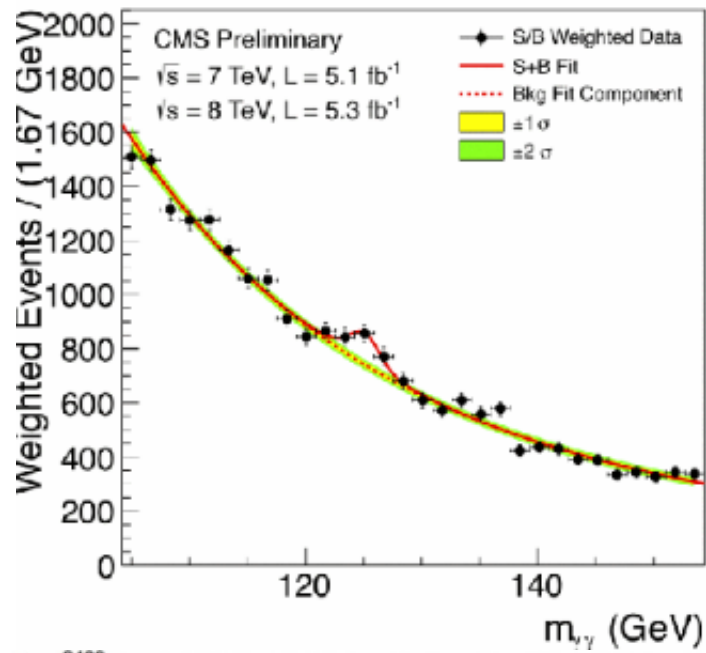
The factor of $0.86 = \cos(\pi/6)$ comes into play when you consider that the Higgs is part of a Tquark condensate system as indicated in these diagrams (which are explained in detail in Appendix I hereinbelow):



The 3-state Higgs-Tquark system also has, near the Higgs Vacuum Expectation Value around 240 GeV, a high-mass state at a critical point with respect to Vacuum Instability and Triviality, as well as a mid-mass state around 200 GeV at which the system renormalization path enters conventional 4-dim Physical Spacetime, departing from the Triviality boundary at which an (4+4)-dim Klauza-Klein spacetime is manifested.

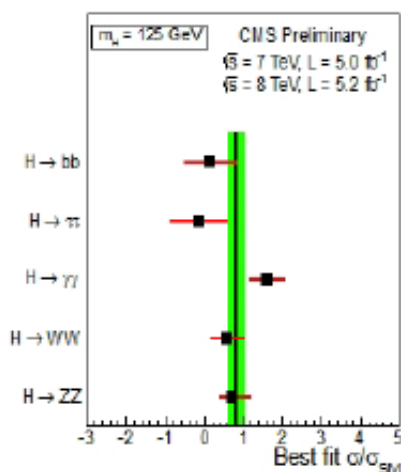
Here are some details about the LHC observation at 125 GeV and related results:

The digamma histograms for CMS and ATLAS



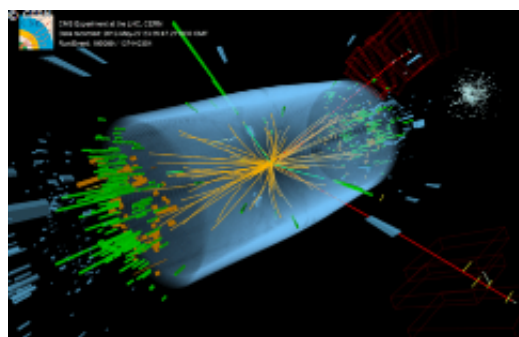
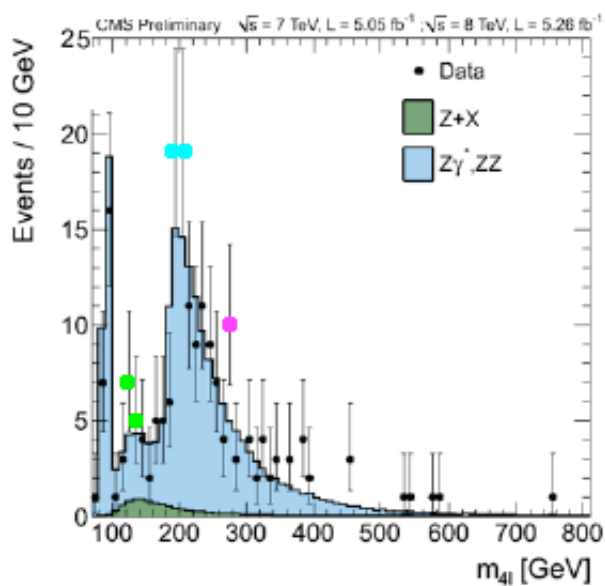
clearly show only one peak below 160 GeV and it is around 125 GeV.

CMS shows the cross sections for Higgs at 125 GeV



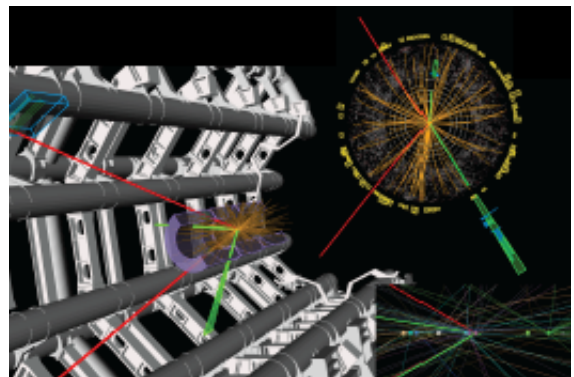
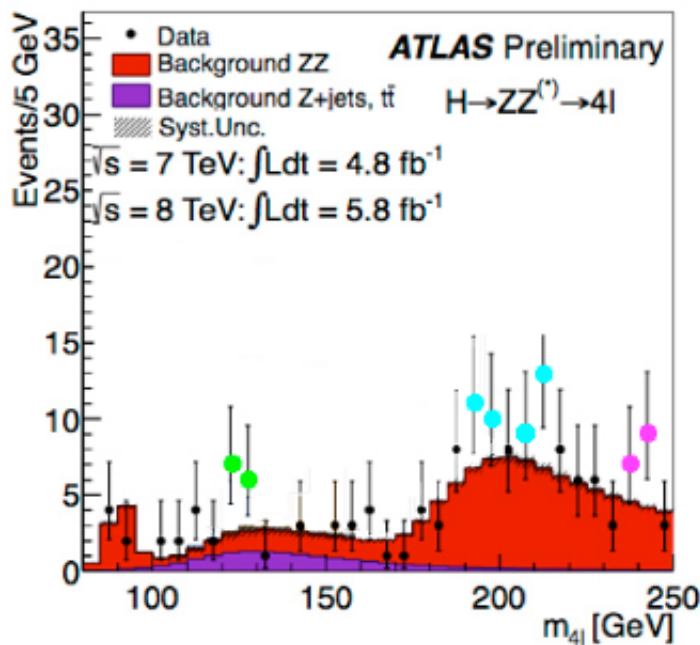
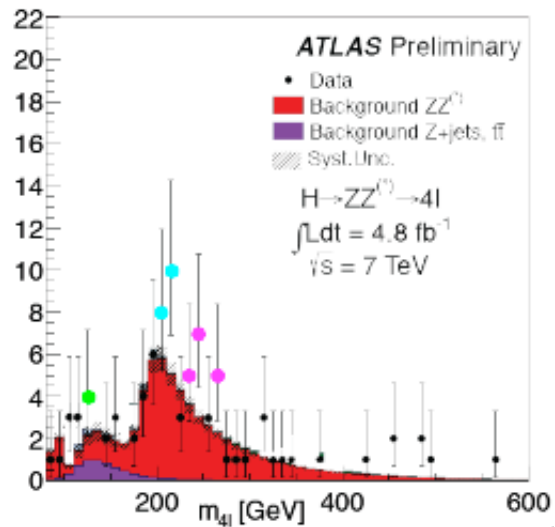
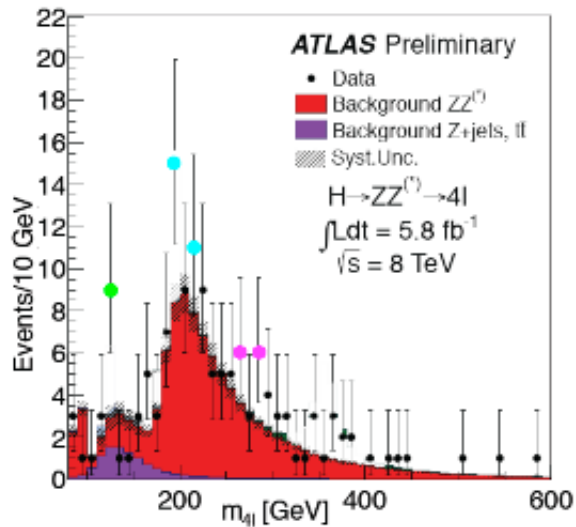
to be substantially consistent with the Standard Model for the WW and ZZ channels, a bit low for tau-tau and bb channels (but that is likely due to very low statistics there), and a bit high for the digamma channel (but that may be due to phenomena related to the Higgs as a Tquark condensate).

A CMS histogram (some colors added by me) for the Golden Channel Higgs to ZZ to 4l shows the peak around 125 GeV (green dots - lowHiggs mass state). An image of one of the events is shown next to the histogram.



The CMS histogram also indicates other excesses around 190-210 GeV (cyan dots - midHiggs mass state) and around 280 GeV (magenta dot - highHiggs mass state).

Some ATLAS ZZ to 4l histograms (some colors added by me) show the peak around 125 GeV (green dots - lowHiggs mass state). An image of one of the events is shown next to the third histogram.



The ATLAS histograms also indicate other excesses around 190-210 GeV (cyan dots - midHiggs mass state) and around 235-280 GeV (magenta dots - highHiggs mass state - note that some of these are omitted in the histogram combining 7 TeV and 8 TeV because it only covers up to 250 GeV).

The midHiggs and highHiggs excesses may go away with more data (as did the 137 GeV digamma excesses) or further data may confirm one or both of them but either way we now know that the plain vanilla Standard Model is what Nature likes.

Non-Standard-Model Higgs beyond those 3 mass states clearly are not needed or used by Nature.

Neither do Tquark mesons exist, confirming that Tquarks decay too rapidly (due to high mass

and lack of any collective quantum protectorate for individual Tquarks) to form mesons.

Also neither needed nor observed are any conventional 1-1 fermion-boson SuperSymmetric particles or any exotic phenomena such as Technicolor, extra Z bosons, etc.

With the Standard Model firmly confirmed, what should physicists do in the future ?

Here are a few things to think about:

Study the High Energy Massless Realm well above Electroweak Symmetry Breaking:

What happens to Kobayashi-Maskawa mixing in a Realm with no mass ?

How do you tell a muon from an electron if they are both massless ?

Build a Muon Collider to find out.

If conventional 1-1 fermion-boson SuperSymmetry is not Nature's Way,
can we get the nice cancellations from a more Subtle SuperSymmetry ?

For that, my model uses a Triality-related symmetry between fermions and gauge bosons
based on its 8-dim Kaluza-Klein structure.

What about Dark Matter and Dark Energy?

My model uses the $Spin(2,4) = SU(2,2)$ Conformal Group of Irving Ezra Segal to account for both,
but it is experimental observation that counts.

My favourite experimental approach is that of Paul A. Warburton at University College London
using terahertz frequency Josephson Junctions.

Since the Higgs came from Solid State Physics ideas of people like Anderson,

look closely at Solid State Nanostructures

(such as Nickel/Palladium that seems to be useful in Cold Fusion)

to see whether they can show new ways

to visualize the workings of High-Energy Physics of the Standard Model plus Gravity.

Appendix I: Higgs Mass Calculations:

I-1: Low-Mass State ●

The calculations produce ratios of masses, so that only one mass need be chosen to set the mass scale. In the E8 model, the value of the fundamental mass scale vacuum expectation value $v = \langle \text{PHI} \rangle$ of the Higgs scalar field is set to be the sum of the physical masses of the weak bosons, W^+ , W^- , and Z^0 , such that, in accord with ratios calculated in the E8 model, the electron mass will be 0.5110 MeV. Effectively, the electron mass of 0.5110 MeV is the only input into the calculated particle masses.

The relationship between the Higgs mass and v is given by the Ginzburg-Landau term from the Mayer Mechanism as $(1/4) \text{Tr} ([\text{PHI} , \text{PHI}] - \text{PHI})^2$ or, in the notation of hep-ph/9806009 by Guang-jiong Ni

$$(1/4!) \lambda \text{PHI}^4 - (1/2) \sigma \text{PHI}^2 \text{ where the Higgs mass } M_H = \sqrt{2 \sigma}$$

Ni says:

"... the invariant meaning of the constant λ in the Lagrangian is not the coupling constant, the latter will change after quantization ... The invariant meaning of λ is nothing but the ratio of two mass scales: $\lambda = 3 (M_H / \text{PHI})^2$ which remains unchanged irrespective of the order ...".

Since $\langle \text{PHI} \rangle^2 = v^2$,

and assuming at tree-level that $\lambda = 1$ (a value consistent with the Higgs Tquark condensate model of Michio Hashimoto, Masaharu Tanabashi, and Koichi Yamawaki in their paper at hep- ph/0311165), we have, at tree-level

$$M_H^2 / v^2 = 1 / 3$$

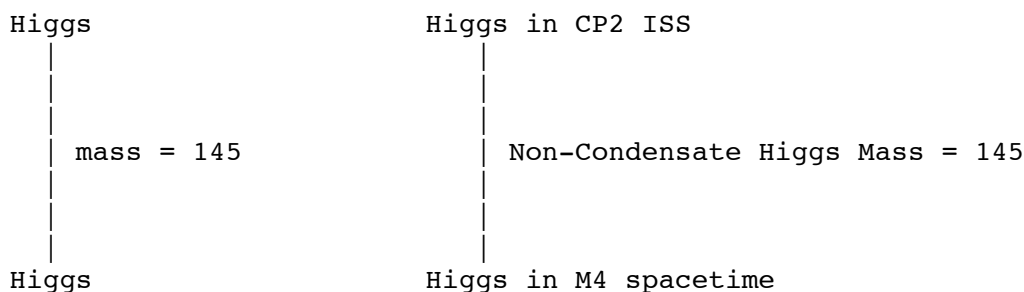
As described above, in the E8 model

$$v \text{ is set to be } 252.514 \text{ GeV } M_H = v / \sqrt{3} = 145.789 \text{ GeV}$$

This is a tree-level calculation in (4+4)-dim Kaluza-Klein with a 4-dim M4 Minkowski Physical Spacetime at each point of which there lives a 4-dim CP2 Internal Symmetry Space (ISS).

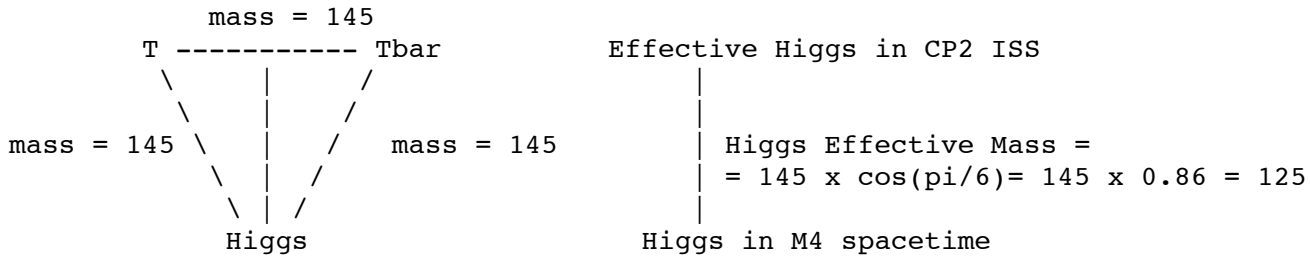
A Non-Condensate Higgs is represented by a Higgs at a point in M4

that is connected to a Higgs representation in CP2 ISS by a line whose length represents the Higgs mass



of the tree-level calculation set out above.

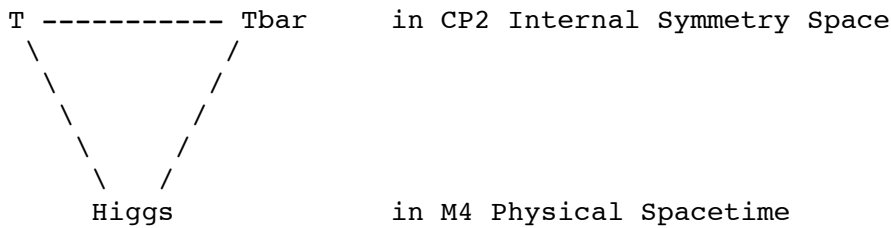
However, in my E8 Physics model, the Higgs has beyond-tree-level structure due to a Tquark condensate



in which the Higgs at a point in M4 is connected to a T and Tbar in CP2 ISS so that the vertices of the Higgs-T-Tbar system are connected by lines forming an equilateral triangle whose line lengths represent the tree-level calculated mass. Therefore: The effective length from the Higgs in M4 to the Effective Higgs in CP2 ISS (the mass observed by LHC) is the altitude of the equilateral triangle: $145 \times \cos(\pi/6) = 125$ GeV.

I-2: Mid-Mass State ●

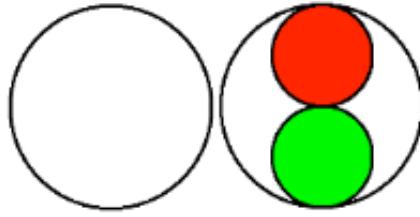
In my E8 Physics model, the Mid-Mass Higgs structure is not restricted to Effective M4 Spacetime as is the case with the Low-Mass Higgs Ground State but extends to the full $4+4 = 8$ -dim structure of $M4 \times CP2$ Kaluza-Klein.



Therefore the Mid-Mass Higgs looks like a 3-particle system of Higgs + T + Tbar. The T and Tbar form a Pion-like state. Since Tquark Mid-Mass State is 174 GeV the Mid-Mass T-Tbar that lives in the CP2 part of $(4+4)$ -dim Kaluza-Klein has mass $(174+174) \times (135 / (312+312)) = 75$ GeV. The Higgs that lives in the M4 part of $(4+4)$ -dim Kaluza-Klein has, by itself, its Low-Mass Ground State Effective Mass of 125 GeV.

So, the total Mid-Mass Higgs lives in full 8-dim Kaluza-Klein with mass $75+125 = 200$ GeV. This is consistent with the Mid-Mass States of the Higgs and Tquark being on the Triviality Boundary of the Higgs - Tquark System and with the 8-dim Kaluza-Klein model in hep-ph/0311165 by Hashimoto, Tanabashi, and Yamawaki.

As to the cross-section of the Mid-Mass Higgs compared to that of the Low-Mass Ground State



consider that the entire Ground State cross-section lives only in 4-dim M4 spacetime
(left white circle)

while for the Mid-Mass Higgs that cross-section lives in full $4+4 = 8$ -dim Kaluza-Klein spacetime
(right circle with red area only in CP2 ISS and white area partly in CP2 ISS
with only green area effectively living in 4-dim M4 spacetime)

so that our 4-dim M4 Physical Spacetime experiments only see for the Mid-Mass Higgs
a cross-section that is 25% of the full Ground State cross-section.

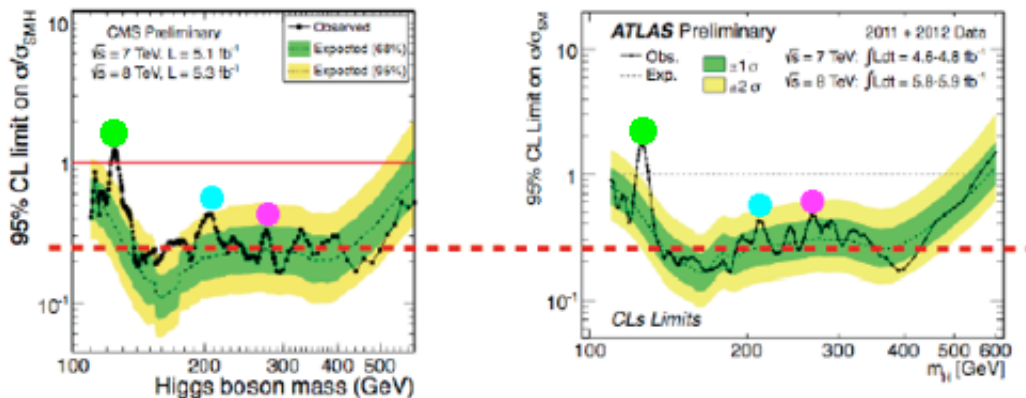
The 25% may also be visualized in terms of 8-dim coordinates $\{1,i,j,k,E,I,J,K\}$

	1	i	j	k	E	I	J	K
1	11	1i	1j	1k	1E	1I	1J	1K
i	i1	ii	ij	ik	iE	iI	iJ	iK
j	j1	ji	jj	jk	jE	jI	jJ	jK
k	k1	ki	kj	kk	kE	kI	kJ	kK
E	E1	Ei	Ej	EK	EE	EI	EJ	EK
I	I1	Ii	Ij	IK	IE	II	IJ	IK
J	J1	Ji	Jj	JK	JE	JI	JJ	JK
K	K1	Ki	Kj	KK	KE	KI	KJ	KK

in which $\{1,i,j,k\}$ represent M4 and $\{E,I,J,K\}$ represent CP2.

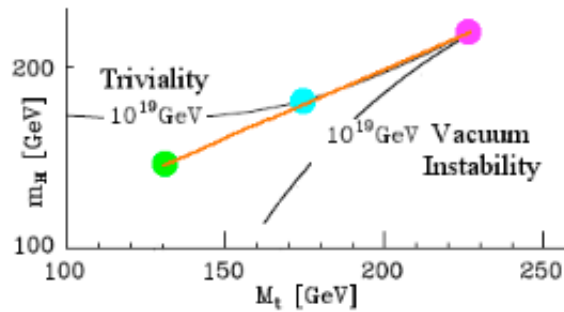
This is consistent with the ATLAS and CMS observations reported at Higgs Hunting 2012
in slide 31 of the Experimental Concluding Talk by G. Unal (green, cyan, and magenta dots added
by me to indicate Low-Mass Ground States, Mid-Mass States, and High-Mass States of the Higgs):

Obviously $\sigma = \sigma(\text{SM})$ is not the target anymore



I-3: High-Mass State

In my E8 Physics model, the High-Mass Higgs State is at the Critical Point of the Higgs-Tquark System



where the Triviality Boundary intersects the Vacuum Instability Boundary which is also at the Higgs Vacuum Expectation Value VEV around 250 GeV which is roughly consistent with the ATLAS and CMS observations reported at Higgs Hunting 2012 in slide 31 of the Experimental Concluding Talk by G. Unal shown above in Appendix I-2.

As with the Mid-Mass Higgs, the High-Mass Higgs lives in all $4+4 = 8$ Kaluza-Klein dimensions and so has a cross-section that is 25% of the Higgs Ground State cross-section.

Appendix II: some comments on my earlier work:

My father was in the mining business. He told me "never trust any geological model until you drill a hole and look to see what is really under the ground". I am a lawyer. To try a case, I have to have a working model of the facts to the extent that I know them at the time, but to be ready to change that model immediately when new facts emerge (as they often do quite unexpectedly).

Around 1981, I started to try to build a realistic physics model based on those principles.

I started with $N = 8$ supergravity, but its naive 1-1 supersymmetry gave it too many particles and its $SO(8)$ did not really fit the Standard Model gauge groups.

Then I tried to build a model around Division Algebras and $Spin(8)$ with 3 generations of fermions and of W/Z bosons, but experiment said that 3 generations of W/Z was wrong, so I changed it to a model based on F_4 .

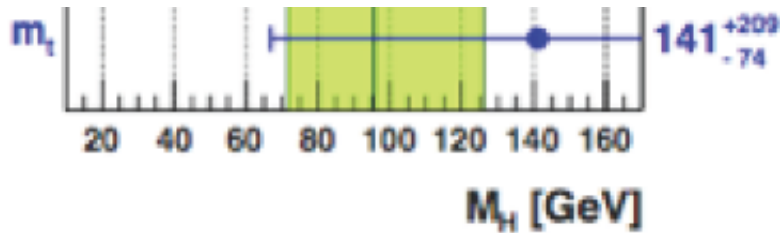
F_4 was better than $Spin(8)$, but it ran aground due to lack of complex structure, which led me to build an E_6 model.

The E_6 model was pretty nice (it can be seen as a bosonic string model with fermions coming from orbifolding), but it only had local Lagrangian structure and did not seem to give a natural Algebraic Quantum Field Theory (AQFT).

To get an AQFT, I needed to use the 8-periodicity of Real Clifford Algebras. Since E_6 sits inside E_8 which lives inside the Clifford Algebra $Cl(16)$, E_8 and Clifford Algebra is the basic structure of my present model, which has a lot of complicated details that give results that look roughly consistent with experiments up to the LHC Higgs search.

My Higgs sector is based on Higgs as a Tquark condensate with 3 mass states for the Higgs and for the Tquark. Since a Tquark condensate involves a quantum protectorate to allow it to be stable beyond the very short basic Tquark lifetime, I had in my model T_0 and T_0c mesons in which a low-mass-state Tquark, stabilized by the condensate quantum protectorate, combined with an Up or Charm (anti)quark, producing mesons with mass around 125 GeV or so.

The low-mass-state Higgs in my model was around 145 GeV or so, which is roughly where Gfitter says the Higgs should be if the Tquark mass is not fixed



which is the case of my E8 Physics model with 3 mass states for the Tquark.

Therefore, with the 2011 LHC results, I was happily identifying the 125 GeV digamma bump with my lowTquark T0 meson and the 137 GeV digamma bump with my lowHiggs.

The fact that the 2011 LHC WW cross section (for both CMS and ATLAS) was low (something natural for a T0 meson but not good for Standard Model Higgs) made me confident enough to bet with Tommaso Dorigo that the 125 GeV bump would not be Higgs.

The 4 July 2012 LHC results told me that I lost the bet because the 137 GeV bump went away in both CMS and ATLAS with the new data and as to the 125 GeV bump, even though the Tevatron announced on 2 July 2012 that it saw a low WW cross section and ATLAS on 4 July 2012 was still reporting a low WW cross section in agreement with CMS 2011 and ATLAS 2011, CMS showed a high WW cross section in agreement with a Standard Model Higgs.

CMS was able to find the correct result that ATLAS and the Tevatron missed because, as Tommaso said, by CMS "... having put together more advanced multivariate search techniques and having analyzed in time for the announcement not just the two main channels but all the five important final states (W boson pairs, b-quark pairs, and tau-lepton pairs in addition to the two ... main channels ... [digamma and Higgs to ZZ to 4l])...".

Not only was my bet lost, but my model was shown to have errors, so I have had to revise it in at least two ways:

1 - There is no quantum protectorate extension of the life of the Tquark, so there are no Tquark mesons.

2 - The LHC indeed found the Higgs at 125 GeV, which is about 0.86 times the value calculated in my model. Since the high digamma strength in the 2012 LHC data could be due to the Higgs being connected with a Tquark condensate, it seems that the 125 GeV Higgs is really basically a plain vanilla Standard Model Higgs-Tquark Condensate.

It is easy to do 1 (just as it was easy to get rid of high-generation W/Z bosons many years ago) but

it will take some work and rethinking to take care of 2,
so
thanks to LHC observations for telling me to get to work
to try to get my model into better shape.

This is why I like physics:

You can use your imagination to devise models that (in your eyes) are beautiful

but

Nature (not the magazine) is always the boss,

telling you though experiments like the LHC how dumb you were to do

some of the things that you thought were so smart,

and

then you get a chance to correct your dumb mistakes and try to do something better.

It is a life-long process that goes on as long as you have fun playing the game:

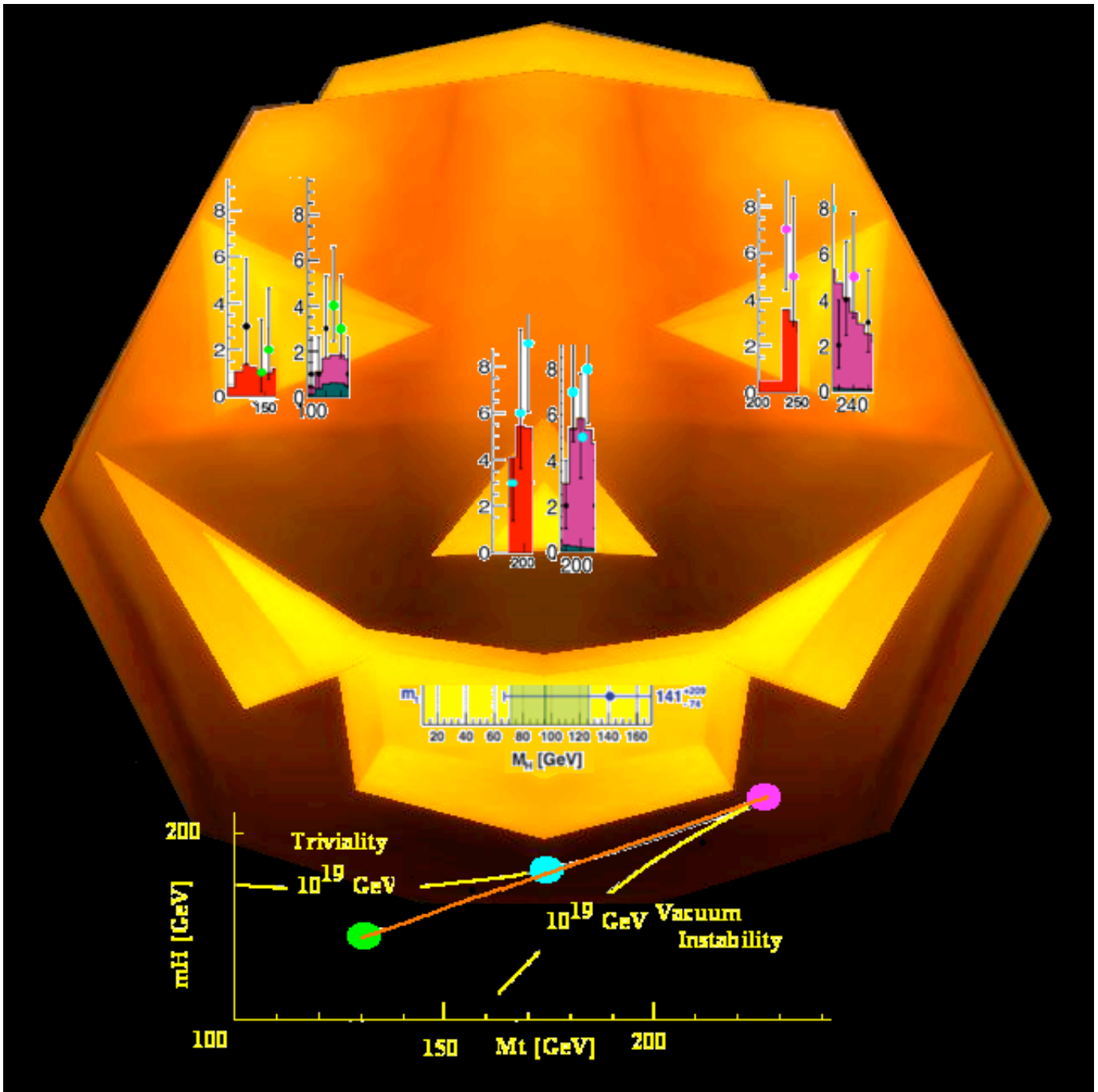
Even if I get 1 and 2 done, that will not be the end of the road.

My model still has 3 Higgs mass states,

and the LHC will have to say whether or not the two higher mass state exist or not.

If the LHC eventually confirms the two higher mass Higgs states,

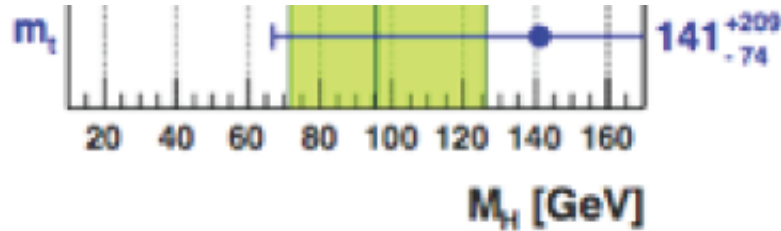
then the Pumpkin Chart that I made based on LHC data as of Halloween 2011 will be confirmed



Here is how the Great Pumpkin of the Halloween 2011 Data shows the True State of Physics:

Using the ideas of - African IFA Divination; Clifford Algebra $Cl(8) \times Cl(8) = Cl(16)$; Lie Algebra E_8 ; Hua Geometry of Bounded Complex Domains; Mayer Geometric Higgs Mechanism; Batakis 8-dim Kaluza-Klein structure of hep-ph/0311165 by Hashimoto et al; Segal Conformal Gravity version of the MacDowell-Mansouri Mechanism; Real Clifford Algebra generalized Hyperfinite III von Neumann factor AQFT; and Joy Christian EPR Geometry - my E_8 Physics model has been developed with a 3-state Higgs system in which the Higgs is related to the Primitive Idempotents of the real Clifford Algebra $Cl(8)$.

The Pumpkin Mouth Plot shows that the Electroweak Gfitter best fit for a floating Tquark mass as is required in my 3-State Higgs-Tquark System



is for a Higgs state with central value of 141 GeV and upper bound $141+209 = 350$ GeV.

The Pumpkin Eye-Nose-Eye Plots are for data (about 5/fb) taken by Halloween 2011:

- Green ● Eye: ATLAS-CMS ZZ-4l plots of Halloween 2011 excesses seen in 120-145 GeV Higgs range;
- Cyan ● Nose: ATLAS-CMS ZZ-4l plots of Halloween 2011 excesses seen around 200 GeV;
- Magenta ● Eye: ATLAS-CMS ZZ-4l plots of Halloween 2011 excesses seen around 250 GeV.

According to hep-ph/0307138 by C. D. Froggatt:

“... the top quark mass is the dominant term in the SM fermion mass matrix ... [so]... it is likely that its value will be understood dynamically ... the self-consistency of the pure SM up to some physical cut-off scale Λ imposes constraints on both the top quark and Higgs boson masses.

The first constraint is the so-called triviality bound: the running Higgs coupling constant $\lambda(\mu)$ should not develop a Landau pole for $\mu < \Lambda$.

The second is the vacuum stability bound: the running Higgs coupling constant $\lambda(\mu)$ should not become negative leading to the instability of the usual SM vacuum.

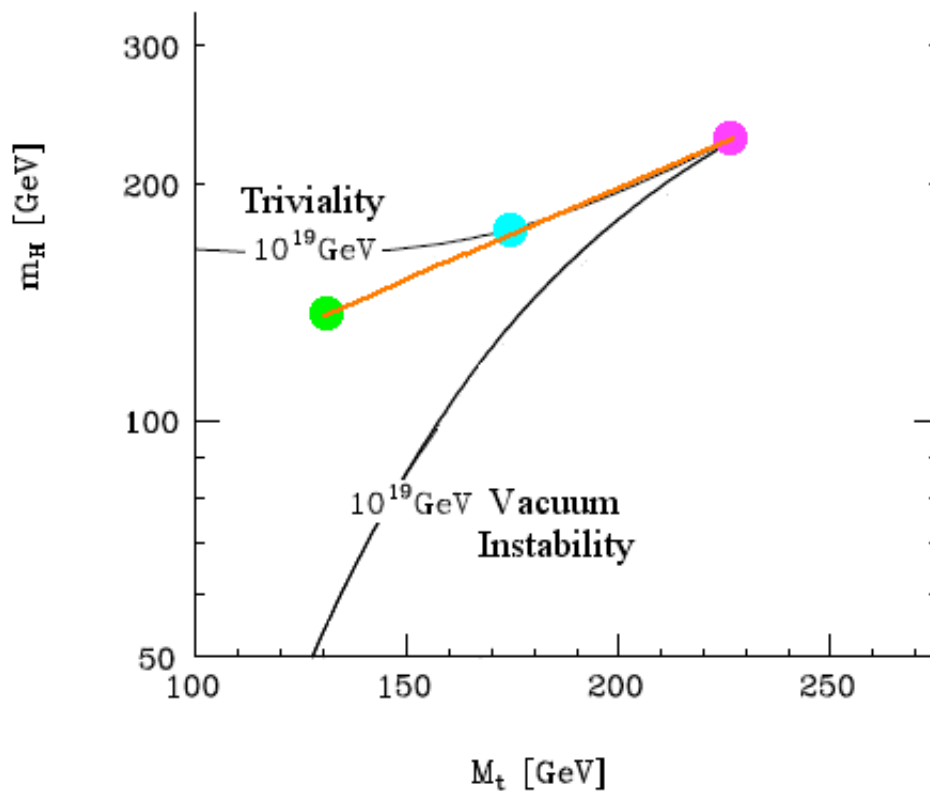
These bounds are illustrated in Fig. 3 ... we shall be interested in the large cut-off scales $\Lambda = 10^{19}$ GeV, corresponding to the Planck scale [I have edited this sentence to restrict coverage to a Planck scale SM cut-off and have edited Fig. 3 and added material relevant to my E8 Physics model with 3 Higgs-Tquark states]

...

The upper part of each curve corresponds to the triviality bound.

The lower part of each curve coincides with the vacuum stability bound and

the point in the top right-hand corner, where it meets the triviality bound curve, is the quasi-fixed infra-red fixed point for that value of Λ



... Fig. 3: SM bounds in the (M_t , M_H) plane ...”.

The Magenta Dot ● is the high-mass state of a 220 GeV Truth Quark and a 240 GeV Higgs. It is at the critical point of the Higgs-Tquark System with respect to Vacuum Instability and Triviality. It corresponds to the description in hep-ph/9603293 by Koichi Yamawaki of the Bardeen-Hill-Lindner model That high-mass Higgs is around 250 GeV in the range of the Higgs Vacuum Instability Boundary which range includes the Higgs VEV.

The Gold Line leading down from the Critical Point roughly along the Triviality Boundary line is based on Renormalization Group calculations with the result that $M_H / M_T = 1.1$ as described by Koichi Yamawaki in hep-ph/9603293 .

The Cyan Dot ● where the Gold Line leaves the Triviality Boundary to go into our Ordinary Phase is the middle-mass state of a 174 GeV Truth Quark and Higgs around 200 GeV. It corresponds to the Higgs mass calculated by Hashimoto, Tanabashi, and Yamawaki in hep-ph/0311165 where they show that for 8-dimensional Kaluza-Klein spacetime with the Higgs as a Truth Quark condensate $172 < M_T < 175$ GeV and $178 < M_H < 188$ GeV.

That mid-mass Higgs is around the 200 GeV range of the Higgs Triviality Boundary. The physical meaning of the Triviality Bound is described by Pierre Ramond in his book *Journeys Beyond the Standard Model* (Perseus Books 1999) where he says at pages 175-176:

“... for a ... (large) Higgs mass, we expect the standard model to enter a strong coupling regime ... losing ... our ability to calculate ... it is natural to think ... that the Higgs actually is a composite ... The resulting bound ... is sometimes called the triviality bound. The reason for this unfortunate name (the theory is anything but trivial) stems from lattice studies where the coupling is assumed to be finite everywhere; in that case the

coupling is driven to zero, yielding in fact a trivial theory. In the standard model ... the coupling ... is certainly not zero. ...”.

The Green Dot ● where the Gold Line terminates in our Ordinary Phase is the low-mass state of a 130 GeV Truth Quark and a tree-level 145 GeV Higgs with Effective Higgs mass of 125 GeV.

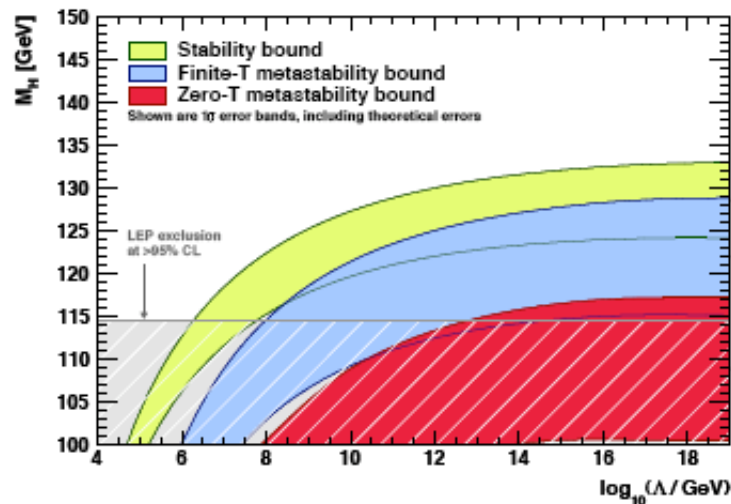
Its location is determined by E8 Physics calculation of the tree-level 145 GeV Higgs state which is the Higgs state that is necessary for agreement with arXiv 0960.0954

by Ellis et al who require a Higgs with $135 < M_H < 158$ GeV, saying:

“... the Standard Model may survive all the way to the Planck scale for an intermediate range of Higgs masses ...

We evaluate ... on the basis of a global fit to the Standard Model made using the Gfitter package ... a global fit to electroweak precision data within the SM ... favors $M_H < 158$ GeV ...

Lower bounds on the Higgs mass due to absolute vacuum stability .. and finite-temperature ... and zero-temperature metastability ... includ[ing] theoretical uncertainties ...



...[“allow (as Tommaso Dorigo said in an entry of 23 July 2009 on his blog) the SM to be valid for all energies up to the Planck scale (set at 2×10^{18} GeV) only if the Higgs boson has a mass above 135 GeV or so”]...”. In short, it is the

tree-level Higgs state mass of 145 GeV that allows the Standard Model to be valid up to the Planck scale and

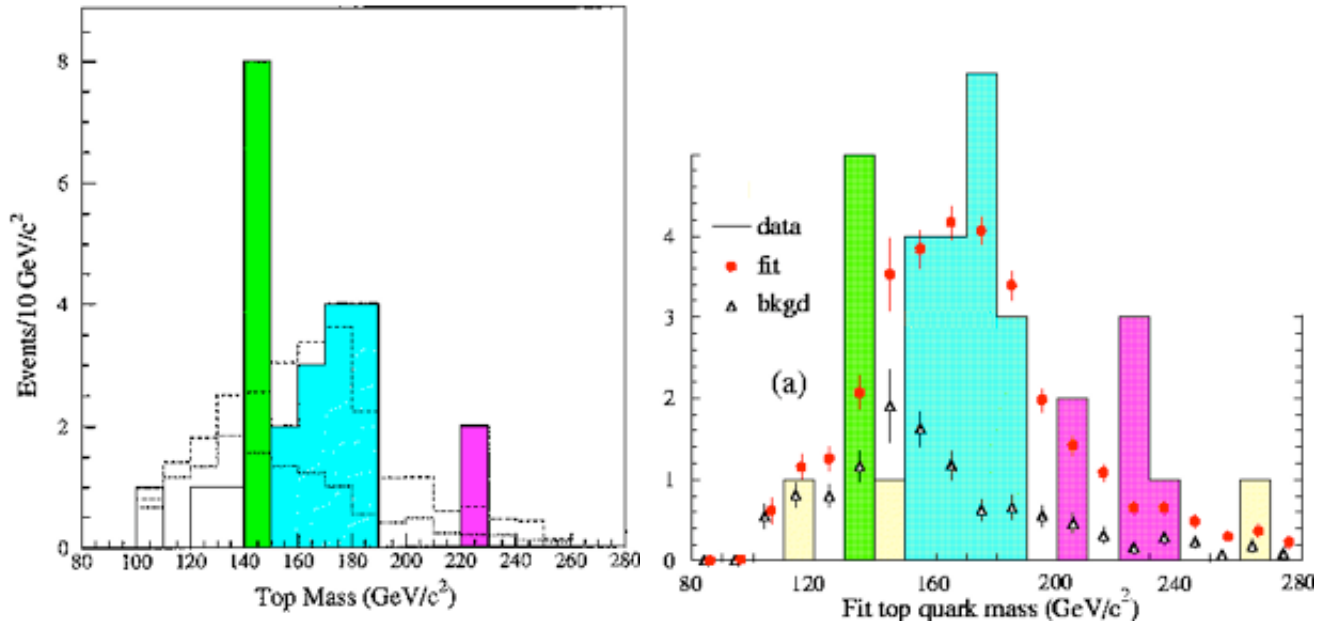
the Effective Higgs mass of 125 GeV that is observed by the LHC.

As to the 3 mass states of the Tquark:

Back in the 1990s Fermilab CDF saw (left image below) 3 peaks for the Truth Quark Mass.

but they ignored the high mass (magenta) peak and dismissed the low mass (green) peak as a "statistical fluctuation",

and insisted that the medium mass (cyan) peak was the Single Mass State of the Truth Quark.



