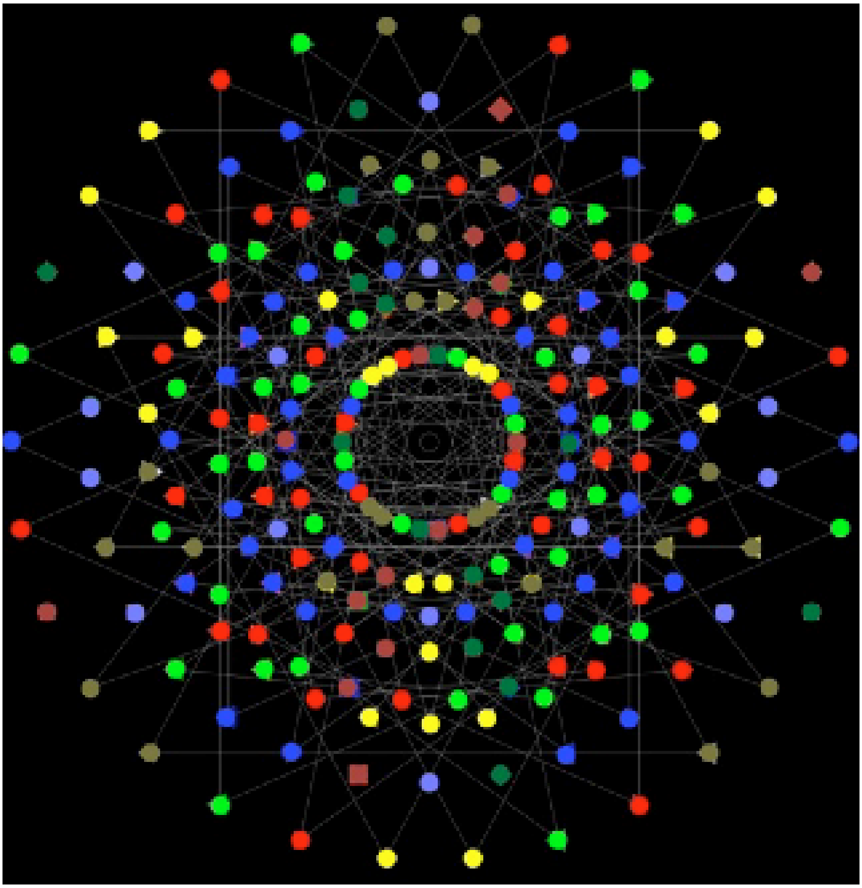
E8 Time

by Frank D. (Tony) Smith, Jr. - September 2008

E8 is a unique and elegant structure: the maximal exceptional Lie algebra, generated by 248 elements that can be described in terms of 240 points (known as “root vectors”) arranged in a symmetric 8-dimensional pattern. A projection of that pattern into two dimensions is:



E8 has long been used in the context of superstring theory, such as in E8xE8 heterotic models, and in fact one of the best places to learn about E8 is to read the sections written by Ed Witten in the

classic 2-volume work “Superstring Theory” by Green, Schwarz and Witten (Cambridge 1987).
An excellent pure math book about E8 is “Lectures on Exceptional Lie Groups” (Chicago 1996) by J. F. Adams, edited after his untimely death by Zafer Mahmud and Mamoru Mimura from Adams’s Cambridge lecture notes.

Now, two decades after the publication of the Green, Schwarz and Witten classic, Keith R. Dienes and Michael Lennek, in arXiv 0809.0036 [hep-th], ask
“To What Extent is String Theory Predictive?”
and say:
“…it is unlikely that the landscape as a whole will exhibit unique correlations amongst low-energy observables, but rather that different regions of the landscape will exhibit different overlapping sets of correlations. …”.

Some are satisfied to continue pursuing superstring theory through studying various “regions of the landscape”,
but others do not want to give up the search for a single unique elegant model that produces the parameters of
Gravity and the Standard Model that we observe, and some of them are working on constructing models based on unique and elegant E8:

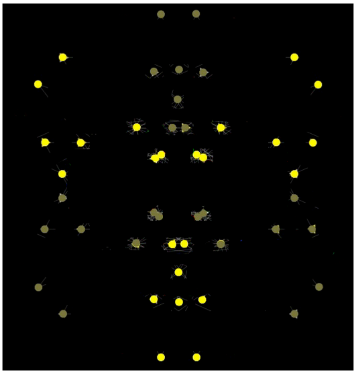
Garrett Lisi (arXiv 0711.0770 [hep-th]), with “… an E8 superconnection … over a four dimensional base manifold …”.

