Quantum Gravity Research
Los Angeles, U.S.A.

Nonification

v. 1.0.1

Raymond Aschheim
raymond@quantumgravityresearch.org

v 1.0.1 presented at AQG V, Los Angeles, October 29th, 2018
Advances in Quantum Gravity V in honor of Piero Truini

October 30, 2018

Content

- This talk is dedicated to the career of Piero Truini which opened the path to an exceptional an magic unification.
- We shall see how the partition of the E8 lattice into three A8 lattices, inviting us to use 9 dimensions coordinates, guide also us to an exceptionally symmetric unification... without supersymmetry.
- "It is amusing to speculate on the possibility of a theory based on E9." is the conclusion of the chapter V, Exceptional Unification, of Pr. Anthony Zee's book.

REF:

0a Zee, A. Unity of forces in the universe World Scientific. 1982

Introduction

9D coordinates

- A_n Simplex lattices are naturally expressed in $n+1$ dimension coordinates satisfying $\sum_{k=1}^{n+1} x_k = 0$

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- E_8 lattice is the superposition of three A_8 lattices: $E_8 = \bigcup_{i=0}^{2} A_8^i$
- 72 of its roots are permutations of $\{3^1, -3^1, 0^7\}, \cong 0[3], \in 3A_8^0$
- 84 of its roots are $\mathfrak{P}(-2^3, 1^6), \cong 1[3], \in 3A_8^1$
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$$E_8 = SU(3)_F + E_6 = A_{2F} + E_6$$

$$248 \backslash A_{2F} + E_6 = (1, 78) + (8, 1) + (3, 27) + (\overline{3}, \overline{27})(1)$$

- E_6 lattice is the superposition of three A_8 lattices satisfying $\sum_{k=1}^{3} x_k = \sum_{k=4}^{6} x_k = \sum_{k=7}^{9} x_k = 0$.
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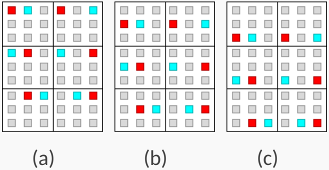
- 

Figure: 3 orthogonal A2 in E6; from left to right: **(a)** A2L **(b)** A2C **(c)** A2R.

Introduction

E6 subgroup in 9D

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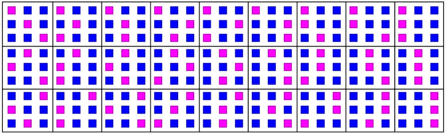
- 

Figure: 27 lepto-quarks bosons B from $E6 \bigcap A_8^1$;

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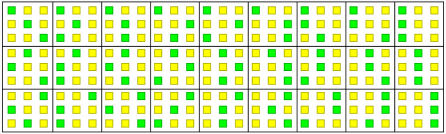
- 

Figure: $\overline{27}$ anti-lepto-quarks bosons $\hat{B}$ from $E6 \bigcap A_8^2$;

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- $$\mathbf{27} = (\mathbf{3},\overline{\mathbf{3}},\mathbf{1}) + (\mathbf{1},\mathbf{3},\overline{\mathbf{3}}) + (\overline{\mathbf{3}},\mathbf{1},\mathbf{3}) = q_\alpha^\gamma + \hat{q}_\gamma^\beta + l_\beta^\alpha \tag{4}$$
- $$q_\alpha^\gamma = \begin{bmatrix} u_r & u_g & u_b \\ d_r & d_g & d_b \\ h_r & h_g & h_b \end{bmatrix} \hat{q}_\gamma^\beta = \begin{bmatrix} \hat{u}_c & \hat{d}_c & \hat{h}_c \\ \hat{u}_m & \hat{d}_m & \hat{h}_m \\ \hat{u}_y & \hat{d}_y & \hat{h}_y \end{bmatrix} l_\beta^\alpha = \begin{bmatrix} N_1 & E^- & e^- \\ E^+ & N_2 & \nu_e \\ e^+ & \hat{\nu}_e & N_3 \end{bmatrix} \tag{5}$$

$$E_8 = SU(9) + \mathbf{84} + \overline{\mathbf{84}} \tag{6}$$

- The relationship between the E_8 lattice and the Simplex lattice, $E_8 = 3A_8$, is illustrated and has been extended to exceptional periodicity algebras [oh,oi].
- exceptionally $\mathbf{84} = \Lambda^3\mathbb{C}^9$ 3-form and $\overline{\mathbf{84}} = \Lambda^6\mathbb{C}^9$ 6-form in $SU(9)$ [oj].
- or generally $\mathbf{84} = \mathbf{28} + \mathbf{56} = \Lambda^2\mathbb{C}^8 \bigoplus \Lambda^3\mathbb{C}^8$ 2-form and 3-form, and $\overline{\mathbf{84}} = \overline{\mathbf{56}} + \overline{\mathbf{28}} = \Lambda^6\mathbb{C}^8 \bigoplus \Lambda^5\mathbb{C}^8$ 6-form and 5-form in $Cl(8)$.