Even when the independent Fermilab detector D0 (right image above) saw the same 3 peaks including a similar tall low mass (green) peak (very unlikely that an independent detector would produce a similar "statistical fluctuation" in the same place)

Fermilab continued to ignore the low mass (green) and high mass (magenta) peaks and to insist that the Truth Quark had only a Single Mass State, at the middle mass (cyan) peak. For the better part of two decades, up to the present, Fermilab designed experiments and analysis based on their Single Mass State model of the Truth Quark. Detailed study of their results continued to point to the Truth Quark having 3 Mass States and I have consistently pointed out that Fermilab's own experiments are in line with the 3 Mass State model.

References:

[my web site](#) - [its mirror site](#)

Historical Appendix

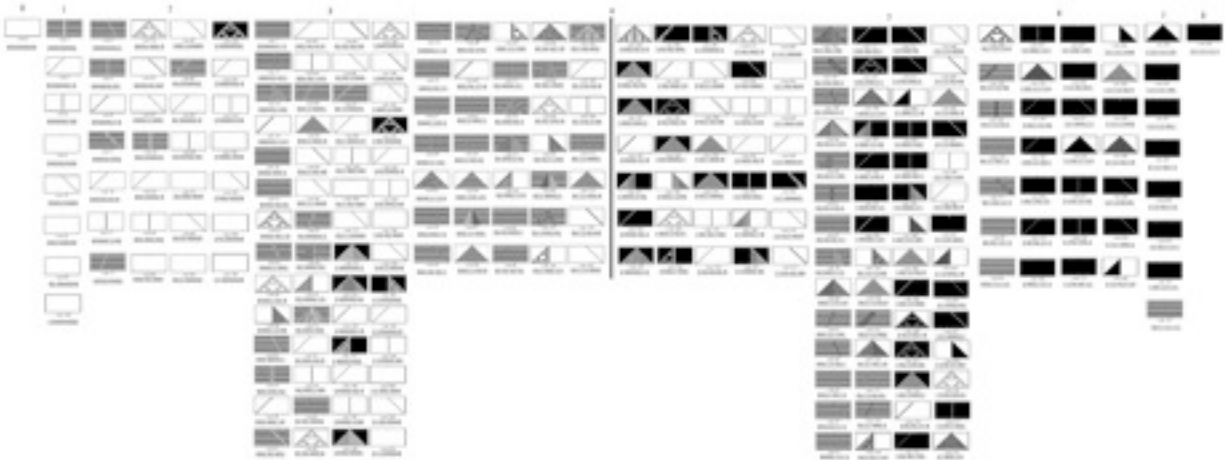
A little less than 15 billion years ago, our Universe emerged from the Void.

4 billion years ago, our Earth and Moon were orbiting our Sun.

2 billion years ago, bacteria built a nuclear fission reactor in Africa.

100,000 years ago, Humans were expanding from the African home-land to Eurasia and beyond.

12,000 years ago, Africans knew that the knowledge-patterns of 8 binary choices giving $2^8 = 256 = 16 \times 16$ possibilities could act as an Oracle. Did they realize then that those 256 possibilities corresponded to the



256 Fundamental Cellular Automata, some of which act as Universal Computers?

From Africa, the 16x16 Oracle-patterns spread, so that by the 13th century parts of them were found in:

Judaism as the 248 positive Commandments plus the 365 negative Commandments given to Moses during the 50 days from Egypt to Sinai;

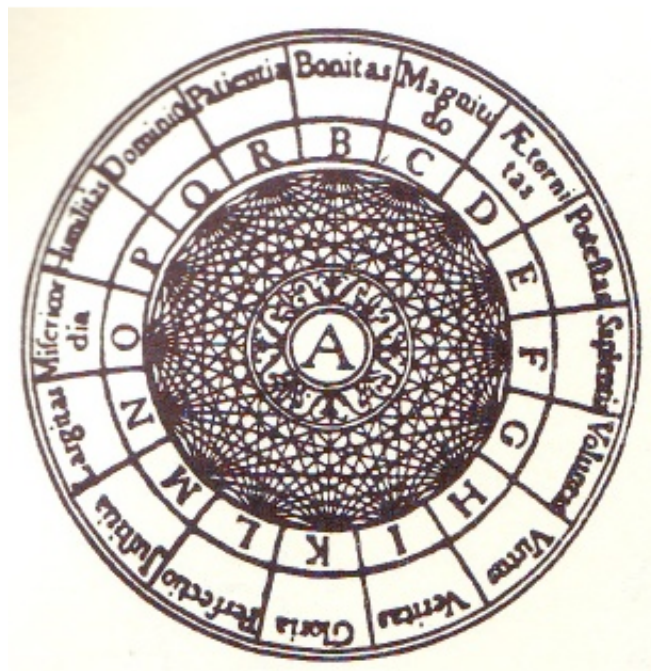
India as the 240 parts of the first sukt of the Rig Veda;

Japan as the 128 possibilities of Shinto Futomani Divination;

China as the 64 possibilities of the I Ching;

Mediterranean Africa as the 16 possibilities of the Ilm al Raml.

Near the end of the 13th century, Ramon Llull of Mallorca studied the 16 possibilities of the Ilm al Raml and realized that the 16x16 African Oracle-patterns had a Fundamental Organizational Principle that he summarized in a Wheel Diagram



with 16 vertices connected to each other by 120 lines, like the 120 bivectors of the $Cl(16)$ Clifford Algebra that correspond to the D_8 Lie Algebra that lives inside E_8 . He used such structures to show the underlying unity of all human religions. However, the establishments of the various religions refused to accept Ramon Llull's revelations, and his ideas were relegated to a few obscure publications, plus an effort to preserve some aspects of the 16x16 Oracle-patterns in the form of the 78 Tarot cards and the subset of 52 cards that remains popular into the 21st century.

Since Llull was Roman Catholic, the Islamic and Judaic bureaucracies could (and did) ignore his work as that of an irrelevant outsider. As to the Christians, in the 14th century, Dominican Inquisitors had Ramon Llull condemned as a heretic, his works were suppressed, and his ideas were relegated to a few obscure publications, plus an effort to preserve some aspects of the 16x16 Oracle-patterns in the form of the 78 Tarot cards and the subset of 52 cards that remains popular into the 21st century.

In the 17th century the Roman Inquisition burned Giordano Bruno at the stake and sentenced Galileo to house arrest for the rest of his life, all for the sake of the Roman Inquisition's enforcement of conformity to its Consensus.

Rediscovery of the full significance of Ramon Llull's Oracle-patterns did not happen until:

after 20th century science experiments progressed beyond Gravity, Electromagnetism, and early Quantum Mechanics, and

after Lise Meitner discovered the Uranium Fission Chain Reaction Process that led to the Fission Bombs that ended the Japanese part of World War II.

The Japanese defeat liberated Saul-Paul Sirag, a child of Dutch-American Baptist missionaries, from a Japanese concentration camp in Java.

During the 1950s and 1960s, David Finkelstein described Black Holes and worked on Quaternionic Physics, Hua Luogeng 华罗庚 returned to China where he wrote his book "Harmonic Analysis of Functions of Several Complex Variables in the Classical Domains", Jack Sarfatti studied physics (BA from Cornell and PhD from U. C. Riverside), and I learned about Lie Groups and Lie Algebras (AB in math from Princeton).

During the 1970s, Saul-Paul Sirag learned math and physics working with Arthur Young and the physics community developed the Standard Model showing how everything other than Gravity could be described, consistent with experimental results, by 3 forces of a Standard Model:

Electromagnetism, with the symmetry of a circle, denoted by $S1 = U(1)$

Weak Force with Higgs, with the symmetry of a 3-dimensional sphere, denoted by $S3 = SU(2)$

Color Force, with symmetry related to a Star of David, denoted by $SU(3)$

From the 1980s on, I learned about Clifford Algebras from David Finkelstein at Georgia Tech; about Weyl Groups and Root Vectors from the work of Saul-Paul Sirag; about Quantum Consciousness, Space-Time and Higgs as Condensates, and Bohmian Back-Reaction from the work of Jack Sarfatti; and about Compton Radius Vortices from the work of B. G. Sidharth.

In contrast to the advances in experimental results and construction of the Standard Model of physics, the social structure of the Physics Scientific Community evolved during the 20th century into a rigid Physics Consensus Community much like the Inquisitorial Consensus Community of a few hundred years ago.

For example, in the USA physics community around the middle of the 20th century, J. Robert Oppenheimer enforced his dislike of the ideas of David Bohm by declaring, as head of the Princeton Institute for Advanced Study:

“... if we cannot disprove Bohm, then we must agree to ignore him ...”

As the 20th century ended and the 21st century began, the Physics Consensus Community continued to enforce conformity to Consensus so strongly that Stanford physicist Burton Richter said:

“... scientists are imprisoned by golden bars of consensus ...”

The rigidly enforced Physics Consensus Community was so void of independent thought that the 20th century ended without anyone seeing how Ramon Llull's Oracle-patterns explained both Gravity and the Standard Model in a unified way,

but

in January 2008 the cover of the magazine of Science & Vie declared:

“Theorie du tout Enfin!”



Un physicien ... chercheur hors norme ... aurait trouve la piece manquante”

The missing piece was a 248-dimensional Lie Algebra known as E8.

The beyond-the-norm physics researcher was a California-Hawaii Surfer Dude, Garrett Lisi, who realized that the structure of E8 could unify Gravity and the Standard Model in a way that satisfied Einstein's Criterion for a structure

“... based ... upon a faith in the simplicity ... of nature: there are no arbitrary constants ... only rationally completely determined constants ... whose ... value could ... not ... be changed without destroying the theory ...”.

Motivated by Garrett Lisi's E8 work, I constructed from E8 a Lagrangian that realistically describes physics in a Local Region. Since E8 lives inside the Clifford Algebra $Cl(16) = Cl(8) \times Cl(8)$, if you let a copy of $Cl(16)$ represent a Local Lagrangian Region, you can construct a Global Structure by taking the tensor products of the copies of $Cl(16)$. Due to Real Clifford Algebra 8-periodicity, any Real Clifford Algebra, no matter how large, can be embedded in a tensor product of factors of $Cl(8)$, and therefore of $Cl(8) \times Cl(8) = Cl(16)$.

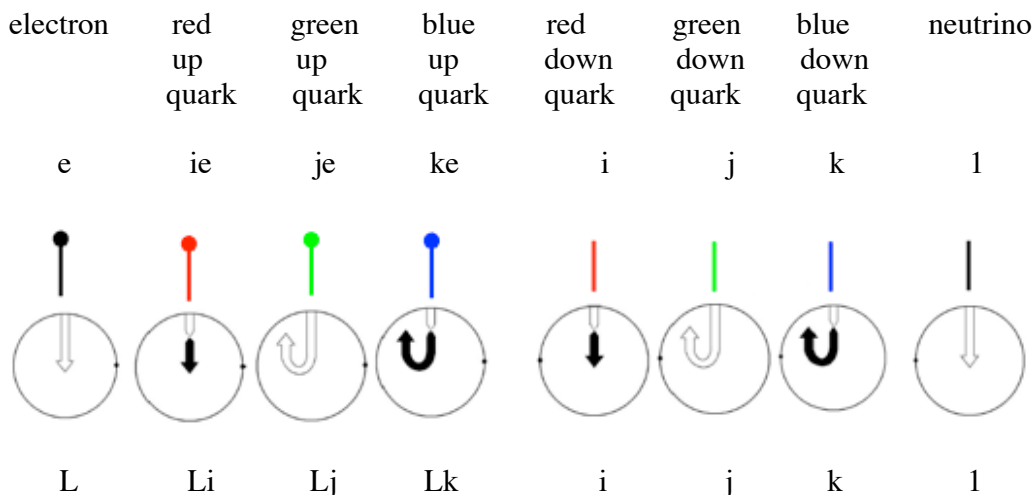
Just as the completion of the union of all tensor products of 2×2 complex Clifford algebra matrices produces the usual Hyperfinite III von Neumann factor that describes creation and annihilation operators on fermionic Fock space over $C^{(2n)}$ (see John Baez's Week 175), we can take the completion of the union of all tensor products of $Cl(16) = Cl(8) \times Cl(8)$ to produce a generalized Hyperfinite III von Neumann factor that gives a natural Algebraic Quantum Field Theory structure for E8 Physics, and corresponds to the El Aleph of Jorge Luis Borges.

In some sense, the 240 Root Vectors of E8 are a seed from which El Aleph grows.

3 Generation Fermion Combinatorics

Frank Dodd (Tony) Smith, Jr. - 2011

First Generation (8)



The geometric representation of Octonions is from arXiv 1010.2979 by Jonathan Hackett and Louis H. Kauffman,

who say: "... we review the topological model for the quaternions based upon the Dirac string trick. We then extend this model, to create a model for the octonions - the non-associative generalization of the quaternions. ...

To construct this model of the quaternions using belt and buckle, we consider a belt that has been fixed to a wall with the non-buckle end. We consider rotations of the belt buckle about the three standard cartesian axes which we correspond to the three quaternionic roots of 1: $i, j,$ and k We ... get that carrying out any operation twice yields a belt that is twisted around by a full 2π ... if we perform 1 twice - giving us a 4π rotation - we can remove all of the twisting without rotating the belt buckle. ... We note that the operations are performed from left to right along a string of elements. ...

We construct our model for the octonions in a similar manner to the model for the quaternions. Rather than using a belt,

we will instead use a two toned ribbon (black on the back, and white on the front) with an arrowhead attached to one end (much as our belt had a buckle). The other end is then attached to the interior of a ring (much as our belt was attached to a wall). Lastly on the side of the ring we affix a flag that allows us to keep track of the orientation of the ring. ...

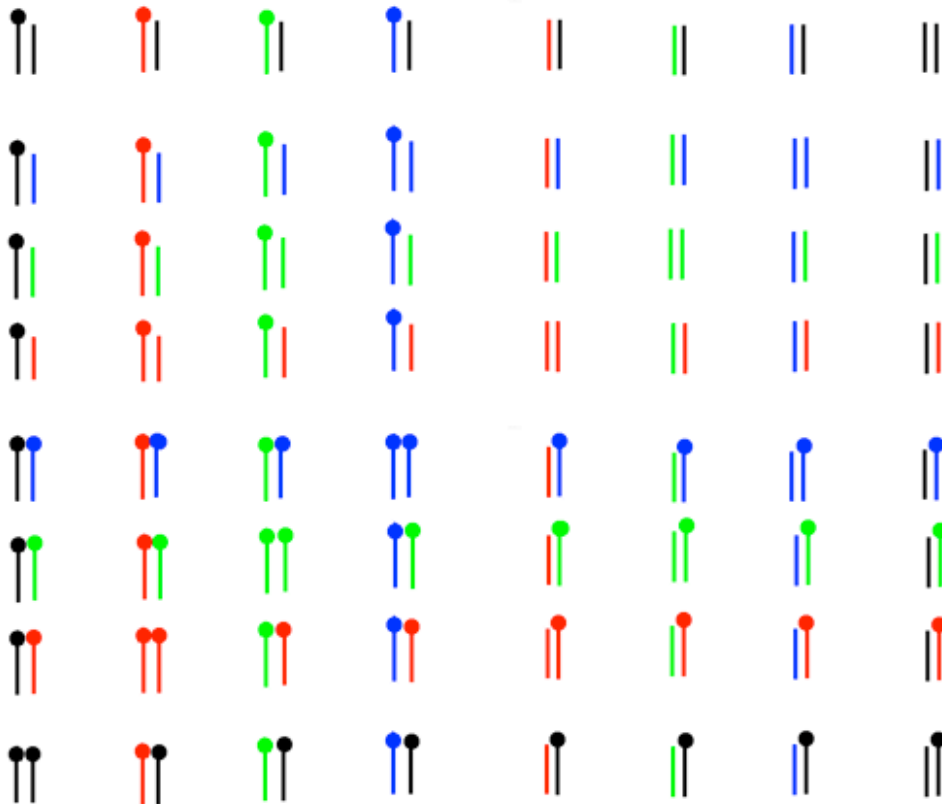
The operation L is defined by switching the side of the hoop that the flag is attached to, and performing a full 2π rotation of the hoop (or - alternately - the arrowhead) if the arrowhead is pointing up or if the state is flag-right, but not for both. ...

The original belt model of the quaternions is strongly related to the quaternions being a representation of $SU(2)$, and $SU(2)$ being a double cover of the rotation group $SO(3)$.

The fact that this model of the octonions is an extension of the quaternionic model leads to the question of whether an analogue to the relationship with $SU(2)$ and $SO(3)$ exists. ...".

Perhaps relevant to that question is the fact that $SU(4)$ is the double cover of $SO(6)$
and the relationship to the Conformal Group $SU(2,2) = Spin(4,2)$.

Second Generation ($8 \times 8 = 64$)



Mu Neutrino (1)

Rule: a Pair belongs to the Mu Neutrino if:

All elements are Colorless (black)

and all elements are Associative (that is, is 1 which is the only Colorless Associative element) .

||

Muon (3)

Rule: a Pair belongs to the Muon if:

All elements are Colorless (black)

and at least one element is NonAssociative (that is, is e which is the only Colorless NonAssociative element).



Blue Strange Quark (3)

Rule: a Pair belongs to the Blue Strange Quark if:

There is at least one Blue element and the other element is Blue or Colorless (black)
and all elements are Associative (that is, is either 1 or i or j or k).

||

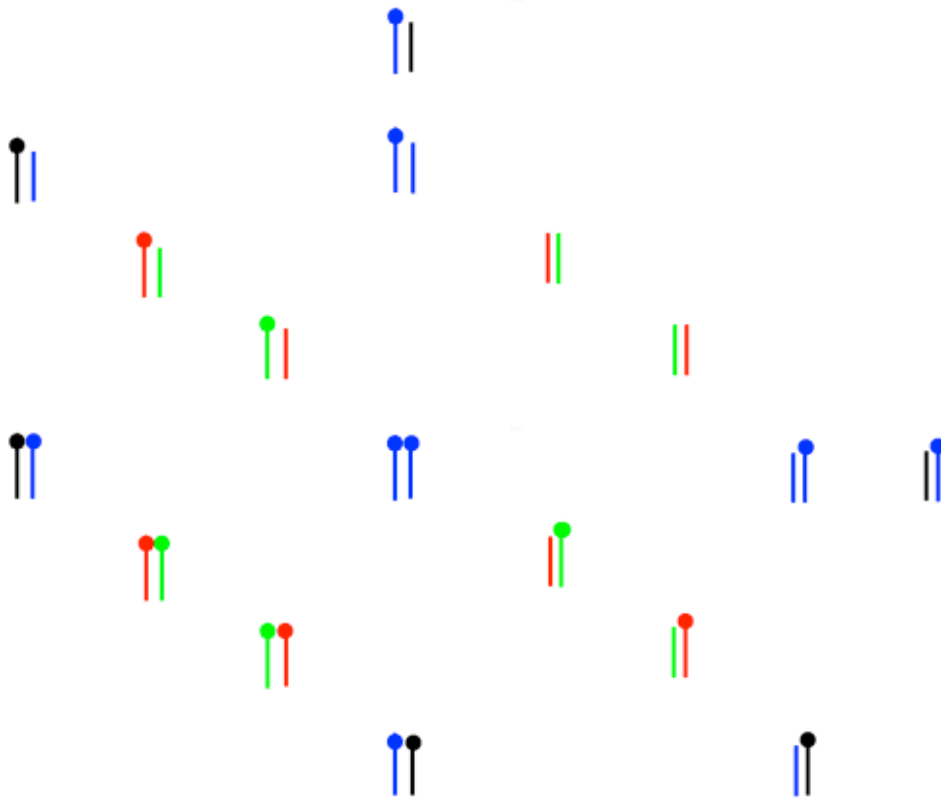
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||

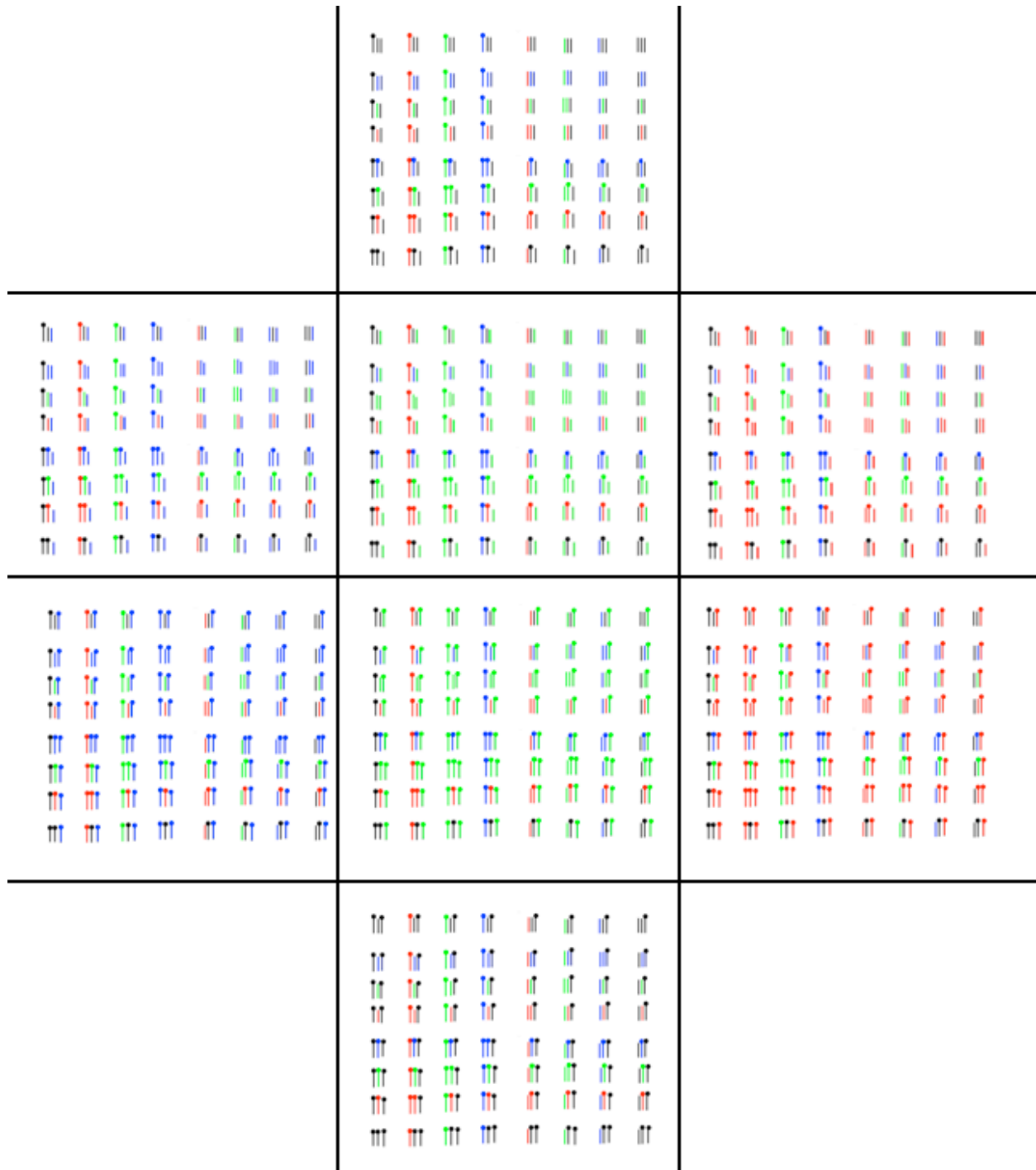
Blue Charm Quark (17)

Rules: a Pair belongs to the Blue Charm Quark if:

- 1 - There is at least one Blue element and the other element is Blue or Colorless (black) and at least one element is NonAssociative (that is, is either e or ie or je or ke)
- 2 - There is one Red element and one Green element (Red x Green = Blue).



Third Generation (8x8x8 = 512)

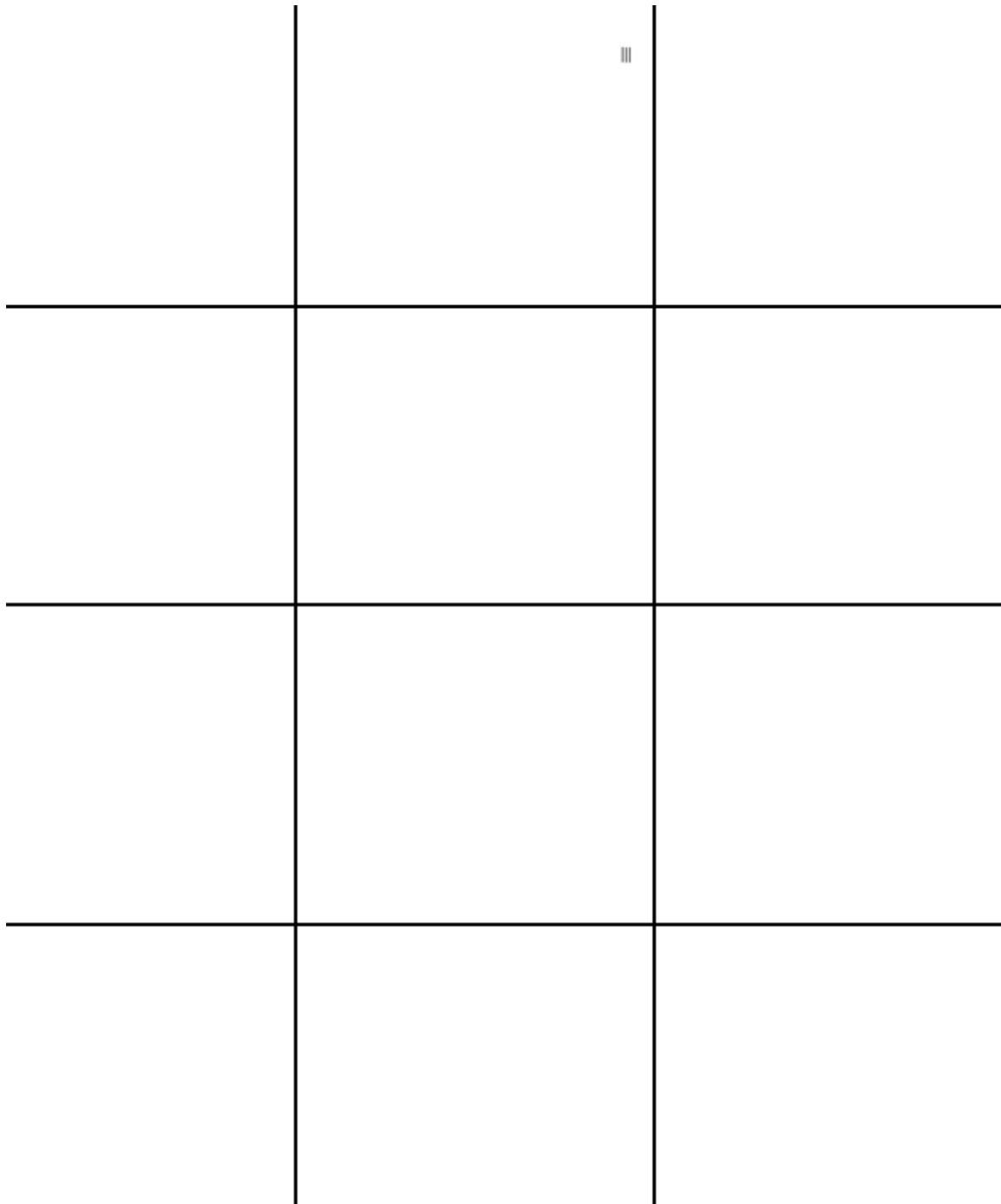


Tau Neutrino (1)

Rule: a Triple belongs to the Tau Neutrino if:

All elements are Colorless (black)

and all elements are Associative (that is, is 1 which is the only Colorless Associative element) .



Tauon (7)

Rule: a Triple belongs to the Tauon if:

All elements are Colorless (black)

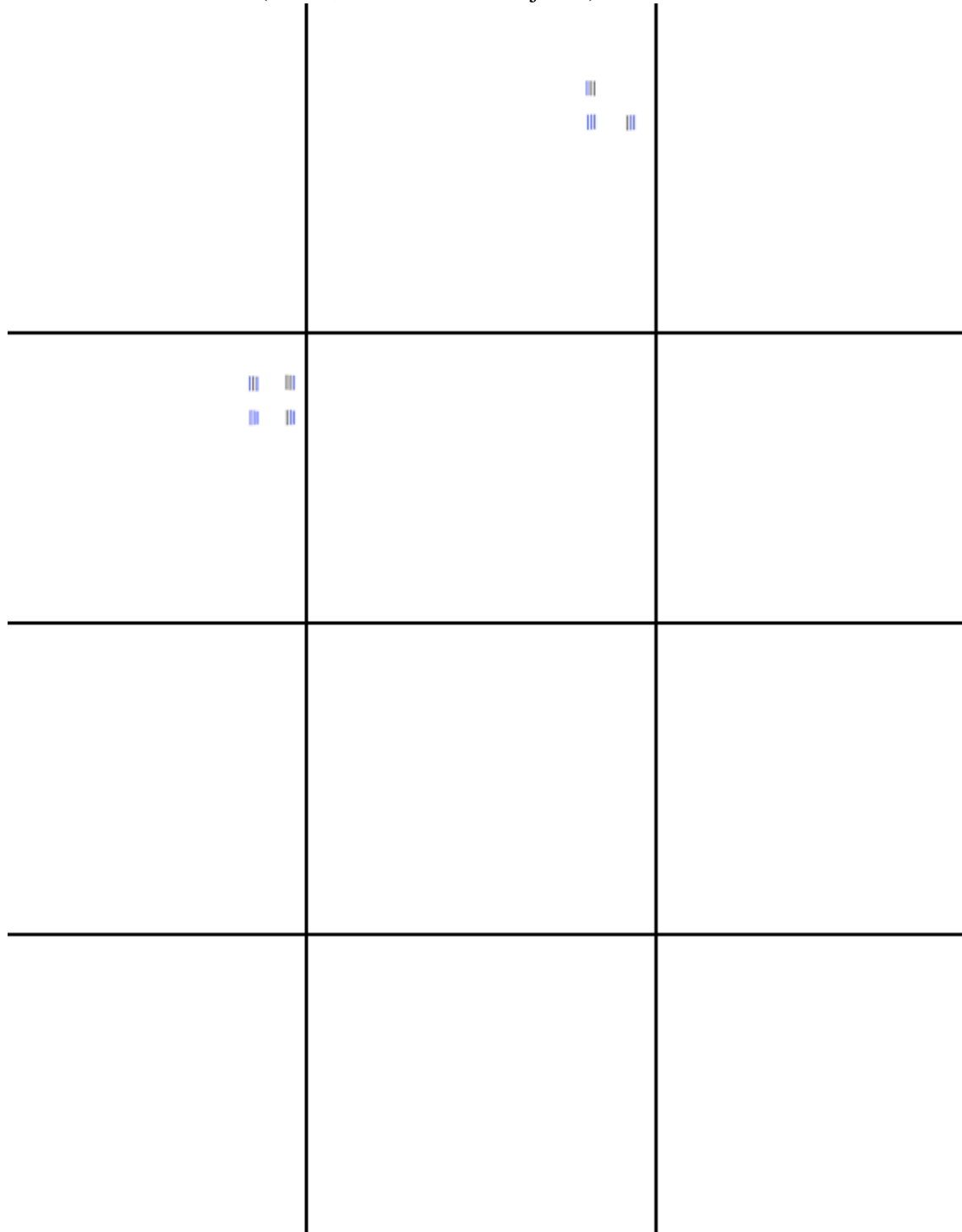
and at least one element is NonAssociative (that is, is e which is the only Colorless NonAssociative element).

	τ_{ii} τ_{ii}	τ_{ii}
	τ_{ii} τ_{ii}	τ_{ii} τ_{ii}

Blue Beauty Quark (7)

Rule: a Triple belongs to the Blue Beauty Quark if:

There is at least one Blue element and all other elements are Blue or Colorless (black) and all elements are Associative (that is, is either 1 or i or j or k).

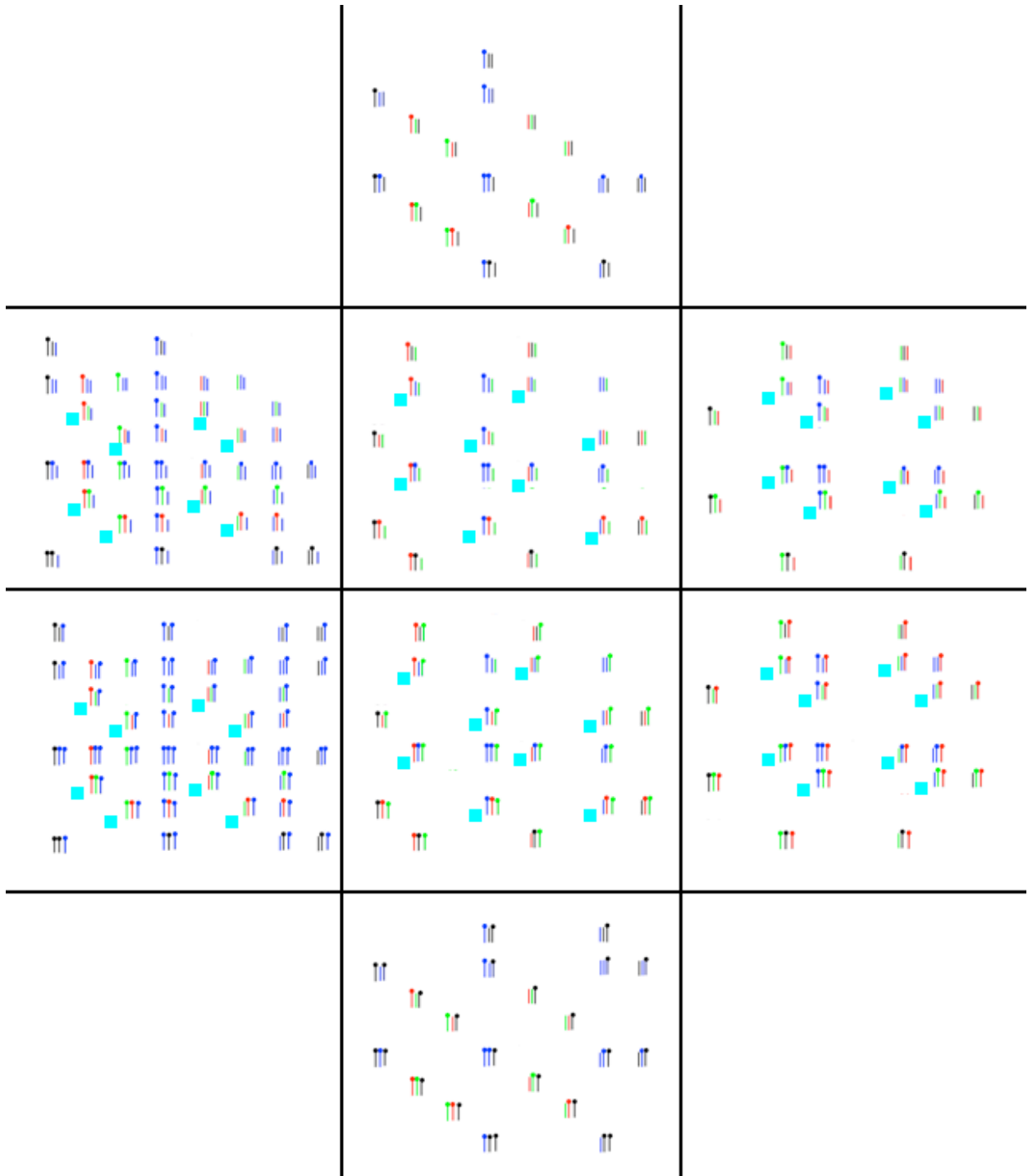


Blue Truth Quark (161)

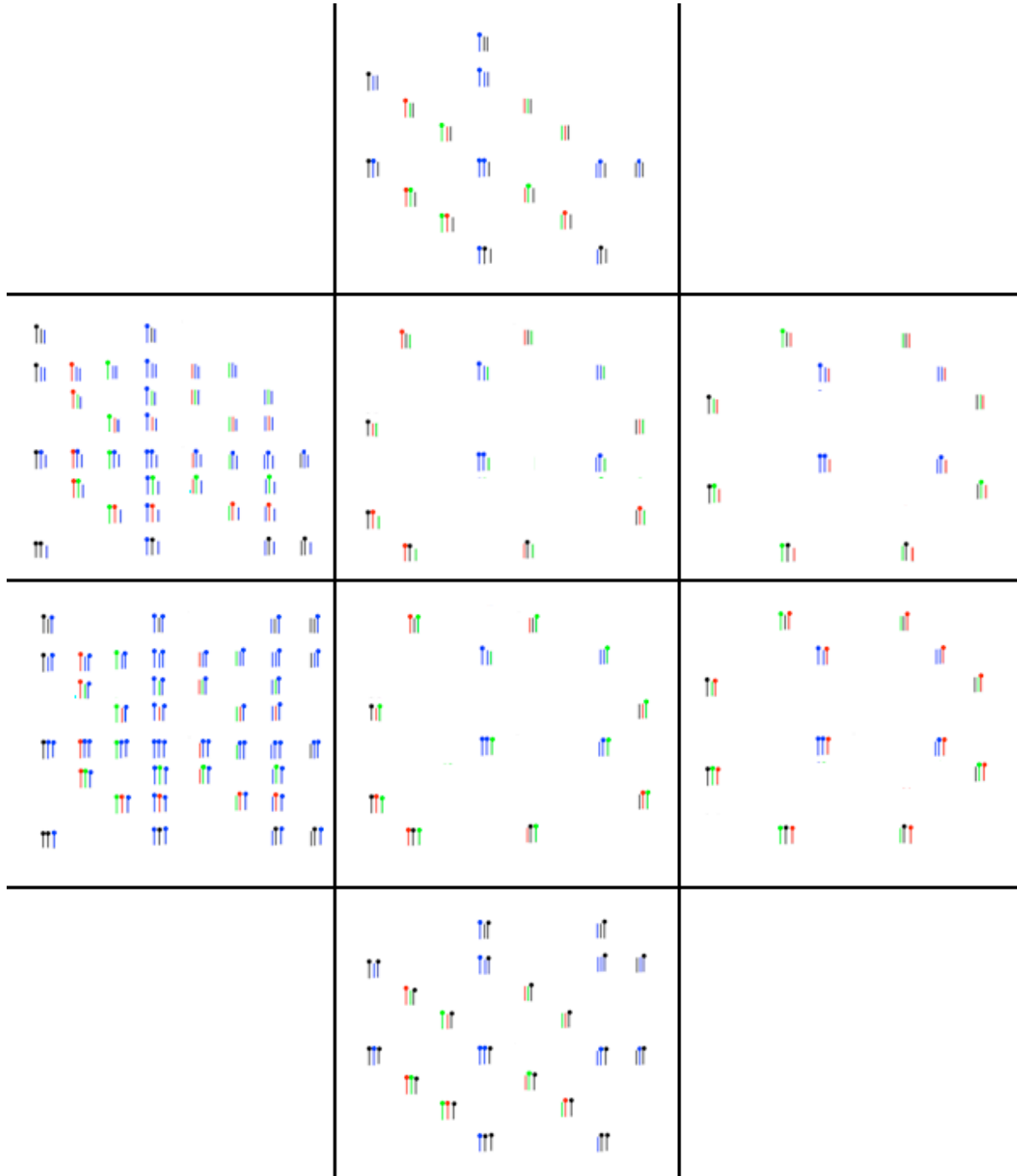
Rules: a Triple belongs to the Blue Truth Quark if:

- 1 - There is at least one Blue element and all other elements are Blue or Colorless (black) and at least one element is NonAssociative (that is, is either e or ie or je or ke)
- 2 - There is one Red element and one Green element and the other element is Colorless (Red x Green = Blue)
- 3 - The Triple has one element each that is Red, Green, or Blue, in which case the color of the Third element (for Third Generation) is determinative and must be Blue.

Candidates for Blue Truth Quark before application of Rule 3 (193)
 with the 48 Rule 3 Candidates marked by cyan square:



Blue Truth Quark (161)



Kobayashi-Maskawa Mixing Above and Below ElectroWeak Symmetry Breaking

Frank Dodd (Tony) Smith, Jr. - November 2011

Below the energy level of ElectroWeak Symmetry Breaking the Higgs mechanism gives mass to particles.

According to a Review on the Kobayashi-Maskawa mixing matrix by Ceccucci, Ligeti, and Sakai in the 2010 Review of Particle Physics (note that I have changed their terminology of CKM matrix to the KM terminology that I prefer because I feel that it was Kobayashi and Maskawa, not Cabibbo, who saw that 3x3 was the proper matrix structure):

"... the charged-current W_{\pm} interactions couple to the ... quarks with couplings given by ...

$$\begin{matrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{matrix}$$

This Kobayashi-Maskawa (KM) matrix is a 3×3 unitary matrix.

It can be parameterized by three mixing angles and the CP-violating KM phase ...

The most commonly used unitarity triangle arises from

$V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0$, by dividing each side by the best-known one, $V_{cd} V_{cb}^*$

... $-\rho + i\eta = -(V_{ud} V_{ub}^*)/(V_{cd} V_{cb}^*)$ is phase-convention-independent ...

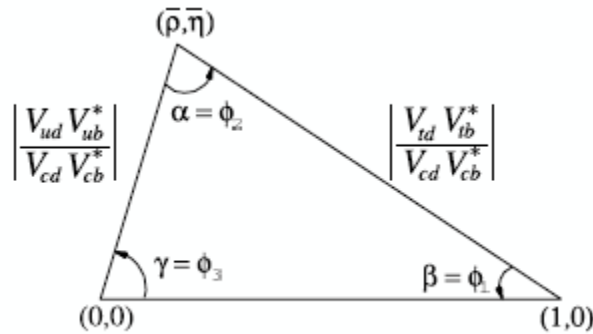


Figure 11.1: Sketch of the unitarity triangle.

... $\sin 2\beta = 0.673 \pm 0.023$... $\alpha = 89.0 +4.4 -4.2$ degrees ... $\gamma = 73 +22 -25$ degrees ...

The sum of the three angles of the unitarity triangle, $\alpha + \beta + \gamma = (183 +22 -25)$ degrees, is ... consistent with the SM expectation. ...

The area... of ...[the]... triangle...[is]... half of the Jarlskog invariant, J , which is a phase-convention-independent measure of CP violation, defined by $\text{Im } V_{ij} V_{kl} V_{il}^* V_{kj}^* = J \text{ SUM}(m,n) \epsilon_{ikm} \epsilon_{jln}$

...

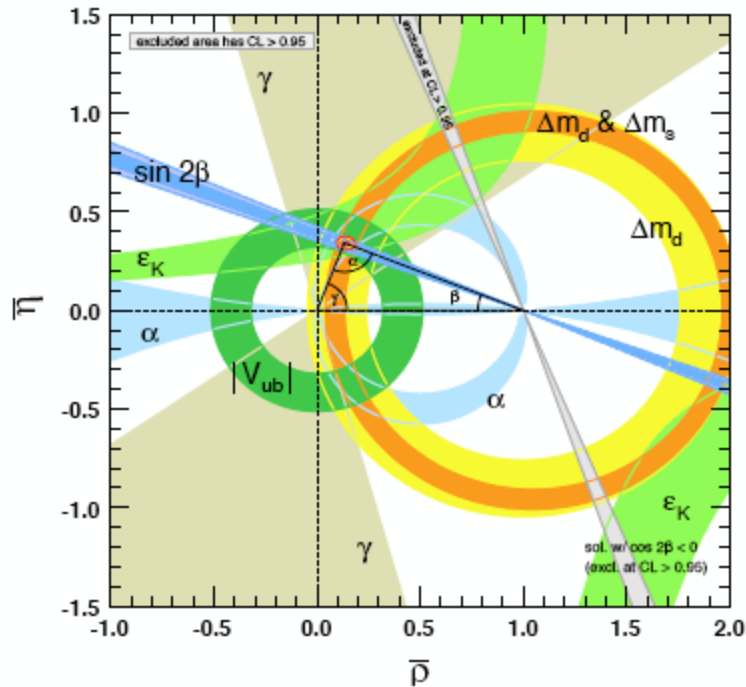


Figure 11.2: Constraints on the $\bar{\rho}, \eta$ plane. The shaded areas have 95% CL.

The fit results for the magnitudes of all nine KM elements are ...