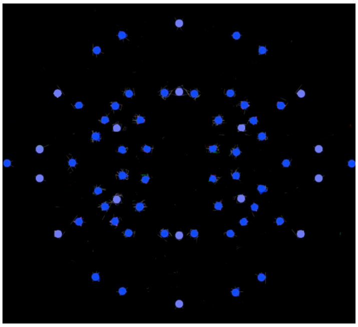
Matej Pavsic (arXiv 0806.4365 [hep-th]), with an “… extension of the 4-dimensional spacetime … to … a 16-dimensional … Clifford space C … whose tangent space … is the Clifford algebra Cl(1,3) … E8 thus arises from … C …[since]… E8 consists of the Lie algebra of rotations so(16) in a 16-dimensional vector space and the corresponding spinor space S16+ …”.

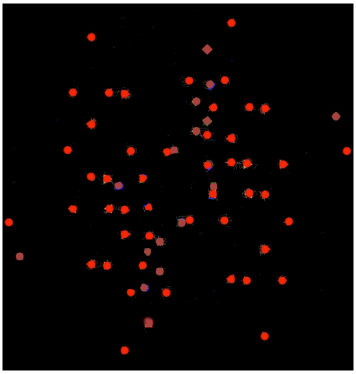
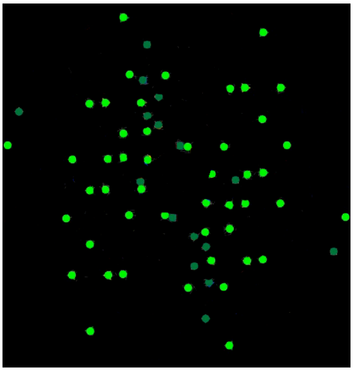
Carlos Castro (International Journal of Geometric Methods in Modern Physics v.4 no.8 (2007) 1-19), with a "… Chern-Simons E8 gauge theory of gravity in D = 15 …".

In those three models, a SpaceTime base manifold is assumed from the start, so the Nature of Time is given and not derived. Here, I propose to start only with E8 itself, and to derive the Nature of Time as a natural component of E8, as part of a realistic physics model that is as unique and elegant as E8 itself. Since this Essay is restricted in length to 10 pages and in scope to the Nature of Time, I refer for full details of the model to the pdf file at
www.tony5m17h.net/E8physicsbook.pdf
(background at www.tony5m17h.net/E8popphys.pdf)
and restrict discussion of other components of E8 to a minimal level necessary to give a context for E8 Time.

Here are the separated yellow, blue, red, and green root vectors of E8:





To see their physical meaning, look at E8 as

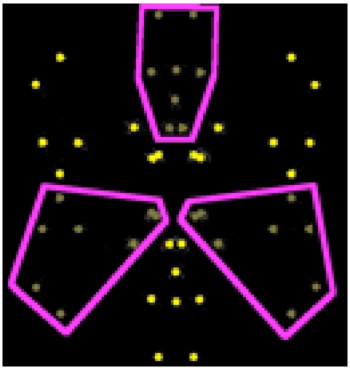
248-dim E8 = 120-dim D8 + 128-dim half-spinor D8

120-dim D8 = 28-dim D4 + 28-dim D4 + 8x8=64-dim

128-dim half-spinor D8 = 64-dim + 64-dim = 8x8 + 8x8

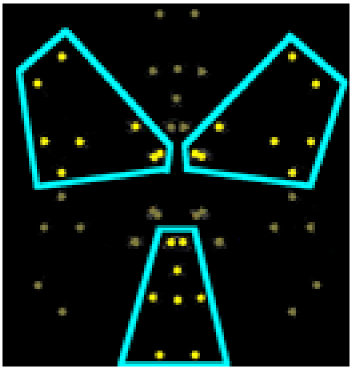
Since D8 and its spinors live inside the Cl(16) Clifford algebra, E8 has a natural embedding into Cl(16).