REF:

oh Marrani, Alessio, and Piero Truini. “Exceptional Lie Algebras at the Very Foundations of Space and Time.” , p-Adic Numbers, Ultrametric Analysis and Applications, 2016, Vol. 8, No. 1, pp. 68–86.

oi Truini, Piero, Michael Rios, and Alessio Marrani. “The Magic Star of Exceptional Periodicity.” ArXiv:1711.07881 .

oj Ferrara, Sergio, Alessio Marrani, and Mario Trigiante. “Super-Ehlers in Any Dimension.” Journal of High Energy Physics 2012, no. 11 (November 2012).

- A_8 includes A_{2L}, A_{2C} and A_{2R}
- $$\mathbf{27} = (\mathbf{3}, \bar{\mathbf{3}}, \mathbf{1}) + (\mathbf{1}, \mathbf{3}, \bar{\mathbf{3}}) + (\bar{\mathbf{3}}, \mathbf{1}, \mathbf{3}) \tag{7}$$
- **27** breaks under $SU(3)_C x SU(2)_L x U(1)_Y$ as

$$\begin{aligned}\mathbf{27} = {} & 2(1,1,0) + (1,2,\frac{1}{2}) + (3,2,-\frac{1}{3}) + 2(1,2,-\frac{1}{2}) \\ & + 2(3,1,-\frac{1}{3}) + (1,1,1) + (3,1,-\frac{2}{3}) + (3,2,\frac{1}{6})\end{aligned} \tag{8}$$

Tensor Network

E8 as a tensor

- 248D algebra E_8 is coded by $G_\pm \in \Im(\mathbb{O})$, $H_1, \dots H_7, H_+, H_- \in Tr_o(\mathfrak{M}_8^3)$
- Its action on $J \in \mathfrak{M}^3_{\mathbb{O}\otimes\mathbb{O}}$ is

$$E_8(H_1, \dots, H_-)(J) = \delta J = [H_+, \Re(J), H_-] - \sum_{k=1}^{7} \mathbf{e}^{G_+} e_k \mathbf{e}^{G_-} H_k \cdot \Re(e_k J)$$

$$T = \sum_{j_i, j_j, o_i, o_j, z_i, z_j = 1}^{3} T^{j_i\ o_i\ z_i}_{\ j_j\ o_j\ z_j} j_i\ o_i\ z_i j_j\ o_j\ z_j \tag{9}$$

Or:

$$T = \begin{matrix} J_1^1 & J_2^1 & J_3^1 \\ J_1^2 & J_2^2 & J_3^2 \\ J_1^3 & J_2^3 & J_3^3 \end{matrix}, \quad J^{m_i}_{m_j} = \begin{matrix} o_1^1 & o_2^1 & o_3^1 \\ o_1^2 & o_2^2 & o_3^2 \\ o_1^3 & o_2^3 & o_3^3 \end{matrix}, \quad o^{j_i}_{j_j} = \begin{matrix} z_1^1 & z_2^1 & z_3^1 \\ z_1^2 & z_2^2 & z_3^2 \\ z_1^3 & z_2^3 & z_3^3 \end{matrix} \tag{10}$$

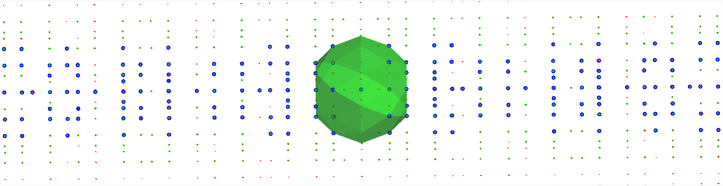


Figure: Fibonacci spaced tensor network projection

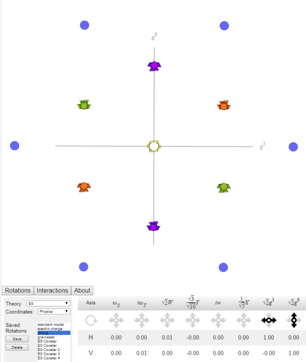
- We insert the standard model in a spinfoam by a fermionic quantum tetrahedron whose 4 vertices have SU(3) values coming from the 4 A2 of E8