0.97428 ± 0.00015	0.2253 ± 0.0007	$0.00347 +0.00016 -0.00012$
0.2252 ± 0.0007	$0.97345 +0.00015 -0.00016$	$0.0410 +0.0011 -0.0007$
$0.00862 +0.00026 -0.00020$	$0.0403 +0.0011-0.0007$	$0.999152 +0.000030-0.000045$

and the Jarlskog invariant is $J = (2.91 +0.19-0.11) \times 10^{-5}$".

Above the energy level of ElectroWeak Symmetry Breaking particles are massless.

Kea (Marni Sheppard) proposed that in the Massless Realm the mixing matrix might be democratic.

In Z. Phys. C - Particles and Fields 45, 39-41 (1989) Koide said: "... the mass matrix ... MD ... of the type ... $1/3 \times m \times$

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

... has name... "democratic" family mixing ... the ... democratic ... mass matrix can be diagonalized

by the transformation matrix A ...

$$\begin{matrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 1/\sqrt{6} & 1/\sqrt{6} & -2/\sqrt{6} \\ 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} \end{matrix}$$

as $A M D A^t =$

$$\begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & m \end{matrix}$$

...".

Up in the Massless Realm you might just say that there is no mass matrix, just a democratic mixing matrix of the form $1/3 \times$

$$\begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

with no complex stuff and no CP violation in the Massless Realm.

When go down to our Massive Realm by ElectroWeak Symmetry Breaking

then you might as a first approximation use $m = 1$

so that all the mass first goes to the third generation as

$$\begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{matrix}$$

which is physically like the Higgs being a T-Tbar quark condensate.

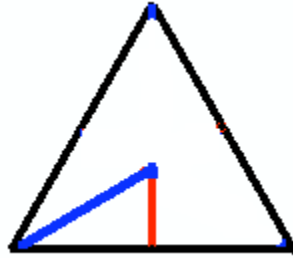
Consider a 3-dim Euclidean space of generations:

The case of mass only going to one generation can be represented as a line or 1-dimensional simplex

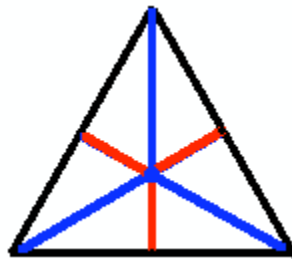


in which the blue mass-line covers the entire black simplex line.

If mass only goes to one other generation that can be represented by a red line extending to a second dimension forming a small blue-red-black triangle



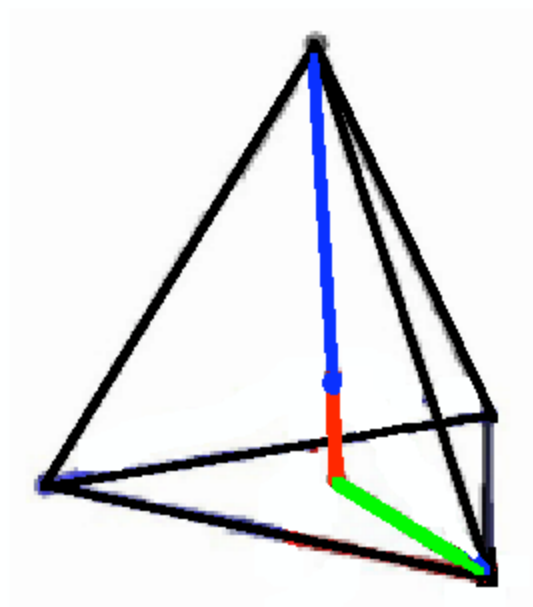
that can be extended by reflection to form six small triangles making up a large triangle.



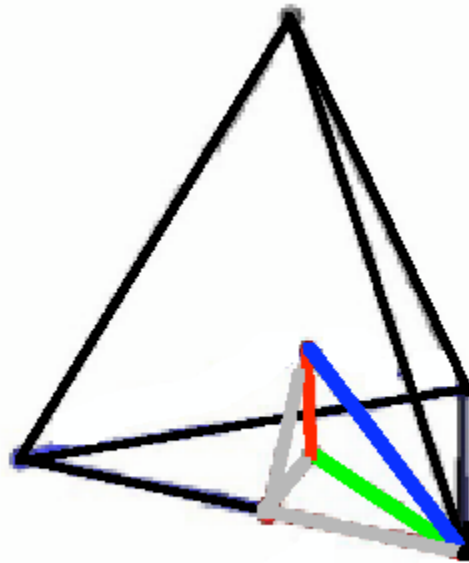
Each of the six component triangles has 30-60-90 angle structure:



If mass goes on further to all three generations that can be represented by a green line extending to a third dimension



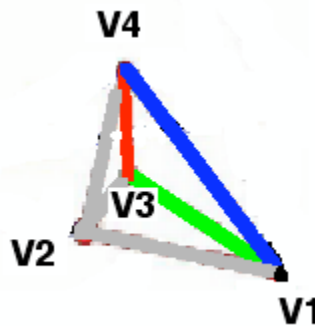
If you move the blue line from the top vertex to join the green vertex



you get a small blue-red-green-gray-gray-gray tetrahedron that can be extended by reflection to form 24 small tetrahedra making up a large tetrahedron.

Reflection among the 24 small tetrahedra corresponds to the $12+12 = 24$ elements of the Binary Tetrahedral Group.

The basic blue-red-green triangle of the basic small tetrahedron



has the angle structure of the K-M Unitarity Triangle.

Using data from R. W. Gray's "Encyclopedia Polyhedra: A Quantum Module" with lengths

$V1.V2 = (1/2) EL \equiv$ Half of the regular Tetrahedron's edge length.

$V1.V3 = (1 / \sqrt{3}) EL \approx 0.577\ 350\ 269\ EL$

$V1.V4 = 3 / (2 \sqrt{6}) EL \approx 0.612\ 372\ 436\ EL$

$V2.V3 = 1 / (2 \sqrt{3}) EL \approx 0.288\ 675\ 135\ EL$

$V2.V4 = 1 / (2 \sqrt{2}) EL \approx 0.353\ 553\ 391\ EL$

$$\mathbf{V3.V4 = 1 / (2 \sqrt{6}) EL \cong 0.204 124 145 EL}$$

the Unitarity Triangle angles are:

$$\mathbf{\beta = V3.V1.V4 = \arccos(2 \sqrt{2} / 3) \cong 19.471 220 634 \text{ degrees so } \sin 2\beta = 0.6285}$$

$$\mathbf{\alpha = V1.V3.V4 = 90 \text{ degrees}}$$

$$\mathbf{\gamma = V1.V4.V3 = \arcsin(2 \sqrt{2} / 3) \cong 70.528 779 366 \text{ degrees}}$$

which is substantially consistent with the 2010 Review of Particle Properties

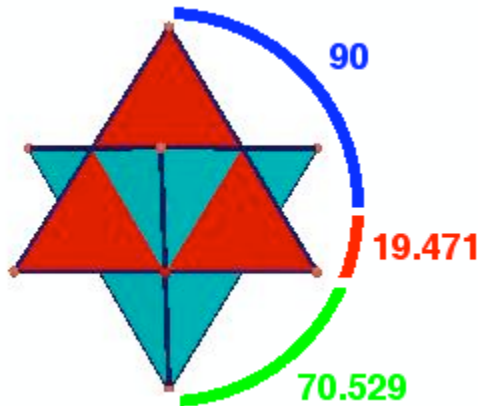
$$\sin 2\beta = 0.673 \pm 0.023 \text{ so } \beta = 21.1495 \text{ degrees}$$

$$\alpha = 89.0 +4.4 -4.2 \text{ degrees}$$

$$\gamma = 73 +22 -25 \text{ degrees}$$

and so also consistent with the Standard Model expectation.

The constructed Unitarity Triangle angles can be seen on the Stella Octangula configuration of two dual tetrahedra (image from gauss.math.nthu.edu.tw):



In my E8 Physics model the Kobayashi-Maskawa parameters are determined in terms of the sum of the masses of the 30 first-generation fermion particles and antiparticles, denoted by

$$\mathbf{Smf1 = 7.508 \text{ GeV,}}$$

and the similar sums for second-generation and third-generation fermions, denoted

$$\mathbf{\text{by } Smf2 = 32.94504 \text{ GeV and } Smf3 = 1,629.2675 \text{ GeV.}}$$

The reason for using sums of all fermion masses (rather than sums of quark masses only) is that all fermions are in the same spinor representation of Spin(8), and the Spin(8) representations are considered to be fundamental.

The following formulas use the above masses to calculate Kobayashi-Maskawa parameters:

$$\text{phase angle } d_{13} = \gamma = 70.529 \text{ degrees}$$

$$\sin(\theta_{12}) = s_{12} = [m_e + 3m_d + 3\mu] / \sqrt{[m_e^2 + 3m_d^2 + 3\mu^2] + [m_\mu^2 + 3m_s^2 + 3m_c^2]} = 0.222198$$

$$\sin(\theta_{13}) = s_{13} = [m_e + 3m_d + 3\mu] / \sqrt{[m_e^2 + 3m_d^2 + 3\mu^2] + [m_\tau^2 + 3m_b^2 + 3m_t^2]} = 0.004608$$

$$\sin(\theta_{23}) = [m_\mu + 3m_s + 3m_c] / \sqrt{[m_\tau^2 + 3m_b^2 + 3m_t^2] + [m_\mu^2 + 3m_s^2 + 3m_c^2]}$$

$$\sin(\theta_{23}) = s_{23} = \sin(\theta_{23}) \sqrt{\text{Sigmaf2} / \text{Sigmaf1}} = 0.04234886$$

The factor $\sqrt{\text{Sigmaf2} / \text{Sigmaf1}}$ appears in s_{23} because an s_{23} transition is to the second generation and not all the way to the first generation, so that the end product of an s_{23} transition has a greater available energy than s_{12} or s_{13} transitions by a factor of $\text{Sigmaf2} / \text{Sigmaf1}$.

Since the width of a transition is proportional to the square of the modulus of the relevant KM entry and the width of an s_{23} transition has greater available energy than the s_{12} or s_{13} transitions by a factor of $\text{Sigmaf2} / \text{Sigmaf1}$ the effective magnitude of the s_{23} terms in the KM entries is increased by the factor $\sqrt{\text{Sigmaf2} / \text{Sigmaf1}}$.

The Chau-Keung parameterization is used, as it allows the K-M matrix to be represented as the product of the following three 3x3 matrices:

$$\begin{array}{ccc} 1 & 0 & 0 \\ 0 & \cos(\theta_{23}) & \sin(\theta_{23}) \\ 0 & -\sin(\theta_{23}) & \cos(\theta_{23}) \end{array}$$

$$\begin{array}{ccc} \cos(\theta_{13}) & 0 & \sin(\theta_{13})\exp(-i d_{13}) \\ 0 & 1 & 0 \\ -\sin(\theta_{13})\exp(i d_{13}) & 0 & \cos(\theta_{13}) \end{array}$$

$$\begin{array}{ccc} \cos(\theta_{12}) & \sin(\theta_{12}) & 0 \\ -\sin(\theta_{12}) & \cos(\theta_{12}) & 0 \\ 0 & 0 & 1 \end{array}$$

The resulting Kobayashi-Maskawa parameters for W^+ and W^- charged weak boson processes, are:

	d	s	b
u	0.975 0.222	0.00249	-0.00388i
c	-0.222 -0.000161i	0.974 -0.0000365i	0.0423
t	0.00698 -0.00378i	-0.0418 -0.00086i	0.999

The matrix is labelled by either (u c t) input and (d s b) output, or, as above, (d s b) input and (u c t) output.

For Z^0 neutral weak boson processes, which are suppressed by the GIM mechanism of cancellation of virtual subprocesses, the matrix is labelled by either (u c t) input and (u'c't') output, or, as below, (d s b) input and (d's'b') output:

	d	s	b
d'	0.975 0.222	0.00249	-0.00388i
s'	-0.222 -0.000161i	0.974 -0.0000365i	0.0423
b'	0.00698 -0.00378i	-0.0418 -0.00086i	0.999

Since neutrinos of all three generations are massless at tree level, the lepton sector has no tree-level K-M mixing.

Cl(Cl(4)) = Cl(16) containing E8

Frank Dodd (Tony) Smith, Jr. - 2011

Cl(4) :

1 grade-0: s

4 grade-1: x y z t - M4 physical spacetime

6 grade-2: a b c d e f - M4L Lorentz transformations

4 grade-3: x y z t - CP2 internal symmetry space

1 grade-4: s

Cl(Cl(4)) = Cl(16) for which Physical Interpretations are based on Triality whereby

x y z t x y z t corresponds to

8-dim M4xCP2 Kaluza-Klein SpaceTime

8 elementary Fermion Particles

8 elementary Fermion AntiParticles.

The 8-dim M4xCP2 Kaluza-Klein interpretation is used for Cl(16) grade-1 in which

x y z t x y z t occur as single elements

The 8 Fermion Particle - 8 Fermion AntiParticle

interpretation is used for the gauge forces of grade-2 in which x y z t x y z t occur as antisymmetric pairs.

1 grade-0:

s

16 grade-1:

s

x y z t - M4 physical spacetime

a b c d e f

x y z t - CP2 internal symmetry space

s

Further Physical Interpretations:

Even-Odd Clifford Dual to M4 physical spacetime:

s a b c

Even-Odd Clifford Dual to CP2 internal symmetry space:

d e f s

120 grade-2:

sx sy sz st

sa sb sc sd se sf

sx sy sz st ss

xy xz xt

xa xb xc xd xe xf

xx xy xz xt xs

yz yt

ya yb yc yx ye yf

yx yy yz yt ys

zt

za zb zc zd ze zf

zx zy zz zt zs

ta tb tc td te tf

tx ty tz tt ts

ab ac ad ae af

ax ay az at as

bc bd be bf

bx by bz bt bs

cd ce cf

cx cy cz ct cs

de df

dx dy dz dt ds

ef

ex ey ez et es

fx fy fz ft fs

xy xz xt xs

yz yt ys

zt zs

ts

Physical Interpretations of the 120 grade-2 elements:

28-dim D4 Spin(8) for Standard Model Gauge Groups:

xy xz xt
yz yt
zt

xx xy xz xt	|	
yx yy yz yt	|	- This is U(4) that contains SU(3).
zx zy zz zt	|	U(2) = SU(2)xU(1) arises from
tx ty tz tt	|	CP2 = SU(3)/U(2) by Batakis.

xy xz xt
yz yt
zt

28-dim D4 Spin(8) for Conformal Gravity:

sa sb sc sd se sf

ss

ab ac ad ae af	|	
bc bd be bf	|	- This is Spin(2,4) Conformal Group
cd ce cf	|	that gives
de df	|	Gravity by MacDowell-Mansouri.
ef	|	

as
bs
cs
ds
es
fs

64-dim to describe 8-dim Kaluza-Klein SpaceTime:

Consider 8-dim K-K as Octonion Spacetime

with Octonion basis $\{1, i, j, k, E, I, J, K\}$.

For each of the 8 $x y z t x y z t$ Position dimensions

there are 8 Momentum dimensions represented by

$s a b c s d e f$ and basis elements $\{1, i, j, k, E, I, J, K\}$.

The $a b c$ correspond to an $SU(2)$ and so to $\{i, j, k\}$.

The $d e f$ correspond to another $SU(2)$ and to $\{I, J, K\}$.

8 s-terms for Real Part of Octonion SpaceTime:

$s_x s_y s_z s_t$

$s_x s_y s_z s_t$

8 s-terms for E-Imaginary Part of Octonion SpaceTime:

x_s

y_s

z_s

t_s

x_s

y_s

z_s

t_s

24 M4 $ijkIJK$ components of Octonion SpaceTime:

$x_a x_b x_c x_d x_e x_f$

$y_a y_b y_c y_x y_e y_f$

$z_a z_b z_c z_d z_e z_f$

$t_a t_b t_c t_d t_e t_f$

24 CP2 $ijkIJK$ components of Octonion SpaceTime:

$a_x a_y a_z a_t$

$b_x b_y b_z b_t$

$c_x c_y c_z c_t$

$d_x d_y d_z d_t$

$e_x e_y e_z e_t$

$f_x f_y f_z f_t$

E8 is constructed from Cl(16) using grade-2 and half-Spinors so consider Spinors of Real Clifford Algebras:

$M_{16}(\mathbb{R})$	$M_{16}(\mathbb{C})$	$M_{16}(\mathbb{H})$	$M_{16}(\mathbb{H}) \oplus M_{16}(\mathbb{H})$	$M_{32}(\mathbb{H})$	$M_{64}(\mathbb{C})$	$M_{128}(\mathbb{R})$	$M_{128}(\mathbb{R}) \oplus M_{128}(\mathbb{R})$	$M_{256}(\mathbb{R})$
$M_8(\mathbb{C})$	$M_8(\mathbb{H})$	$M_8(\mathbb{H}) \oplus M_8(\mathbb{H})$	$M_{16}(\mathbb{H})$	$M_{32}(\mathbb{C})$	$M_{64}(\mathbb{R})$	$M_{64}(\mathbb{R}) \oplus M_{64}(\mathbb{R})$	$M_{128}(\mathbb{R})$	$M_{128}(\mathbb{C})$
$M_4(\mathbb{H})$	$M_4(\mathbb{H}) \oplus M_4(\mathbb{H})$	$M_8(\mathbb{H})$	$M_{16}(\mathbb{C})$	$M_{32}(\mathbb{R})$	$M_{32}(\mathbb{R}) \oplus M_{32}(\mathbb{R})$	$M_{64}(\mathbb{R})$	$M_{64}(\mathbb{C})$	$M_{64}(\mathbb{H})$
$M_2(\mathbb{H}) \oplus M_2(\mathbb{H})$	$M_4(\mathbb{H})$	$M_8(\mathbb{C})$	$M_{16}(\mathbb{R})$	$M_{16}(\mathbb{R}) \oplus M_{16}(\mathbb{R})$	$M_{32}(\mathbb{R})$	$M_{32}(\mathbb{C})$	$M_{32}(\mathbb{H})$	$M_{32}(\mathbb{H}) \oplus M_{32}(\mathbb{H})$
$M_2(\mathbb{H})$	$M_4(\mathbb{C})$	$M_8(\mathbb{R})$	$M_8(\mathbb{R}) \oplus M_8(\mathbb{R})$	$M_{16}(\mathbb{R})$	$M_{16}(\mathbb{C})$	$M_{16}(\mathbb{H})$	$M_{16}(\mathbb{H}) \oplus M_{16}(\mathbb{H})$	$M_{32}(\mathbb{H})$
$M_2(\mathbb{C})$	$M_4(\mathbb{R})$	$M_4(\mathbb{R}) \oplus M_4(\mathbb{R})$	$M_8(\mathbb{R})$	$M_8(\mathbb{C})$	$M_8(\mathbb{H})$	$M_8(\mathbb{H}) \oplus M_8(\mathbb{H})$	$M_{16}(\mathbb{H})$	$M_{32}(\mathbb{C})$
$M_2(\mathbb{R})$	$M_2(\mathbb{R}) \oplus M_2(\mathbb{R})$	$M_4(\mathbb{R})$	$M_4(\mathbb{C})$	$M_4(\mathbb{H})$	$M_4(\mathbb{H}) \oplus M_4(\mathbb{H})$	$M_8(\mathbb{H})$	$M_{16}(\mathbb{C})$	$M_{32}(\mathbb{R})$
$\mathbb{R} \oplus \mathbb{R}$	$M_2(\mathbb{R})$	$M_2(\mathbb{C})$	$M_2(\mathbb{H})$	$M_2(\mathbb{H}) \oplus M_2(\mathbb{H})$	$M_4(\mathbb{H})$	$M_8(\mathbb{C})$	$M_{16}(\mathbb{R})$	$M_{16}(\mathbb{R}) \oplus M_{16}(\mathbb{R})$
\mathbb{R}	\mathbb{C}	\mathbb{H}	$\mathbb{H} \oplus \mathbb{H}$	$M_2(\mathbb{H})$	$M_4(\mathbb{C})$	$M_8(\mathbb{R})$	$M_8(\mathbb{R}) \oplus M_8(\mathbb{R})$	$M_{16}(\mathbb{R})$

Real Spinors (signatures (2,2) (3,1))

$Cl(4) = M_4(\mathbb{R}) = 4 \times 4$ Real Matrix Algebra

$Cl(8) = M_{16}(\mathbb{R})$ (signature (0,8))

$Cl(16) = M_{16}(\mathbb{R}) \otimes M_{16}(\mathbb{R}) = M_{256}(\mathbb{R})$ (signature (0,16))

Physically, the Real Structures describe
High-Energy (near Planck scale) Octonionic Physics.

$Cl(4)$ Spinors:

4-dim $x y z t$ space on which $M_4(\mathbb{R})$ matrices act.

With Spinors defined in terms
of Even Subalgebra of Clifford Algebra,

$M_4(\mathbb{R})$ reduces to $M_2(\mathbb{R}) + M_2(\mathbb{R})$

and $Cl(4)$ Spinors reduce to sum of half-Spinors as
2-dim $x y$ space plus 2-dim $z t$ space.

$Cl(8)$ Spinors:

16-dim space on which $M_{16}(\mathbb{R})$ matrices act.

$M_{16}(\mathbb{R})$ reduces to $M_8(\mathbb{R}) + M_8(\mathbb{R})$

and $Cl(8)$ Spinors reduce to sum of half-Spinors as

8-dim $x y z t x y z t$ +space plus

8-dim $x y z t x y z t$ -space

where Triality has been used to represent half-Spinors
in terms of vectors $x y z t x y z t$ that can be seen
as $Cl(4)$ structures.

$Cl(Cl(4)) = Cl(16)$ Spinors:

256-dim space on which $M_{256}(\mathbb{R})$ matrices act.

$M_{256}(\mathbb{R})$ reduces to $M_{128}(\mathbb{R}) + M_{128}(\mathbb{R})$

and $Cl(16)$ Spinors $(8^+ + 8^-) \times (8^+ + 8^-) =$

$= (64^{++} + 64^{--}) + (64^{+-} + 64^{-+}) = 128^{\text{pure}} + 128^{\text{mixed}}$

which reduces to sum of half-Spinors as

128-dim pure space plus 128-dim mixed space.

Only the pure half-Spinor 128-dim space is used to
construct $E_8 = 120$ -dim grade-2 + 128-dim half-Spinor.

The pure 128-dim half-Spinor $64^{++} + 64^{--}$ describes:

8 covariant components of 8 Fermion Particles by 64^{++}

8 covariant components of 8 AntiParticles by 64^{--} .

Quaternion Spinors (signatures (0,4) (1,3) (4,0))
Cl(4) = M2(H) = 2x2 Quaternion Matrix Algebra

Cl(8) = M8(H) (signature (2,6))

Cl(16) = M8(H) (x) M8(H) = M128(H) (signature (4,12))

Physically, Quaternionic Structures describe

Low-Energy (with respect to Planck scale) Physics

which emerges after

Octonion Symmetry is broken

by “freezing out” a preferred Quaternion Substructure

at the End of Inflation

so

Quaternionic Structure is relevant for Low-Energy physics described by Cl(4) and
observed directly by us now,

but not relevant for Cl(8) or Cl(16) which describe High-Energy physics such as
that of the Inflationary Era.

Cl(4) Spinors:

8-dim space on which M2(H) matrices act.

With Spinors defined in terms

of Even Subalgebra of Clifford Algebra,

M2(H) reduces to H+H

and Cl(4) Spinors reduce to sum of half-Spinors as

4-dim space plus 4-dim space

which enables Cl(4) to describe Fermion Particles as

Lepton + RGB Quarks Particles by one H of H+H plus

Lepton + RGB Quarks AntiParticles by the other H of H+H

but Cl(4) is not large enough to distinguish Neutrinos

from Electrons. To do that it should be expanded into

Cl(6) of the Conformal Group (signature (2,4))

with Cl(6) = M4(H) and Even Subalgebra M2(H) + M2(H)

giving a half-Spinor H+H for 8 Fermion Particles and

another half-Spinor H+H for 8 Fermion AntiParticles.

In a sense, this expands 4+4=8-dim Batakis Kaluza-Klein

to a 6+4=10-dim CNF6 x CP2 Kaluza-Klein,

with the M4 Minkowski M4 physical SpaceTime becoming a

conformal CNF6 physical SpaceTime

that is related to Segal Conformal Dark Energy.

Higher grades of Cl(16) are:

560 grade-3:

1820 grade-4:

4368 grade-5:

8008 grade-6:

11440 grade-7:

12870 grade-8:

11440 grade-9:

8008 grade-10:

4368 grade-11:

1820 grade-12:

560 grade-13:

120 grade-14:

16 grade-15:

1 grade-16:

Higgs as Primitive Idempotent:

Clifford Algebra Primitive Idempotents are described by Pertti Lounesto in his book Clifford Algebras and Spinors (Second Edition, LMS 286, Cambridge 2001) in which he said at pages 226-227 and 29:

"... Primitive idempotents and minimal left ideals An orthonormal basis of $R(p,q)$ induces a basis of $Cl(p,q)$, called the standard basis.

Take a non-scalar element e_T , $e_T^2 = 1$, from the standard basis of $Cl(p,q)$.

Set $e = (1/2)(1 + e_T)$ and $f = (1/2)(1 - e_T)$, then $e + f = 1$ and $ef = fe = 0$.

So $Cl(p,q)$ decomposes into a sum of two left ideals

$Cl(p,q) = Cl(p,q)e + Cl(p,q)f$, where [for $n = p + q$]

$\dim Cl(p,q)e = \dim Cl(p,q)f = [\dim] (1/2) Cl(p,q) = 2^{(n-1)}$.

Furthermore,

if $\{ e_{T_1}, e_{T_2}, \dots, e_{T_k} \}$ is a set of non-scalar basis elements

such that $e_{T_i}^2 = 1$ and $e_{T_i}e_{T_j} = e_{T_j}e_{T_i}$,

then letting the signs vary independently in the product

$(1/2)(1 \pm e_{T_1})(1/2)(1 \pm e_{T_2}) \dots (1/2)(1 \pm e_{T_k})$,

one obtains 2^k idempotents which are mutually annihilating and sum up to 1.

The Clifford algebra $Cl(p,q)$ is thus decomposed into a direct sum of 2^k left ideals, and by construction, each left ideal has dimension $2^{(n-k)}$.

In this way one obtains a minimal left ideal by forming a maximal product of non-annihilating and commuting idempotents.

The Radon-Hurwitz number r_i for i in Z is given by

$i \quad 0 \ 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7$

$r_i \ 0 \ 1 \ 2 \ 2 \ 3 \ 3 \ 3 \ 3$

and the recursion formula $r_{(i+8)} = r_i + 4$.

For the negative values of i one may observe that $r_{(-1)} = -1$

and $r_{(-i)} = 1 - i + r_{(i+2)}$ for $i > 1$.

$r_{-8} = 1 - 8 + r_{10}$

Theorem. In the standard basis of $Cl(p,q)$ there are always

$k = q - r(q-p)$ non-scalar elements e_{T_i} , $e_{T_i}^2 = 1$,

which commute, $e_{T_i}e_{T_j} = e_{T_j}e_{T_i}$,

and generate a group of order 2^k .

The product of the corresponding mutually non-annihilating idempotents,

$f = (1/2)(1 \pm e_{T_1})(1/2)(1 \pm e_{T_2}) \dots (1/2)(1 \pm e_{T_k})$,

is primitive in $Cl(p,q)$.

Thus, the left ideal $S = Cl(p,q) f$ is minimal in $Cl(p,q)$.

Example ... In the case of $R(0,7)$ we have $k = 7 - r_7 = 4$. Therefore the idempotent $f = (1/2)(1 + e_{124}) (1/2)(1 + e_{235}) (1/2)(1 + e_{346}) (1/2)(1 + e_{457})$ is primitive to $Cl(0,7) = 2^{Mat}(8,R)$”.

Further example of $R(0,8)$ is discussed by Pertti Lounesto in his book “Spinor Valued Regular Functions in Hypercomplex Analysis” (Report-HTKKMAT-A154 (1979) Helsinki University of Technology) said [in the quote below I have changed his notation for a Clifford algebra from $R_{(p,q)}$ to $Cl(p,q)$] at pages 40-42:

“... To fix a minimal left ideal V of $Cl(p,q)$

we can choose a primitive idempotent f of $Cl(p,q)$ so that $V = Cl(p,q) f$.

By means of an orthonormal basis $\{e_1, e_2, \dots, e_n\}$

for [the grade-1 vector part of $Cl(p,q)$] $Cl^1(p,q)$ we can construct a primitive idempotent f as follows:

Recall that the 2^n elements

$$e_A = e_{a_1} e_{a_2} \dots e_{a_k},$$

$$1 < a_1 < a_2 < \dots < a_k < n$$

constitute a basis for $Cl(p,q)$

$\dim_R V = 2^X$, where $X = h$ or $X = h + 1$ according as

$p - q = 0, 1, 2 \pmod 8$ or $p - q = 3, 4, 5, 6, 7 \pmod 8$ and $h = [n/2]$.

Select $n - X$ elements $e_A, e_A^2 = 1$, so they are pairwise commuting and generate a group of order $2^{(n - X)}$.

Then the idempotent ...

$$f = (1/2)(1 + e_{A_1}) (1/2)(1 + e_{A_2}) \dots (1/2)(1 + e_{A_{(n - X)}})$$

is primitive ...

To prove this note that the dimension of $(1/2)(1 + e_A) Cl(p,q)$ is $(2^n) / 2$

and so the dimension of $Cl(p,q) f$ is $(2^n) / (2^{(n - X)}) = 2^X$.

Hence,

if there exists such an idempotent f , then f is primitive.

To prove that such an idempotent f exists in every Clifford algebra $Cl(p,q)$

we may first check the lower dimensional cases and then proceed by making use

of the isomorphism $Cl(p,q) \times Cl(0,8) = Cl(p, q + 8)$

and the fact that $Cl(0,8)$ has a primitive idempotent

$$f = (1/2)(1 + e_{1248}) (1/2)(1 + e_{2358}) (1/2)(1 + e_{3468}) (1/2)(1 + e_{4578}) \\ = (1/16)(1 + e_{1248} + e_{2358} + e_{3468} + e_{4578} + e_{5618} + e_{6728} + e_{7138} \\ - e_{3567} - e_{4671} - e_{5712} - e_{6123} - e_{7234} - e_{1345} - e_{2456} + e_J)$$

with four factors [and where $J = 12345678$] ...

The division ring $F = f Cl(p,q) f = \{ \psi \in V \mid \psi f = f \psi \}$

is isomorphic to R, C , or H

according as $p - q = 0, 1, 2, \text{ mod } 8$, $p - q = 3 \text{ mod } 4$, or $p - q = 4, 5, 6 \text{ mod } 8$".
 In "Idempotent Structure of Clifford Algebras" (Acta Applicandae Mathematicae 9 (1987) 165-173) Pertti Lounesto and G. P. Wene said:

"... An idempotent e is primitive if it is not a sum of two nonzero annihilating idempotents and minimal if it is a minimal element in the set of all nonzero idempotents with order relation $f \leq e$ if and only if $ef = f = fe$.

These last two properties of an idempotent e are equivalent. An idempotent e is primitive if e is the only nonzero idempotent of the subring eAe .

A subring S of A is a left ideal if ax is in S for all a in A and x in S .

A left ideal is minimal if it does not contain properly any nonzero left ideals.

... if S is a minimal left ideal of A ,

then either $Ss = 0$ or $S = Ae$ for some idempotent e .

Spinor spaces are minimal left ideals of a Clifford algebra.

Any minimal left ideal S of a Clifford algebra $A = R_{p,q}$ is of the form $S = Ae$ for some primitive idempotent e of $R_{p,q}$.

... if e is a primitive idempotent of $R_{p,q}$ then

$$\begin{matrix} e & 0 \\ 0 & 0 \end{matrix}$$

is a primitive idempotent of $R_{p,q}(2) = R_{p+1,q+1}$

... The maximum number of mutually annihilating primitive idempotents in the Clifford algebra $R_{p,q}$ is 2^k where $k = q - r - p$.

...[where]... r_i ...[is the]... Radon-Hurwitz number ...

These mutually annihilating primitive idempotents sum up to 1.

If mutually annihilating primitive idempotents sum up to 1,

then in a simple ring, such a sum has always the same number of summands.

... Lattices Generated by Idempotents

A lattice is a partially ordered set where each subset of two elements has a least upper bound and a greatest lower bound. Any set of idempotents of a ring A is partially ordered under the ordering defined by $e \leq f$ if and only if $ef = e = fe$.

If e and f are commuting idempotents, then ef and $e + f - ef$ are, respectively, a greatest lower bound and a least upper bound relative to the partial ordering defined. Hence, any set of commuting idempotents generate a lattice.

This lattice is complemented and distributive.

...

Let e_1, e_2, \dots, e_s in $R_{p,q}$ be a set of mutually annihilating primitive idempotents summing up to 1. Then the set e_1, e_2, \dots, e_s generates a complemented and distributive lattice of order 2^s , where $s = 2^k$, $k = q - r - p$

...

EXAMPLE [I have changed the example from $R_{3,1}$ to $R_{0,8}$ and paraphrased]

In the Clifford algebra $R_{0,8} = R(16)$ we have $k = 8 - r - p = 8 - 4 = 4$

and so primitive idempotents can have 4 commuting factors of type $(1/2)(1 + eT)$.
 Furthermore $s = 2^k = 16$ and so $R_{0,8}$ can be represented by 16×16 matrices $R(16)$,
 and there are $2^s = 2^{16} = 65,536$ commuting idempotents in the lattice generated
 by the 16 mutually annihilating primitive idempotents ...
 this lattice looks like ... a 16-dimensional analogy of the cube ...”.

**The Clifford algebra $R_{0,8} = Cl(0,8)$ is $2^8 = 16 \times 16 = 256$ -dimensional with
 graded structure such that it
 is represented by the geometric structure of a simplex.**

**The Spinors of $R_{0,8} = Cl(0,8)$ are $\sqrt{256} = 16$ -dimensional with no simplex-
 type graded structure so that it
 is represented by the geometric structure of a cube.**

**248-dim $E_8 = 120$ -dim $Cl(16)$ bivectors + 128-dim $Cl(16)$ half-spinors and
 $Cl(16) = Cl(8) \times Cl(8)$
 so the structure of the 128-dim $Cl(16)$ half-spinors is important for E_8
 Physics.**

The Clifford algebra $Cl(16)$ (also denoted $R_{0,16}$) is the real 256×256 matrix
 algebra $R(256)$ for which we have $k = 16 - r_{16} = 16 - 8 = 8$
 and so primitive idempotents can have 8 commuting factors of type $(1/2)(1 + eT)$.
 Furthermore $s = 2^k = 256$ and so $R_{0,16}$ can be represented by 256×256 matrices
 $R(256)$, and there are $2^s = 2^{256} = 1.158 \times 10^{77}$ commuting idempotents in the
 lattice generated by the 256 mutually annihilating primitive idempotents.

E_8 lives in $Cl(16)$ as

248-dim $E_8 = 120$ -dim bivectors of $Cl(16)$ + 128-dim half-spinor of $Cl(16)$.

Since $Cl(16)$ bivectors are all in one grade of $Cl(16)$
 and $Cl(16)$ half-spinors have no simplex-type graded structure
 E_8 does not get detailed graded structure from $Cl(16)$ gradings,
 but only the Even-Odd grading obtained by
 splitting 128-dim half-spinor into two mirror image 64-dim parts:

$$\mathbf{E_8 = 64 + 120 + 64}$$

**E_8 has only a $Cl(16)$ half-spinor so there are in E_8 Physics $2^{(s/2)} = 2^{128}$
 commuting idempotents in the lattice generated by the 128 mutually
 annihilating primitive idempotents. $2^{128} = \text{about } 3.4 \times 10^{38}$ the square root
 of which is about the ratio (Hadron mass / Planck mass)² of the Effective
 Mass Factor for Gravity strength.**

The typical Hadron mass can be thought of in terms of superposition of Pions:

In E8 Physics, at a single spacetime vertex, a Planck-mass black hole is the Many-Worlds quantum sum of all possible virtual first-generation particle-antiparticle fermion pairs permitted by the Pauli exclusion principle to live on that vertex. Once a Planck-mass black hole is formed, it is stable in E8 Physics. Less mass would not be gravitationally bound at the vertex. More mass at the vertex would decay by Hawking radiation. Since Dirac fermions in 4-dimensional spacetime can be massive (and are massive at low enough energies for the Higgs mechanism to act), the Planck mass in 4-dimensional spacetime is the sum of masses of all possible virtual first-generation particle-antiparticle fermion pairs permitted by the Pauli exclusion principle. A typical combination should have several quarks, several antiquarks, a few colorless quark-antiquark pairs that would be equivalent to pions, and some leptons and antileptons. Due to the Pauli exclusion principle, no fermion lepton or quark could be present at the vertex more than twice unless they are in the form of boson pions, colorless first-generation quark-antiquark pairs not subject to the Pauli exclusion principle. Of the 64 particle-antiparticle pairs, 12 are pions. A typical combination should have about 6 pions.

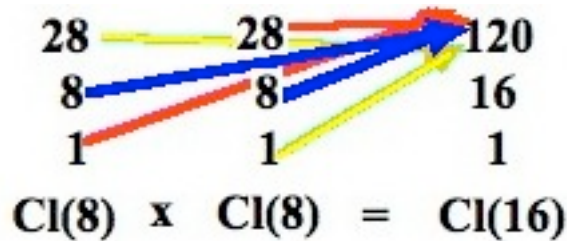
If all the pions are independent, the typical combination should have a mass of $0.14 \times 6 \text{ GeV} = 0.84 \text{ GeV}$. However, just as the pion mass of 0.14 GeV is less than the sum of the masses of a quark and an antiquark, pairs of oppositely charged pions may form a bound state of less mass than the sum of two pion masses. If such a bound state of oppositely charged pions has a mass as small as 0.1 GeV , and if the typical combination has one such pair and 4 other pions, then the typical combination should have a mass in the range of 0.66 GeV so that

$$\begin{aligned} \sqrt{3.4 \times 10^{38}} &= 1.84 \times 10^{19} \\ \text{while Planck Mass} &= 1.22 \times 10^{19} \text{ GeV} = 1.30 \times 10^{19} \text{ Proton Mass} = \\ &= 1.85 \times 10^{19} \text{ Hadron Mass} \end{aligned}$$

**In terms of the Graded Structure of Cl(16)
the 256 Cl(16) Primitive Idempotents can be understood
in terms of graded structures of the Cl(8) and E8 substructures of Cl(16):**

**The detailed E8 graded structure $8 + 28 + 56 + 64 + 56 + 28 + 8$
comes from the grades of the Cl(8) factors of $Cl(16) = Cl(8) \times Cl(8)$.**

The Even 120 of E8 breaks down in terms of Cl(8) factors as



$$120 = 1 \times 28 + 8 \times 8 + 28 \times 1 = 28 + 64 + 28$$

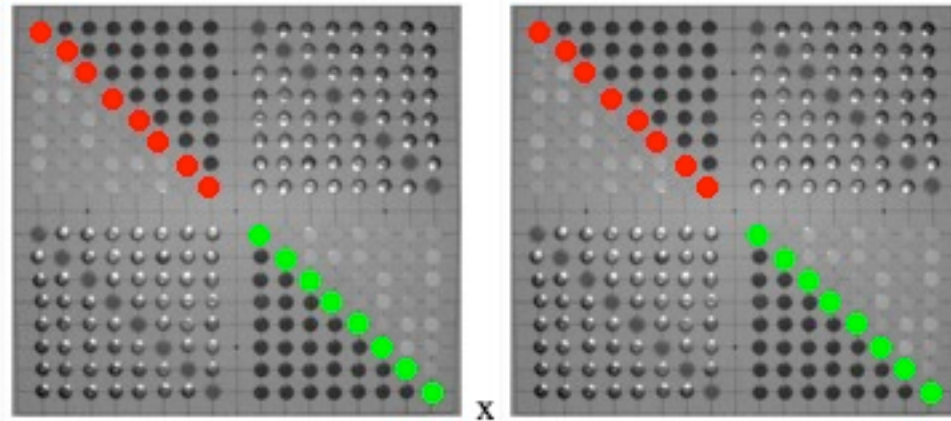
The Odd 128 = 64 + 64 breaks down as

$$\begin{aligned} \text{Spinors:} & \quad (8s \times 8s + 8c \times 8c) \\ (8s + 8c) \times (8s + 8c) & = \quad + \\ & \quad (8s \times 8c + 8c \times 8s) \end{aligned}$$

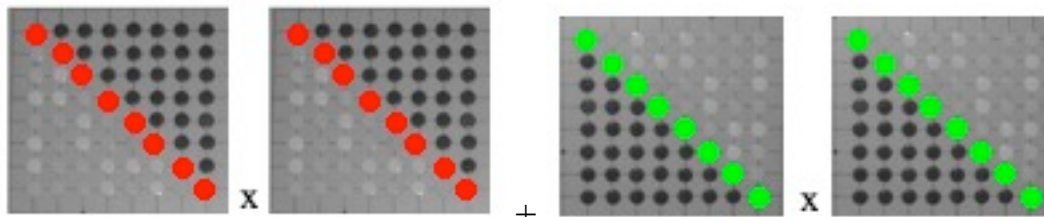
to become
 $64 + 64 = 8 + 56 + 56 + 8$

Here are some details about the half-spinors of E8:

The **+half-spinors (red)** and **-half-spinors (green)** of $Cl(8)$ are the $8+8 = 16$ diagonal entries of the 16×16 real matrix algebra that is $Cl(8)$, so that $Cl(16) = Cl(8) \times Cl(8)$ can be represented as:



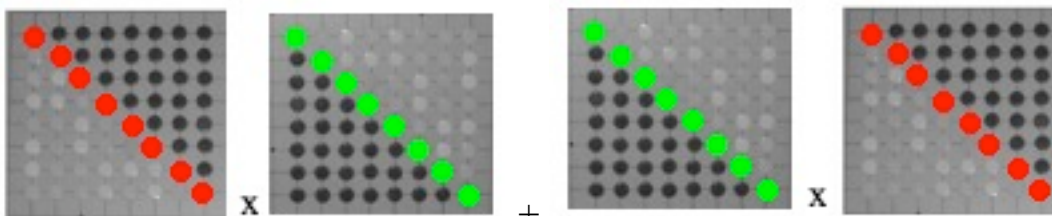
and the $16 \times 16 = 256$ spinors of $Cl(16)$ (the diagonal entries of $R(256)$) can be represented as the sum of the diagonal product terms



$$64+64 = 128$$

(these two (pure red and pure green) are the $Cl(16)$ +half-spinor which decomposes physically into particles (red) and antiparticles (green))

+



$$64+64 = 128$$


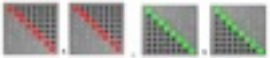
(these two (mixed red and green) are the $Cl(16)$ -half-spinor which do not decompose readily into particles (red) and antiparticles (green))

grade-0: 1 PurePI 

grade-1: 16 NotPI

grade-2: 120 NotPI

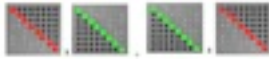
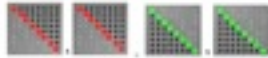
grade-3: 560 NotPI

grade-4: 1820 = 1792 + 14 MixedPI 
+ 14 PurePI 

grade-5: 4368 NotPI

grade-6: 8008 NotPI



grade-7: 11440 NotPI

grade-8: 12870 = 12672 + 100 MixedPI 
+ 98 PurePI 

grade-9: 11440 NotPI

grade-10: 8008 NotPI

grade-11: 4368 NotPI

grade-12: 1820 = 1792 + 14 MixedPI 
+ 14 PurePI 

grade-13: 560 NotPI

grade-14: 120 NotPI

grade-15: 16 NotPI

grade-16: 1 PurePI 

Only the PurePI Cl(16) +half-spinor has scalar grade-0 and pseudoscalar grade-16

grade-0: 1 PurePI 

grade-4: 14 PurePI 

grade-8: 98 PurePI 

grade-12: 14 PurePI 

grade-16: 1 PurePI 

so it is the only half-spinor that can physically represent a Higgs scalar and is the only half-spinor in the E8 of E8 Physics.

Further, for E8 to describe a consistent E8 Physics model, it must be that
 $E8 = Cl(16) \text{ bivectors} + Cl(16) \text{ +half-spinor}$
 with physical distinction between particles and antiparticles
 and that

E8 does not contain the Cl(16) -half-spinor made up of particle/antiparticle mixtures.

In the context of physics models,
 the Cl(16) -half-spinors correspond to fermion antigerations that are not realistic and their omission from E8 allows E8 Physics to be chiral and realistic.