The 3x8 = 24 dark yellow root vectors



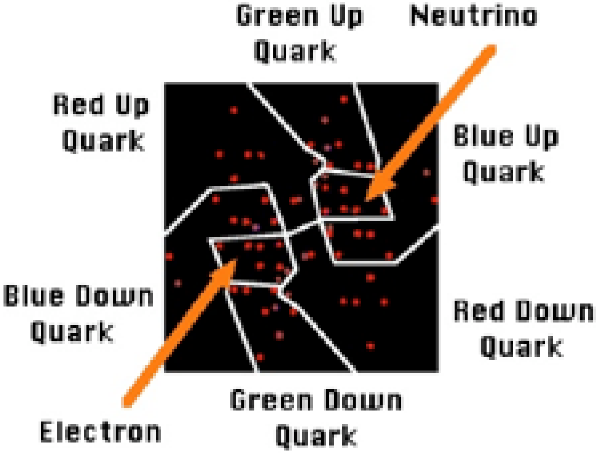
form the 4-dimensional 24-cell root vector polytope of a D4 Lie algebra and 12 of them form the 3-dimensional cuboctahedron root vector polytope of the D3 = A3 Lie algebra, which by the MacDowell-Mansouri mechanism describes Gravity.

The 3x8 = 24 bright yellow root vectors



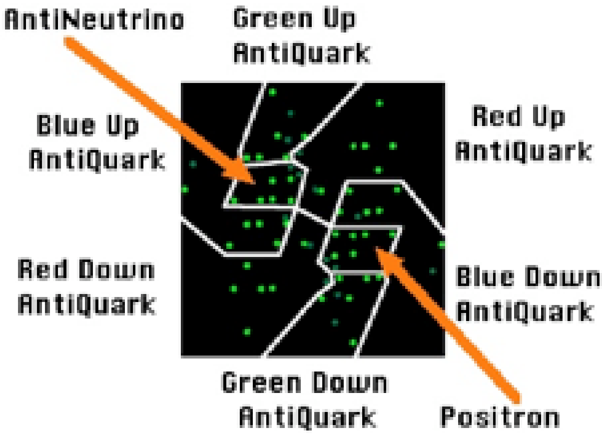
form a second 4-dimensional 24-cell root vector polytope of a second D4 Lie algebra and 12 of them can be projected into 1-dim and 2-dim configurations that describe the root vector polytopes of the Standard Model Gauge Groups: U(1) of Electromagnetism; SU(2) of the Weak Force; and SU(3) of the Color Force

The 8x8 = 64 red root vectors



correspond to the 8 covariant components (with respect to 8-dim SpaceTime) of the 8 fundamental first-generation fermion particles.

The 8x8 = 64 green root vectors

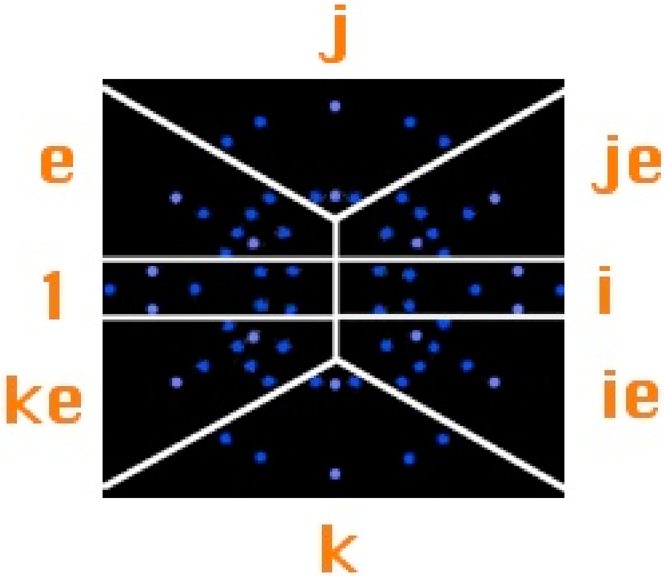


correspond to the 8 covariant components (with respect to 8-dim SpaceTime) of the 8 fundamental first-generation fermion antiparticles.