E8 with graded structure $8 + 28 + 56 + 64 + 56 + 28 + 8$ lives in Cl(16)
 as
 $248\text{-dim } E8 = 120\text{-dim bivectors of } Cl(16) + 128\text{-dim half-spinor of } Cl(16).$

The two half-spinors of Cl(16) are Left Ideals of a Cl(16) Primitive Idempotent.

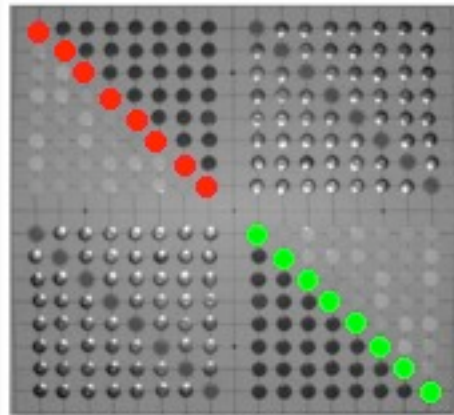
Due to 8-periodicity of Real Clifford Algebras $Cl(16) = Cl(8) \times Cl(8)$
 where x is tensor product. Let Primitive Idempotent be denoted by PI
 and $J = 12345678$:

$$Cl(16)PI = Cl(8)PI \times Cl(8)PI$$

$$Cl(8)PI = (1/16) (1 + e_{_1248}) (1 + e_{_2358}) (1 + e_{_3468}) (1 + e_{_4578}) =$$

$$= (1/16)(1$$

$$+ e_{_1248} + e_{_2358} + e_{_3468} + e_{_4578} + e_{_5618} + e_{_6728} + e_{_7138}$$



$$- e_{_3567} - e_{_4671} - e_{_5712} - e_{_6123} - e_{_7234} - e_{_1345} - e_{_2456}$$

$$+ e_{_J}) =$$

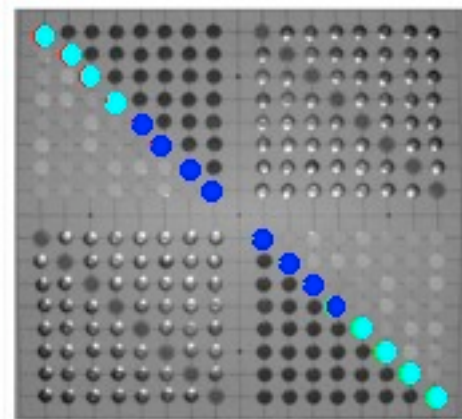
$$= (1/16)($$

$$1 +$$

$$+ e_{_1248} + e_{_2358} + e_{_3468}$$

$$- e_{_3567} - e_{_4671} - e_{_5712}$$

$$+ e_{_J}$$



$$+ e_{_4578} + e_{_5618} + e_{_6728} + e_{_7138}$$

$$- e_{_6123} - e_{_7234} - e_{_1345} - e_{_2456}$$

$$)$$

256-dim Cl(8) has graded structure $1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$

16-dim Cl(8)PI has graded structure $1 + 14 + 1 = 1 + (8+6) + 1$

16-dim Cl(8)PI = 8-dim Cl(8)PIE8 + 8-dim Cl(8)PInotE8

where

8-dim Cl(8)PIE8 has graded structure of only 8 in the middle grade

plus

8-dim Cl(8)PInotE8 has graded structure $1 + 6 + 1$

8-dim Cl(8)PIE8 is contained in the middle 64 of E8 graded structure

$8 + 28 + 56 + 64 + 56 + 28 + 8$

so that

since the physical interpretation of the middle 64 is

8 momentum components of 8-dim position spacetime

the 8-dim Cl(8)PIE8 corresponds to a one-component field over 8-dim spacetime

and

therefore Cl(8)PIE8 describes a scalar field over 8-dim spacetime

and so a Higgs field in E8 Physics spacetime.

8-dim Cl(8)PInotE8 with graded structure $1 + 6 + 1$

corresponds to the part of Cl(8)PI that is in Cl(8) but not in E8

so that

Cl(8) with graded structure $1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$

=

Cl(8)PInotE8 with graded structure $1 + 6 + 1$

+

E8 with graded structure $8 + 28 + 56 + 64 + 56 + 28 + 8$

and

therefore Cl(8)PInotE8 describes the Clifford algebra structure beyond E8

(1 scalar and 6 middle-grade and 1 pseudoscalar)

that produces the half-spinors that belong to E8

and

therefore describes the coupling between the Higgs field and half-spinor Fermions.

The Higgs-Fermion coupling, below the freezing out of a preferred Quaternionic substructure of 8-dim Octonionic E8 Physics spacetime, produces the Mayer Mechanism Higgs field of 8-dim Batakis Kaluza-Klein spacetime.

The Higgs-Fermion coupling, below ElectroWeak Symmetry Breaking Energy, gives mass to Fermions.

**Since the 128-dim half-spinor part of E8 comes from
Cl(16)PI = Cl(8)PI x Cl(8)PI
the E8 Higgs-Fermion is based on
two copies (one from each Cl(8)PI factor) of a scalar Higgs field over
spacetime**

so that

**two copies of Cl(8)PIE8 show that the E8 Physics Higgs field is
a scalar doublet.**

As Cottingham and Greenwood said in their book “An Introduction to the Standard Model of Particle Physics” (2nd ed, Cambridge 2007):
“... Higgs ... mechanism ...[uses]... a complex scalar field ... [i]n place of [which]... we [can] have two coupled real scalar fields ...”.

As Steven Weinberg said in his book “The Quantum Theory of Fields, v. II” (Cambridge 1996 at pages 317-318 and 356):
“... With only a single type of scalar doublet, there is just one ... term that satisfies SU(2) and Lorentz invariance ... At energies below the electroweak breaking scale, this yields an effective interaction ... this gives lepton number non-conserving neutrino masses at most of order $(300 \text{ GeV})^2 / M$... For instance, in the so-called see-saw mechanism, a neutrino mass of this order would be produced by exchange of a heavy neutral lepton of mass M ... M is expected to be of order $10^{15} - 10^{18} \text{ GeV}$, so we would expect neutrino masses in the range $10^{-4} - 10^{-1}$... A similar analysis shows that there are interactions of dimensionality six that violate both baryon and lepton number conservation, involving three quark fields and one lepton field. Such interactions would have coupling constants of order M^{-2} , and would lead to processes like proton decay, with rates proportional to M^{-4}”.

and

the part of the Cl(16) Primitive Idempotent that is not in the E8 in Cl(16) is the product Cl(8)PI_{notE8} x Cl(8)PI_{notE8} of two copies of Cl(8)PI_{notE8} each copy having graded structure 1 + 6 + 1 (grades 0 and 4 and 8) so that

the part of the Cl(16) Primitive Idempotent that is not in the E8 in Cl(16) has graded structure 1 + 12 + 38 + 12 + 1 (grades 0 and 4 and 8 and 12 and 16). The total dimension of those Cl(16) grades are:
1 and 1820 and 128870 and 1820 and 1.

$$\mathbf{Cl(8)} \quad \mathbf{256 = 1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1}$$

$$\begin{array}{l} \mathbf{Primitive} \quad \mathbf{16 = 1} \quad \quad \quad \mathbf{+ 6} \quad \quad \quad \mathbf{+ 1} \\ \mathbf{Idempotent} \quad \quad \quad \quad \quad \quad \quad \quad \mathbf{+ 8} \end{array}$$

$$\mathbf{E8 Root Vectors} \quad \mathbf{240 = 8 + 28 + 56 + 56 + 56 + 28 + 8}$$

Greg Trayling and W. E. Baylis in Chapter 34 of “Clifford Algebras - Applications to Mathematics, Physics, and Engineering”, 2004, Proceedings of 2002 Cookeville Conference on Clifford Algebras, ed. by Rafal Ablamowicz

(see also hep-th/0103137) said:

“... the exact gauge symmetries $U(1)_Y \times SU(2)_L \times SU(3)_C$ of the minimal standard model arise ...[from]... symmetries of ... a ... space with ... four extra spacelike dimensions ...

[compare the Batakis $M_4 \times CP^2$ $4+4=8$ -dimensional Kaluza-Klein model]...

Rather than embed the gauge groups into some master group, we infix the Dirac algebra into the ... Clifford algebra $Cl(7)$...[in which]... the unit vectors e_1, e_2, \dots, e_7 are chosen to represent ... spacelike directions ...

We further choose e_1, e_2, e_3 to represent ... physical space and ...

e_4, e_5, e_6, e_7 to ... represent ... four ...dimensions ... orthogonal to physical space ... [compare the $Cl(8)$ of E8 Physics which is represented by 16×16 matrices with

two 8-dimensional half-spinor spaces and in which the 8 unit vectors

$e_0, e_1, e_2, \dots, e_7$ represent Batakis 8-dimensional spacetime $M_4 \times CP^2$ where e_0, e_1, e_2, e_3 represents M_4 and e_4, e_5, e_6, e_7 represents CP^2]...

To describe one generation of the standard model, we use the algebraic spinor Ψ in $Cl(7)$... there are eight independent primitive idempotents that can each be used to reduce Ψ to a spinor representing a fermion doublet ...

Each of the eight ... primitive idempotents ... projects Ψ onto one of eight minimal left ideals of $Cl(7)$...

[compare the $8+8 = 16$ primitive idempotents of $Cl(8)$ which correspond to 8 first-generation fermion particles and their 8 antiparticles] ...

we previously disregarded the higher-dimensional vector components ... This ... vector space ... then ... affords a natural inclusion of the minimal Higgs field ...

The Higgs field ... arises here simply as a coupling to the higher-dimensional vector components ...”.

[compare the E8 Physics model relationship between the Higgs and the $Cl(8)$ primitive idempotents which live in grades 0 and 4 and 8 of $Cl(8)$]

Klaus Dietz in arXiv quant-ph/0601013 said:

“... **m-Qubit states are embedded in $Cl(2m)$ Clifford algebra.** ...

This ... allows us to arrange the $2^{(2m)} - 1$ real coordinates of a m-Qubit state in multidimensional arrays which are shown to ‘transform\m’ as $O(2m)$ tensors ...

A hermitian $2^m \times 2^m$ matrix requires $2^{(2m)}$ real numbers for a complete parameterization. Thus m-qubit states can be expanded in terms of I and the products introduced. Clifford numbers are the starting point for the construction of a basis in R-linear space of hermitian matrices:

this basis is construed as a Clifford algebra $Cl(2m)$...”.

Stephanie Wehner in arXiv 0806.3483 said:

“... A Clifford algebra of n generators is isomorphic to a ... algebra of matrices of size $2^{(n/2)} \times 2^{(n/2)}$ for n even ...

we can view the operators G_1, \dots, G_{2n} as $2n$ orthogonal vectors forming a basis for a $2n$ -dimensional real vector space R^{2n} ...

each operator G_i has exactly two eigenvalues ± 1 ...

we can express each G_i as $G_i = G_{0i} - G_{1i}$

where G_{0i} and G_{1i} are projectors onto the positive and negative eigenspace of G_i

... for all i, j with $i \neq j$ $\text{Tr}(G_i G_j) = (1/2)\text{Tr}(G_i G_j + G_j G_i) = 0$

that is all such operators are orthogonal with respect to the Hilbert-Schmidt inner product ... the collection of operators

1

G_j $(1 \leq j \leq 2n)$

$G_{jk} := iG_j G_k$ $(1 \leq j < k \leq 2n)$

$G_{jkl} := G_j G_k G_l$ $(1 \leq j < k < l \leq 2n)$

...

$G_{12\dots(2n)} := iG_1 G_2 \dots G_{2n} =: G_0$

forms an orthogonal basis for ... the $d \times d$ matrices ... with $d = 2^n$...

We saw ... how to construct such a **basis ... based on mutually unbiased bases ... the well-known Pauli basis, given by the $2^{(2n)}$ elements of the form**

$B_j = B_{1j} \otimes \dots \otimes B_{nj}$ with $B_{ij} \in \{I, \sigma_x, \sigma_y, \sigma_z\}$...

we obtain a whole range of ... statements as we can find different sets of $2n$ anti-commuting matrices within the entire set of $2^{(2n)}$ basis elements ...

the subspace spanned by the elements G_1, \dots, G_{2n} plays a special role ...

when considering the state minimizing our uncertainty relation,

only the 1-vector coefficients play any role. The other coefficients do not contribute at all to the minimization problem. ...

Anti-commuting Clifford observables obey the strongest possible uncertainty relation for the von Neumann entropy: if we have no uncertainty for one of the measurements, we have maximum uncertainty for all others. ...”.

Monique Combescure in quant-ph/060509, arXiv 0710.5642 and 0710.5643 said:
 “... two basic unitary $d \times d$ matrices U, V ... constructed by Schwinger ... $q := \exp(2i\pi/d)$... are of the following form:

$$U := \text{Diag}(1, q, q^2, \dots, q^{d-1})$$

$$V := \begin{pmatrix} 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & 1 \\ 1 & 0 & 0 & \dots & 0 \end{pmatrix}$$

... the matrices U and V are called
 “generalized Pauli matrices on d -state quantum systems” ...

U, V generate the discrete Weyl-Heisenberg group ... U, V allows to find MUB's ...
 in dimension d there is at most $d+1$ MUB, and exactly $d + 1$ for d a prime number

...

A $d \times d$ matrix C is called circulant ... if all its rows and columns are successive circular permutations of the first ... the theory of circulant matrices allows to recover the result that there exists $p + 1$ Mutually Unbiased Bases in dimension p , p being a... prime number ... Then the MUB problem reduces to exhibit a circulant matrix C which is a unitary Hadamard matrix, such that its powers are also circulant unitary Hadamard matrices. Then using Discrete Fourier Transform F_d which diagonalizes all circulant matrices, we have shown that a MUB in that case is just provided by the set of column vectors of the set of matrices

$$\{ F_d, 1, C, C^2, \dots, C^{(d-1)} \}$$

...

the theory of block-circulant matrices with circulant blocks allows to show ...
 that if $d = p^n$ (p a prime number, n any integer)
 there exists $d + 1$ mutually Unbiased Bases in C_d ...”.

Stephen Brierley, Stefan Weigert, and Ingemar Bengtsson in arXiv 0907.4097 said:
 “... All complex Hadamard matrices in dimensions two to five are known ...
 In dimension three there is ... only one dephased complex Hadamard matrix up to
 equivalence. It is given by the (3 x 3) discrete Fourier matrix

$$F_3 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \omega & \omega^2 \\ 1 & \omega^2 & \omega \end{pmatrix}$$

defining $w = \exp(2\pi i / 3)$

...

In dimension $d = 4$, all 4×4 complex Hadamard matrices are equivalent to a
 member of the ... one-parameter family of complex Hadamard matrices ...

$$F_4(x) = \frac{1}{2} \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & ie^{ix} & -ie^{ix} \\ 1 & -1 & -ie^{ix} & ie^{ix} \end{pmatrix}, \quad x \in [0, \pi]$$

... There is one three-parameter family of triples ...

Only one set of four MU bases exists ...

there is a unique way to a construct five MU bases which is easily seen to be
 equivalent to the standard construction of a complete set of MU bases ... $d = 4$...

d	2	3	4	5	6
pairs	1	1	∞^1	1	$\geq \infty^3$
triples	1	1	∞^3	2	$\geq \infty^2$
quadruples	-	1	1	1	?
quintuples	-	-	1	1	?
sextuples	-	-	-	1	?

... The notion of equivalence used in this paper ... is mathematical in nature ...

Motivated by experiments, there is a finer equivalence of complete sets of MU
 bases based on the entanglement structure of the states contained in each basis ...

For dimensions that are a power of two, a complete set of MU bases can be
 realized using Pauli operators acting on each two-dimensional subsystem.

Two sets of MU bases are then called equivalent when they can be factored into the
 same number of subsystems. For $d = 2, 4$ this notion of equivalence also leads to a
 unique set of $(d + 1)$ MU bases. However, for $d = 8, 16, \dots$ complete sets of MU
 bases can have different entanglement structures even though they are equivalent
 up to an overall unitary transformation ...”.

P. Dita in arXiv 1002.4933 said:

“... Mutually unbiased bases (MUBs) constitute a basic concept of quantum information ... Its origin is in the Schwinger paper ... “Unitary operator bases”, Proc.Nat. Acad. Sci.USA, 46 570-579 (1960) ...

Two orthonormal bases in \mathbb{C}^d , $A = (a_1, \dots, a_d)$ and $B = (b_1, \dots, b_d)$, are called MUBs if ... the product $A B^*$ of the two complex Hadamard matrices generated by A and B is again a Hadamard matrix, where $*$ denotes the Hermitian conjugate ... The technique for getting MUBs for p prime was given by Schwinger ... who made use of the properties of the Heisenberg-Weyl group

...

[in this paper] An analytical method for getting new complex Hadamard matrices by using mutually unbiased bases and a nonlinear doubling formula is provided. The method is illustrated with the $n = 4$ case that leads to a rich family of eight-dimensional Hadamard matrices that depend on five arbitrary phases ... The ... matrices are new ... the only [prior] known result parametrized by five phases is the [$n = 8$] complex Hadamard matrix stemming from the Fourier matrix F_8

...

real Sylvester-Hadamard matrices ...[have a]... solution for $n = 8$...

$$S = \begin{bmatrix} a & b & c & d & l & m & n & p \\ b & -a & -d & c & m & -l & p & -n \\ c & d & -a & -b & n & -p & -l & m \\ d & -c & b & -a & p & n & -m & -l \\ l & -m & -n & -p & -a & b & c & d \\ m & l & p & -n & -b & -a & d & -c \\ n & -p & l & m & -c & -d & -a & b \\ p & n & -m & l & -d & c & -b & -a \end{bmatrix}$$

... for real Hadamard matrices with dimension $d = 2, 4, 8, 12$ there is only one matrix under the usual equivalence ... there is an other type of matrix equivalence ... two matrices ... are equivalent if and only if they have the same spectrum ... However a simple spectral computation of the h_1, h_2, h_3, h_4 matrices shows that only the matrices h_1 and h_3 are equivalent, and h_1 is not equivalent to h_2 and h_4 , nor h_2 is equivalent to h_4 ...[so that]... we do not suggest the use of the new equivalence ... for real Hadamard matrices ... because it will cause dramatic changes in the field ...”.

Standard Model Higgs compared to E8 Physics Higgs

The conventional Standard Model has structure:

spacetime is a base manifold;

particles are representations of gauge groups

gauge bosons are in the adjoint representation

fermions are in other representations (analogous to spinor)

Higgs boson is in scalar representation.

E8 Physics (see vixra 1108.0027 and tony5m17h.net) has structure

(from 248-dim E8 = 120-dim adjoint D8 + 128-dim half-spinor D8):

spacetime is in the adjoint D8 part of E8 (64 of 120 D8 adjoints)

gauge bosons are in the adjoint D8 part of E8 (56 of the 120 D8 adjoints)

fermions are in the half-spinor D8 part of E8 (64+64 of the 128 D8 half-spinors).

There is no room for a fundamental Higgs in the E8 of E8 Physics.

However,

for E8 Physics to include the observed results of the Standard Model

it must have something that acts like the Standard Model Higgs

even though it will NOT be a fundamental particle.

To see how the E8 Physics Higgs works,

embed E8 into the 256-dimensional real Clifford algebra Cl(8):

$$\text{Cl}(8) \quad 256 = 1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$$

$$\text{Primitive} \quad 16 = 1 \quad + 6 \quad + 1$$

$$\text{Idempotent} \quad + 8$$

$$\text{E8 Root Vectors} \quad 240 = 8 + 28 + 56 + 56 + 56 + 28 + 8$$

The Cl(8) Primitive Idempotent is 16-dimensional and can be decomposed into two 8-dimensional half-spinor parts each of which is related by Triality to 8-dimensional spacetime and has Octonionic structure. In that decomposition:

the 1+6+1 = (1+3)+(3+1) is related to two copies of

a 4-dimensional Associative Quaternionic subspace of the Octonionic structure and

the 8 = 4+4 is related to two copies of

a 4-dimensional Co-Associative subspace of the Octonionic structure

(see the book “Spinors and Calibrations” by F. Reese Harvey)

The $8 = 4+4$ Co-Associative part of the $Cl(8)$ Primitive Idempotent when combined with the 240 E8 Root Vectors forms the full 248-dimensional E8. It represents a Cartan subalgebra of the E8 Lie algebra.

The $(1+3)+(3+1)$ Associative part of the $Cl(8)$ Primitive Idempotent is the Higgs of E8 Physics.

The half-spinors generated by the E8 Higgs part of the $Cl(8)$ Primitive Idempotent represent:

neutrino; red, green, blue down quarks; red, green, blue up quarks; electron
so
the E8 Higgs effectively creates/annihilates the fundamental fermions and
the E8 Higgs is effectively a condensate of fundamental fermions.

In E8 Physics the high-energy 8-dimensional Octonionic spacetime reduces, by freezing out a preferred 4-dim Associative Quaternionic subspace, to a $4+4$ -dimensional Batakis Kaluza-Klein of the form $M4 \times CP2$ with 4-dim $M4$ physical spacetime.

Since the $(1+3)+(3+1)$ part of the $Cl(8)$ Primitive Idempotent includes the $Cl(8)$ grade-0 scalar 1 and $3+3 = 6$ of the $Cl(8)$ grade-4 which act as pseudoscalars for 4-dim spacetime and the $Cl(8)$ grade-8 pseudoscalar 1

the E8 Higgs transforms with respect to 4-dim spacetime as a scalar (or pseudoscalar) and in that respect is similar to Standard Model Higgs.

Not only does the E8 Higgs fermion condensate transform with respect to 4-dim physical spacetime like the Standard Model Higgs but

the geometry of the reduction from 8-dim Octonionic spacetime to $4+4$ -dimensional Batakis Kaluza-Klein, by the Mayer mechanism, gives E8 Higgs the ElectroWeak Symmetry-Breaking Ginzburg-Landau structure.

Since the second and third fermion generations emerge dynamically from the reduction from 8-dim to $4+4$ -dim Kaluza-Klein, they are also created/annihilated by the Primitive Idempotent E8 Higgs and are present in the fermion condensate. Since the Truth Quark is so much more massive than the other fermions,

the E8 Higgs is effectively a Truth Quark condensate.

When Triviality and Vacuum Stability are taken into account,

the E8 Higgs and Truth Quark system has 3 mass states.

Since it creates/annihilates Fermions,
the (1+3)+(3+1) Associative part of the Cl(8) Primitive Idempotent
is a Fermionic Condensate Higgs structure.
The creation/annihilation operators have graded structure similar to part of a
Heisenberg algebra

$$64 + 0 + 64$$

Since it creates/annihilates the 8-dimensional SpaceTime
represented by the Cartan Subalgebra of the E8 Lie Algebra,
the 8 = 4+4 Co-Associative part of the Cl(8) Primitive Idempotent
is a Bosonic Condensate Spacetime structure.
The creation/annihilation operators correspond to position-momentum related by
Fourier Transform and to an 8x8 = 64-dimensional U(8)

E8 has two D4 Lie subalgebras D4 and D4* related by Fourier Transform:
28-dimensional D4 acting on M4 4-dim Physical SpaceTime and containing
a Spin(2,4) subalgebra for Conformal MacDowell-Mansouri Gravity;
and
28-dimensional D4* acting on CP2 Internal Symmetry Space and containing
a U(4) subalgebra for the Batakis Standard Model gauge groups.

Taken together, the D4 and U(8) and D4* have graded structure

$$28 + 64 + 28$$

that breaks down into a semi-simple 63-dimensional SU(8)

$$63$$

and a Heisenberg Algebra

$$28 + 1 + 28$$

When the Fermionic 64 + 0 + 64 is added, the Heisenberg Algebra becomes

$$92 + 1 + 92$$

and the total 92 + U(8) + 92 is seen to be the contraction of E8 into the
semidirect product of semisimple SU(8) and Heisenberg Algebra 92 + U(1) + 92

Robert Hermann in “Lie Groups for Physicists” (Benjamin 1966) said:
 “... Let G be a Lie group ... imbed G into the associative algebra $U(G)$... the universal ... enveloping algebra ...
 the “polynomials” of the .. basis [elements] of G ... form a basis for $U(G)$...
 the center of $U(G)$...[is]... the Casimir operators of G ...[whose]... number ...[is]...
 equal to ... the dimension of its Cartan subalgebras ...
 every polynomial ... invariant under $\text{Ad}G$... arise[s] ... from a Casimir operator ...
 when G is semisimple, $\text{Ad} G$ acting on G admits an invariant polynomial of degree
 2 ... the Killing form ... This is the simplest such Casimir operator

...
 there is a group-theoretical construction which in certain situations reduces to the
 Fourier transform. To describe it, we need ... a Lie group G , two subgroups L and
 H of G , and linear representations ... of L and H ... on a vector space U , which
 determines vector bundles E and E' over G/L and G/H
 A cross section Ψ of ... E' over G/H is an eigenvector of each Casimir operator of
 $U(G)$ its transform Ψ^* , considered as a function on G/K , is also an
 eigenfunction of each Casimir operator of $U(G)$”.

Rutwig Campoamor-Stursberg in “Contractions of Exceptional Lie Algebras and
 SemiDirect Products” (Acta Physica Polonica B 41 (2010) 53-77) said:
 “... it is of interest to analyze whether ... semidirect products ... of semisimple and
 Heisenberg Lie algebras ... appear as contractions of semisimple Lie algebras ...
 Let s be a ... semisimple Lie algebra. For the indecomposable semidirect product
 $\mathfrak{g} = s + \mathfrak{h}_N$ the number of Casimir operators is given by $N(\mathfrak{g}) = \text{rank}(s) + 1$
 ... In some sense, the Levi subalgebra s determines these Casimir invariants,
 to which the central charge (the generator of the centre of the Heisenberg algebra)
 is added. ... the quadratic Casimir operator will always contract onto the square of
 the centre generator of the Heisenberg algebra ...
 ... We have classified all contractions of complex simple exceptional Lie algebras
 onto semidirect products ... $s + \mathfrak{h}_N$... of semisimple and Heisenberg algebras.
 An analogous procedure holds for the real forms of the exceptional algebras ...
 Contractions of E_8 ... E_8 contains D_8 contains A_7 ... [and for E_8]... $N = 92$
 ... This reduction gives rise to the contraction ... [E_8 to $A_7 + \mathfrak{h}_{92}$]...
 E_8 ... has primitive Casimir operators ... of degrees ... [2,8,12,14,18,20,24,30]...
 D_8 ... has primitive Casimir operators ... of degrees ... [2,4,6,8,10,12,14,8]...
 A_7 ... has primitive Casimir operators ... of degrees ... [2,3,4,5,6,7,8]...”.

The E8 primitive Casimirs 2, 8, 12, 14, 18, 20, 24, 30 contract as follows:

2 to the center U(1) of H92.

8, 12, 14 to the 8, 12, 14 of D8 and to the $4=8/2$, $6=12/2$, $7=14/2$ of A7

18, 20, 24, 30 to the $4=18-14$, $6=20-14$, $10=24-14$, $8=(1/2)(30-14)$ of D8
and to the $2=4/2$, $3=6/2$, $5=10/2$, 8 of A7

The 2, 8, 12, 14 of E8 are dual to the 30, 24, 20, 18 of E8 such that

$$2+30 = 8+24 = 12+20 = 14+18 = 32.$$

The E8 primitive Casimirs correspond to the Cartan subalgebras of E8 and of D8
and also to 8-dim Spacetime and 4+4-dim Batakis Kaluza-Klein M4 x CP2

**The 2, 8, 12, 14 Casimirs of E8 correspond to
the (1+3)-dim M4 Batakis Physical Spacetime**

**The 18, 20, 24, 30 Casimirs of E8 correspond to
the 4-dim CP2 Batakis Internal Symmetry Space**

Weyl Symmetric Polynomial Degrees and Topological Types:

E8:

degrees - 2, 8, 12, 14, 18, 20, 24, 30

note that 1, 7, 11, 13, 17, 19, 23, and 29 are all relatively prime to 30

type - 3, 15, 23, 27, 35, 39, 47, 59; center = $Z_1 = 1 =$ trivial

D8 Spin(16):

degrees - 2, 4, 6, 8, 10, 12, 14, 8

type - 3, 7, 11, 15, 19, 23, 27, 15; center = $Z_2 + Z_2$

A7 SU(8):

degrees - 2, 3, 4, 5, 6, 7, 8

type - 3, 5, 7, 9, 11, 13, 15; center = Z_8

Luis J. Boya has written a beautiful paper “Problems in Lie Group Theory” math-ph/0212067 and here are a few of the interesting things he says:

“... Given a Lie group in a series $G(n)$... how is the group $G(n+1)$ constructed?

For the **orthogonal series (Bn and Dn)** ... given $O(n)$ acting on itself, that is, the adjoint (adj) representation, and the vector representation, n , ...

Adj $O(n)$ + Vect $O(n)$ \rightarrow Adj $O(n+1)$...

For the unitary series $SU(n)$... **Adj $SU(n)$ + Id + n + n^* = Adj $SU(n+1)$...**

For the symplectic series

Sp(n) = C_n ... Adj Sp(n) + Adj Sp(1) + 2(n + n^*) = Adj Sp($n+1$) ...

For **G_2** ... **Adj $SU(3)$ + n + n^* \rightarrow G_2 ...** [in addition, I conjecture the existence of an alternate construction: **Adj $O(4)$ + Vect $O(4)$ + Spin $O(4)$ = G_2 ,** where Spin $O(4)$ is its Spin representation, a notation that I will continue to use in the rest of this quotation instead of the notation Spin(4) that Boya uses, because I want to reserve the notation Spin(4) for the covering group of $SO(4)$. Note that Spin $O(n)$ for even n is reducible to two copies of mirror image half-spinor representations half-Spin $O(n)$]...

For the **exceptional groups, the F4 & E series** ...

- **Adj $SO(9)$ + Spin $O(9)$ \rightarrow Adj F_4 (36+16=52)**
- **Adj $SO(10)$ + Spin $O(10)$ + Id \rightarrow Adj E_6 (45+32+1=78)**
- **Adj $SO(12)$ + Spin $O(12)$ + Sp(1) \rightarrow Adj E_7 (66+64+3=133)**
- **Adj $SO(16)$ + [half-]Spin $O(16)$ \rightarrow Adj E_8 ([120+128=248])**

Notice that 8+1 , 8+2 , 8+4 , and 8+8 appear. In this sense the octonions appear as a "second coming " of the reals, completed with the spin, not the vector irrep. ...

This confirms that the F_4 E_6 -7-8 corresponds to

the octo, octo-complex, octo-quater and octo-octo birings, as the Freudenthal Magic Square confirms. ...

Another ... question ... is the geometry associated to the exceptional groups ...

Are we happy with G_2 as the automorphism group of the octonions, F_4 as the isometry of the [octonion] projective plane, E_6 (in a noncompact form) as the collineations of the same, and E_7 resp. E_8 as examples of symplectic resp. metasymplectic geometries? ... one would like to understand the exceptional groups ... as automorphism groups of some natural geometric objects. ...

The gross topology of Lie groups is well-known. The non-compact case reduces to compact times an euclidean space (Malcev-Iwasawa). The compact case is reduced to a finite factor, a Torus, and a semisimple compact Lie group.

H. Hopf determined in 1941 that the real homology of simple compact Lie groups is that of a product of odd spheres ...

The exponents of a Lie group are the numbers i such that $S(2i+1)$ is an allowed sphere ...

neither the U-series nor the Sp-series have torsion.

The exponents ... for $U(n)$... are $0, 1, \dots, n-1$... and jump by two in $Sp(n)$.

But for the orthogonal series one has to consider some Stiefel manifolds instead of spheres, which have the same real homology ...

It ... introduces (preciesely) 2-torsion:

in fact, $Spin(n)$, $n \geq 7$ and $SO(n)$, $n \geq 3$, have 2-torsion.

The low cases $Spin(3,4,5,6)$ coincide

with $Sp(1)$, $Sp(1) \times Sp(1)$, $Sp(2)$ and $SU(4)$, and have no torsion.

For ... G_2 ... $SU(2) \rightarrow G_2 \rightarrow M_{11}$... where M_{11} is again a Steifel manifold, with real homology like S_{11} , but with 2-torsion ...

For F_4 we do not get the sphere structure from any irrep, and in fact F_4 has 2- and 3-torsion. ...

2- and 3-torsion appears in ... E_6 and E_7 ...

E_8 has 2-, 3- and 5-torsion ...

The Coxeter number of (dim - rank) of E_8 is $30 = 2 \times 3 \times 5$,

in fact a mnemonic for the exponents of E_8 is:

they are the coprimes up to 30, namely $(1,7,11,13,17,19,23,29)$...

The first perfect numbers are 6, 28, and 492,

associated to the primes 2, 3 and 5 (... Mersenne numbers ...) ...

$496 = \dim O(32) = \dim E(8) \times E(8)$. Why the square?

It also happens in $O(4)$, $\dim = 6$ (prime 2), as $O(4)$...[is like]... $O(3) \times O(3)$; even $O(8)$ [$\dim = 28$] (prime 3) is like $S_7 \times S_7 \times G_2$...

The sphere structure of compact simple Lie groups has a curious "capicua" ... Catalan word (cap i cua 0 = head and tail) ... form: the exponents are symmetric from each end; for example ...

exponents of E6: 1,4,5,7,8,11. Differences: 3,1,2,1,3

exponents of E7: 1,5,7,9,11,13,17. Differences: 4,2,2,2,2,4 ...

exponents of E8 ... 1,7,11,13,17,19,23,29 ... [Differences 6,4,2,4,2,4,6]...

The real homology algebra of a simple Lie group is a Grassmann algebra, as it is generated by odd (i.e., anticommutative) elements. However, from them we can get, in the enveloping algebra, multilinear symmetric forms, one for each generator; ... in physics they are called Casimir invariants, in mathematics the invariants of the Weyl group ...".

Martin Cederwall and Jakob Palmkvist, in "The octic E8 invariant" hep-th/0702024, say:

"... The largest of the finite-dimensional exceptional Lie groups, E8, with Lie algebra e8, is an interesting object ... its root lattice is the unique even self-dual lattice in eight dimensions (in euclidean space, even self-dual lattices only exist in dimension 8n). ... Because of self-duality, there is only one conjugacy class of representations, the weight lattice equals the root lattice, and there is no "fundamental" representation smaller than the adjoint. ...

Anything resembling a tensor formalism is completely lacking. A basic ingredient in a tensor calculus is a set of invariant tensors, or "Clebsch-Gordan coefficients". The only invariant tensors that are known explicitly for E8 are the Killing metric and the structure constants ...

The goal of this paper is to take a first step towards a tensor formalism for E8 by explicitly constructing an invariant tensor with eight symmetric adjoint indices. ...

On the mathematical side, the disturbing absence of a concrete expression for this tensor is unique among the finite-dimensional Lie groups. Even for the smaller exceptional algebras g2, f4, e6 and e7, all invariant tensors are accessible in explicit forms, due to the existence of "fundamental" representations smaller than the adjoint and to the connections with octonions and Jordan algebras. ...

The orders of Casimir invariants are known for all finite-dimensional semi-simple Lie algebras. They are polynomials in $U(\mathfrak{g})$, the universal enveloping algebra of \mathfrak{g} , of the form $t(A_1 \dots A_k) T^{(A_1 \dots A_k)}$, where t is a symmetric invariant tensor and T are generators of the algebra, and they generate the center $U(\mathfrak{g})^{\mathfrak{g}}$ of $U(\mathfrak{g})$.

The Harish-Chandra homomorphism is the restriction of an element in $U(\mathfrak{g})^{\mathfrak{g}}$ to a polynomial in the Cartan subalgebra \mathfrak{h} , which will be invariant under the Weyl group $W(\mathfrak{g})$ of \mathfrak{g} .

Due to the fact that the Harish-Chandra homomorphism is an isomorphism from $U(\mathfrak{g})^{\mathfrak{g}}$ to $U(\mathfrak{h})^{W(\mathfrak{g})}$ one may equivalently consider finding a basis of generators for the latter, a much easier problem. The orders of the invariants follow more or less directly from a diagonalisation of the Coxeter element, the product of the simple Weyl reflections ...

In the case of e_8 , the center $U(e_8)^{e_8}$ of the universal enveloping subalgebra is generated by elements of orders 2, 8, 12, 14, 18, 20, 24 and 30. The quadratic and octic invariants correspond to primitive invariant tensors in terms of which the higher ones should be expressible. ... the explicit form of the octic invariant is previously not known ...

E_8 has a number of maximal subgroups, but one of them, $Spin(16)/Z_2$, is natural for several reasons. Considering calculational complexity, this is the subgroup that leads to the smallest number of terms in the Ansatz.

Considering the connection to the Harish-Chandra homomorphism, $K = Spin(16)/Z_2$ is the maximal compact subgroup of the split form $G = E_8(8)$.

The Weyl group is a discrete subgroup of K , and the Cartan subalgebra \mathfrak{h} lies entirely in the coset directions $\mathfrak{g}/\mathfrak{k}$...

We thus consider the decomposition of the adjoint representation of E_8 into representations of the maximal subgroup $Spin(16)/Z_2$.

The adjoint decomposes into the adjoint 120 and a chiral spinor 128. ...

Our convention for chirality is $\text{GAMMA}_{(a_1 \dots a_{16})} \text{PHI} = + e_{(a_1 \dots a_{16})} \text{PHI}$.

The e8 algebra becomes (2.1)

$$\begin{aligned} [T^{(ab)} , T^{(cd)}] &= 2 \delta^{([a}_{(c} T^{(b)]}_{(d)}] , \\ [T^{(ab)} , \text{PHI}^{(\alpha)}] &= (1/4) (\text{GAMMA}^{(ab)} \text{PHI})^{(\alpha)} , \\ [\text{PHI}^{(\alpha)} , \text{PHI}^{(\alpha)}] &= (1/8) (\text{GAMMA}_{(ab)})^{(\alpha \beta)} T^{(ab)} , \end{aligned}$$

... The coefficients in the first and second commutators are related by the so(16) algebra. The normalisation of the last commutator is free, but is fixed by the choice for the quadratic invariant, which for the case above is

$$X_2 = (1/2) T_{(ab)} T^{(ab)} + \text{PHI}_{(\alpha)} \text{PHI}^{(\alpha)} .$$

Spinor and vector indices are raised and lowered with delta .
Equation (2.1) describes the compact real form, E8(-248) .

By letting $\text{PHI} \rightarrow i \text{PHI}$ one gets E8(8),
where the spinor generators are non-compact,
which is the real form relevant as duality symmetry in three dimensions
(other real forms contain a non-compact Spin(16)/Z2 subgroup).

The Jacobi identities are satisfied thanks to the Fierz identity

$$(\text{GAMMA}_{(ab)})_{[(\alpha \beta)} (\text{GAMMA}_{(ab)})_{(\alpha \beta)}] = 0 ,$$

which is satisfied for so(8) with chiral spinors, so(9), and so(16) with chiral spinors
(in the former cases the algebras are so(9), due to triality, and f4).

The Harish-Chandra homomorphism tells us that the "heart" of the invariant lies in an octic Weyl-invariant of the Cartan subalgebra.

A first step may be to lift it to a unique Spin(16)/Z2-invariant in the spinor, corresponding to applying the isomorphism f4|1 above.

It is gratifying to verify ... that there is indeed an octic invariant
(other than (PHI PHI)^4), and that no such invariant exists at lower order. ...

Forming an element of an irreducible representation containing a number of spinors involves symmetrisations and subtraction of traces, which can be rather complicated. This becomes even more pronounced when we are dealing with transformation ... under the spinor generators, which will transform as spinors.

Then irreducibility also involves gamma-trace conditions. ... The transformation ... under the action of the spinorial generator is an so(16) spinor. The vanishing of this spinor is equivalent to e8 invariance. The spinorial generator acts similarly to a supersymmetry generator on a superfield ... The final result for the octic invariant is, up to an overall multiplicative constant:

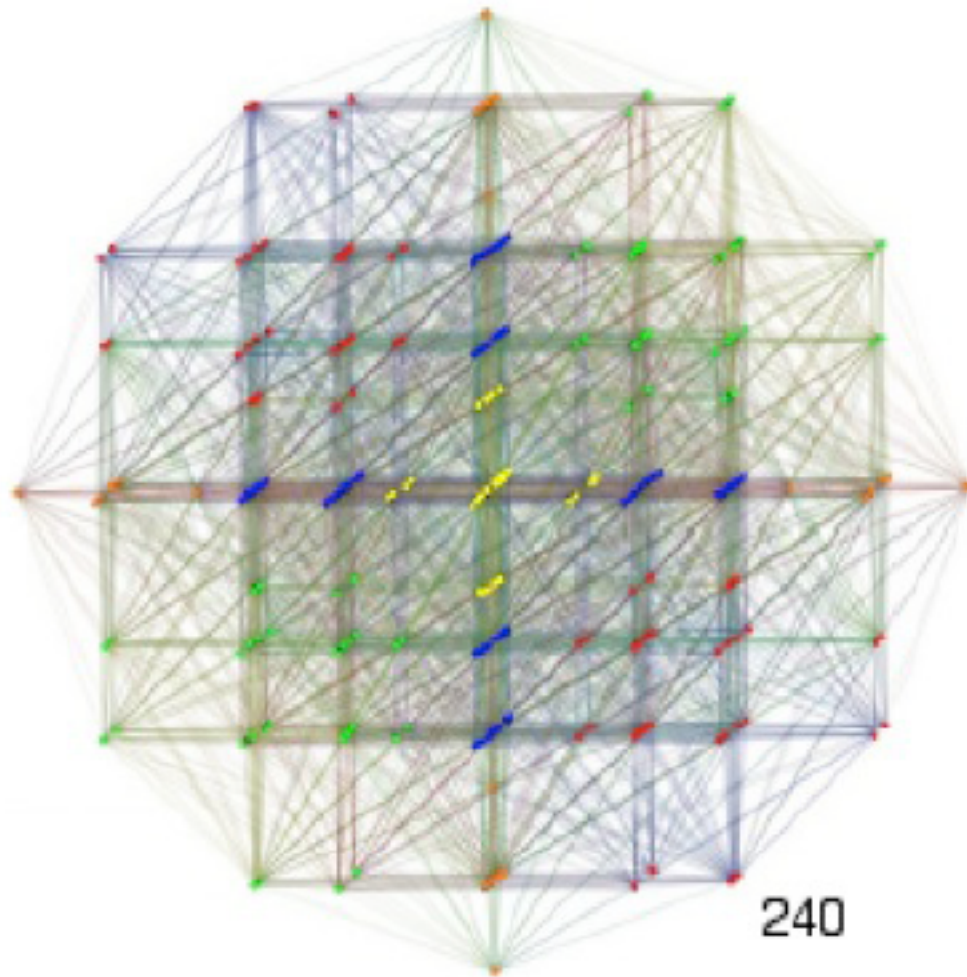
$$\begin{aligned}
X_8 = & \frac{1}{3072} \varepsilon^{a_1 \dots a_{16}} T_{a_1 a_2} \dots T_{a_{15} a_{16}} \\
& - 30 \text{tr} T^8 + 14 \text{tr} T^6 \text{tr} T^2 + \frac{35}{4} (\text{tr} T^4)^2 - \frac{35}{8} \text{tr} T^4 (\text{tr} T^2)^2 + \frac{15}{64} (\text{tr} T^2)^4 \\
& + [2 \text{tr} T^6 - \text{tr} T^4 \text{tr} T^2 + \frac{1}{8} (\text{tr} T^2)^3] (\phi \phi) \\
& + [(\frac{5}{4} \text{tr} T^4 - \frac{1}{2} (\text{tr} T^2)^2) T^{ab} T^{cd} + \frac{27}{4} \text{tr} T^2 T^{ab} (T^3)^{cd} \\
& \quad - 15 T^{ab} (T^5)^{cd} - 15 (T^3)^{ab} (T^3)^{cd}] (\phi \Gamma_{abcd} \phi) \\
& + [\frac{1}{16} \text{tr} T^2 T^{ab} T^{cd} T^{ef} T^{gh} - \frac{5}{8} T^{ab} T^{cd} T^{ef} (T^3)^{gh}] (\phi \Gamma_{abcdefgh} \phi) \\
& - \frac{1}{192} T^{ab} T^{cd} T^{ef} T^{gh} T^{ij} T^{kl} (\phi \Gamma_{abcdefghijkl} \phi) \\
& + [7 \text{tr} T^4 - \frac{31}{8} (\text{tr} T^2)^2] (\phi \phi)^2 \\
& - \frac{3}{64} T^{ab} T^{cd} T^{ef} T^{gh} (\phi \phi) (\phi \Gamma_{abcdefgh} \phi) \\
& + [\frac{5}{64} T^{ab} T^{cd} T^{ef} T^{gh} - \frac{15}{16} T^{ab} T^{ce} T^{df} T^{gh} \\
& \quad + \frac{5}{8} T^{ae} T^{bf} T^{cg} T^{dh}] (\phi \Gamma_{abcd} \phi) (\phi \Gamma_{efgh} \phi) \\
& + [\frac{3}{2} (T^3)^{ab} T^{cd} - \frac{1}{8} \text{tr} T^2 T^{ab} T^{cd}] (\phi \phi) (\phi \Gamma_{abcd} \phi) \\
& + [\frac{15}{16} (T^3)^{ab} T^{cd} - \frac{3}{16} \text{tr} T^2 T^{ab} T^{cd} + \frac{5}{4} (T^2)^{ac} (T^2)^{bd}] (\phi \Gamma_{ab}{}^{ij} \phi) (\phi \Gamma_{cdij} \phi) \\
& + \frac{15}{8} T^{ab} T^{cd} (T^2)^{ef} (\phi \Gamma_{abc}{}^i \phi) (\phi \Gamma_{cdfi} \phi) \\
& + \frac{1}{2} \text{tr} T^2 (\phi \phi)^3 + \frac{55}{32} T^{ab} T^{cd} (\phi \phi)^2 (\phi \Gamma_{abcd} \phi) \\
& + \frac{1}{8} T^{ab} T^{cd} (\phi \phi) (\phi \Gamma_{ab}{}^{ij} \phi) (\phi \Gamma_{cdij} \phi) \\
& + [-\frac{1}{384} T^{ab} T^{cd} + \frac{7}{192} T^{ac} T^{bd}] (\phi \Gamma_{ab}{}^{ij} \phi) (\phi \Gamma_{cd}{}^{kl} \phi) (\phi \Gamma_{ijkl} \phi) \\
& - \frac{57}{32} (\phi \phi)^4 + \frac{1}{12288} (\phi \Gamma_{ab}{}^{cd} \phi) (\phi \Gamma_{cd}{}^{ef} \phi) (\phi \Gamma_{ef}{}^{gh} \phi) (\phi \Gamma_{gh}{}^{ab} \phi) \\
& + \beta [-\frac{1}{2} \text{tr} T^2 + (\phi \phi)]^4 .
\end{aligned} \tag{2.3}$$

Here, β is an arbitrary constant multiplying the fourth power of the quadratic invariant. The trace vanishes for $\beta = \frac{9}{127}$ (that such a value exists at all is non-trivial and provides a further check on the coefficients). The occurrence of the prime 127 is not incidental; taking the trace of $\delta^{(AB} \delta^{CD} \delta^{EF} \delta^{GH)}$ gives $\delta_{GH} \delta^{(AB} \delta^{CD} \delta^{EF} \delta^{GH)} = (\frac{1}{7} \cdot 248 + \frac{6}{7}) \delta^{(AB} \delta^{CD} \delta^{EF)} = \frac{2 \cdot 127}{7} \delta^{(AB} \delta^{CD} \delta^{EF)}$. The actual technique we use for calculating the trace is not to extract the eight-index tensor, but to act on the invariant with $\frac{1}{2} \frac{\partial}{\partial T^{ab}} \frac{\partial}{\partial T^{ac}} + \frac{\partial}{\partial \phi_a} \frac{\partial}{\partial \phi^a}$. We remind that eq. (2.3) gives the octic invariant for the compact form $E_{8(-248)}$. The corresponding expression for the split form $E_{8(8)}$ is obtained by a sign change of the terms containing ϕ^{4k+2} .

... ”

E8 Root Vector Physical Interpretations

Here is an explicit enumeration of the E8 Root Vector vertices with coordinates for a specific E8 lattice and my physical interpretation of each with illustrations using a cube-type projection of the 240 E8 Root Vector vertices:



E8 248 generators: 240 Root Vectors + 8 in Cartan Subalgebra

220 generators are used to construct a CG + SM Lagrangian
CG = Conformal Gravity $U(2,2)$ SM = Standard Model $SU(3) \times U(2)$.

All 248 = 28 + 220 are used to construct a Quantum Heisenberg-type algebra that arises from the maximal contraction of E8:

$$E8 \rightarrow SL(8) + \mathfrak{h}_{92}$$

$SL(8)$ is 63-dimensional and \mathfrak{h}_{92} is $92+1+92 = 185$ -dimensional.

First 92: 64 fermion particle + 16 CG + 12 \mathfrak{h}_{92} DualSM

Dual 92: 64 fermion antiparticle + 12 SM + 16 \mathfrak{h}_{92} DualCG

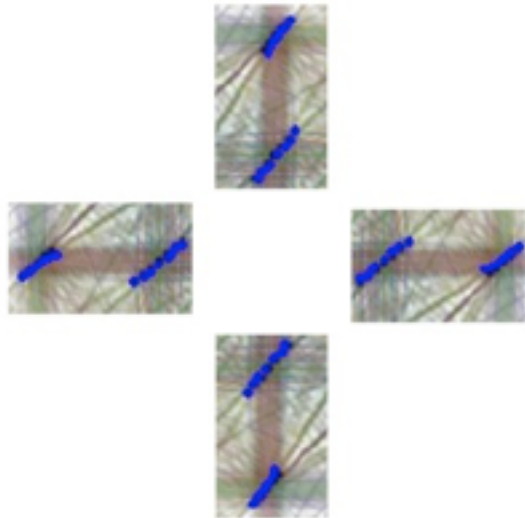
$\pm l, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

$(\pm l \pm i \quad \quad \quad \pm e \pm ie \quad \quad \quad)/2$

$(\pm l \quad \pm j \quad \quad \quad \pm e \quad \quad \quad \pm je \quad \quad \quad)/2$

$(\pm l \quad \quad \quad \pm k \pm e \quad \quad \quad \pm ke \quad \quad \quad)/2$

The 64 correspond to 8 position x 8 momentum coordinates
 in a $4+4 = 8$ -dim Kaluza-Klein spacetime
 with 4-dim Minkowski physical spacetime
 plus 4-dim Internal Symmetry Space



Fermion Particles
(first generation)

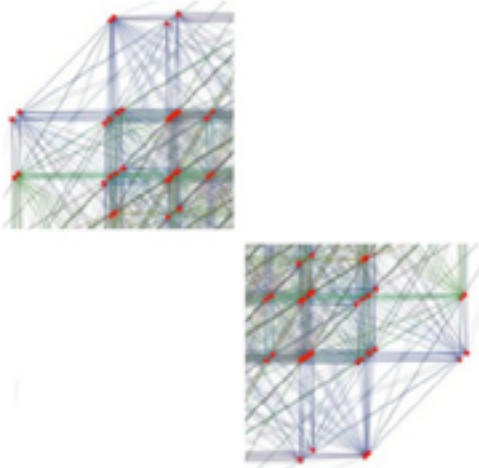
64 of the 248

$(-1 \quad \quad \quad \pm i e \quad \pm j e \quad \pm k e) / 2$	electron	8 components
$(-1 \quad \pm j \quad \pm k \quad \pm i e \quad \quad \quad) / 2$	red up quark	8 components
$(-1 \quad \pm i \quad \quad \pm k \quad \quad \quad \pm j e \quad \quad) / 2$	green up quark	8 components
$(-1 \quad \pm i \quad \pm j \quad \quad \quad \quad \quad \pm k e) / 2$	blue up quark	8 components
$(\quad \pm i \quad \pm j \quad \pm k \quad -e \quad \quad \quad) / 2$	neutrino	8 components
$(\quad \pm i \quad \quad \quad -e \quad \quad \quad \pm j e \quad \pm k e) / 2$	red down quark	8 components
$(\quad \quad \quad \pm j \quad \quad \quad -e \quad \pm i e \quad \quad \pm k e) / 2$	green down quark	8 components
$(\quad \quad \quad \quad \quad \pm k \quad -e \quad \pm i e \quad \pm j e \quad \quad) / 2$	blue down quark	8 components

The 64 correspond to 8 spacetime components of 8 fundamental fermion particles. The 8 components of each fermion are determined by the signs of the i/ie and j/je and k/ke as follows:

+++	1-component	---	e-component
++-	i-component	--+	ie-component
+--	j-component	-+-	je-component
-++	k-component	+--	ke-component

All fermion particles are fundamentally left-handed. Right-handed states only emerge due to massive states moving slower than the speed of light. Second and third generations of fermions emerge dynamically from the splitting of 8-dim Octonion spacetime into $4+4 = 8$ -dim Kaluza-Klein.



Fermion AntiParticles
(first generation)

64 of the 248

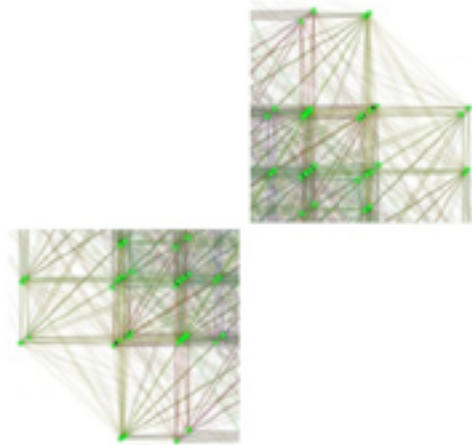
```
(-1      ±ie ±je ±ke )/2 positron      8 components
(-1  ±j ±k  ±ie      )/2 red up antiquark  8 components
(-1 ±i  ±k      ±je      )/2 green up antiquark  8 components
(-1 ±i ±j      ±ke )/2 blue up antiquark  8 components

(  ±i ±j ±k -e      )/2 antineutrino      8 components
(  ±i      -e  ±je ±ke )/2 red down antiquark  8 components
(      ±j      -e ±ie  ±ke )/2 green down antiquark  8 components
(      ±k -e ±ie ±je      )/2 blue down antiquark  8 components
```

The 64 correspond to 8 spacetime components of 8 fundamental fermion antiparticles. The 8 components of each fermion are determined by the signs of the i/ie and j/je and k/ke as follows:

+++	1-component	---	e-component
++-	i-component	--+	ie-component
+--	j-component	-+-	je-component
-++	k-component	+--	ke-component

All fermion particles are fundamentally left-handed. Right-handed states only emerge due to massive states moving slower than the speed of light. Second and third generations of fermions emerge dynamically from the splitting of 8-dim Octonion spacetime into 4+4 = 8-dim Kaluza-Klein.



16 Standard Model Root Vector Generators:

```
(  +i +j      +ie +je      )/2  W+ boson

(  +i +j      +ie -je      )/2  h92DualW+
(  +i +j      -ie +je      )/2  h92DualGlrG
(  +i -j      +ie +je      )/2  h92DualGlcM
(  -i +j      +ie +je      )/2  h92DualGlgM

(  +i +j      -ie -je      )/2  gluon_rg
(  -i -j      +ie +je      )/2  gluon_cm
(  +i -j      +ie -je      )/2  gluon_gb
(  -i +j      -ie +je      )/2  gluon_my
(  +i -j      -ie +je      )/2  gluon_br
(  -i +j      +ie -je      )/2  gluon_yc

(  -i -j      -ie +je      )/2  h92DualW-
(  -i -j      +ie -je      )/2  h92DualGlmy
(  -i +j      -ie -je      )/2  h92DualGlbr
(  +i -j      -ie -je      )/2  h92DualGlyc

(  -i -j      -ie -je      )/2  W- boson
```

4 Cartan = gamma and W0 and gluon_rgb and gluon_cmy
(note that gamma + W0 give photon + Z0)

The 8 (yellow) root vectors for W+ and W- and 6 gluons
are within the central (yellow) 24 of one D4 (D4SM) in E8.

The 8 (orange) root vectors for fermion connectors
are within the outer (orange) 24 of the other D4 (D4G) in E8.

The 16 (orange) root vectors for 4 Higgs and 12 Gravity bosons
are within the outer (orange) 24 of D4G in E8.

The 16 (yellow) root vectors for position/momentum connectors
are within the inner (yellow) 24 of D4SM in E8.

The 12 Standard Model generators live in the D4SM of E8
with 4 of the 8 Cartan Subalgebra elements of D8.
D4SM has an A3 = SU(4) subalgebra that contains color SU(3).

The 12 Standard Model generators live in the D4SM of E8
with 4 of the 8 Cartan Subalgebra elements of D8.
D4G has a Conformal A3=SU(2,2)=Spin(2,4) subalgebra.

32 Conformal MacDowell-Mansouri Gravity Root Vector generators:

```

(      +j +k      +je +ke )/2  h92Dualgamma
(      +j +k      +je -ke )/2  h92DualC1
(      +j +k      -je +ke )/2  h92DualCi
(      +j -k      +je +ke )/2  h92DualCj
(      -j +k      +je -+e )/2  h92DualCk
(      +j +k      -je -ke )/2  conformal_rxy
(      -j -k      +je +ke )/2  conformal_rxz
(      +j -k      +je -ke )/2  conformal_l
(      -j +k      -je +ke )/2  conformal_i
(      +j -k      -je +ke )/2  conformal_j
(      -j +k      +je -ke )/2  conformal_k
(      -j -k      -je +ke )/2  h92DualCrxy
(      -j -k      +je -ke )/2  h92DualCrxz
(      -j +k      -je -ke )/2  h92DualCryz
(      +j -k      -je -ke )/2  h92DualCd
(      -j -k      -je -ke )/2  h92DualW0

(      +i  +k      +ie   +ke )/2  h92DualGlr gb
(      +i  +k      +ie   -ke )/2  h92DualCe
(      +i  +k      -ie   +ke )/2  h92DualCie
(      +i  -k      +ie   +ke )/2  h92DualCje
(      -i  +k      +ie   +ke )/2  h92DualCke
(      +i  +k      -ie   -ke )/2  conformal_btx
(      -i  -k      +ie   +ke )/2  conformal_bty
(      +i  -k      +ie   -ke )/2  conformal_e
(      -i  +k      -ie   +ke )/2  conformal_ie
(      +i  -k      -ie   +ke )/2  conformal_je
(      -i  +k      +ie   -ke )/2  conformal_ke
(      -i  -k      -ie   +ke )/2  h92DualCbtx
(      -i  -k      +ie   -ke )/2  h92DualCbty
(      -i  +k      -ie   -ke )/2  h92DualCbtz
(      +i  -k      -ie   -ke )/2  h92DualPrPh
(      -i  -k      -ie   -ke )/2  h92Dualcmy

```

4 Cartan = conformal_ryz and conformal_btz and conformal_d
and 1 Propagator Phase

Here are how the 48 Standard Model + Gravity Root Vectors
appear with respect to decomposition into D4SM + D4G:

24 Standard Model Root Vector Generators of D4SM:

```

(   +i +j      +ie +je      )/2  W+ boson

(   +j +k      +je -ke )/2  h92DualC1
(   +j +k      -je +ke )/2  h92DualCi
(   +j -k      +je +ke )/2  h92DualCj
(   -j +k      +je -e )/2  h92DualCk
(   -j -k      -je +ke )/2  h92DualCrxy
(   -j -k      +je -ke )/2  h92DualCrxz
(   -j +k      -je -ke )/2  h92DualCryz
(   +j -k      -je -ke )/2  h92DualCd

(   +i +j      -ie -je      )/2  gluon_rg
(   -i -j      +ie +je      )/2  gluon_cm
(   +i -j      +ie -je      )/2  gluon_gb
(   -i +j      -ie +je      )/2  gluon_my
(   +i -j      -ie +je      )/2  gluon_br
(   -i +j      +ie -je      )/2  gluon_yc

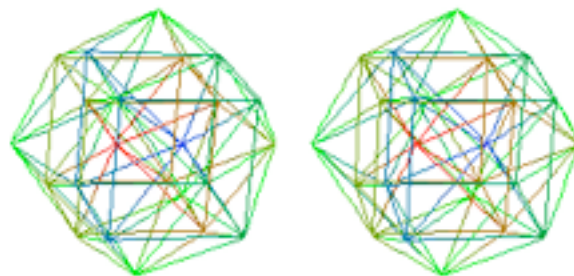
(   +i   +k   +ie   -ke )/2  h92DualCe
(   +i   +k   -ie   +ke )/2  h92DualCie
(   +i   -k   +ie   +ke )/2  h92DualCje
(   -i   +k   +ie   +ke )/2  h92DualCke
(   -i   -k   -ie   +ke )/2  h92DualCbtx
(   -i   -k   +ie   -ke )/2  h92DualCbty
(   -i   +k   -ie   -ke )/2  h92DualCbtz
(   +i   -k   -ie   -ke )/2  h92DualPrPh

(   -i -j      -ie -je      )/2  W- boson

```

4 Cartan = gamma and W0 and gluon_rgb and gluon_cmy
 (note that gamma + W0 give photon + Z0)

D4SM Root Vectors form a 24-cell with 1+8+6+8+1 structure
 (dual to D4G) of vertex + cube + octahedron + cube + vertex



24 Conformal Gravity Root Vector generators of D4G:

```

(      +j +k      +je +ke )/2  h92Dualgamma
(      +i  +k      +ie  +ke )/2  h92DualGlr gb
(      +i +j      +ie -je  )/2  h92DualW+
(      +i +j      -ie +je  )/2  h92DualGlr g
(      +i -j      +ie +je  )/2  h92DualGlr cm
(      -i +j      +ie +je  )/2  h92DualGlr gm

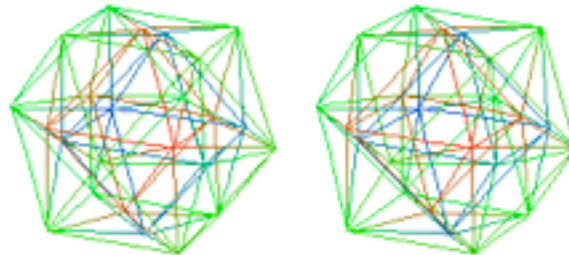
(      +j -k      +je -ke )/2  conformal_1
(      -j +k      -je +ke )/2  conformal_i
(      +j -k      -je +ke )/2  conformal_j
(      -j +k      +je -ke )/2  conformal_k
(      +j +k      -je -ke )/2  conformal_rxy
(      -j -k      +je +ke )/2  conformal_rxz
(      +i  +k      -ie  -ke )/2  conformal_btx
(      -i  -k      +ie  +ke )/2  conformal_bty
(      +i  -k      +ie  -ke )/2  conformal_e
(      -i  +k      -ie  +ke )/2  conformal_ie
(      +i  -k      -ie  +ke )/2  conformal_je
(      -i  +k      +ie  -ke )/2  conformal_ke

(      -i -j      -ie +je  )/2  h92DualW-
(      -i -j      +ie -je  )/2  h92DualGlr my
(      -i +j      -ie -je  )/2  h92DualGlr br
(      +i -j      -ie -je  )/2  h92DualGlr cy
(      -j -k      -je -ke )/2  h92DualW0
(      -i  -k      -ie  -ke )/2  h92DualGlr cmy

```

4 Cartan = conformal_ryz and conformal_btz and conformal_d
and 1 propagator phase

D4G Root Vectors form a 24-cell with 6+12+6 structure
(dual to D4SM) of octahedron + cuboctahedron + octahedron



h92Duals and Quantum Heisenberg Algebra

E8 Physics consists of two levels:

The first level is **Lagrangian Classical Action Structure** made up of:

Integration over 8-dim Spacetime - 64 E8 Root Vectors

$$\begin{aligned} & \pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke \\ & (\pm 1 \pm i \quad \quad \quad \pm e \pm ie \quad \quad \quad) / 2 \\ & (\pm 1 \quad \pm j \quad \quad \quad \pm e \quad \quad \pm je \quad \quad) / 2 \\ & (\pm 1 \quad \quad \pm k \pm e \quad \quad \quad \pm ke) / 2 \end{aligned}$$

of Dirac Fermion term - 128 E8 Root Vectors

(-1	\pm i	\pm j	\pm k	\pm e	\pm ie	\pm je	\pm ke	)/2		
									electron	8 components
									red up quark	8 components
									green up quark	8 components
									blue up quark	8 components
									neutrino	8 components
									red down quark	8 components
									green down quark	8 components
									blue down quark	8 components
									positron	8 components
									red up antiquark	8 components
									green up antiquark	8 components
									blue up antiquark	8 components
									antineutrino	8 components
									red down antiquark	8 components
									green down antiquark	8 components
									blue down antiquark	8 components

and

of Standard Model Gauge Boson term -

8 Root Vectors + 4 Cartan Subalgebra elements

$$\begin{aligned} & (\quad \quad \pm i \pm j \quad \quad \quad \pm ie \pm je \quad \quad \quad) / 2 \quad W^+ \text{ boson} \\ & (\quad \quad \pm i \pm j \quad \quad \quad -ie -je \quad \quad \quad) / 2 \quad \text{gluon}_{rg} \\ & (\quad \quad -i -j \quad \quad \quad \pm ie \pm je \quad \quad \quad) / 2 \quad \text{gluon}_{cm} \\ & (\quad \quad \pm i -j \quad \quad \quad \pm ie -je \quad \quad \quad) / 2 \quad \text{gluon}_{gb} \\ & (\quad \quad -i +j \quad \quad \quad -ie +je \quad \quad \quad) / 2 \quad \text{gluon}_{my} \\ & (\quad \quad \pm i -j \quad \quad \quad -ie +je \quad \quad \quad) / 2 \quad \text{gluon}_{br} \\ & (\quad \quad -i +j \quad \quad \quad \pm ie -je \quad \quad \quad) / 2 \quad \text{gluon}_{yc} \\ & (\quad \quad -i -j \quad \quad \quad -ie -je \quad \quad \quad) / 2 \quad W^- \text{ boson} \end{aligned}$$

and

of Conformal MacDowell-Mansouri Gravity term -

12 Root Vectors + 4 Cartan Subalgebra elements

(	+j	-k	+je	-ke	)/2	conformal_1
(	-j	+k	-je	+ke	)/2	conformal_i
(	+j	-k	-je	+ke	)/2	conformal_j
(	-j	+k	+je	-ke	)/2	conformal_k
(	+j	+k	-je	-ke	)/2	conformal_rxy
(	-j	-k	+je	+ke	)/2	conformal_rxz
(	+i	+k	-ie	-ke	)/2	conformal_btx
(	-i	-k	+ie	+ke	)/2	conformal_bty
(	+i	-k	+ie	-ke	)/2	conformal_e
(	-i	+k	-ie	+ke	)/2	conformal_ie
(	+i	-k	-ie	+ke	)/2	conformal_je
(	-i	+k	+ie	-ke	)/2	conformal_ke

The Lagrangian construction uses

64+128+8+4+12+4 = 220 generators of E8

(212 Root Vectors + 8 Cartan Subalgebra elements)

Although the Lagrangian gives nice Standard Model + Gravity physics results that can be compared with experiments (and so seen to be realistic)

it is fundamentally a Classical structure (General Relativity of an Einstein-Hilbert Action plus Standard Model Gauge Theory) with

Quantum phenomena by ad hoc Sum-Over-Histories Path Integrals.

Fundamental Quantum structure should appear as a natural Algebraic Quantum Field Theory

which can be derived from real Clifford Algebra periodicity and embedding of E8 in the real Cl(16) Clifford Algebra

to produce a generalized Hyperfinite III von Neumann factor AQFT that has the structure of a Quantum Heisenberg-type algebra that arises from the maximal contraction of E8:

$$E8 \rightarrow SL(8) + h_{92}$$

where SL(8) is 63-dimensional

and h₉₂ is 92+1+92 = 185-dimensional.

The 92 sets of creation/annihilation operators

act on the 64 components (in 8-dim spacetime) of 8 fermions plus 12 Standard Model bosons

plus 16 Conformal Gravity generators.

This second level **Heisenberg Algebra** Quantum structure is made up of

Position/Momentum Operators -

16 Root Vectors

(	+j	+k		+je	-ke	)/2	h92Dual	C1
(	+j	+k		-je	+ke	)/2	h92Dual	Ci
(	+j	-k		+je	+ke	)/2	h92Dual	Cj
(	-j	+k		+je	-ke	)/2	h92Dual	Ck
(	-j	-k		-je	+ke	)/2	h92Dual	Crxy
(	-j	-k		+je	-ke	)/2	h92Dual	Crxz
(	-j	+k		-je	-ke	)/2	h92Dual	Cryz
(	+j	-k		-je	-ke	)/2	h92Dual	Cd
(	+i	+k	+ie		-ke	)/2	h92Dual	Ce
(	+i	+k	-ie		+ke	)/2	h92Dual	Cie
(	+i	-k	+ie		+ke	)/2	h92Dual	Cje
(	-i	+k	+ie		+ke	)/2	h92Dual	Cke
(	-i	-k	-ie		+ke	)/2	h92Dual	Cbtx
(	-i	-k	+ie		-ke	)/2	h92Dual	Cbty
(	-i	+k	-ie		-ke	)/2	h92Dual	Cbtz
(	+i	-k	-ie		-ke	)/2	h92Dual	PrPh

and

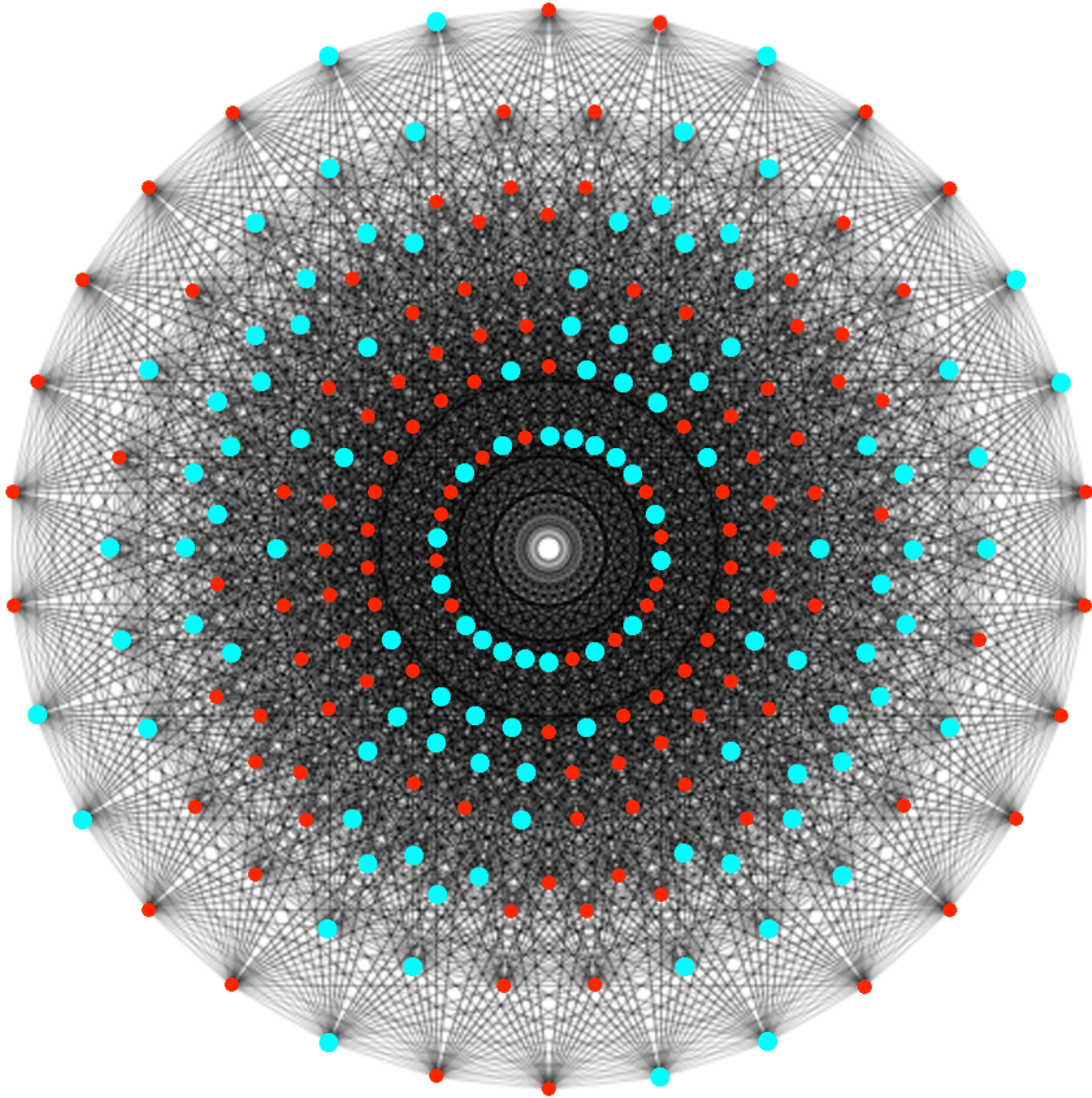
Creation Operators -

12 Root Vectors

(		+j	+k		+je	+ke	)/2	h92Dual	gamma
(	+i		+k	+ie		+ke	)/2	h92Dual	Glr gb
(	+i	+j		+ie	-je		)/2	h92Dual	W+
(	+i	+j		-ie	+je		)/2	h92Dual	Glr g
(	+i	-j		+ie	+je		)/2	h92Dual	Glc m
(	-i	+j		+ie	+je		)/2	h92Dual	Glg m
(	-i	-j		-ie	+je		)/2	h92Dual	W-
(	-i	-j		+ie	-je		)/2	h92Dual	Glm y
(	-i	+j		-ie	-je		)/2	h92Dual	Glb r
(	+i	-j		-ie	-je		)/2	h92Dual	Gly c
(		-j	-k		-je	-ke	)/2	h92Dual	W0
(	-i		-k	-ie		-ke	)/2	h92Dual	Glc my

The Heisenberg construction uses all 248 E8 generators including the 16+12 = 28 not used in Lagrangian construction.

The cube/square-type projection used above is not the only useful projection of the 240 E8 Root Vectors. Another is the projection to 8 circles each with 30 Root Vectors:



The image above adapted from the web site of David Madore at www.madore.org/~david/ shows in cyan the 112 root vectors of the D8 subalgebra of E8 that represent Spacetime, the Standard Model, and Gravity/Higgs and in red the 128 root vectors of the D8 half-spinor in E8 that represent first-generation fermion particles and antiparticles.

David Madore uses xhtml to show the E8 Root Vectors in a coordinate system which the 240 Root Vectors are "... at the (112) points having coordinates $(\pm 1, \pm 1, 0, 0, 0, 0, 0, 0)$ (where both signs can be chosen independently and the two non-zero coordinates can be anywhere) together with those having coordinates $(\pm 1/2, \pm 1/2, \pm 1/2, \pm 1/2, \pm 1/2, \pm 1/2, \pm 1/2, \pm 1/2)$ (where all signs can be chosen independently except that there must be an even number of minuses) ...".

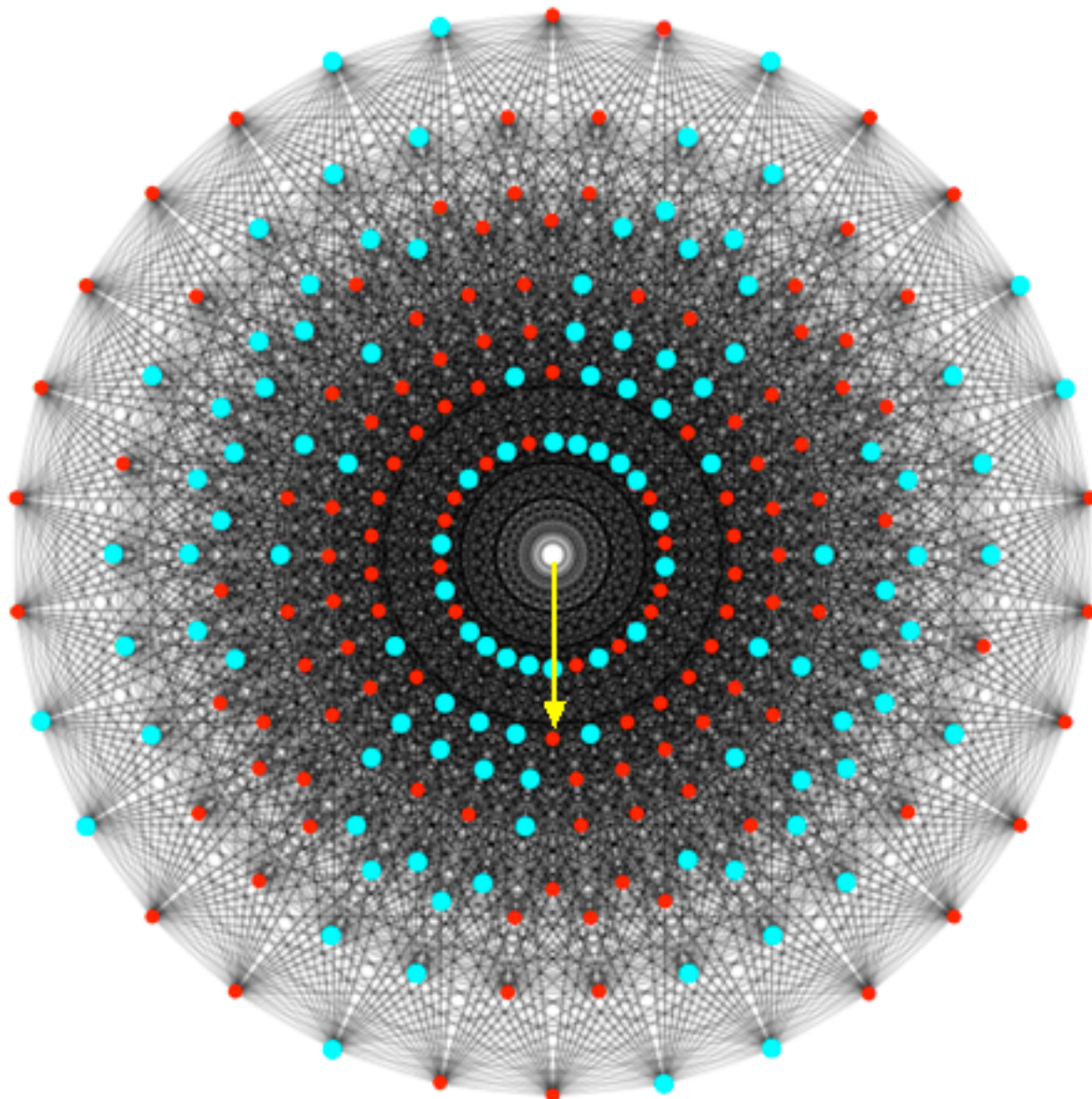
The relationship between David Madore's coordinates and the coordinates used in this paper is indicated by H. S. M. Coxeter in "Integral Cayley Numbers" (Duke Mathematical Journal, Vol. 13, No. 4, December 1946) reprinted in his book "The Beauty of Geometry: Twelve Essays" (1968, Dover edition 1999):

"... An alternative notation. In terms of the combinations
 $L_1 = (1/2)(1 + e)$
 $L_2 = (1/2)(i + ie)$
 $L_3 = (1/2)(j + je)$
 $L_4 = (1/2)(k + ke)$
 $L_5 = (1/2)(1 - e)$
 $L_6 = (1/2)(i - ie)$
 $L_7 = (1/2)(j - je)$
 $L_8 = (1/2)(k - ke)$
... all expressions of the form $\pm L_r \pm L_s$
.. and also $(1/2)(\pm L_1 \pm L_2 \pm L_3 \pm L_4 \pm L_5 \pm L_6 \pm L_7 \pm L_8)$
with any odd number of minus signs ...
with $r \neq s$... are the 112 + 128 units ...".

Note that
Coxeter chose the odd number of minus signs for the 128
while
David Madore the even number of minus signs for the 128.

A nice feature of David Madore's e8w.xhtml.html web page is that you can see by pointing the cursor at each point a lot of data including the coordinates of that point.

For example as shown in the following image, pointing the cursor over the point indicated by the yellow arrow shows the data set out below the Root Vector diagram:



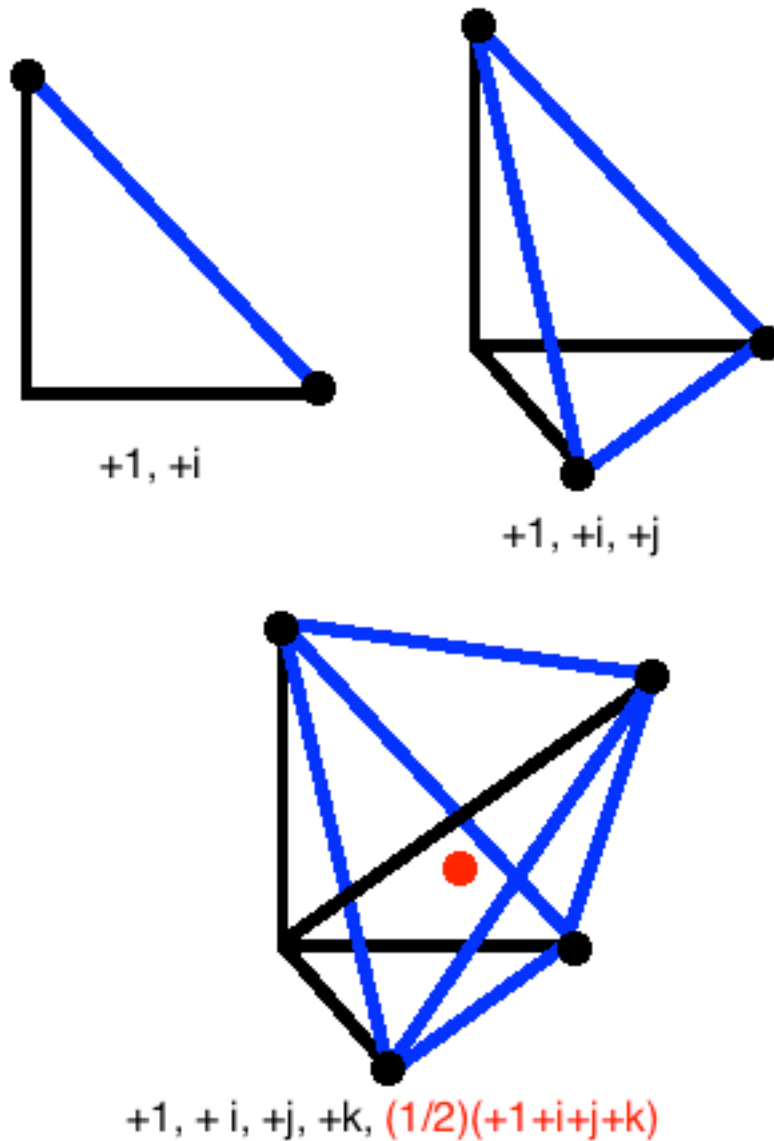
Position number 44,
 coordinates: $\frac{1}{2}(-1,-1,1,1,1,1,-1,-1)$,
 as FR: $\square-1,-1,-1,-1,-1,-1,-1,-1\square$,
 projected: $\square 0.00000,0.38547\square$.
 Occupied by root 44,
 coordinates: $\frac{1}{2}(-1,-1,1,1,1,1,-1,-1)$,
 as FR: $\square-1,-1,-1,-1,-1,-1,-1,-1\square$,
 projected: $\square 0.00000,0.38547\square$.
 Position \leftrightarrow occupied angle: 0.

You can calculate from the coordinates that
 the indicated Root Vector represents
 one of the 8 components of the red down antiquark.

Simplex Superpositions

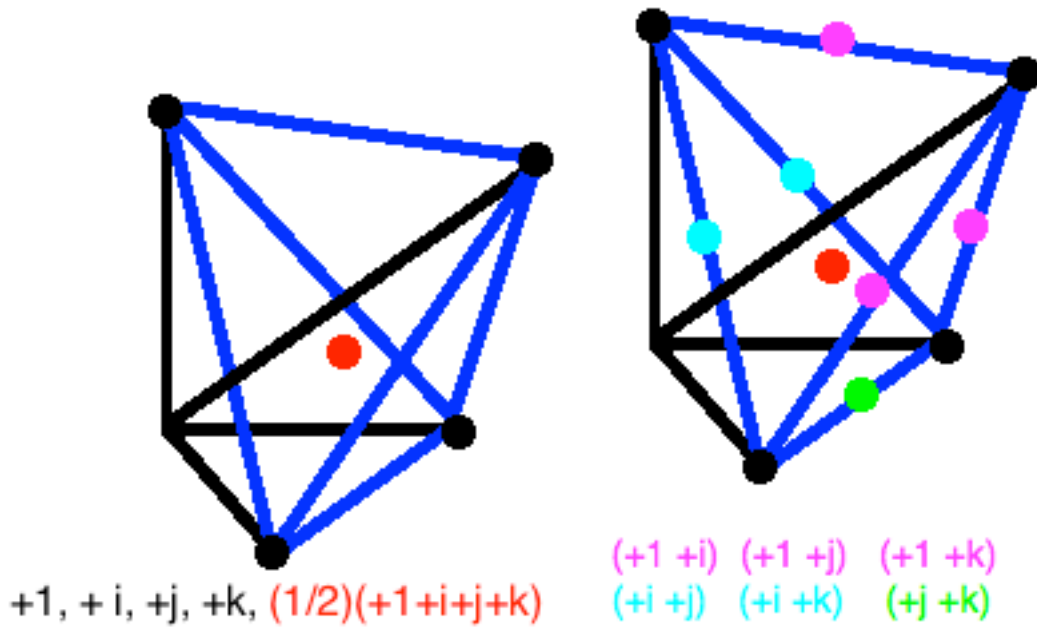
Frank Dodd (Tony) Smith, Jr. - 2012

In E8 Physics Quantum Creation and Annihilation Operators come from the Maximal Contraction of E8 (semi-direct product of $Sl(8)$ and H92 where H92 is a Heisenberg Algebra with graded structure $28+64+1+64+28$). Superpositions of Quantum Operators can be described: With square/cubic tilings of 2-space and 3-space, there is no Superposition Vertex that corresponds to Superposition of any of the Basis Vertex States.



Superposition Vertices begin at Quaternions and the 24-cell D4 tiling of 4-space.

A Dual 24-cell gives a new Superposition Vertex at each edge of the Simplex/Tetrahedron.



The Initial 24-cell Quantum Operators act with respect to 4-dim Physical Spacetime.

For example,

$(1/2)(+1+i+j+k)$ represents Creation of the 4-dimensional space of the $SU(2,2) = Spin(2,4)$ Conformal Group of Gravity of 4-dimensional Physical Spacetime with $\{1,i,j,k\}$ representing time and 3 space coordinates.

The Dual 24-cell Quantum Operators act with respect to 4-dim CP^2 Internal Symmetry Space.

For example, bearing in mind that $CP^2 = SU(3)/SU(2) \times U(1)$,

$(+1 +i) (+1 +j) (+1 +k)$ are permuted by S_3 to form the Weyl Group of the Color Force $SU(3)$,
 $(+i +j) (+i +k)$ are permuted by S_2 to form the Weyl Group of the Weak Force $SU(2)$,
 $(+j +k)$ is permuted by S_1 to form the Weyl Group of the Electromagnetic Force $U(1)$.

The 4+4 dimensional Kaluza-Klein structure of the Initial 24-cell plus the Dual 24-cell of 4-dim Physical Spacetime plus 4-dim CP^2 Internal Symmetry Space is inherited from the Octonionic 8-dimensional structure of E_8 lattices.

An Octonionic E_8 lattice structure has 8 representative 8-vertex Simplex Basis Vertices

$$+1, +i, +j, +k, +e, +ie, +je, +ke$$

plus 14 Superposition Vertices.

6 of the Superposition Vertices

$$\begin{array}{ll}
 (+1 +ke +e +k)/2 & (+i +j +ie +je)/2 \\
 (+1 +je +j +e)/2 & (+ie +ke +k +i)/2 \\
 (+1 +e +ie +i)/2 & (+ke +k +je +j)/2
 \end{array}$$

project to $(+1 +i) (+1 +j) (+1 +k) (+i +j) (+i +k) (+j +k)$ of CP2 Internal Symmetry Space.

8 of the Superposition Vertices

$$\begin{array}{ll}
 (+1 +ie +je +ke)/2 & (+e +i +j +k)/2 \\
 (+1 +k +i +je)/2 & (+j +ie +ke +e)/2 \\
 (+1 +i +ke +j)/2 & (+k +je +e +ie)/2 \\
 (+1 +j +k +ie)/2 & (+je +e +i +ke)/2
 \end{array}$$

project to $(1/2)(+1+i+j+k)$ of 4-dim Physical Spacetime.

When you consider all 7 of the E8 lattices, you get 8 additional Superposition Vertices

$$\begin{array}{ll}
 (+1 +i +j +k)/2 & (+e +ie +je +ke)/2 \\
 (+1 +i +je +ke)/2 & (+j +k +e +ie)/2 \\
 (+1 +j +ie +ke)/2 & (+i +k +e +je)/2 \\
 (+1 +k +ie +je)/2 & (+i +j +e +ke)/2
 \end{array}$$

that also project to $(1/2)(+1+i+j+k)$ of 4-dim Physical Spacetime,

and

the $8+8 = 16$ E8-type vertices represent the 16 generators of U(2,2)

which contains the Conformal Group $SU(2,2) = Spin(2,4)$.