The 8x8 = 64 blue root vectors tell how the 8 vector spacetime dimensions of the D4 giving Gravity correlate with the 8 vector dimensions of the D4 giving the Standard Model that correspond to 8 Dirac gammas.

Each set of 8 root vectors represent the 8 components, with respect to 8 Dirac gammas, of one of the 8 spacetime dimensions of this E8 physics model.

Giving the 8 E8 spacetime dimensions Octonionic coordinates with basis {1, i, j, k, e, ie, je, ke} shows the meaning of the 8x8 = 64 blue root vectors to be



The dimension represented by the octonion basis element { 1 }, that is, the Octonion real axis, describes Local Time in this E8 physics model.

The Local Lagrangian of this E8 physics model is constructed from the parts of E8 as the Integral

over the 8-dimensional SpaceTime described by the 64 blue root vectors

of Gravity and Standard Model terms described by the 24 + 24 = 48 yellow root vectors and

of Fermion Particle-Antiparticle terms described by the 64 + 64 = 128 red and green root vectors.

At the low (relative to Inflationary Regime) energies where we do our experiments and see most of our observations, a 4-dimensional Quaternionic substructure Freezes Out, breaking 8-dimensional Octonionic symmetry and producing a Kaluza-Klein SpaceTime made up of our usual 4-dimensional Physical SpaceTime and a 4-dimensional Internal Symmetry Space with the structure of a Complex Projective Plane CP2.

The symmetry breaking produces the second and third generations of Fermion Particles and AntiParticles and, by a process described by Meinhard Mayer (Acta Physica Austriaca, Suppl.XXIII (1981) 477-490), gives a Higgs mechanism.

Since the E8 Local Lagrangian structure only describes a Local Time, it is necessary to patch together Local Regions to form a Global Structure describing E8 Global Time.

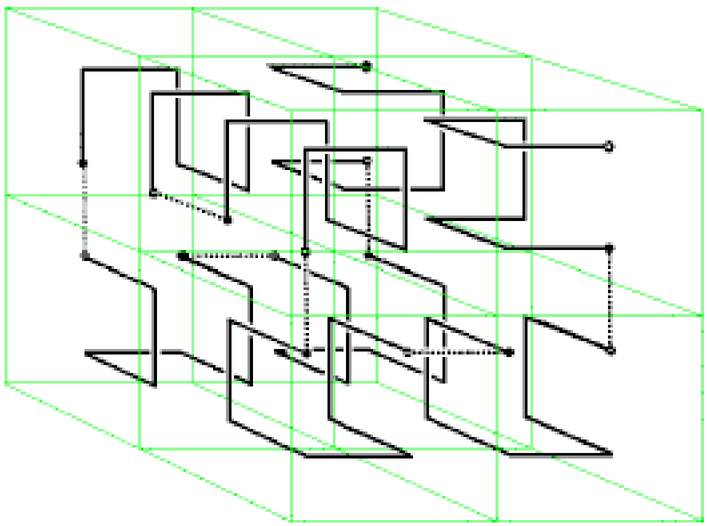
Mathematically, this is done by embedding E8 into Cl(16) and using a copy of Cl(16) to represent each Local Lagrangian Region. A Global Structure is then formed by taking the tensor products of the copies of Cl(16).

Due to Real Clifford Algebra 8-periodicity, Cl(16) = Cl(8)xCl(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)xCl(8) = Cl(16).

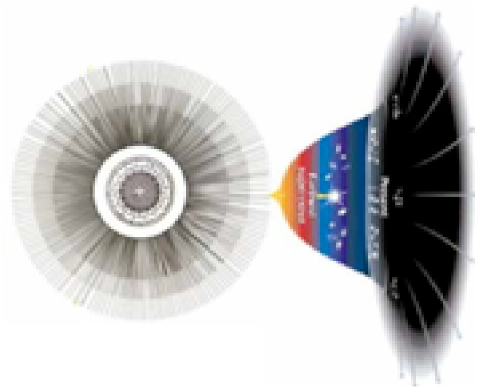
Therefore, taking the completion of the union of all such tensor products produces a generalized Hyperfinite II1 von Neumann factor that gives a natural Algebraic Quantum Field Theory structure for E8 physics.

If you go back to the origin of our universe, you begin with a single Cl(16) Local E8 Region with Octonionic Structure.