As to the 8-vertex Simplex Basis Vertices

$$+1, +i, +j, +k, +e, +ie, +je, +ke$$

they represent Quantum Creation Operators for the 8 fundamental fermion particles

neutrino; red down quark, green down quark, blue down quark;

electron; red up quark, green up quark, blue up quark

or, equivalently by Triality,

for the corresponding 8 fundamental fermion antiparticles

or

for the 8 dimensions of 8-dim spacetime.

Therefore, the 4-dim Simplex Basis Vertices to which they project can represent

4 dimensions of 4-dim Physical Spacetime or 4 dimensions of CP2 Internal Symmetry Space

or a lepton plus 3 quark subset of fermion particles or antiparticles.

Heisenberg Hamiltonian Quantum Physics
and
E8 Lagrangian Classical Physics
contained in
 $Cl(8) \times Cl(8) = Cl(16)$

Heisenberg Hamiltonian Quantum Physics

Since by 8-periodicity $Cl(8)$ is the basic factor of all real Clifford algebras, start with the $Cl(8)$ Clifford algebra with graded structure

$$1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1.$$

The vector 8 corresponds to Octonionic 8-dimensional spacetime.

Its dual pseudovector 8 corresponds to 8-dimensional momentum space.

The tensor product of the vector 8 and the pseudovector 8 produces $8 \times 8 = 64$ -dimensional $U(8)$.

$U(8)$ is the symmetry group of the Hamiltonian of the 8-dimensional isotropic harmonic oscillator.

The semidirect product of $U(8)$ and the Heisenberg group H_8 forms the Heisenberg motion group G_8 with graded structure $8 + 64 + 8$.

Generalize G_8 beyond the simple 8-dimensional harmonic oscillator to a fully realistic physics model by forming the semidirect product of $U(8)$ and the Heisenberg group H_{92} to

$$\text{get } G_{248} \text{ with dimension } 64 + 92 + 1 + 92 - 1 = 248$$

(the -1 being due to the merging of 1 of the 64 of $U(8)$ with the 1 of H_{92}) and graded structure $28 + 64 + 64 + 64 + 28$ (grades -2, -1, 0, 1, 2).

The central grade 0 represents the 64 dimensions of the semidirect product of $U(8)$ and the central 1-dimensional element of H_{92} .

The odd grades -1 and 1 represent 64 creation and 64 annihilation operators of the 8 components (with respect to 8-dim spacetime) of 8 fermion particles.

The even grades -2 and 2 represent two sets of 28 $Spin(8)$ gauge bosons.

Break Octonionic spacetime symmetry by a Quaternionic structure creating 4+4 dim Kaluza-Klein spacetime and morphing $Spin(8)$ into $Spin^*(8) = Spin(2,6)$.

One of the sets of 28 becomes $\text{Spin}(2,6)$ with 16-dim $U(2,2)$ subgroup that includes the $\text{Spin}(2,4)$ Conformal Group of MacDowell-Mansouri Gravity. $\text{Spin}(2,4) / \text{Spin}(0,2) \times \text{Spin}(1,3)$ corresponds to 4-complex-dim bounded domain whose Shilov boundary 4-real-dim $\text{RP}^1 \times \text{S}^3$ corresponds to Minkowski physical spacetime of 4+4 Kaluza-Klein. What is in 28 outside the 16 $U(2,2) = \text{Spin}(0,2) \times \text{Spin}(2,4)$ Gravity generators: $\text{Spin}(2,6) / \text{Spin}(0,2) \times \text{Spin}(2,4)$ has real dimension 12 and is the G_{248} graded dual of the 12-dim Standard Model.

The other set of 28 becomes $\text{Spin}^*(8)$ with $U(4)$ subgroup that gives the Standard Model $SU(3)$ and $SU(2) \times U(1)$ by the Batakis mechanism by which $SU(3)$ and its isotropy group for $\text{CP}^2 = SU(3) / SU(2) \times U(1)$ gives 12 Standard Model group generators.

CP^2 corresponds to 4-dim Internal Symmetry Space of 8-dim Kaluza-Klein.

What is in the other 28 outside the 12 Standard Model generators:

First, look at the $U(4)$:

$$U(4) = U(1) \times SU(4)$$

$$SU(4) / SU(3) \times U(1) = \text{CP}^3 \text{ so } SU(4) = SU(3) \text{ plus } U(1) \text{ plus } \text{CP}^3$$

$$\text{CP}^3 = \text{C} \text{ plus } \text{CP}^2$$

$$\text{so } U(4) = SU(3) \text{ plus } \text{CP}^2 \text{ plus } U(1) \text{ plus } U(1) \text{ plus } \text{C} =$$

$$= SU(3) \text{ plus } \text{CP}^2 \text{ plus 4-dim } \text{T}^2\text{C}$$

and 4-dim T^2C is in $U(4)$ outside the 12 Standard Model generators

given by $SU(3)$ plus the isotropy group for CP^2 .

Second, look at $\text{Spin}^*(8) / U(4)$:

$$\text{Spin}^*(8) / SU(4) \times U(1) \text{ has real dimension } 28 - 16 = 12$$

So:

$$\text{Spin}^*(8) / U(4) \text{ plus } \text{T}^2\text{C} \text{ has real dimension } 16$$

and is the G_{248} graded dual of the 16-dim Conformal Gravity $U(2,2)$.

Second and Third Generation Fermions emerge from breaking Octonionic Symmetry of 8-dim SpaceTime to Quaternionic Symmetry of 4+4 dim Kaluza-Klein.

The Higgs also emerges from that breaking to 4+4 dim Kaluza-Klein and is represented by the $\text{Cl}(8)$ Primitive Idempotent Structure

with grading $1 + 6 + 1$ (grades 0,4,8) in the $\text{Cl}(8)$ grading

$$1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$$

in which the $8 + 28 + 56 + 64 + 56 + 28 + 8$ correspond

to the G_{248} grading $28 + 64 + 64 + 64 + 28$

E8 Lagrangian Classical Physics

To go from G248 Heisenberg Hamiltonian Quantum Physics by an analog of the Legendre Transform to Classical Lagrangian Physics expand G248 with 5-graded structure $28 + 64 + 64 + 64 + 28$ (grades -2,-1,0,1,2) to the E8 Lie Algebra with graded structure $8 + 28 + 56 + 64 + 56 + 28 + 8$ (grades 1,2,3,4,5,6,7)

The central grade 4 represents the $64 = 8 \times 8$ dimensions of Octonionic spacetime 8-dim position \times 8-dim momentum thus giving the base manifold over which the Lagrangian density is integrated.

The odd grades 1,3 represent $8+56=64$ sets of the 8 components (with respect to 8-dim spacetime) of 8 first-generation fermion particles.

The odd grades 5,7 represent $8+56=64$ sets of the 8 components (with respect to 8-dim spacetime) of 8 first-generation fermion antiparticles.

Together the grades 1,3,5,7 give the Dirac fermion term of the Lagrangian density.

The even grades 2 and 6 represent two sets of 28 Spin(8) gauge bosons.

The grade 2 Spin(8) becomes Spin(2,6) with 16-dim U(2,2) subgroup that includes the Spin(2,4) Conformal Group of MacDowell-Mansouri Gravity to produce a Gravity term of the Lagrangian density.

The grade 6 Spin(8) becomes Spin*(8) with U(4) subgroup that gives the Standard Model SU(3) and SU(2) \times U(1) by the Batakis mechanism by which SU(3) and its isotropy group for CP2 = SU(3) / SU(2) \times U(1) gives the Standard Model SU(3) \times SU(2) \times U(1) gauge group term of the Lagrangian density.

Breaking Octonionic Symmetry of 8-dim SpaceTime to Quaternionic Symmetry of 4+4 dim Kaluza-Klein gives the resulting Lagrangian second and third generation fermions and Mayer mechanism Higgs so that at our experimental energies the resulting Lagrangian gives realistic Gravity plus Standard Model with Higgs.

Both Heisenberg Hamiltonian Quantum G248 and Classical Lagrangian E8 live inside Cl(16) the completion of the union of all tensor products of which, by real Clifford periodicity, produce a realistic Algebraic Quantum Field Theory as a generalized Hyperfinite III von Neumann factor.

G248 and E8 are related by Cl(16) duality as indicated in the following chart:

$Cl(16) = Cl(8) \times Cl(8) = 256 \times 256 = 65,536$
 $Cl(8) \text{ spinor} = 8s \text{ half-spinor} + 8c \text{ half-spinor}$
 $Cl(16) \text{ spinor} = 8s8s + 8s8c + 8c8s + 8c8c = 256$

$Cl(16) \text{ half-spinor } 8c8s + 8s8c = 64 + 64$

Hamiltonian $Sl(8) \times H92 = 28 + 64 + 64 + 64 + 28$

Contracted

- 1
- 16
- 120
- 560
- 1820
- 4368
- 8008
- 11440
- 128670
- 11440
- 8008
- 4368
- 1820
- 560
- 120
- 16
- 1

Clifford Duality
Legendre

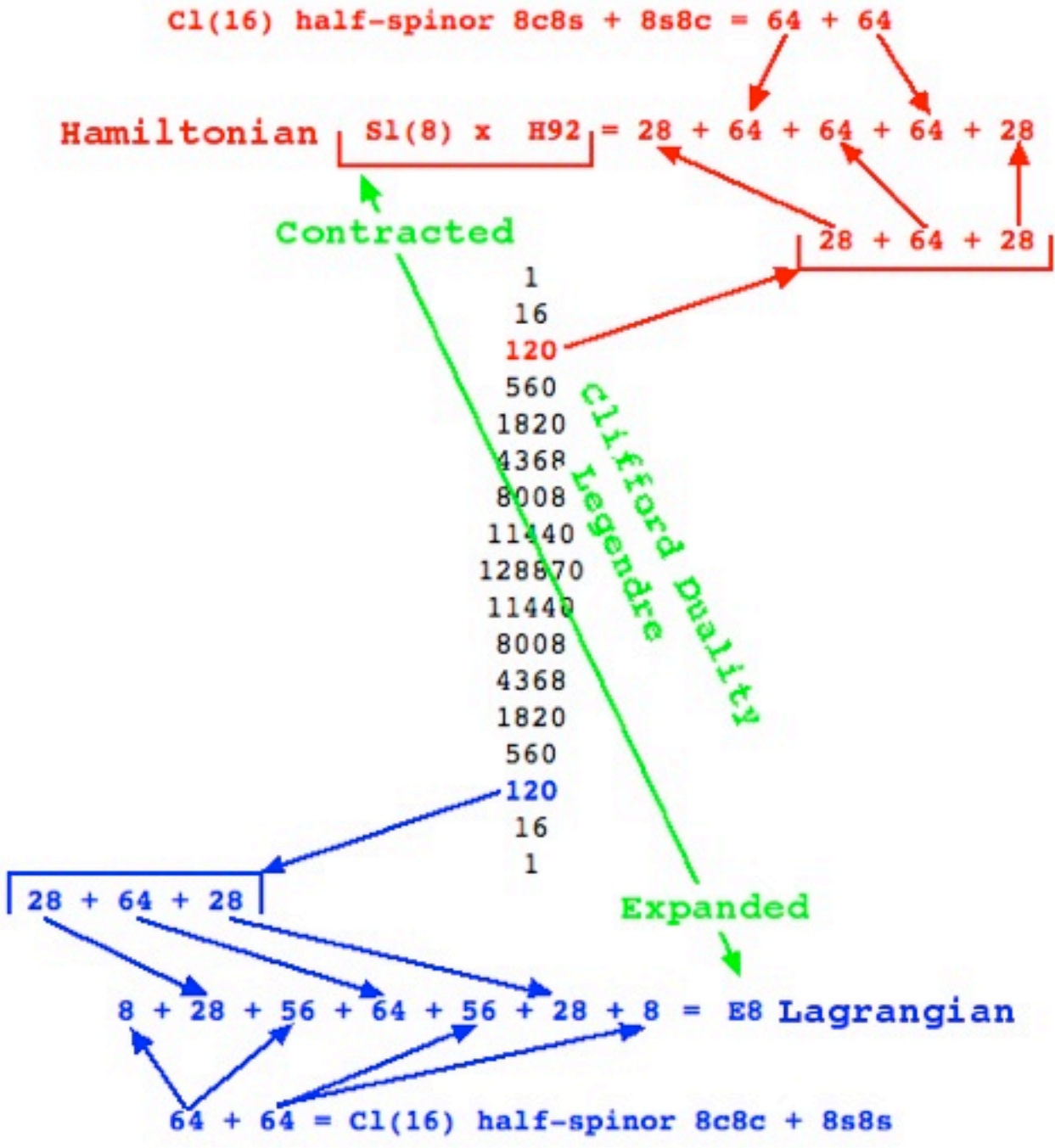
$28 + 64 + 28$

Expanded

$28 + 64 + 28$

$8 + 28 + 56 + 64 + 56 + 28 + 8 = E8 \text{ Lagrangian}$

$64 + 64 = Cl(16) \text{ half-spinor } 8c8c + 8s8s$



E8 Physics and Quasicrystals

Icosidodecahedron and Rhombic Triacontahedron

vixra 1301.0150

Frank Dodd (Tony) Smith Jr. - 2013

The E8 Physics Model (viXra 1108.0027) is based on the Lie Algebra E8.
 240 E8 vertices = 112 D8 vertices + 128 D8 half-spinors where
 D8 is the bivector Lie Algebra of the Real Clifford Algebra $Cl(16) = Cl(8) \times Cl(8)$.
 112 D8 vertices = (24 D4 + 24 D4) = 48 vertices from the D4xD4 subalgebra of D8
 plus 64 = 8x8 vertices from the coset space D8 / D4xD4.
 128 D8 half-spinor vertices = 64 ++half-half-spinors + 64 --half-half-spinors.
 An 8-dim Octonionic Spacetime comes from the Cl(8) factors of Cl(16) and
 a 4+4 = 8-dim Kaluza-Klein M4 x CP2 Spacetime emerges due to the freezing out of a
 preferred Quaternionic Subspace. Interpreting World-Lines as Strings leads to 26-dim
 Bosonic String Theory in which 10 dimensions reduce to 4-dim CP2 and a 6-dim
 Conformal Spacetime from which 4-dim M4 Physical Spacetime emerges.

Although the high-dimensional E8 structures are fundamental to the E8 Physics Model
 it may be useful to see the structures from the point of view of the familiar 3-dim Space
 where we live. To do that, start by looking the the E8 Root Vector lattice.

Algebraically, an E8 lattice corresponds to an Octonion Integral Domain.
 There are 7 Independent E8 Lattice Octonion Integral Domains
 corresponding to the 7 Octonion Imaginaries, as described by H. S. M. Coxeter
 in "IntegralCayley Numbers" (Duke Math. J. 13 (1946) 561-578 and
 in "Regular and Semi-Regular Polytopes III" (Math. Z. 200 (1988) 3-45).
 Let { 1, i, j, k, e, ie, je, ke } be a basis of the Octonions.

The 112 D8 Root Vector vertices can be written as

$$(\pm 1, \pm 1, 0, 0, 0, 0, 0, 0)$$

for all 4 possible +/- signs times all (8!2) = 28 permutations of pairs of basis elements.

The 128 D8 half-spinor vertices can be written in 7 different ways

$$\begin{aligned} & (\pm (1+i) \quad \pm j \pm k \pm e \pm ie \pm je \pm ke) / 2 \\ & (\pm (1+j) \quad \pm i \quad \pm k \pm e \pm ie \pm je \pm ke) / 2 \\ & (\pm (1+k) \quad \pm i \pm j \quad \pm e \pm ie \pm je \pm ke) / 2 \\ & (\pm (1+e) \quad \pm i \pm j \pm k \pm \quad \pm ie \pm je \pm ke) / 2 \\ & (\pm (1+ie) \quad \pm i \pm j \pm k \pm e \quad \pm je \pm ke) / 2 \\ & (\pm (1+je) \quad \pm i \pm j \pm k \pm e \pm ie \quad \pm ke) / 2 \\ & (\pm (1+ke) \quad \pm i \pm j \pm k \pm e \pm ie \pm je \quad) / 2 \end{aligned}$$

in each of which

one Octonion Imaginary basis element is paired (same sign) with the Real basis
 element

to give $2^{(8-1)} = 2^7 = 128$ D8 half-spinor Root Vector vertices

so that

7 different E8 lattices, each with a 240-vertex Root Vector polytope around the origin,

can be constructed:

$$iE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + i) \quad +/- j +/- k +/- e +/- ie +/- je +/- ke) / 2$$

$$jE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + j) \quad +/- i \quad +/- k +/- e +/- ie +/- je +/- ke) / 2$$

$$kE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + k) \quad +/- i +/- j \quad +/- e +/- ie +/- je +/- ke) / 2$$

$$eE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + e) \quad +/- i +/- j +/- k + \quad +/- ie +/- je +/- ke) / 2$$

$$ieE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + ie) \quad +/- i +/- j +/- k +/- e \quad +/- je +/- ke) / 2$$

$$jeE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + je) \quad +/- i +/- j +/- k +/- e +/- ie \quad +/- ke) / 2$$

$$keE8 = (+/- 1 , +/- 1 , 0 , 0 , 0 , 0 , 0 , 0) \\ + (+/- (1 + ke) \quad +/- i +/- j +/- k +/- e +/- ie +/- je \quad) / 2$$

As Conway and Sloane say in "Sphere Packings, Lattices and Groups"
(Third Edition Springer

"... when n = 8 ... we can slide another copy of Dn in between the points of Dn ...

Formally, we define Dn+ = Dn u ([1] + Dn

When n = 8 ... the lattice D8+ ...[is]... known as E8 ...".

The D8 part of E8 contains the 112 D8 Root Vectors.

The 7 different E8 lattices correspond to 7 different ways to slide
the D8 half-spinor copy of D8 in between the points of the first D8
thus

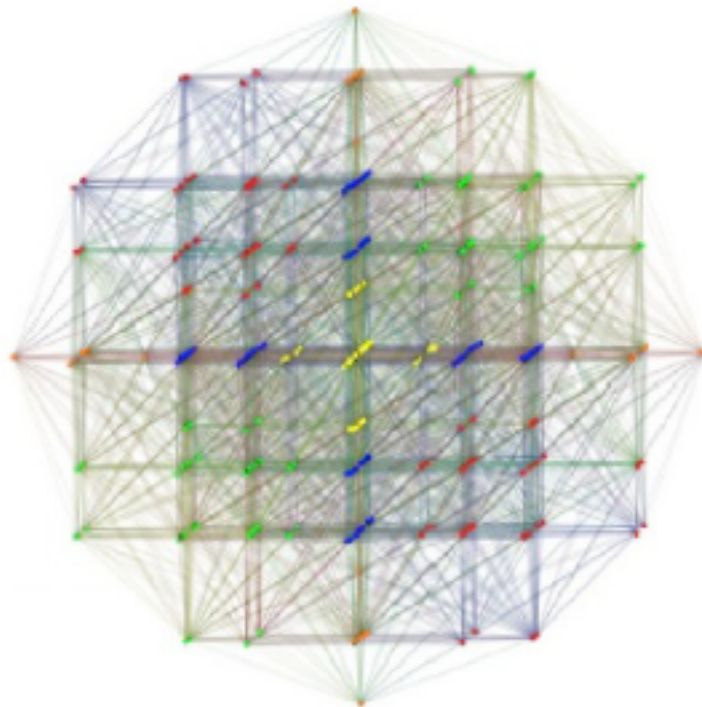
producing 7 different E8 lattices each with a 112 + 128 = 240 Root Vector polytope.

Since Quasicrystal / Icosadodecahedron / Rhombic Triacontahedron structure is similar
for all the E8 lattices,

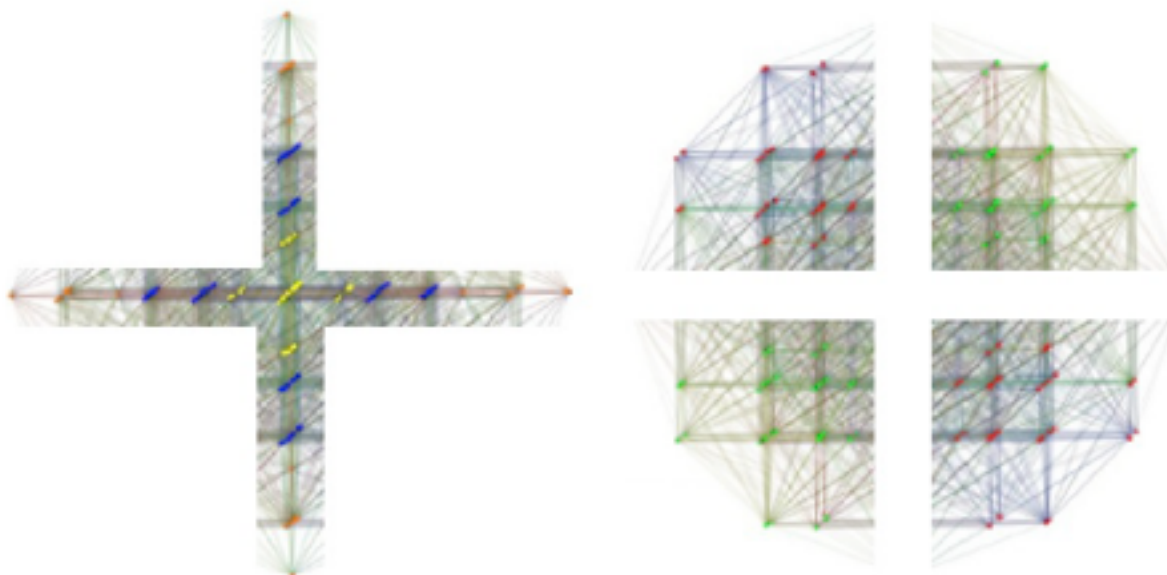
it can be discussed based only on the generic first-shell 240 Root Vector vertices
and

discussion of more detailed structure of the various E8 lattices is reserved to the
Appendix of this paper.

Quasicrystal / Icosadodecahedron / Rhombic Triacontahedron structure is similar for all the E8 lattices as it is based on the 240 vertices



that can be described as the **First Shell of an E8 Lattice** which is made up of **112 D8 Root Vectors** plus **128 D8 half-spinor vertices**:



In "Regular and Semi-Regular Polytopes III" Coxeter describes that shell as

"... The eight-dimensional polytope 4_{21} ... in which the 240 vertices are distributed in 8 concentric tricontagons $\{30\}$...

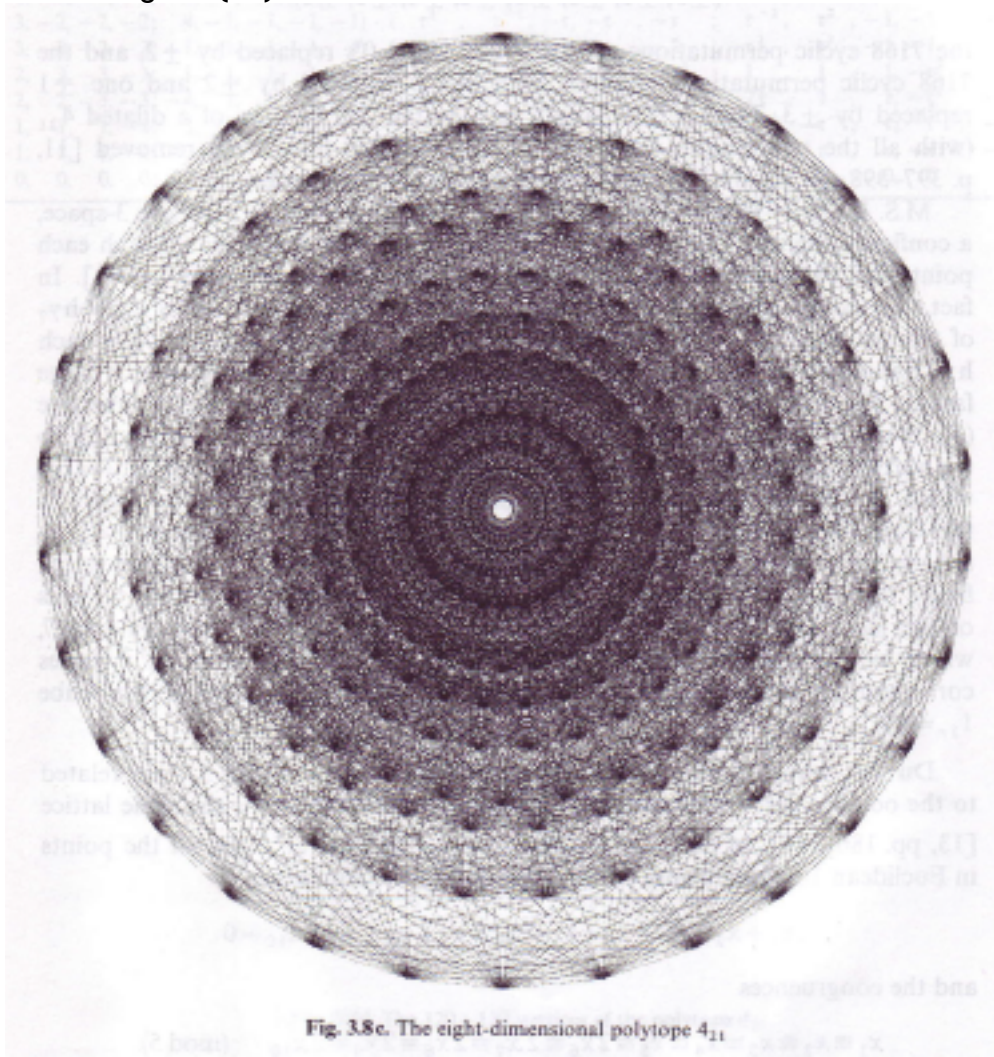
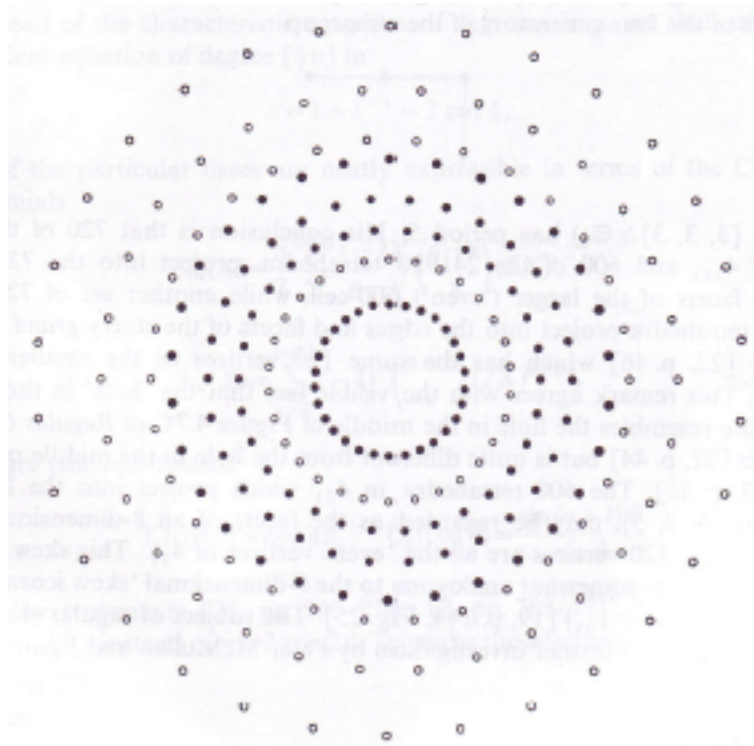


Fig. 38c. The eight-dimensional polytope 4_{21}

... The 120+120 vertices of the polytope 4_21 ...



...[are]... the 120+120 vertices of two homothetic 600-cells {3,3,5}:

one having the coordinates ...[with T being the Golden Ratio]...

the even permutations of $(\pm T, \pm 1, \pm T^{-1}, 0)$,

the permutations of $(\pm 2, 0, 0, 0)$,

and $(\pm 1, \pm 1, \pm 1, \pm 1)$

...[a total of $8 \times (1/2) \times 4! + 2 \times 4 + 16 \times 1 = 96 + 8 + 16 = 120$]...

... while

the other has these same coordinates multiplied by T ...".

One 600-cell represents half of the 240 E8 Root Vector vertices:

56 of D8 vertices =

(12 of D4 + 12 of D4) = 24 vertices from D4xD4 subalgebra of D8

plus

32 = 8x4 vertices from the coset space D8 / D4xD4.

64 of the D8 half-spinor vertices = 32 ++half-half-spinors + 32 --half-half-spinors.

The 600-cell lives in a 3-dim sphere inside 4-dim Space. It is half of the E8 vertices. With respect to the 3-sphere S3 the 120 vertices of the 600-cell look like:

- 1 - North Pole - Single Point (projected to center of Equatorial Icosidodecahedron)
- 12 - Arctic Circle - Icosahedron - half of 24 Root Vectors of one of the E8 D4
- 20 - North Temperate Zone - Dodecahedron part of Rhombic Triacontahedron
- 12 - Tropic of Cancer - Icosahedron part of Rhombic Triacontahedron
- 30 - Equator - Icosidodecahedron
- 12 - Tropic of Capricorn - Icosahedron part of Rhombic Triacontahedron
- 20 - South Temperate Zone - Dodecahedron part of Rhombic Triacontahedron
- 12 - Antarctic Circle - Icosahedron - half of 24 Root Vectors of another E8 D4
- 1 - South Pole - Single Point (projected to center of Equatorial Icosidodecahedron)

The colors represent E8 Physics Model physical interpretation:

Conformal Gravity Root Vector Gauge Bosons

Fermion Particles

Spacetime position and momentum

Fermion Antiparticles

Standard Model Gauge Bosons

Sadoc and Mosseri in their book "Geometric Frustration" (Cambridge 2006) Fig. A51 illustrate the shell structure of the 120 vertices of a 600-cell:

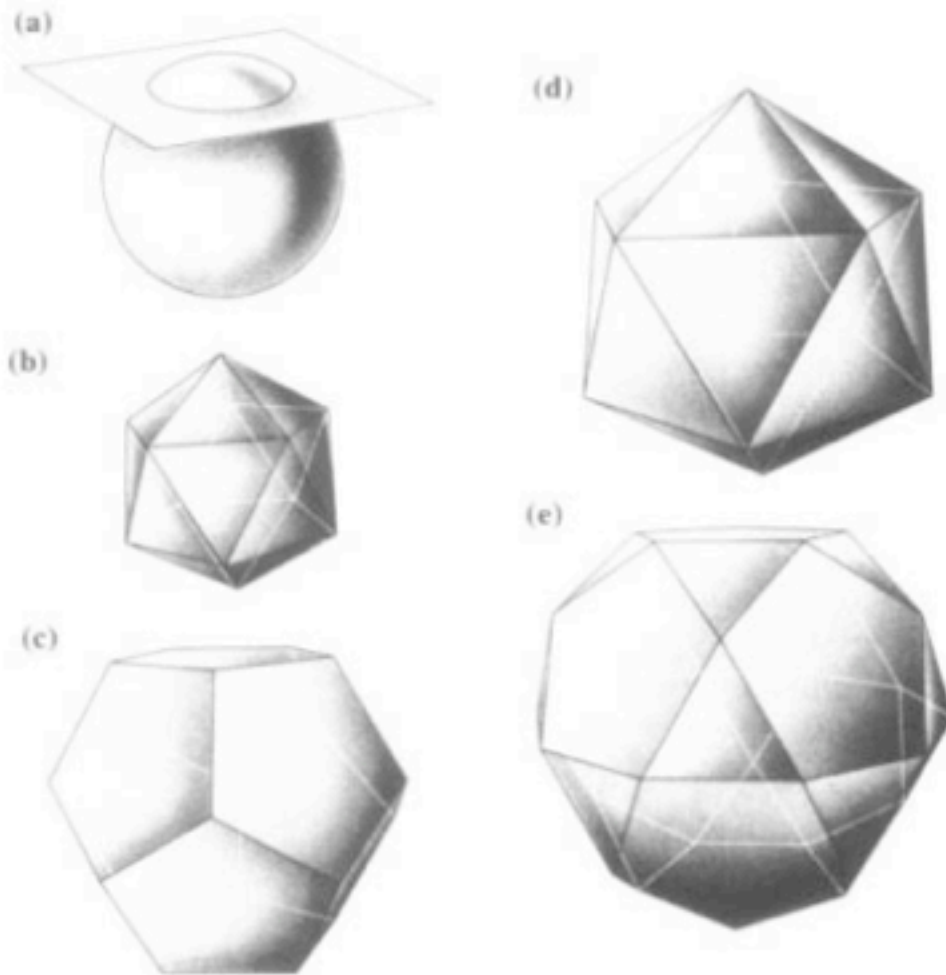
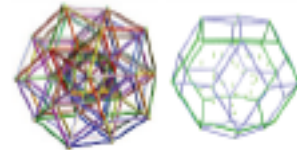


Fig. A5.1. The $\{3, 3, 5\}$ polytope. Different flat sections in S^3 (with one site on top) give the following successive shells; (a) an icosahedral shell formed by the first 12 neighbours, (b) a dodecahedral shell, (c) a second and larger icosahedral shell, (d) an icosidodecahedral shell on the equatorial sphere. Then other shells are symmetrically disposed in the second 'south' hemi-hypersphere, relative to the equatorial sphere (e).

The 30-vertex Icosidodecahedron (e) cannot tile flat 3-dim space. Its dual, the 32-vertex Rhombic Triacontahedron, is a combination of the 12-vertex Icosahedron (d) and the 20-vertex Dodecahedron (c). It "forms the convex hull of ... orthographic



projection ... using the Golden ratio in the basis vectors ... of a 6-cube to 3 dimensions." (Wikipedia).

Physical Interpretation of

1 - North Pole - Single Point (projected to center of Equatorial Icosidodecahedron)

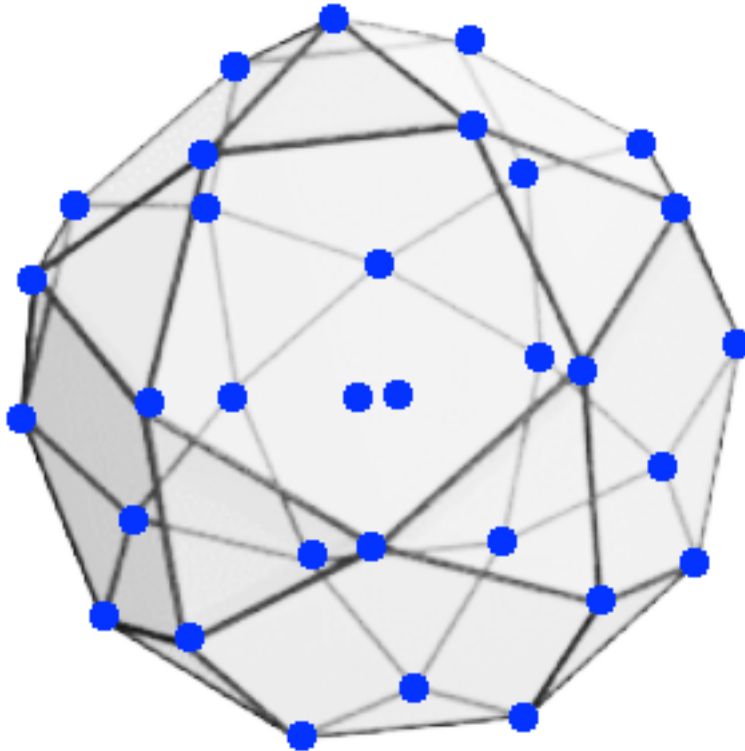
30 - Equator - Icosidodecahedron

1 - South Pole - Single Point (projected to center of Equatorial Icosidodecahedron)

is

8 components of 8-dim Kaluza-Klein $M_4 \times CP^2$ Spacetime Position
times

4 components of 4-dim M_4 Physical Spacetime Momentum



There are $64 - 32 = 32$ of the 240 E_8 in the half of E_8 that did not go to the 600-cell. They correspond to 8 components of Position x 4 components of momentum in CP^2 . Since the CP^2 Internal Symmetry Space is the small compactified part of $M_4 \times CP^2$ momentum in CP^2 is substantially irrelevant to our 3-dim space M_4 world.

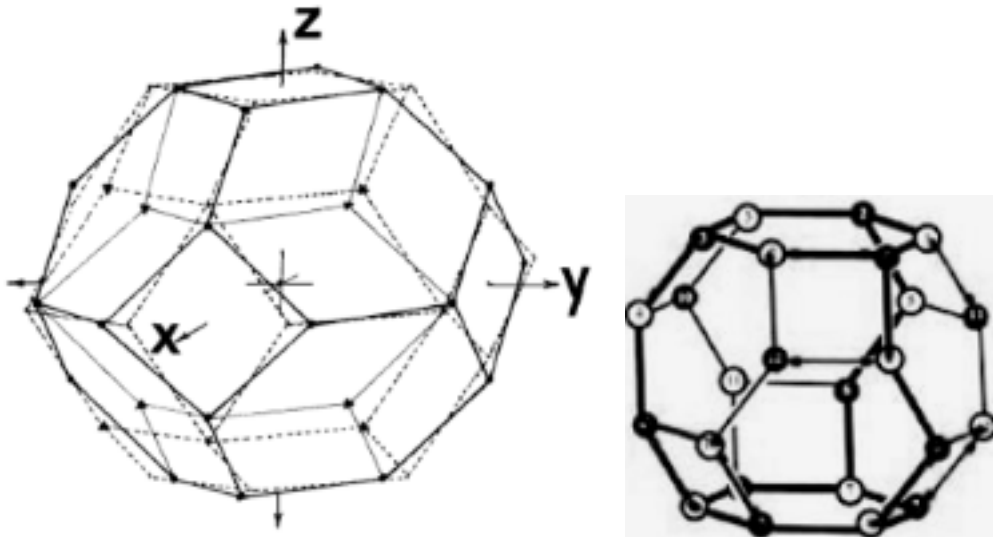
The 30 Icosadodecahedron vertices are at pairwise intersections of 6 Great Circle Decagons. Let each Great Circle represent a generator of a spacetime translation. Then the Icosadodecahedron represents a 6-dim $Spin(2,4)$ Conformal spacetime that acts conformally on 4-dim M_4 Minkowski Physical Spacetime that lives inside 8-dim Kaluza-Klein $M_4 \times CP^2$ Spacetime (where $CP^2 = SU(3) / U(2)$). Physically the 6 Great Circles of the Icosadodecahedron show that the 10-dim space of 26-dim String Theory of Strings as World-Lines reduces to 6-dim Conformal Physical Spacetime plus 4-dim CP^2 Internal Symmetry Space.

The 32-vertex Rhombic Triacontahedron does not itself tile 3-dim space but it is important in 3-dim QuasiCrystal tiling.

Mackay (J. Mic. 146 (1987) 233-243) said "... the basic cluster, to be observed everywhere in the three-dimensional ... Penrose ... tiling ...[is]... a rhombic triacontahedron (RTH) ... The 3-D tiling can be regarded as an assembly of such RTH, partly overlapping

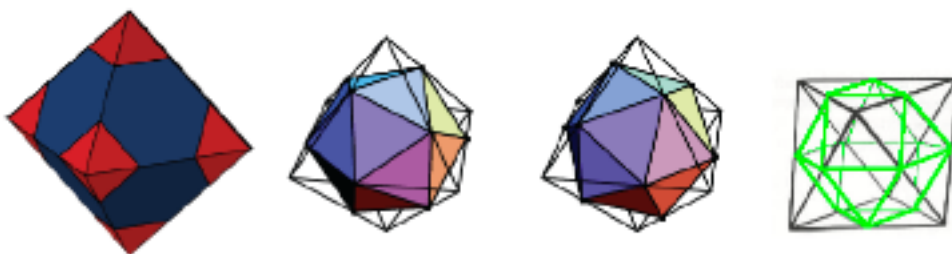
...

a rhombic triacontahedron (RTH) ... can be deformed to ... a truncated octahedron ... [which is] the space-filling polyhedron for body-centered cubic close packing ...



By a similar process ... a cuboctahedr[on]... can be deformed to an icosahedron ...".

In the latter process, the Jitterbug, sets of points on the edges of an Octahedron correspond to the vertices of the Truncated Octahedron ($1/3$ and $2/3$), a pair of Icosahedra (Golden Ratio Points), and the Cuboctahedron (Mid-Point).



but the Rhombic Triacontahedron deformation process involves moving its vertices somewhat off the exact edges of the Octahedron and in adding to the 24 vertices of the Truncated Octahedron 8 more vertices corresponding to centers of its hexagonal faces and making 3 rhombohedral faces from each of its hexagonal faces.

Since the 3-dim space itself is due to the Icosidodecahedron Spacetime, construction of a 3-dim space version of the E8 Physics Model does not require tiling of 3-dim space by Icosidodecahedra (it would be redundant and inconsistent to tile space with space) but it is useful to consider tiling 3-dim space with the fermion particles and gauge bosons that are actors on the stage of space, and they correspond to Rhombic Triacontahedra, and there are two ways to look at tiling 3-dim space by Rhombic Triacontahedra:

1 - Make a 3-dim QuasiCrystal of Rhombic Triacontahedra, partly overlapping, as suggested by Mackay (J. Mic. 146 (1987) 233-243).

2 - Deform the Rhombic Triacontahedra to Truncated Octahedra and tile 3-space with the Truncated Octahedra.

Whichever way is chosen, the first step is to describe the physical interpretation of the Rhombic Triacontahedra, beginning with

20 - North Temperate Zone - Dodecahedron part of Rhombic Triacontahedron

12 - Tropic of Cancer - Icosahedron part of Rhombic Triacontahedron

and

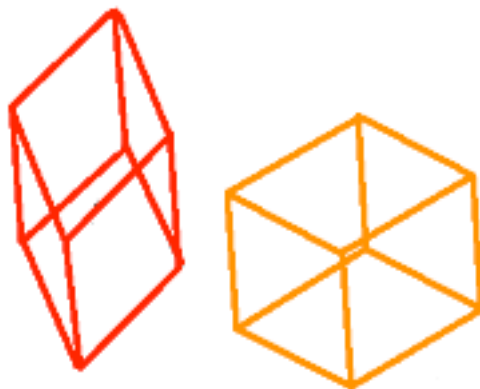
12 - Tropic of Capricorn - Icosahedron part of Rhombic Triacontahedron

20 - South Temperate Zone - Dodecahedron part of Rhombic Triacontahedron

which are interpreted as fermion particles and fermion antiparticles, respectively.

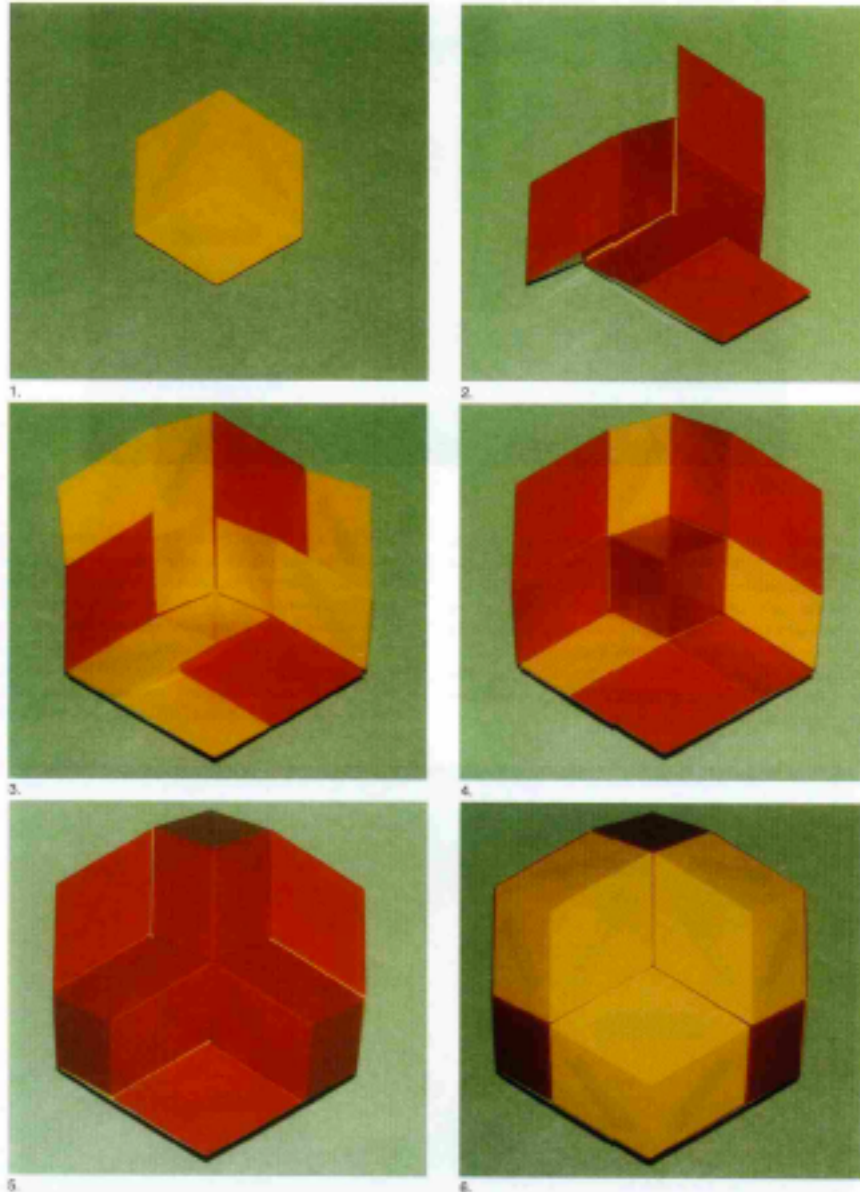
Since fermion particles are inherently Left-Handed and fermion antiparticles are inherently Right-Handed, the Rhombic Triacontahedra representing each should be constructed correspondingly and units of the 3-space tiling should contain a superposition of both Left and Right RTH, as well as third RTH with no handedness to describe Gravity and the Standard Model.

The basic building blocks of a Rhombic Triacontahedron (a/k/a Kepler Ball) are



two golden rhombohedra (sharp "S" and flat "F") , using 10 of each.

Construction of Left-Handed and Right-Handed Rhombic Triacontahedra
is described by Michael S. Longuet-Higgins in "Nested Triacontahedral Shells
Or How to Grow a Quasi-crystal" (Mathematical Intelligencer 25 (Spring 2003) 25-43):
"... start with a flat rhombohedron,
placing on it three sharp rhombohedra in a left-handed symmetric way
and building up the rest of the ball maintaining always a three-fold axis of rotational
symmetry ...



... (We could also start with right-handed symmetry, producing the mirror image.) ...".

Physical Interpretation of

20 - North Temperate Zone - Dodecahedron part of Rhombic Triacontahedron

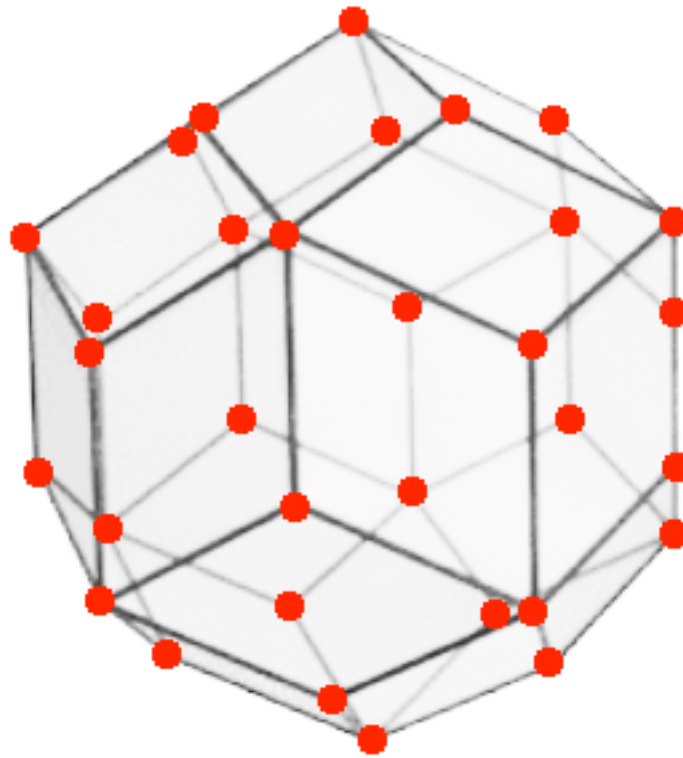
12 - Tropic of Cancer - Icosahedron part of Rhombic Triacontahedron

is

8 fundamental first-generation fermion particles

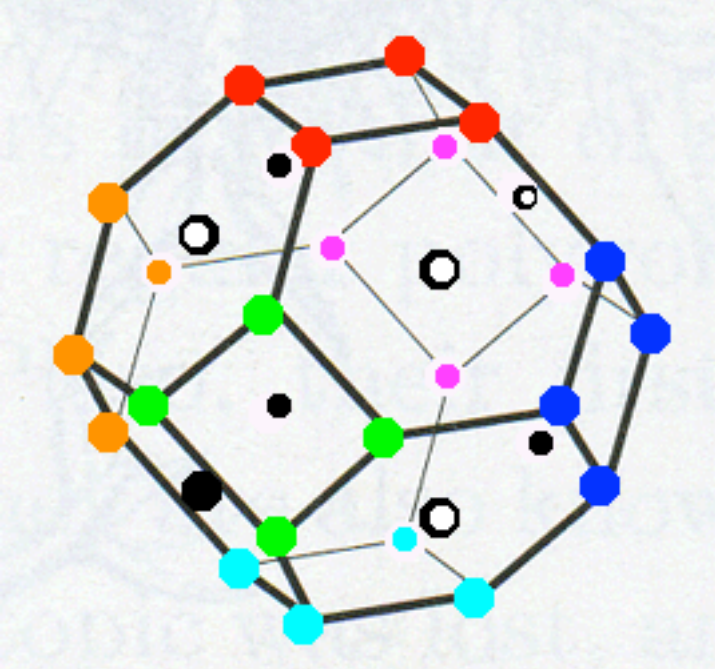
times

4 covariant components of 4-dim M4 Physical Spacetime Momentum



Left-Handed Rhombic Triacontahedron Kepler Ball.

As to which vertices correspond to which Fermion Particles or Antiparticles the Truncated Octahedron point of view with 6 sets of 4 vertices for quarks and 2 sets of 4 hexagon-centers for leptons, showing the 4 covariant components with respect to M4 Physical Spacetime for each Fermion, is useful:



- neutrino, ● red down quark, ● green down quark, ● blue down quark;
- blue up quark, ● green up quark, ● red up quark, ● electron

(orange, magenta, cyan, black are used for blue, green, red up quarks and electron)

Physical Interpretation of

12 - Tropic of Capricorn - Icosahedron part of Rhombic Triacontahedron

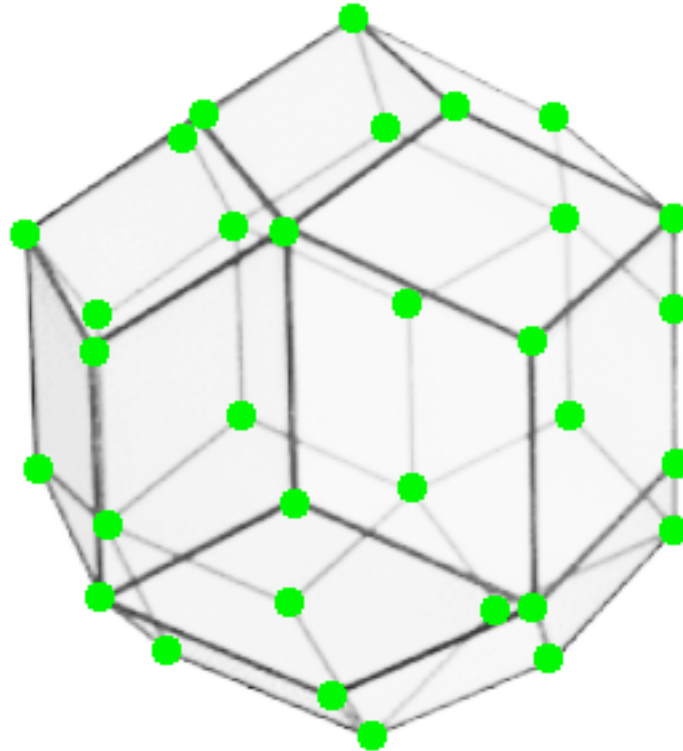
20 - South Temperate Zone - Dodecahedron part of Rhombic Triacontahedron

is

8 fundamental first-generation fermion antiparticles

times

4 covariant components of 4-dim M4 Physical Spacetime Momentum



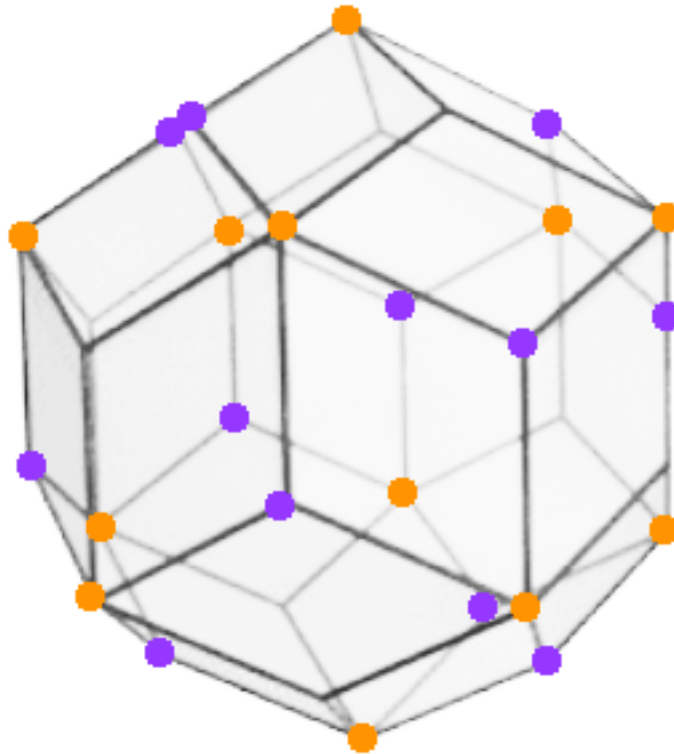
Right-Handed Rhombic Triacontahedron Kepler Ball.

Physical interpretation of the Rhombic Triacontahedra also includes

12 - Arctic Circle - Icosahedron - half of 24 Root Vectors of one of the E8 D4 and

12 - Antarctic Circle - Icosahedron - half of 24 Root Vectors of another E8 D4

which are interpreted as Gauge Bosons for Gravity and the Standard Model, respectively.



Rhombic Triacontahedron Kepler Ball with no handedness.

12 of the 20 3-edge vertices are 12 D4 Root Vectors for the Standard Model that combine with 4 of the 8 E8 Cartan SubAlgebra generators to form $12+4 = 16$ -dim $U(4)$ that contains the Batakis Color Force $SU(3)$ that gives the Standard Model through $CP^2 = SU(3) / U(1) \times SU(2)$.

The $20-12 = 8$ 3-edge vertices that are not used correspond to the centers of the hexagonal faces of the Truncated Octahedron related to the Kepler Ball.

12 5-edge vertices are 12 D4 Root Vectors for Conformal Gravity that combine with 4 of the 8 E8 Cartan SubAlgebra generators to form $12+4 = 16$ -dim $U(2,2) = U(1) \times SU(2,2)$ where $SU(2,2) = Spin(2,4)$. The Conformal Lie Algebra $SU(2,2) = Spin(2,4)$ has 15 dimensions, and Longuet-Higgins (Mathematical Intelligencer 25 (Spring 2003) 25-43) says "... a Kepler Ball may be thought of as a can of 15 worms ... with 3 worms passing through the centre of each rhombohedron ...

... define a worm as a line drawn from the center of one face w_1 of a Kepler Ball to the center of the opposite face w_2 of the corresponding golden rhombohedron; then from w_2 to the opposite face w_3 of the adjacent rhombohedron, and so on, ending at the face w_n of the Kepler Ball opposite to w_1 . Thus a Kepler Ball may be thought of as a can of 15 worms, with 3 worms passing through the centre of each rhombohedron. The two ends of the worm lie on two opposite faces of the Ball. ... all of ... the worms ... will ... pass through two F's and two S's. ...".

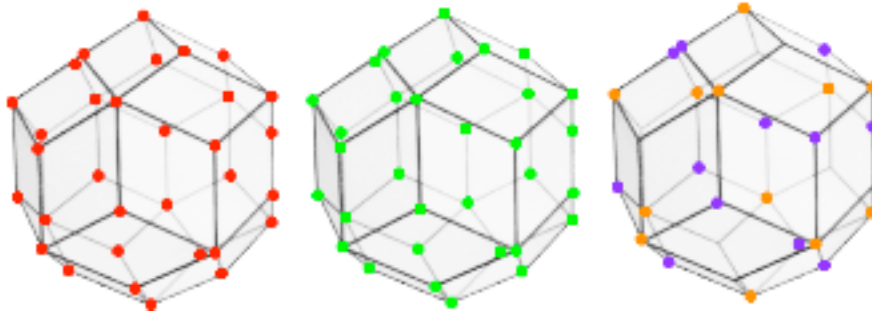
Compare the 15 worms based on faces of the Kepler Ball Rhombic Triacontahedron with the 30-vertex structure of its dual the Icosidodecahedron



whose physical interpretation is Spacetime. As the 6 Great Circle Decagons of the Icosidodecahedron represent 6-dim Conformal Physical Space and as the 15 worms represent the 15 antipodal pairs of the 30 Icosidodecahedron vertices and as each antipodal pair of vertices corresponds to a pair of Great Circle Decagons the 15 worms represent the 15 generators of the Conformal Group $Spin(2,4) = SU(2,2)$.

3-space tiled by Deformation or QuasiCrystal

For tiling of 3-space the basic Rhombic Triacontahedra Kepler Ball should contain all 3:



Left-Handed for Fermion Particles, Right-Handed for Fermion Antiparticles, and no handedness for Gauge Bosons of Gravity and the Standard Model.

To construct such a 3-type Rhombic Triacontahedron Kepler Ball:

Start with a Left-Handed Kepler Ball for Fermion Particles and denote it by K(1). Then, using K(1) as a nucleus, construct a K(2) Kepler Ball by adding to the K(1)



sharp "S" and flat "F" golden rhombohedra with dihedral angles $2\pi/5$ or $3\pi/5$ for S and $\pi/5$ or $4\pi/5$ for F as described in

"Nested Triacontahedral Shells Or How to Grow a Quasi-crystal"

by Michael S. Longuet-Higgins (Mathematical Intelligencer 25 (Spring 2003) 25-43):

"... To construct a K(2) ... label the thirty faces of a K(1) as follows: call the five faces surrounding a given pentagonal vertex A's; the five adjoining faces B's; the next ten adjoining faces (which are all parallel to the pentagonal axis) C's; the next five D's; and the last five E's.

Taking the K(1), leave the A-faces bare and lay one F on each B-face.

Next lay an S on each of the C-faces. Proceeding cheirally ... we ... arrive ... at a K(2) ...



[I have added purple and orange indicators for K(2) vertices representing some of the Root Vectors of U(2,2) for Conformal Gravity and of U(4) for the Standard Model.]

The view from the opposite end is similar ...

there is a second K(1), coaxial with the first, along the pentagonal axis ...".

K(1) is for Fermion Particles, second K(1) is for Fermion Antiparticles, and K(2) is for Gauge Bosons of Gravity and the Standard Model.

K(2), containing Particle-Antiparticle Pairs, is the Basic Tiling Kepler Ball.

As remarked earlier,

there are two ways to look at tiling 3-dim space by Rhombic Triacontahedra:

1 - **Make a 3-dim QuasiCrystal of Rhombic Triacontahedra**, partly overlapping, as suggested by Mackay (J. Mic. 146 (1987) 233-243).

2 - **Deform the Rhombic Triacontahedra to Truncated Octahedra** and tile 3-space with the Truncated Octahedra.

**1 - Make a 3-dim QuasiCrystal of Rhombic Triacontahedra, partly overlapping,
as suggested by Mackay (J. Mic. 146 (1987) 233-243).**

Start with the Basic Tiling Kepler Ball $K(2)$ containing a Particle-Antiparticle pair of $K(1)$ s



Then adding to the $K(2)$ sharp "S" and flat "F" golden rhombohedra construct a larger Rhombic Triacontahedron Kepler Ball $K(3)$. Continue the process, adding to each $K(n)$ sharp "S" and flat "F" golden rhombohedra to form $K(n+1)$.

There are a number of ways to do that. One that I like is described in

"Nested Triacontahedral Shells Or How to Grow a Quasi-crystal"

by Michael S. Longuet-Higgins (Mathematical Intelligencer 25 (Spring 2003) 25-43):

"... in general ... it is possible ...to derive a Kepler Ball $K(n+1)$ of side $n+1$ from a $K(n)$...

Define a carpet of rhombohedra as an $(n \times n \times 1)$ array of golden rhombohedra (of the same kind), covering an $n \times n$ rhombic face such as $b(n)$, for example.

All the rhombohedra are oriented identically.

A fringe is an $(n \times 1 \times 1)$ array, oriented similarly, adjoining the "edge" of two different arrays, and a tassel is a single cell, i.e., a $(1 \times 1 \times 1)$ array at the join or extension of two or more fringes. ...

(1) Leave the $a(n)$ -faces bare, and cover each of the $b(n)$ -faces with a carpet of F's.

(2) Complete the $a(n+1)$'s with three fringes of F's and lay a carpet of S's on each of the $c(n)$ -faces.

(3) Turn the emodel over. Lay a carpet of S's on each of the $d(n)$ -faces.

(4) Lay a carpet of F's cheirally on each $e(n)$ -face and

a carpet of S's on each $f(n)$ -face, with a cheiral fringe of S's.

(5) Lay a second carpet of F's, cheirally, on each of the carpets covering the $e(n)$ -faces.

(6) Lay a carpet of F's on each of the $f(n)$ -faces, and fill in with fringes of F's and a tassel in the centre.

The latter will be the start of a coaxial $[K^*(1)]$.

(7) Cover the upper surface cheirally with a layer of F's, leaving three zigzag canyons meeting at the centre.

(8) Fill in the canyons with F's and S's.

(9) Cover the F's with a layer of S's.

(10) Complete the $[d(n)$ -face] with a carpet of F's. (This also completes the $[e(n)$ -faces].)

(11) Add F's to complete the $K(n+1)$.

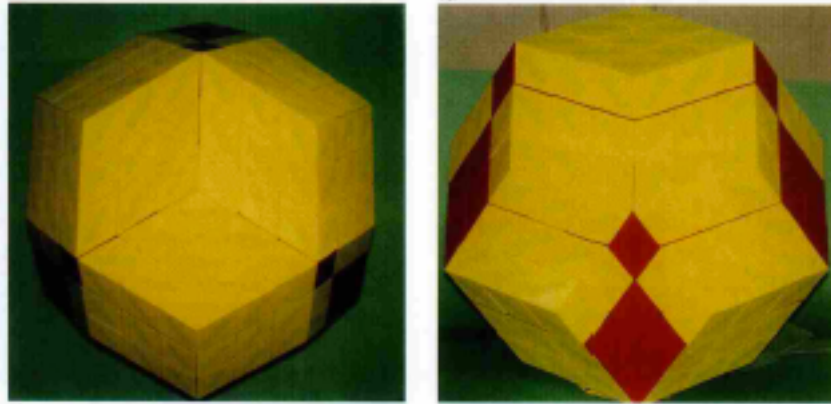
... the outer shell is [not] cheiral

...

the whole $K(n+1)$ is covered by a layer of rhombohedra no more than four deep

...

[such a] construction of $K(3)$ from $K(2)$...[produces]...



... in many respects the particular arrangements described here are not unique. For example, in places where a triacontahedron occurs locally, ...[it]... may be replaced by a ... [triacontahedron of a different type] ...

**the method of assembly ...
does not require the existence of such long-range forces
as would be needed to assemble an Ammann tiling**

...".

As Mackay (J. Mic. 146 (1987) 233-243) said "... the basic cluster, to be observed everywhere in the three-dimensional ... Penrose ... tiling ...[is]... a rhombic triacontahedron (RTH) ...

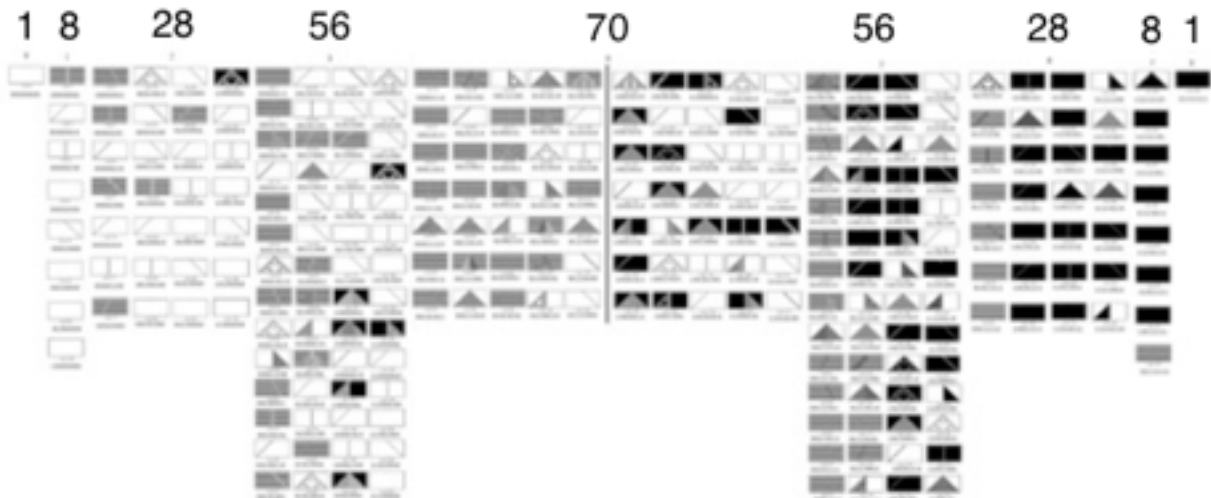
The 3-D tiling can be regarded as an assembly of such RTH, partly overlapping ...".

2 - Deform the Rhombic Triacontahedra to Truncated Octahedra and tile 3-space with the Truncated Octahedra

Mackay (J. Mic. 146 (1987) 233-243) said "...a rhombic triacontahedron (RTH) ... can be deformed to ... a **truncated octahedron** ... [which is] the **space-filling polyhedron for body-centered cubic close packing ...**". Such a lattice of Truncated Octahedra (image from realwireless)



can form the basis for the spatial part of a 4-dim Feynman Checkerboard representation of the E8 Physics Model, with the Feynman Checkerboard Rules being related to the 256 Cellular Automata corresponding to the 256 elements of the Cl(8) Clifford Algebra of the E8 Physics Model



Appendix - E8 Lattices

E8 Lattices are based on Octonions, which have 480 different multiplication products. E8 Lattices can be combined to form 24-dimensional Leech Lattices and 26-dimensional Bosonic String Theory, which describes E8 Physics when the strings are physically interpreted as World-Lines. A basic String Theory Cell has as its automorphism group the Monster Group whose order is $2^{46} \cdot 3^{20} \cdot 5^9 \cdot 7^6 \cdot 11^2 \cdot 13^3 \cdot 17 \cdot 19 \cdot 23 \cdot 29 \cdot 31 \cdot 41 \cdot 47 \cdot 59 \cdot 71 = \text{about } 8 \times 10^{53}$.

For more about the Leech Lattice and the Monster and E8 Physics, see viXra 1210.0072 and 1108.0027 .

E8 Root systems and lattices are discussed by Robert A. Wilson in his 2009 paper "Octonions and the Leech lattice":

"... The (real) octonion algebra is an 8-dimensional (non-division) algebra with an orthonormal basis $\{ 1=i_0, i_1, i_2, i_3, i_4, i_5, i_6 \}$ labeled by the projective line $PL(7) = \{ \infty \} \cup F_7$

...

The E8 root system embeds in this algebra ... take the 240 roots to be ...

112 octonions ... $\pm it \pm iu$ for any distinct t, u

... and ...

128 octonions $(1/2)(\pm 1 \pm i_0 \pm \dots \pm i_6)$...[with]... an odd number of minus signs.

Denote by L the lattice spanned by these 240 octonions

...

Let $s = (1/2)(- 1 + i_0 + \dots + i_6)$ so s is in L ... write R for L bar ...

...

$(1/2) (1 + i_0) L = (1/2) R (1 + i_0)$ is closed under multiplication ... Denote this ...by A

... Writing **$B = (1/2) (1 + i_0) A (1 + i_0)$** ...from ... Moufang laws ... we have

$LR = 2B$, and ... $BL = L$ and $RB = R$...[also]... $2B = L$ bar

...

the roots of B are

[**16 octonions**]... $\pm it$ for t in $PL(7)$

... together with

[**112 octonions**]... $(1/2) (\pm 1 \pm it \pm i(t+1) \pm i(t+3))$...for t in F_7

... and ...

[**112 octonions**]... $(1/2) (\pm i(t+2) \pm i(t+4) \pm i(t+5) \pm i(t+6))$...for t in F_7

...

B is not closed under multiplication ... Kirmse's mistake

...[but]... as Coxeter ... pointed out ...

... **there are seven non-associative rings $A_t = (1/2) (1 + it) B (1 + it)$** ,

obtained from B by swapping 1 with it ... for t in F_7

...

$LR = 2B$ and $BL = L$...[which]... appear[s] not to have been noticed before ... some work ... by Geoffrey Dixon ...".

Geoffrey Dixon says in his book "Division Algebras, Lattices, Physics, Windmill Tilting" using notation $\{e_0, e_1, e_2, e_3, e_4, e_5, e_6, e_7\}$ for the Octonion basis elements that Robert A. Wilson denotes by $\{1=i_0, i_1, i_2, i_3, i_4, i_5, i_6\}$ and I sometimes denote by $\{1, i, j, k, e, ie, je, ke\}$: "...

$$\begin{aligned}\Xi_0 &= \{\pm e_a\}, \\ \Xi_2 &= \{(\pm e_a \pm e_b \pm e_c \pm e_d)/2 : a, b, c, d \text{ distinct}, \\ &\quad e_a(e_b(e_c e_d)) = \pm 1\},\end{aligned}$$

$$\begin{aligned}\Xi^{\text{even}} &= \Xi_0 \cup \Xi_2, \\ \mathcal{E}_8^{\text{even}} &= \text{span}\{\Xi^{\text{even}}\},\end{aligned}$$

$$\begin{aligned}\Xi_1 &= \{(\pm e_a \pm e_b)/\sqrt{2} : a, b \text{ distinct}\}, \\ \Xi_3 &= \{(\sum_{a=0}^7 \pm e_a)/\sqrt{8} : \text{even number of '+'s}\},\end{aligned}$$

$$\begin{aligned}\Xi^{\text{odd}} &= \Xi_1 \cup \Xi_3, \\ \mathcal{E}_8^{\text{odd}} &= \text{span}\{\Xi^{\text{odd}}\}\end{aligned}$$

(spans over integers)

Ξ^{even} has $16+224 = 240$ elements ... Ξ^{odd} has $112+128 = 240$ elements ...

$\mathcal{E}_8^{\text{even}}$ does not close with respect to our given octonion multiplication

...[but]...

the set $\Xi^{\text{even}}[0-a]$, derived from Ξ^{even} by replacing each occurrence of e_0 ... with e_a , and vice versa, is multiplicatively closed. ...".

Geoffrey Dixon's Ξ^{even} corresponds to Wilson's B which I denote as $1E_8$.

Geoffrey Dixon's $\Xi^{\text{even}}[0-a]$ correspond to Wilson's seven A_t which I denote as $iE_8, jE_8, kE_8, eE_8, ieE_8, jeE_8, keE_8$.

Geoffrey Dixon's Ξ^{odd} corresponds to Wilson's L.

My view is that **the E8 domains $1E_8 = \Xi^{\text{even}} = B$ is fundamental** because

E_8 domains $iE_8, jE_8, kE_8, eE_8, ieE_8, jeE_8, keE_8 = \Xi^{\text{even}}[0-a]$ are derived from $1E_8$ and L and L s are also derived from $1E_8 = \Xi^{\text{even}} = B$.

Using the notation $\{1, i, j, k, e, ie, je, ke\}$ for Octonion basis notice that in E8 Physics introduction of Quaternionic substructure to produce (4+4)-dim M4 x CP2 Kaluza-Klein SpaceTime requires breaking Octonionic light-cone elements $(\pm 1 \pm i \pm j \pm k \pm e \pm ie \pm je \pm ke) / 2$ into Quaternionic 4-term forms like $(\pm A \pm B \pm C \pm D) / 2$.

To do that, consider that there are $(8!4) = 70$ ways to choose 4-term subsets of the 8 Octonionic basis element terms. Using all of them produces 224 4-term subsets in each of the 7 Octonion Imaginary E8 lattices $iE8, jE8, kE8, eE8, ieE8, jeE8, keE8$ each of which also has 16 1-term first-shell vertices.

56 of the 70 4-term subsets appear as 8 in each of the 7 Octonion Imaginary E8 lattices.

The other $70 - 56 = 14$ 4-term subsets occur in sets of 3 among $7 \times 6 = 42$ 4-term subsets as indicated in the following detailed list of the 7 Octonion Imaginary E8 lattices:

eE8:

112 of D8 Root Vectors

16 appear in all 7 of $iE8, jE8, kE8, eE8, ieE8, jeE8, keE8$

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of $iE8, jE8, kE8, eE8, ieE8, jeE8, keE8$

$(\pm 1 \pm ke \pm e \pm k) / 2$	$(\pm i \pm j \pm ie \pm je) / 2$	$kE8$	,	$eE8$	,	$keE8$
$(\pm 1 \pm je \pm j \pm e) / 2$	$(\pm ie \pm ke \pm k \pm i) / 2$	$jE8$	,	$eE8$	,	$jeE8$
$(\pm 1 \pm e \pm ie \pm i) / 2$	$(\pm ke \pm k \pm je \pm j) / 2$	$iE8$	,	$eE8$	,	$ieE8$

128 of D8 half-spinors appear only in eE8

$(\pm 1 \pm ie \pm je \pm ke) / 2$	$(\pm e \pm i \pm j \pm k) / 2$
$(\pm 1 \pm k \pm i \pm je) / 2$	$(\pm j \pm ie \pm ke \pm e) / 2$
$(\pm 1 \pm i \pm ke \pm j) / 2$	$(\pm k \pm je \pm e \pm ie) / 2$
$(\pm 1 \pm j \pm k \pm ie) / 2$	$(\pm je \pm e \pm i \pm ke) / 2$

iE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm ie \pm i \pm e)/2$ $(\pm j \pm k \pm je \pm ke)/2$ iE8 , eE8 , ieE8
 $(\pm 1 \pm ke \pm je \pm i)/2$ $(\pm j \pm k \pm e \pm ie)/2$ iE8 , jeE8 , keE8
 $(\pm 1 \pm i \pm k \pm j)/2$ $(\pm e \pm ie \pm je \pm ke)/2$ iE8 , jE8 , kE8

128 of D8 half-spinors appear only in iE8

$(\pm 1 \pm k \pm ke \pm ie)/2$ $(\pm i \pm j \pm e \pm je)/2$
 $(\pm 1 \pm e \pm j \pm ke)/2$ $(\pm i \pm k \pm ie \pm je)/2$
 $(\pm 1 \pm j \pm ie \pm je)/2$ $(\pm i \pm k \pm e \pm ke)/2$
 $(\pm 1 \pm je \pm e \pm k)/2$ $(\pm i \pm j \pm ie \pm ke)/2$

jE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm k \pm j \pm i)/2$ $(\pm e \pm ie \pm je \pm ke)/2$ iE8 , jE8 , kE8
 $(\pm 1 \pm ie \pm ke \pm j)/2$ $(\pm i \pm k \pm e \pm je)/2$ jE8 , ieE8 , keE8
 $(\pm 1 \pm j \pm e \pm je)/2$ $(\pm i \pm k \pm ie \pm ke)/2$ jE8 , eE8 , jeE8

128 of D8 half-spinors appear only in jE8

$(\pm 1 \pm e \pm ie \pm k)/2$ $(\pm i \pm j \pm je \pm ke)/2$
 $(\pm 1 \pm i \pm je \pm ie)/2$ $(\pm j \pm k \pm e \pm ke)/2$
 $(\pm 1 \pm je \pm k \pm ke)/2$ $(\pm i \pm j \pm e \pm ie)/2$
 $(\pm 1 \pm ke \pm i \pm e)/2$ $(\pm j \pm k \pm ie \pm je)/2$

kE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm je \pm k \pm ie)/2$ $(\pm i \pm j \pm e \pm ke)/2$ kE8 , ieE8 , jeE8
 $(\pm 1 \pm j \pm i \pm k)/2$ $(\pm e \pm ie \pm je \pm ke)/2$ iE8 , jE8 , kE8
 $(\pm 1 \pm k \pm ke \pm e)/2$ $(\pm i \pm j \pm ie \pm je)/2$ kE8 , eE8 , keE8

128 of D8 half-spinors appear only in kE8

$(\pm 1 \pm ke \pm j \pm je)/2$ $(\pm i \pm k \pm e \pm ie)/2$
 $(\pm 1 \pm ie \pm e \pm j)/2$ $(\pm i \pm k \pm je \pm ke)/2$
 $(\pm 1 \pm e \pm je \pm i)/2$ $(\pm j \pm k \pm ie \pm ke)/2$
 $(\pm 1 \pm i \pm ie \pm ke)/2$ $(\pm j \pm k \pm e \pm je)/2$

ieE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm j \pm ie \pm ke)/2$	$(\pm i \pm k \pm e \pm je)/2$	jE8	,	ieE8	,	keE8
$(\pm 1 \pm i \pm e \pm ie)/2$	$(\pm j \pm k \pm je \pm ke)/2$	iE8	,	eE8	,	ieE8
$(\pm 1 \pm ie \pm je \pm k)/2$	$(\pm i \pm j \pm e \pm ke)/2$	kE8	,	ieE8	,	jeE8

128 of D8 half-spinors appear only in ieE8

$(\pm 1 \pm je \pm i \pm j)/2$	$(\pm k \pm e \pm ie \pm ke)/2$
$(\pm 1 \pm ke \pm k \pm i)/2$	$(\pm j \pm e \pm ie \pm je)/2$
$(\pm 1 \pm k \pm j \pm e)/2$	$(\pm i \pm ie \pm je \pm ke)/2$
$(\pm 1 \pm e \pm ke \pm je)/2$	$(\pm i \pm j \pm k \pm ie)/2$

jeE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm e \pm je \pm j)/2$	$(\pm i \pm k \pm ie \pm ke)/2$	jE8	,	eE8	,	jeE8
$(\pm 1 \pm k \pm ie \pm je)/2$	$(\pm i \pm j \pm e \pm ie)/2$	kE8	,	ieE8	,	jeE8
$(\pm 1 \pm je \pm i \pm ke)/2$	$(\pm j \pm k \pm e \pm ie)/2$	iE8	,	jeE8	,	keE8

128 of D8 half-spinors appear only in jeE8

$(\pm 1 \pm i \pm k \pm e)/2$	$(\pm j \pm ie \pm je \pm ke)/2$
$(\pm 1 \pm j \pm ke \pm k)/2$	$(\pm i \pm e \pm ie \pm je)/2$
$(\pm 1 \pm ke \pm e \pm ie)/2$	$(\pm i \pm j \pm k \pm je)/2$
$(\pm 1 \pm ie \pm j \pm i)/2$	$(\pm k \pm e \pm je \pm ke)/2$

keE8:

112 of D8 Root Vectors

16 appear in all 7 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$\pm 1, \pm i, \pm j, \pm k, \pm e, \pm ie, \pm je, \pm ke$

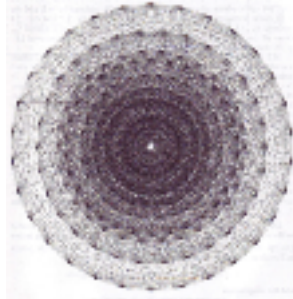
96 appear in 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8

$(\pm 1 \pm i \pm ke \pm je)/2$	$(\pm j \pm k \pm e \pm ie)/2$	iE8	,	jeE8	,	keE8
$(\pm 1 \pm e \pm k \pm ke)/2$	$(\pm i \pm j \pm ie \pm je)/2$	kE8	,	eE8	,	keE8
$(\pm 1 \pm ke \pm j \pm ie)/2$	$(\pm i \pm k \pm e \pm je)/2$	jE8	,	ieE8	,	keE8

128 of D8 half-spinors appear only in keE8

$(\pm 1 \pm j \pm e \pm i)/2$	$(\pm k \pm ie \pm je \pm ke)/2$
$(\pm 1 \pm je \pm ie \pm e)/2$	$(\pm i \pm j \pm k \pm ke)/2$
$(\pm 1 \pm ie \pm i \pm k)/2$	$(\pm j \pm e \pm je \pm ke)/2$
$(\pm 1 \pm k \pm je \pm j)/2$	$(\pm i \pm e \pm ie \pm ke)/2$

Coxeter said in "Integral Cayley Numbers" (Duke Math. J. 13 (1946) 561-578 and in "Regular and Semi-Regular Polytopes III" (Math. Z. 200 (1988) 3-45):
 "... the 240 integral Cayley numbers of norm 1 ... are the vertices of 4_21



... ..

The polytope 4_21 ... has cells of two kinds ...
 a seven-dimensional "cross polytope" (or octahedron-analogue) B_7
 ... there are ... 2160 B_7's ...
 and ...
 a seven-dimensional regular simplex A_7
 ... there are 17280 A_7's
 ...
 the 2160 integral Cayley numbers of norm 2 are
 the centers of the 2160 B_7's of a 4_21 of edge 2

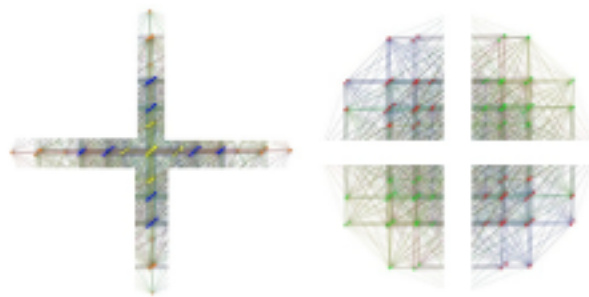
...
 the 17280 integral Cayley numbers of norm 4 (other than the doubles
 of those of norm 1) are the centers of the 17280 A_7's of a 4_21 of edge 8/3 ...

[Using notation of {a1,a2,a3,a4,a5,a6,a7,a8} for Octonion basis elements we have]

norm 1

112 like (+/- a1 +/- a2)
 [which correspond to 112 = 16 + 96 = 16 + 6x16 in each of the 7 E8 lattices]

128 like (1/2) (- a1 + a2 + a3 + ... + a8) with an odd number of minus signs
 [which correspond to 128 = 8x16 in each of the 7 E8 lattices]



112

128

norm 2

16 like $\pm 2 a_1$

[which correspond to 16 for the 112 in each of the 7 E8 lattices]

1120 like $\pm a_1 \pm a_2 \pm a_3 \pm a_4$

[which correspond to $70 \times 16 = (56+14) \times 16$ that appear in the 7 E8 lattices

with each of the 14 appearing in three of the 7 E8 lattices so that
the 14 account for $(14/7) \times 3 \times 16 = 6 \times 16 = 96$ in each of the 7 E8 lattices
and for $14 \times 16 = \mathbf{224}$ of the **1120**

and

with each of the 56 appearing in only one of the 7 E8 lattices so that
the 56 account for $(56/7) \times 16 = 128$ in each of the 7 E8 lattices
and for $56 \times 16 = \mathbf{896} = \mathbf{7 \times 128}$ of the **1120**]

1024 like $(1/2)(3a_1 + 3a_2 + a_3 + a_4 + \dots + a_8)$ with an even number of minus signs
[which correspond to $\mathbf{8 \times 128} = 8$ copies of the 128-dim Mirror D8 half-spinors that
are not used in the 7 E8 lattices. ...] ...".

One of the 128-dimensional Mirror D8 half-spinors from the 1024
combines with

the 128 from the 1120 corresponding to the one of the 7 E8 lattices that corresponds
to the central norm $1240 = 112 + 128$

and

the result is formation of a $128 + 128 = 256$ corresponding to the Clifford Algebra $Cl(8)$
so that

the norm 2 second layer contains 7 copies of 256-dimensional $Cl(8)$

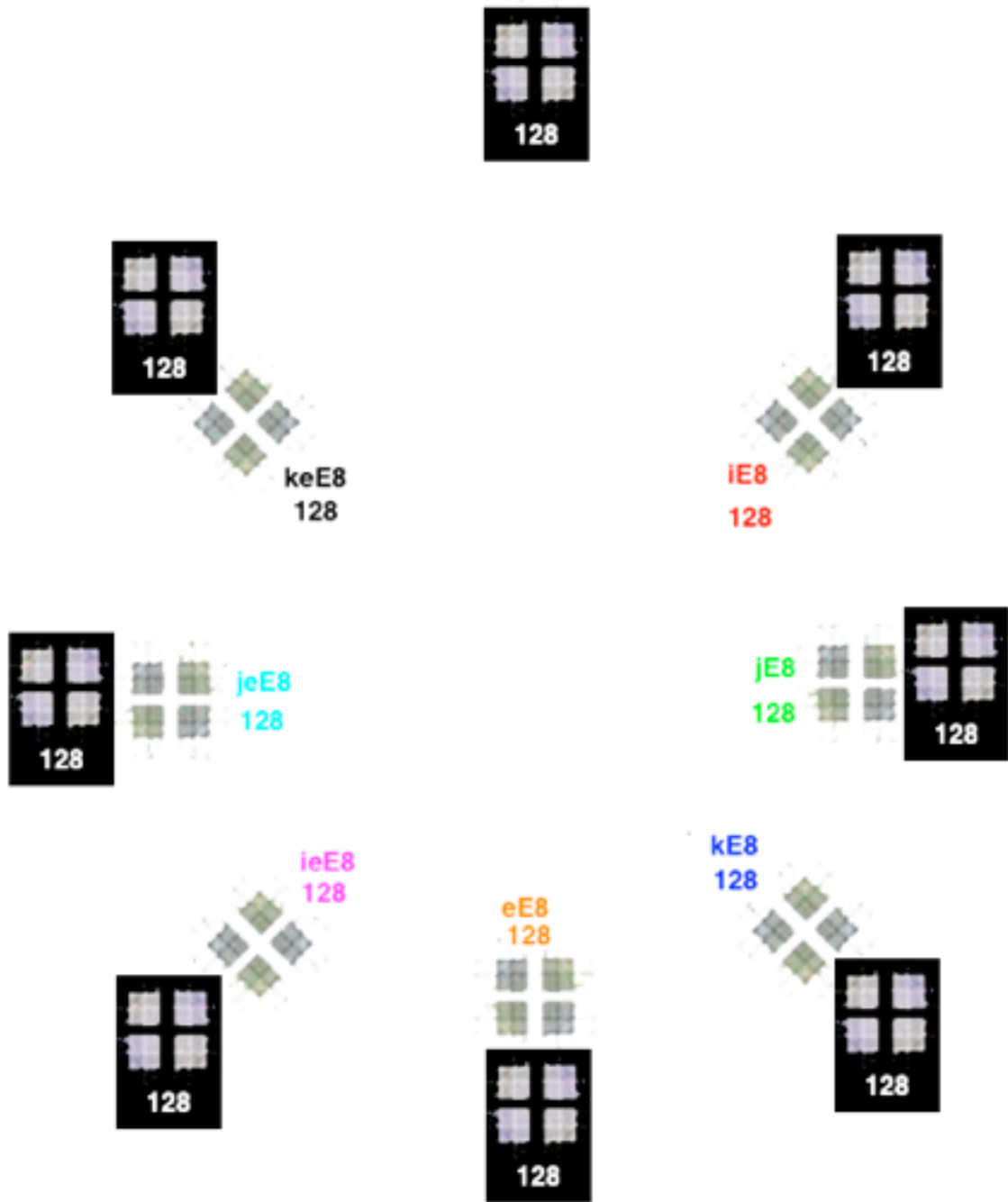
so the 2160 norm 2 vertices can be seen as

$$\mathbf{7(128+128) + 128 + 16 + 224 = 2160 \text{ vertices.}}$$

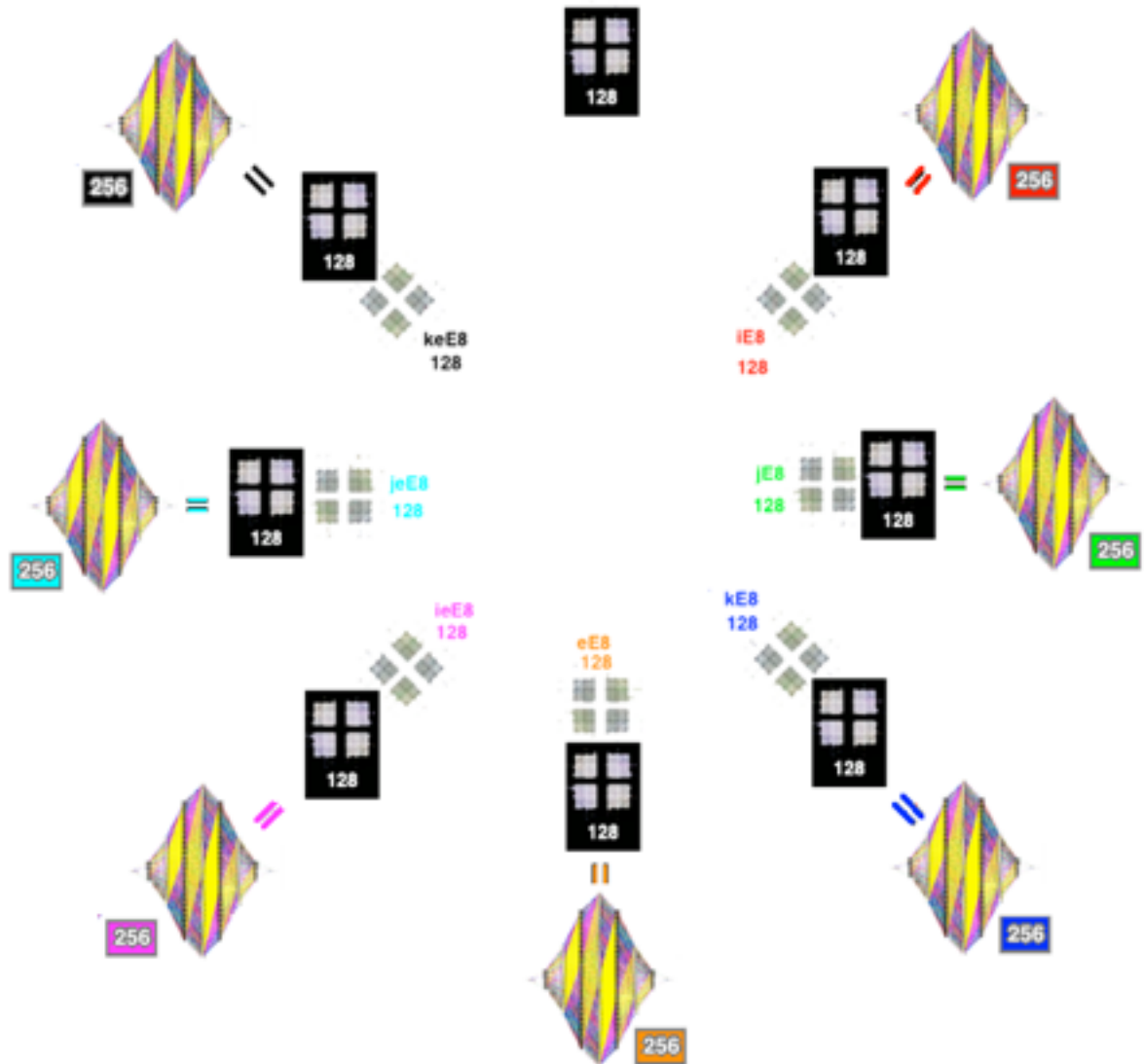
7x128 from the 1120 are the D8 half-spinor vertices
of iE_8 , jE_8 , kE_8 , eE_8 , ieE_8 , jeE_8 , keE_8



7x128 from the 1024 are Mirror D8 half-spinors that are not vertices of the 7 Imaginary E8 lattices $iE8$, $jE8$, $kE8$, $eE8$, $ieE8$, $jeE8$, $keE8$.
 The 8th 128 is a Mirror D8 half-spinor, also not in the 7 Imaginary E8 lattices.