Since, as Stephen Adler said in his book “Quaternionic Quantum Mechanics and Quantum Fields” (Oxford 1995), there is a “… failure of unitarity in octonionic quantum mechanics …”, the initial Octonionic Cl(16) Local E8 Region can replicate, with the Local E8 Regions linking their Local 8-dimensional SpaceTimes together in an 8-dimensional version of a Moore space-filling curve



and our universe thus undergoing a natural Inflationary Expansion based on E8 and its related Cl(16) Clifford Algebra Structure. Such an Inflationary Era is described by Paola Zizzi in gr-qc/0007006 where she says “… during inflation, the universe can be described as a superposed … quantum … state … The self-reduction of the superposed quantum state is … reached at the end of inflation …[at]… the decoherence time …”, which decoherence time she notes is similar to that of Penrose-Hameroff Quantum Consciousness Events. In E8 physics, the Decoherence End of Inflation occurs when our universe reaches a superposition of 2^64 Local E8 Regions. A Quaternionic substructure then freezes out in our universe, producing a Kaluza-Klein SpaceTime and the second and third generations of Fermions, and our universe then decoheres/collapses to Our Single World



which continues to evolve, but without Octonionic non-unitary inflationary processes.

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 explaining The Arrow of Time.

September 7, 2008

FQXi FORUM

CATEGORY: Essay Contest

TOPIC: E8 Time by Frank Dodd Smith

Frank Dodd Smith wrote on Sep. 5, 2008 @ 11:41 GMT

Essay Abstract Time is shown to be a natural component of E8 in an E8 physics model in which our universe is shown to have a low-entropy state at the end of inflation, thus explaining the Arrow of Time.

Author Bio Frank Dodd Smith, Jr., a/k/a Tony Smith, is a lawyer in Georgia USA, was graduated from Cartersville High School in 1959, received an A.B. degree in mathematics from Princeton University in 1963, received a J.D. degree from Emory University in 1966, and received an Honorable Discharge as TSG from the United States Air Force in 1971. More recent material is at www.valdostamuseum.org/hamsmith/

Carlos Castro Perelman wrote on Sep. 8, 2008 @ 02:00 GMT

I would like to add some comments to Tony Smith's interesting essay.

1- In page 4, in the second line, a notation less likely to be misunderstood would have been something like
120 = 28 + 28 + (8 x 8) =
28 + 28 + 64

2- It is known that the E_8 algebra admits the Larsson 7- grading GL (8, R) decomposition of E_8 :
8 + 28 + 56 + 64 + 56 + 28 + 8
with E_8 grades
-3, -2, -1, 0, +1, +2, +3
However, as Smith argues, the E_8

graded structure does not look exactly like the simplex-polytope decompostion graded structure corresponding to the 256-dimensional Cl(8) Clifford algebra with Clifford graded structure
1 + 8 + 28 + 56 + 70 + 56 + 28 + 8 + 1
with Clifford grades 0, 1, 2, 3, 4, 5, 6, 7, 8
which looks like the decomposition of a simplex-polytope in 7-dim space which
has 2^(7+1) = 2^8 = 256 elements (edges, faces, etc).

The 256 - 248 = 8 things missing from E_8 itself are: the 1 element of Clifford grade 0 6 elements of the 70 of Clifford grade 4 the 1 element of Clifford grade 8. Therefore, the most natural embedding of E_8 is not inside Cl (8), but inside Cl(16) which has 120-dim SO (16) bivectors and 128-dim SO (16) chiral-spinors that combine to make E_8.

However, since real 8-periodicity gives Cl(16) = Cl(8) x Cl(8) (tensor product), one can use the Cl(16) embedding to write E_8 as a *subalgebra* of the tensor product of two copies Cl(8) x Cl (8).

The 64 in the zero grade part is the dim of the GL(8,R) algebra with 8 x 8 = 64 generators. Despite that Gl (8, R) group is not compact, from the point of view of compact Lie groups the 64-dimensional Lie algebra U(8) can naturally be embedded in Spin(16). In general, U (n) can be embedded in SO (2n) and admits a realization in terms of the Clifford (2n) algebra generators.

The GL(8,R) algebra is used to construct Metric Affine theories of Gravity in an 8-dimensional spacetime and the 64 root vectors of E_8 are shown in blue in Tony Smith's images.

The other even-grade parts of E_8 are the 28 of grade -2 and the 28 of grade +2, which correspond to two D4 Lie algebras with 24 root vectors each, and they are the yellow (24 dark and 24 bright) root vectors in the images of Tony Smith's essay.

The odd-grade parts are 8 + 56 of grades -3 and -1 and 56 + 8 of grades +1 and +3 and they correspond to the 64 red and 64 green fermionic root vectors shown in those images.

3- Others prefer to look at 248 as

28 + 28 + 3 x (8 x 8) = 28 + 28 + 3x (64) = 248 =
= SO(8) + SO(8) + 3 x (O x O) where O = Octonions.

28 + 28 = 28 bivectors in D = 8 plus their 28 "mirrors" dual momentum conjugates = 56 in total.

Tony Smith sees the bivectors 28 = 16 + 12, as 16 corresponding to the dimensions of the algebra U (2, 2) = SU (2, 2) x U (1) associated to the Macdowell-Mansouri-Chamseddine-West Conformal Gravity approach to
4D gravity. And, 12 corresponding to the dimensions of
SU (3) x SU (2) x U (1) =
= 8 gluons + 3 Weak bosons + 1 photon of the Standard Model.

4- One of the reasons why Supersymmetric E_8 Grand Unification is very appealing is because supersymmetric gauge theories ("superconnections") allows one to work with bosons and fermions at once. So the leptons and quarks associated to the SUSY E_8 theory are the *gluinos*, the super-partners, of the E_8 gauge bosons because the adjoint and fundamental 248-dim representations of E_8 happens to coincide in this "exceptional" case. Usually when one works with a bosonic E_8 gauge theory, the fermions, and the scalar matter fields, are assigned to the sections of a spinor (vector) bundle. Despite this technical subtlety, why supersymmetry is important, it is true that the Octonions O in the factor 3 x (8 x 8) = 3 x (O x O) permits to account for 3 copies = 3 fermion generations as follows : The electron, neutrino, up and down quark (with 3 colors each) gives 8 different degrees of freedom of the Octet = 1 + 1 + 3 + 3 = 8.

When one multiplies 8 times the number of spinorial components of a Weyl spinor (a chiral spinor) in D = 8, given by (1/2) 2^{ 4 } = 8, one then gets 8 x 8 = 64 = the total number of spinorial degrees of freedom of the first generation Octet. Thus the 3 generations yields a net factor of 3 x 64 which is appealing if one works in D = 8.

5- As I've argued in one of the sections of my article on the E_8 Geometry of Clifford (16) Superspace Conformal Gravity and Yang-Mills Grand Unification

http://www.scribd.com/doc/3870934/E8-Geometry-of-Clifford-16-Superspace-

GravityYangMills-GrandUnification

One of the noncompact forms of E_8 contains SO (8, 2) as a subgroup,
and such that a E_8 gauge theory in D = 8 contains
the SO (8, 2) Conformal gauge theory of Gravity in D = 8,
and which upon compactification (from 8 to 4 dim) on a CP^2
manifold as shown by Batakis, with Torsion, furnishes Conformal gravity
and the Standard Model in D = 4.
CP^2 = SU (3) / U (2) = SU (3) / SU (2) x U (1)
The CP^2 has SU (3), SU (2), U (1) built in.
Thus, D = 8 is essential.

6- Tony Smith agrees that his way of getting 3 generations does NOT assign them all in the fundamental E_8, but the second and third generations emerge as composites from the process of converting octonionic 8-dim spacetime into Kaluza-Klein 4+4 spacetime with 4-dim physical spacetime and 4-dim CP^2 internal symmetry space.

This model differs from the SO(10) GUT models, emerging from the E_8 GUT
models of the late 70's and early 80's, with four and three generations (plus their mirror fermions) with a massive neutrino, in that Smith's first-generation, the fundamental neutrino remains massless (the second and third generation neutrinos get small mass by processes beyond tree level) and has no right-handed component.