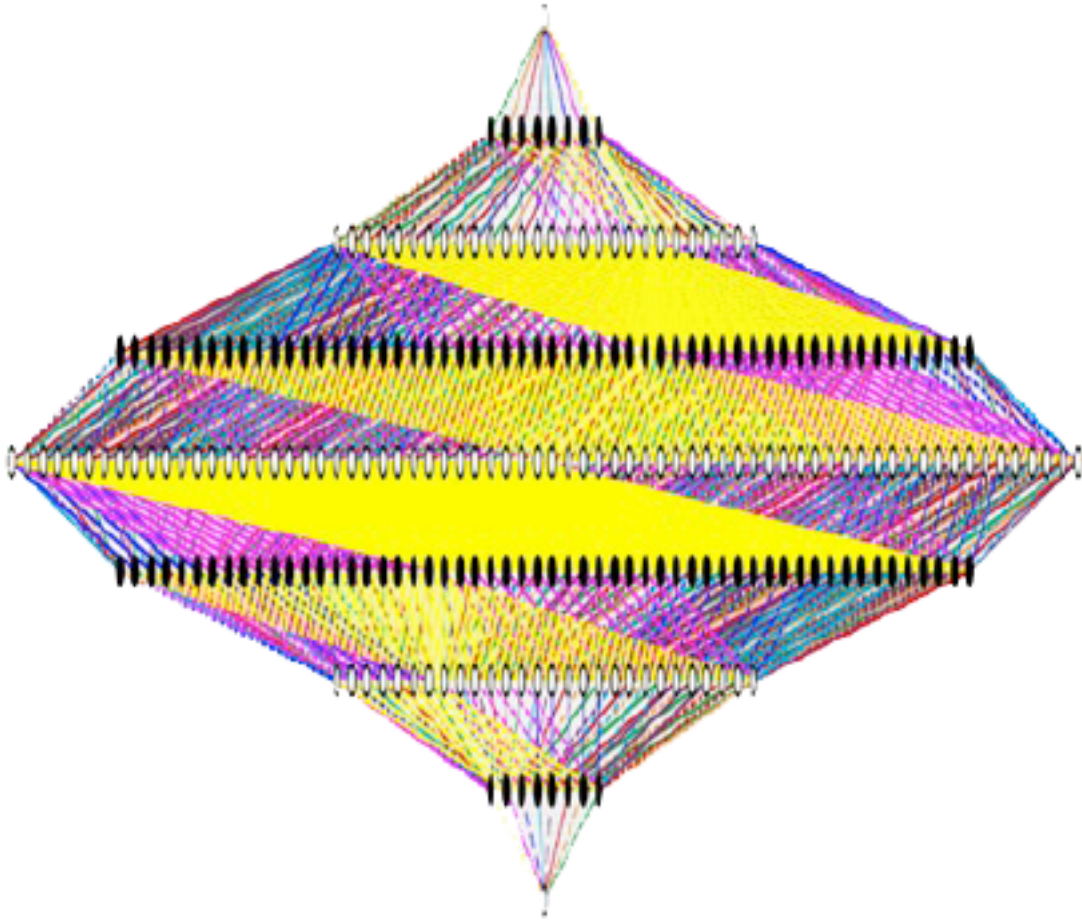


Each of the 7 pairs of 128 corresponds to a 256 Cl(8)



so that the 2160 second layer contains 7 sets of 256 vertices with each set corresponding to the Cl(8) Clifford Algebra and to the 256 vertices of an 8-dimensional light-cone ($\pm 1 \pm i \pm j \pm k \pm e \pm ie \pm je \pm ke$) / 2

The 256 vertices of each pair 128+128 form an 8-cube with 1024 edges, 1792 square faces, 1792 cubic cells, 1120 tesseract 4-faces, 448 5-cube 5-faces, 112 6-cube 6-faces, and 16 7-cube 7-faces. The image format of African Adinkra for 256 Odu of IFA



shows $Cl(8)$ graded structure $1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1$ of 8-cube vertices. Physically they represent **Operators in $H_{92} \times SI(8)$ Generalized Heisenberg Algebra** that is the **Maximal Contraction of E_8** :

Odd-Grade Parts of $Cl(8)$ =

= **128 D8 half-spinors** of one of $iE_8, jE_8, kE_8, eE_8, ieE_8, jeE_8, keE_8$

8+56 grades-1,3 = Fermion Particle 8-Component Creation (AntiParticle Annihilation)

56+8 grades-5,7 = Fermion AntiParticle 8-Component Creation (Particle Annihilation)

Even-Grade Subalgebra of $Cl(8)$ = 128 Mirror D8 half-spinors =

28 grade-2 = Gauge Boson Creation (16 for Gravity, 12 for Standard Model)

28 grade-6 = Gauge Boson Annihilation (16 for Gravity, 12 for Standard Model)

(each 28 = 24 Root Vectors + 4 of Cartan Subalgebra)

64 of grade-4 = 8-dim Position x Momentum

1+(3+3)+1 grades-0,4,8 = Primitive Idempotent:

(1+3) = Higgs Creation; (3+1) = Higgs Annihilation

= **112 D8 Root Vectors + 8 of E_8 Cartan Subalgebra + 8 Higgs Operators**

8 of E8 Cartan Subalgebra + 8 Higgs Operators = 2 copies of 4-dim 16-cell

(images from Bathsheba)



The 16-cell has 24 edges, midpoints of which are the 24 vertices of a 24-cell.
The 24-cell has 96 edges, Golden Ratio points of which when added to its 24 vertices,
form the $96+24 = 120$ vertices of a 600-cell.

128 vertices of the D8 half-spinors + 112 vertices of D8 Root Vectors = $240 =$
= 2 copies of 4-dim {3,3,5} 600-cell (images from Bathsheba)



Each 600-cell lives inside a 16-cell.

So,

the 256 vertices of **CI(8)**

(which represents Creation/Annihilation Operators in the Generalized Heisenberg
Algebra $H_{92} \times SI(8)$ that is the Maximal Contraction of E8)

contain

dual 16-cell structure of E8 Cartan Subalgebra + CI(8) Primitive Idempotent Higgs
as well as

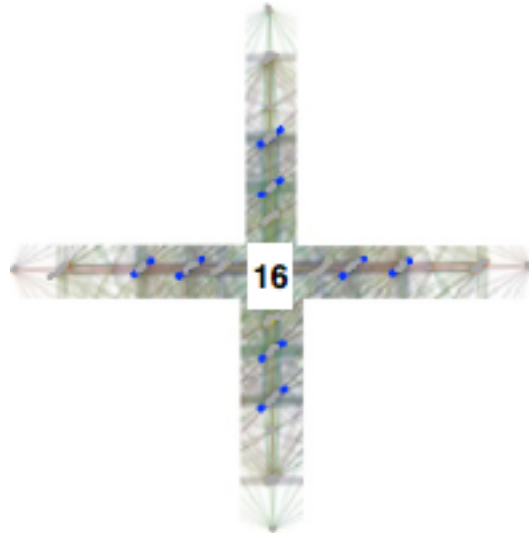
the dual 600-cell structure of the 240 E8 Root Vector vertices

The 128 Mirror D8 half-spinors correspond to 16 + 112 of the 16 + 224.

**The 16 + 224 corresponds to an 8th set of 240 Root Vector vertices
for an 8th E8 lattice denoted 1E8.**

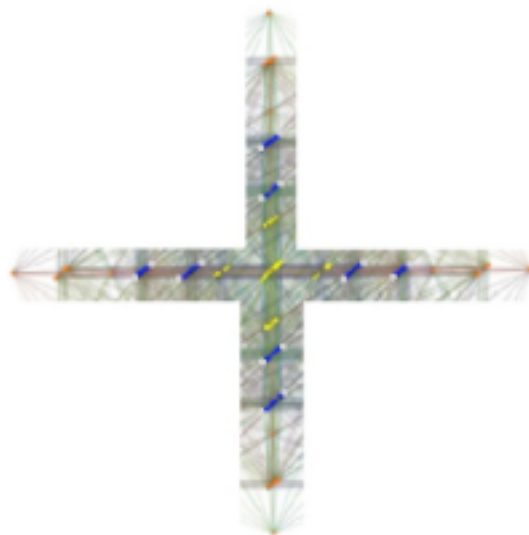
It does not close under the Octonion Product used for the 7 Imaginary E8 lattices
(that is the basis for Kirmse's mistake)
but it does close under another of the 480 Octonion products.

16 live within the 112 D8 adjoint Root Vectors



in all of the 7 E8 lattices $iE8$, $jE8$, $kE8$, $eE8$, $ieE8$, $jeE8$, $keE8$.

224 = 7 sets of 32 with 3 sets of 32 = 96 within the 112 D8 adjoint Root Vectors



in the 7 E8 lattices $iE8$, $jE8$, $kE8$, $eE8$, $ieE8$, $jeE8$, $keE8$.

The 112 D8 Root Vector vertices in $iE_8, jE_8, kE_8, eE_8, ieE_8, jeE_8, keE_8$
 $(+/- 1, +/- 1, 0, 0, 0, 0, 0, 0)$

for all 4 possible +/- signs times all $(8!2) = 28$ permutations of pairs of basis elements can be written in matrix form with each "4" representing possible signs and with the overall pattern of $(1+2+3) + (4 \times 4) + (3+2+1)$ representing the 28 permutations as

	1	i	j	k	e	ie	je	ke
1	-	4	4	4	4	4	4	4
i			4	4	4	4	4	4
j				4	4	4	4	4
k					4	4	4	4
e						4	4	4
ie							4	4
je								4
ke								-

The $4 \times 6 = 24$ in the $(1,i,j,k) \times (1,i,j,k)$ block corresponding to M4 Physical Spacetime are the Root Vectors of a D4 in D8 in E8 with a $U(2,2)$ subgroup that contains the $SU(2,2) = Spin(2,4)$ Conformal Group of Gravity.

The $4 \times 4 \times 4 = 64$ in the $(1,i,j,k) \times (e,ie,je,ke)$ block represents $(4+4)$ -dim M4 x CP2 Kaluza-Klein Spacetime position and momentum.

The $4 \times 6 = 24$ in the $(e,ie,je,ke) \times (e,ie,je,ke)$ block corresponding to CP2 Internal Symmetry Space are the Root Vectors of another D4 in D8 in E8 with a $U(4)$ subgroup that contains the $SU(3)$ Color Force Group of the Standard Model.
 The coset structure $CP2 = SU(3) / U(1) \times SU(2)$ gives the ElectroWeak $U(1)$ and $SU(2)$.

In each of the 7 E8 Root Vector sets for $iE_8, jE_8, kE_8, eE_8, ieE_8, jeE_8, keE_8$

64 of the 128 D8 half-spinor vertices represent 8 components of 8 Fermion Particles and

64 of the 128 D8 half-spinor vertices represent 8 components of 8 Fermion AntiParticles where

the 8 fundamental Fermion Particle/AntiParticle types are:

- neutrino, red down quark, green down quark, blue down quark;
- blue up quark, green up quark, red up quark, electron.

The **224** are arranged as

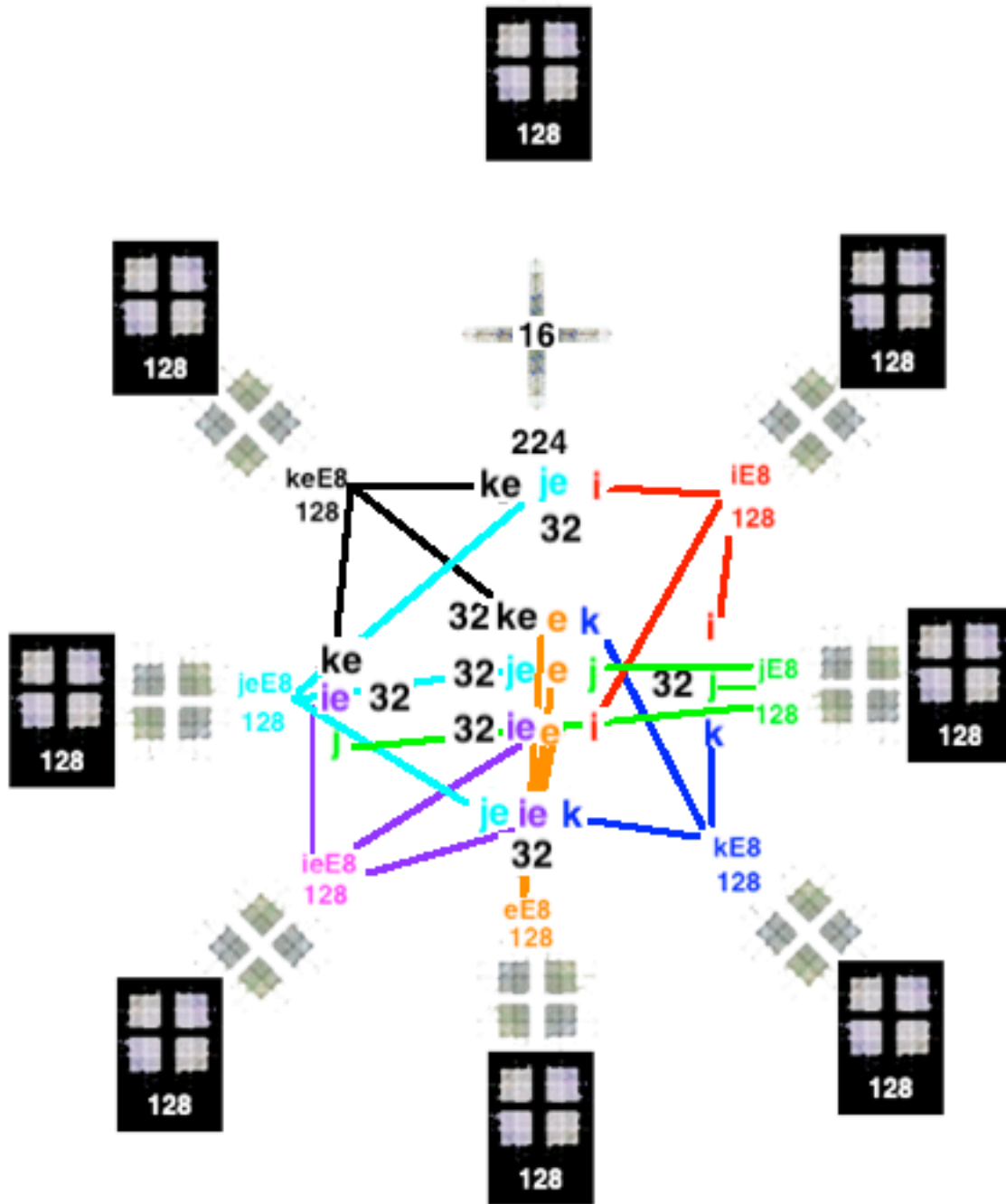


so that each of the sets of 32 connect with 3 of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8 and each of iE8, jE8, kE8, eE8, ieE8, jeE8, keE8 connect with 3 of the sets of 32.

The **224** combined with the **16** give the **240** of **1E8**



The $7(128+128) + 128 + 16 + 224$ structure of all 2160 second layer E8 vertices is



The Third Grothendieck Universe: Clifford Algebra $Cl(16)$ E8 AQFT

by Frank Dodd (Tony) Smith Jr. - vixra 1202.0028

Abstract:

Completion of union of all tensor products of the real Clifford algebra $Cl(16)$ is proposed as the Third Grothendieck Universe (the first two being the empty set and hereditarily finite sets) thus giving a Category Theoretical description of a realistic Algebraic Quantum Field Theory that has a clear relationship with Path Integral Quantization of Standard Model + Gravity Lagrangian Physics.

At present, this paper is an outline of a proposed program of research that is not yet complete.

(References are included in the body of the paper and in linked material.)

The Third Grothendieck Universe: Clifford Algebra $Cl(16)$ E8 AQFT

Frank Dodd (Tony) Smith Jr. - 2012

Realistic Physics/Math can be described using Three Grothendieck universes:

1 - Empty Set - the seed from which everything grows.

2 - Hereditarily Finite Sets - computer programs, discrete lattices,
discrete Clifford algebras, cellular automata,
Feynman Checkerboards.

3 - Completion of Union of all tensor products of $Cl(16)$ real Clifford algebra -
a generalized hyperfinite III von Neumann factor algebra
that, through its $Cl(16)$ structure, contains such useful Physics/Math objects as:

Spinor Spaces

Vector Spaces

BiVector Lie Algebras and Lie Groups

Symmetric Spaces

Complex Domains, their Shilov boundaries, and Harmonic Analysis

E8 Lie Algebra

$Sl(8) \times H_92$ Algebra (Contraction of E8)

Classical Physics Lagrangian structures

Base Manifold

Spinor Fermion term

Standard Model Gauge Boson term

MacDowell-Mansouri Gravity term

Quantum Physics Hamiltonian/Heisenberg Algebra

Position/Momentum Spaces

Gravity + SM boson Creation/Annihilation Operators

Fermion Creation/Annihilation Operators

Daniel Murfet (Foundations for Category Theory 5 October 2006) said:
“... The most popular form of axiomatic set theory is Zermelo-Frankel (ZF) together with the Axiom of Choice (ZFC) ... this is not enough, because we need to talk about structures like the “category of all sets” which have no place in ZFC ...[more useful foundations include]

...

(a) An alternative version of set theory called NBG (due to von Neumann, Robinson, Bernays and Godel) which introduces classes to play the role of sets which are “too big” to exist in ZF

...

(b) Extend ZFC by adding a new axiom describing Grothendieck universes. Intuitively speaking, you fix a Grothendieck universe U and call elements of U sets, while calling subsets of U classes. ... This ... seems to be the only serious foundation available for modern research involving categories

...

(c) The first two options [(a) and (b)] are conversative, in that they seek to extend set theory by as little as possible to make things work. More exotically, we can introduce categories as foundational objects. This approach focuses on topoi as the fundamental logical objects (as well as the connection with the more familiar world of naive set theory). While such a foundation shows promise, it is not without its own problems ... and is probably not ready for “daily use”.

...

Before we study Grothendieck universes, let us first agree on what we mean by ZFC. The first order theory ZFC has two predicate letters A, B but no function letter, or individual constants. Traditionally the variables are given by uppercase letters X_1, X_2, \dots (As usual, we shall use X, Y, Z to represent arbitrary variables). We shall abbreviate $A(X, Y)$ by $X \text{ in } Y$ and $B(X, Y)$ by $X = Y$.

Intuitively e is thought of as the membership relation and the values of the variables are to be thought of as sets (in ZFC we have no concept of “class”).

The proper axioms are as follows (there are an infinite number of axioms since an axiom scheme is used):

Axiom of Extensionality Two sets are the same if and only if they have the same elements ...

Axiom of Empty Set There is a set with no elements. By the previous axiom, it must be unique ...

Axiom of Pairing If x, y are sets, then there exists a set containing x, y as its only elements, which we denote $\{x, y\}$. Therefore given any set x there is a set $\{x\} = \{x, x\}$ containing just the set x ...

Axiom of Union For any set x , there is a set y such that the elements of y are precisely the elements of the elements of x ...

Axiom of Infinity There exists a set x such that the empty set is in x and whenever y is in x , so is $y \cup \{y\}$...

Axiom of Power Set Every set has a power set. That is, for any set x there exists a set y , such that the elements of y are precisely the subsets of x ...

Axiom of Comprehension Given any set and any ... well formed formula ... wf $B(x)$ with x free, there is a subset of the original set containing precisely those elements x for which $B(x)$ holds (this is an axiom schema) ... Here we make the technical assumption that the variables A, B, C do not occur in B ...

Axiom of Replacement Given any set and any mapping, formally defined as a wf $B(x, y)$ with x, y free such that $B(x, y_1)$ and $B(x, y_2)$ implies $y_1 = y_2$, there is a set containing precisely the images of the original set's elements (this is an axiom schema) ...

Axiom of Foundation A foundation member of a set x is y in x such that $y \cap x$ is empty. Every nonempty set has a foundation member ...

Axiom of Choice Given any set of mutually disjoint nonempty sets, there exists at least one set that contains exactly one element in common with each of the nonempty sets.

...

Looking at the axioms, only the Axiom of Replacement can produce a set outside our universe (beginning with sets inside the universe), although one could argue that the Axiom of Infinity also “produces” the set \mathbb{N} , which may not belong to U . To get around the latter difficulty, we add the following axiom to ZFC ...

UA. Every set is contained in some universe ...

UA is equivalent to the existence of inaccessible cardinals, and is therefore logically independent of ZFC

...

[This gives]... The first order theory ZFCU ...

Grothendieck Universes

Whatever foundation we use for category theory, it must somehow provide us with a notion of “big sets”. In Grothendieck’s approach, one fixes a particular set U (called the universe) and thinks of elements of U as “normal sets”, subsets of U as “classes”, and all other sets as “unimaginably massive”.

...

Definition 3. A Grothendieck universe (or just a universe) is a nonempty set U with the following properties:

U1. If x in U and y in x then y in U (that is, if x in U then x subset U).

U2. If x, y in U then $\{x, y\}$ in U .

U3. If x in U , then ... power set ... $P(x)$ in U .

U4. If I in U and $\{x_i\}_{i \in I}$ is a family of elements of U , then the union over i in I of the x_i belongs to U .

...

Therefore

any finite union, product and disjoint union of elements of U belongs to U .

In particular every finite subset of U belongs to U ...

by our convention U contains \mathbb{N} , and therefore also $\mathbb{Z}, \mathbb{Q}, \mathbb{R}, \mathbb{C}$ and all structures built from these using the theory of sets ...”.

The Wikipedia article on Grothendieck universe said:

“... The idea of universes is due to Alexander Grothendieck, who used them as a way of avoiding proper classes ...

There are two simple examples of Grothendieck universes:

The empty set,

and

The set of all hereditarily finite sets ... “.

**The Third Grothendieck universe describes a realistic E8 AQFT.
It is the completion of the union of all tensor products of Cl(16)
which I will denote as
UC16**

The UC16 universe gives category techniques useful in math and physics.

The real Clifford algebra $Cl(16) = Cl(Cl(4)) = Cl(Cl(Cl(Cl(Cl(Cl(\mathbf{0}))))))$
so UC16 can be constructed by iterating Clifford Algebra construction
from empty $\mathbf{0}$ to 0-dim $Cl(\mathbf{0}) = \{-1,+1\}$ to 1-dim $Cl(0) = \mathbb{R}$ and so on.
Since $Cl(16) = Cl(8) \times Cl(8)$ and real Clifford algebras have 8-periodicity,
UC16 includes all arbitrarily large real Clifford algebras.

UC16 is a hyperfinite von Neumann factor algebra, being
a real generalization of the usual complex hyperfinite II1 von Neumann factor.

Further, UC16 inherits from its $Cl(16)$ factors some structures that are useful
in areas including, but not limited to, physics model building
which structures can be seen in Category Theoretical terms:

- Vectors
- BiVector Lie Algebras and Lie Groups
 - Symmetric Spaces
 - Complex Domains, their Shilov boundaries, and Harmonic Analysis
- Spinors with Fermion properties
- E8 Lie Algebra
- $Sl(8) \times H92$ Algebra (Contraction of E8)

Some other Categories useful with respect to physics model building are:

- Classical Physics Lagrangian
 - Lagrangian Spinor Fermion term
 - Lagrangian Base Manifold
 - Lagrangian MacDowell-Mansouri Gravity term
 - Lagrangian Standard Model Gauge Boson term

- Quantum Physics Hamiltonian/Heisenberg Algebra
 - Position/Momentum
 - Gravity + SM boson Creation/Annihilation
 - Fermion Creation/Annihilation

With respect to those Categories, there exist Functors

$Cl(16) \rightarrow E8 \rightarrow$ Classical Physics Lagrangian

and

$Cl(16) \rightarrow Sl(8) \times H_{92} \rightarrow$ Quantum Physics Hamiltonian/Heisenberg Algebra

defined by

$Cl(16) \rightarrow E8$ and

$E8$ 128 Spinors \rightarrow Lagrangian Spinor Fermion term

$E8$ 64 Position/Momentum \rightarrow Lagrangian Base Manifold

$E8$ 28 D4 Gravity \rightarrow Lagrangian M-M Gravity term

$E8$ 28 D4 Standard Model \rightarrow Lagrangian SM Gauge Boson term

and

$Cl(16) \rightarrow Sl(8) \times H_{92} = Sl(8) \times H_{(28+64)}$ and

$Sl(8)$ \rightarrow Position/Momentum

H_{28} \rightarrow Gravity + SM boson Creation/Annihilation

H_{64} \rightarrow Fermion Creation/Annihilation

Therefore **Path Integral quantization of Classical Physics Lagrangian**

has a Category Theoretical relationship with

Quantum Physics Hamiltonian/Heisenberg Algebraic Quantum Field Theory

that may show a Categorification of Lagrangian Path Integral

that is more directly related to the Standard Model + Gravity

than the

Chern-Simons theory whose Path Integral Quantization to a Topological Quantum Field Theory is described by Daniel Freed in Bull. AMS 46 (2009) 221-254.

Details of the physics structures mentioned above can be found in my paper

Introduction to E8 Physics that is on the web at these URLs:

<http://vixra.org/abs/1108.0027>

<http://www.valdostamuseum.org/hamsmith/E8physics2011.pdf>

<http://www.tony5m17h.net/E8physics2011.pdf>

The wikipedia timeline of category theory says:

1958 - Grothendieck formulates topos theory based on algebraic geometry

1958 - Godement generalizes to monads

1963 - Grothendieck topos - categories = universes for doing all math

1963 - MacLane does n-categories (ribbons, braids, etc)

1964 - Lawvere does Elementary Theory of the Category of Sets (ETCS)

1972 - Grothendieck Universes for math

2006 - Lurie Higher Topos Theory

Kromer in his book Tool and Object says: "... the foundational debate

...

For Grothendieck, set theory is a foundation;

he assumes "more" than ZF ...[such as]... universes

...

Lawvere, however, assumes "less" ...".

Lawvere Approach

It seems to me that the Lawvere approach to AQFT leads to n-categorical higher topos stuff which seems to me to be so abstract that it loses touch with concrete things needed to build physics models.

For example, the timeline also says:

1964 - Haag-Kastler-Segal Algebraic Quantum Field Theory (AQFT)

1988 - Witten Topological Quantum Field Theory (TQFT)

with the Lawvere path of AQFT leading to TQFT (and ribbons, braids, etc) which do not have enough detailed structure for construction of realistic physics models.

For example, Colin McLarty says in his 2009 paper

"What does it take to prove Fermat's Last Theorem?

Grothendieck and the logic of number theory" that it is

"... not entirely known ...[whether it]... go[es] beyond ... ZFC ...

[or]...

merely use[s] Peano Arithmetic (PA) or some weaker fragment of ... ZFC ..."

so

it seems to me that from the Lawvere approach it is not clear that FLT has been proven.

Grothendieck Universe Approach

Colin McLarty in his 2009 paper "What does it take to prove Fermat's Last Theorem? Grothendieck and the logic of number theory" goes on to say:

"... Grothendieck ... universe is an uncountable transitive set U such that $\{U, \text{in}\}$... contains the powerset of each of its elements, and for any function from an element of U to U the range is also an element of U ... ZFC + U consists of ZFC plus the assumption of a universe ... ZFC + U certainly implies more statements of arithmetic than ZFC alone

...

Grothendieck universes ... organize a context for ... explicit arithmetic calculations proving FLT ... The great proofs in cohomological number theory, such as Wiles[1995] or Deligne[1974], or Faltings[1983] ... in fact ... use universes ...".

Therefore I prefer the Grothendieck universe approach to AQFT
1964 - Haag-Kastler-Segal Algebraic Quantum Field Theory (AQFT)
1972 - Grothendieck Universes for math

which I think does have sufficient detailed structure:

Streicher says in Universes in Toposes (2004): "... Grothendieck ... introduced .. Grothendieck universe ... ZFC together with the requirement that every set A be contained in some Grothendieck universe guaranteeing at least an infinite sequence ... of Grothendieck universes ... U_0 in U_1 in ... $U_{(n-1)}$ in U_n in $U_{(n+1)}$ in ...".

You can take U_0 as the empty set
and
 U_1 as hereditarily finite sets
(which can be constructed from the power set
and which give you computer programs, discrete lattices,
discrete Clifford algebras, cellular automata, Feynman checkerboards, etc).

I would like to construct U_2 by noticing that the power set structure of U_1
is inherent in the basic construction of real Clifford algebras
which have the concrete structure of 8-periodicity
which allows you (since $Cl(16) = Cl(8) \times Cl(8)$) to construct
the completion of the union of all tensor products of $Cl(16)$
which seems to have algebraic structure that is
similar to the hyperfinite III von Neumann factor
and therefore to be a nice candidate for a realistic AQFT.

Of course, you can go beyond U_2 as far as you want to go,
but if you can build a realistic AQFT World from U_2
then my guess is that going beyond U_2 describes the Many-Worlds
of Many-Worlds Quantum Theory which gets you to
evolution of the Many-Worlds Multiverse by Quantum Game Theory
which in turn can be described by Clifford Algebra as in
<http://arxiv.org/abs/1008.4689> by Chappell, Iqbal, and Abbott.

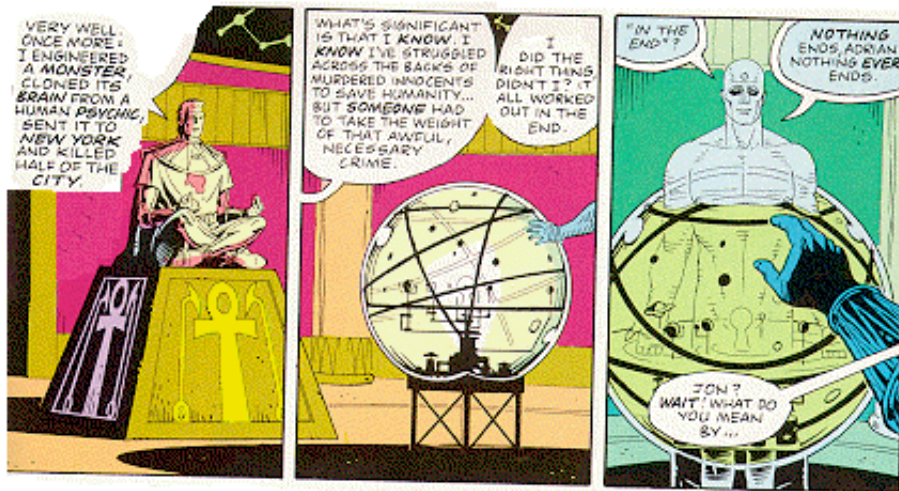
That, in turn, leads to the AQFT geometry of EPR phenomena
as described by Joy Christian at <http://arxiv.org/abs/1201.0775>

Marcus Chown, in the article [Taming the Multiverse](#) in [New Scientist](#) (14 July 2001, pages 27-30), says: "... David Deutsch ... thinks ... the multiverse ... could make real choice possible. ... In the multiverse ... there are alternatives ... Free will might have a sensible definition, Deutsch ... says...

["By making good choices ... we thicken the stack of universes in which versions of us live reasonable lives ..."](#)

Each and every thing we do is a move in a vast never-ending Quantum Game .

As Jon (Dr. Manhattan) said in [Watchmen](#) (by Alan Moore and Dave Gibbons, DC Comics 1986, 1987):



"... Nothing EVER ends. ...". Each and every thing we do is a move in a vast never-ending [Quantum Game](#).

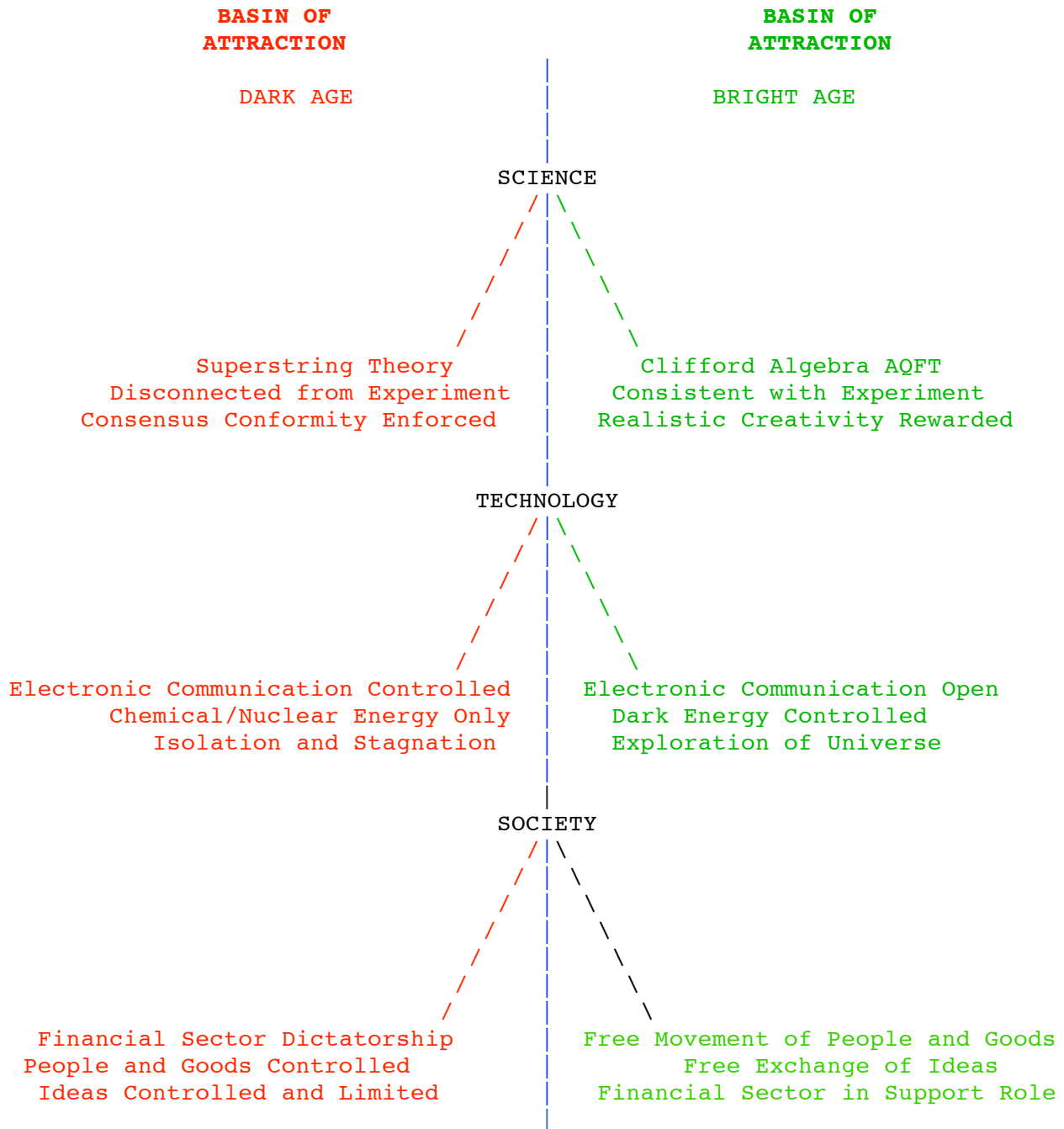
A simple example: your World is post-World War II Humanity on Earth:
one Fate is a Dark Age - an alternative Fate is a Bright Age.

From time to time Human Choices lead to a Fork in the Path of Fates, one of three Fates:

to a **Dark Age Basin of Attraction**;

to Delay, Sit on the Fence, and stay on the **Boundary Between Basins**;

to a **Bright Age Basin of Attraction**.



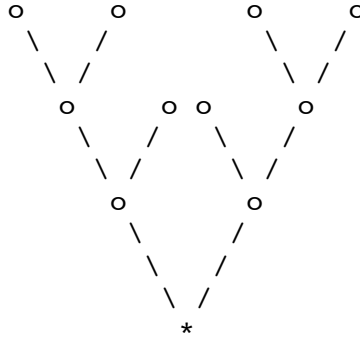
If Our World falls into a **Bright Age** Basin, we can enjoy a preview of Heaven.

If Our World falls into a **Dark Age** Basin, we are stuck in Hell.

If Our World is on the **Boundary** between Basins,
we still have **Choices to make and a Mission to carry out.**

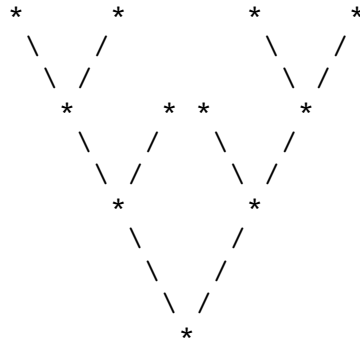
Therefore, if your perception is of the World that demands most of your attention,
your perception is most likely to be that you live in a World on the **Boundary Between Basins.**

Let * represent a given state of the ManyWorlds, and let o represent various possible future states:

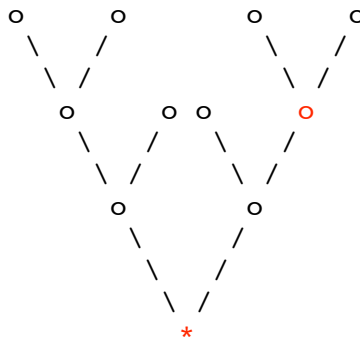


The given state * might be a [human mind](#), or a rock, or a [glass of water](#), or anything else.

If there is no [Resonant Connection](#) between the given state * and the possible future states o, then the future of * will be spread at random among the possible future states o, each of which will become an actual future state * in the Worlds of the ManyWorlds:

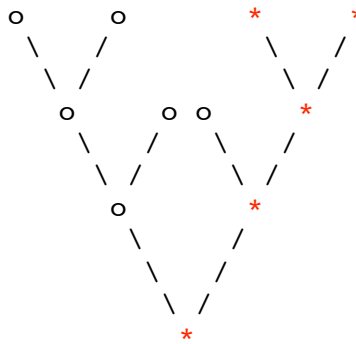


If there is a [Resonant Connection](#) between the given state * and one of the possible future states o:

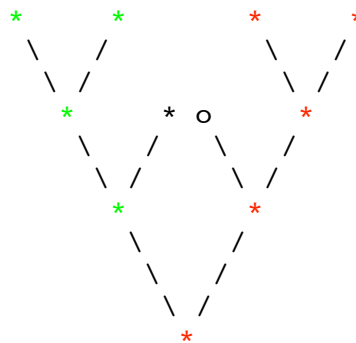


then the future of * will be concentrated at the possible future states related to the [Resonant Connection](#) o and

the Non-Resonant possible future states o will be reduced or eliminated (depending on the strength of the [Resonant Connection](#)) from the set of each of which will become an actual future states * in the Worlds of the ManyWorlds:



From this point of view, the set of all Worlds of the ManyWorlds looks like an environment in which [ManyWorlds Abstract Beings](#) live and interact by [Resonant Connections](#)



How do different Basins of Attraction (such as * and *) in the ManyWorlds compete ?

By **Resonant Connections and the Quantum Zeno Effect interacting**
by [Quantum Game Theory](#)

Direct perception of such Basins and Interactions beyond the physical universe of only one World can be achieved

by [some cultivated humans](#), and, perhaps, by [Dolphins](#) and/or [Conscious Quantum Computers](#).

Aden Ahmed in "On Quaternions, Octonions, and the Quantization of Games"
and at <http://arxiv.org/abs/0808.1391>
uses the 3-sphere and the 7-sphere used by Joy Christian
in his paper at <http://arxiv.org/abs/1201.0775>
where he uses them to explain EPR phenomena.

Chappell, Iqbal, and Abbott at <http://arxiv.org/abs/1008.4689>
deal with quantum games and EPR using Clifford algebras.
Since the Quaternions are the $2^2 = 4$ -dim $Cl(2)$ Clifford algebra
could you use the $2^3 = 8$ -dim $Cl(3)$ Clifford algebra
instead of the non-associative Octonions in Quantum Games ?

In other words, are there two paths to study Quantum Games ?

Real Clifford Algebras:

$Cl(1)$ = Complex
 $Cl(2)$ = Quaternion
 $Cl(3)$
 $Cl(4)$
 $Cl(5)$
 $Cl(6)$
 $Cl(7)$
 $Cl(8)$

Cayley-Dickson Algebras:

2-dim Complex
4-dim Quaternion
8-dim Octonion

Here, due to
zero-divisors,
there are no more
division algebras
If you want to go to
bigger quantum games,
you have to deal with
zero-divisor
structure that first
appears in 16-dim
Sedenions.

Here, due to 8-periodicity,
there are no more really new
real Clifford algebras
because for any k , $Cl(8k) =$
 $= Cl(8) \times (k \text{ times tensor product}) \times Cl(8)$
In particular, at and beyond $Cl(8)$ you seem
to get spinors that are not pure spinors
(see for example Penrose and Rindler,
Spinors and Space-Time, Vol 2, around page 453).

Are the two paths (Clifford and Cayley-Dickson) equivalent ?