7- Finally, pertaining tp the Murray-von Neumann hyperfinite type factor II_1, defined as the complex Clifford algebra of an infinite dim Euclidean space, it is very reasonable to argue that an infinite dim Clifford algebra can be written as
an infinite tensor product of Cl (8) factors (16 x 16 matrices)
or
as an infinite tensor product of 2 x 2 complex matrices,
like the Pauli spin matrices,
furnishing an an infinite dim Fermionic Fock space.

Carlos Castro Perelman, September 7, 2007

Tevian Dray wrote on Dec. 7, 2008 @ 19:09 GMT

Long live E8!

As always, your pictures of E8 are among the best with which I am familiar. But I continue to find your presentation to be difficult to follow. This essay is a good start, but I'd really like to see a *short* description of each of the various subalgebras of E8 you are using -- not just pictures, but instead concise statements of mathematical relationships, possibly together with a *brief* statement of their physical relevance.

Tevian Dray asks for "... a *short* description of each of the various subalgebras of E8 ..." that I am "... are using ... possibly together with a *brief* statement of their physical relevance ...". As Tevian says, my essay may well be "... difficult to follow ....", and for that I apologize. A lot of details that would not fit in the 10-age limit are in my pdf web book at www.tony5m17h.net/E8physicsbook.pdf but it is long (a bit over 400 pages) and probably even more difficult to follow, so here is an effort to describe the various subalgebras of E8 and their physical significance. (To try to keep it not-so-long I will ignore some details such as signature etc.)

The basic picture has 240 points:
64 red; 64 green; 64 blue; 24 bright yellow; and 24 dark yellow.

The 248-dimensional E8 structure that I use is a 7-grading (due to Thomas Larsson I think):
8 + 28 + 56 + 64 + 56 + 28 + 8

The odd part of that grading 8 + 56 + 56 + 8
corresponds to the red 64 + green 64 = 128-dim half-spinors of D8
in the 248 - 120 = 128-dimensional symmetric space E8 / D8

The positive odd part, the red 8+56 = 64,
correspond to the 8 covariant components (with respect to 8-dim spacetime)
of 8 fundamental (first-generation) fermion particles.

The negative odd part, the green 8+56 = 64,
correspond to the 8 covariant components (with respect to 8-dim spacetime)
of 8 fundamental (first-generation) fermion antiparticles.

The even part of that grading 28 + 64 + 28
corresponds to the 28+64+28 = 120-dim D8 of E8 / D8

The grade-0 64 corresponds to the 64 blue points
and to an 8-dim spacetime and 8 Dirac gammas for that spacetime
and to the 8x8 = 64-dim symmetric space D8 / D4xD4

The two 28 even parts correspond to the two 28-dim D4 of D8 / D4xD4

Since each D4 has 24 root vectors,
there are 2 x (28-24) = 8 dimensions of E8 that do not correspond to root vectors,
but represent the 8-dim E8 Cartan subalgebra
(and the 4-dim Cartan subalgebras of the two D4).

One of the D4 (24 dark yellow) can be seen as containing a D3 subalgebra corresponding
to the SU(2,2) = Spin(2,4) conformal group that can, by MacDowell-Mansouri,

give gravity in a 4-dim physical spacetime part of the full 8-dim spacetime,
which is then seen as an 8-dim Kaluza-Klein
with 4-dim physical spacetime and 4-dim internal symmetry space,
which Kaluza-Klein structure is induced by
the "freezing out" below high (Planck-tye) energies
of a preferred quaternionic substructure of the high-energy 8-dim spacetime.

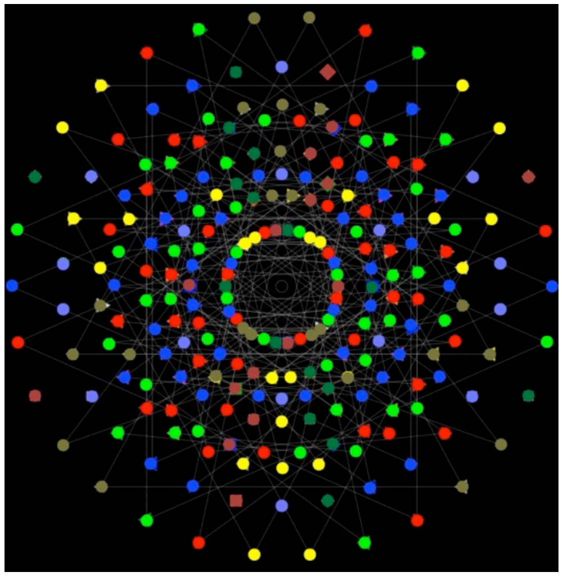
The other D4 (24 bright yellow) can then be seen as corresponding to action of the Standard Model using that 4-dim internal symmetry space with structure of CP2 = SU(3) / U(2)
One way to see how the D4 is related to the CP2 is to look at
the A3 contained in D4 as giving a 6-dim twistor-like space CP3 = SU(4) / U(3)
The U(3) contains a color SU(3) of the Standard Model.
The 6-dim CP3 contains a 4-dim CP2 which has a local U(2) symmetry
for the SU(2) weak force and U(1) electromagnetism of the Standard Model.

The fermion, spacetime, gravity and Standard Model components can be assembled in a natural way (indicated by their physical interpretations)
to form a realistic local Lagrangian over the 8-dim spacetime,
and the reduction to the Kaluza-Klein spacetime gives a natural Higgs structure by using the Geometry of Symmetry Breaking in Gauge Theories described by Meinhard Mayer,
as well as giving the second and third generations of fermions.

Using the geometry of symmetric spaces, complex bounded domains and their Shilov boundaries (motivated by Armand Wyler), along with some simple combinatorics, force strengths and particle constituent masses can be calculated.
In those calculations, the "frozen-out" quaternionic structure is important, as Joseph Wolf had shown that there are 4 equivalence classes of 4-dim Riemannian symmetric spaces with quaternionic structure:
T4 = U(1)^4
S2 x S2 = SU(2) / U(1) x SU(2) / U(1)
CP2 = SU(3) / U(2)
S4 = Spin(5) / Spin(4) = Sp(2) / Sp(1)xSp(1)
and
they have natural physical interpretations:
U(1) of electromagnetism
SU(2) of the weak force
SU(3) of the color force
Spin(5) = Sp(2) of MacDowell-Mansouri gravity.

I hope this is at least somewhat helpful in trying to explain the mathematics of my E8 physics model. - Frank Dodd (Tony) Smith, Jr., 8 December 2008

The 240 units of the 7E8 lattice corresponding to the integral domain 7E8 represent the 8 x 30 = 16 x 15 = 240 lattice points of the E8 root vertex polytope. In terms of the 7E8 lattice, the color-coded root vectors



correspond to the similarly color-coded (with orange for the two shades of yellow) 7E8 lattice points as follows:

±1, ±i, ±j, ±k, ±e, ±ie, ±je, ±ke,

(±1 ±ie ±je ±ke)/2	(±e ±i ±j ±k)/2
(±1 ±ke ±e ±k)/2	(±i ±j ±ie ±je)/2
(±1 ±k ±i ±je)/2	(±j ±ie ±ke ±e)/2
(±1 ±je ±j ±e)/2	(±ie ±ke ±k ±i)/2
(±1 ±e ±ie ±i)/2	(±ke ±k ±je ±j)/2
(±1 ±i ±ke ±j)/2	(±k ±je ±e ±ie)/2
(±1 ±j ±k ±ie)/2	(±je ±e ±i ±ke)/2

Memo Re E8 Time Essay (not posted to FQXi) by Frank Dodd (Tony) Smith, Jr. - 9 Dec 2008

Here is another layout of the240 lattice points of the 7E8 lattice.
The other 6 of the 7 independent E8 lattices (and the 8th dependent one) have similar correspondences.

±1,	±i,	±j,	±k,	±e,	±ie,	±je,	±ke,	
(±1					±ie	±je	±ke	)/2
(	±i	±j	±k	±e				)/2
(±1			±k	±e			±ke	)/2
(	±i	±j			±ie	±je		)/2
(±1	±i		±k			±je		)/2
(		±j		±e	±ie		±ke	)/2
(±1		±j		±e		±je		)/2
(	±i		±k		±ie		±ke	)/2
(±1	±i			±e	±ie			)/2
(		±j	±k			±je	±ke	)/2
(±1	±i	±j					±ke	)/2
(			±k	±e	±ie	±je		)/2
(±1		±j	±k		±ie			)/2
(	±i			±e		±je	±ke	)/2