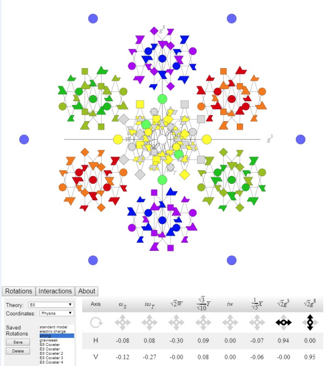
$$
\begin{aligned}
Z = & \sum_{\{c\}} \sum_{j_f} \int_{SL(2,\mathbb{C})} dg_{ve} \int_{SU(2)} dh_{ef} \int_G dU_{ve} \\
& \prod_f d_{j_f} \; \chi^{\gamma j_f, j_f}\Big(\prod_{e \in \partial f} (g_{es_e} h_{ef} g_{et_e}^{-1})^{\epsilon_{lf}} \Big) \prod_{e \in \partial f} \chi^{j_f}(h_{ef}) \\
& \prod_c (-1)^{|c|} \; \chi^{\frac{1}{2}}\Big(\prod_{e \in c_n} (g_{es_e} U_{es_e} U_{et_e}^{\dagger} g_{et_e}^{\dagger})^{\epsilon_{ec}} \Big). \qquad (53)
\end{aligned}
$$

Figure: Partition function with fermion

- Integral on cycles will reduce to SU(3) six-j symbols, when edges SU(2) are embedded in SU(3).

Magic star[ok] projected[ol] from Gosset polytope





REF:

ok Truini, Piero. "Exceptional Lie Algebras, SU(3) and Jordan Pairs." Pacific J. Math. 260, 227 (2012), (arXiv:1112.1258 [math-ph]).

ol Lisi, Garrett. "Elementary Particle Explorer." http://deferentialgeometry.org/epe/.

Magic star
Jordan algebra

Jordan Matrix :

- Each E_8 vertex holds an exceptional Jordan [1,2] matrix $J \in \mathfrak{M}_8^3$
- 10D Minkowski Spacetime with a transversal octonion o as $J_2 = \begin{pmatrix} t - x_8 & \bar{o} = x^0 e_0 - \sum_{k=1}^{7} x^k e_k \\ o = x^0 e_0 + \sum_{k=1}^{7} x^k e_k & t + x_8 \end{pmatrix} \in \mathfrak{M}_8^2 = SL_2(\mathbb{O})$
- Central cross encoding scalar ϕ and $Spin(9,1)$ spinor $\Psi = \begin{pmatrix} \psi + \\ \psi - \end{pmatrix}$, $J = \begin{pmatrix} t - x_8 & \psi_+ = \sum_{k=0}^{7} \psi_+^k e_k & \bar{o} \\ \overline{\psi_+} & \phi - 2t & \psi_- = \sum_{k=0}^{7} \psi_-^k e_k \\ o & \overline{\psi_-} & t + x_8 \end{pmatrix} \in \mathfrak{M}_8^3 = SL_3(\mathbb{O})$
- Jordan product: $J_1 \cdot J_2 = \frac{1}{2}(J_1 J_2 + J_2 J_1)$ [1]

REF:

1. Jordan, P., J. v. Neumann, and E. Wigner. “On an Algebraic Generalization of the Quantum Mechanical Formalism.” The Annals of Mathematics 35, no. 1 (January 1934): 29.
2. Albert, A. Adrian. “On a Certain Algebra of Quantum Mechanics.” The Annals of Mathematics 35, no. 1 (January 1934): 65.

- Freudenthal product:
  $J_1 \times J_2 = \frac{1}{2}(2J_1 \cdot J_2 - Tr(J_1)J_2 - Tr(J_2)J_1 + I(Tr(J_1)Tr(J_2) - Tr(J_1 \cdot J_2)))$ [3]
- Associator: $[J_1, J_2, J_3] = (J_1 \cdot J_2) \cdot J_3 - J_1 \cdot (J_2 \cdot J_3)$ [4]
- Left quasi multiplication: $L_x : L_x(y) = x \cdot y$
- Quadratic map: $U_x = 2L_x^2 - L_{x^2}$ [4B]
- Linearized map: $V_{x,y} : V_{x,y}(z) = (U_{x+z} - U_x - U_z)(y)$ [4C]
- Trilinear map: $\{x, y, z\} = V_{x,y}(z) = 2(L_{x.y} + [L_x, L_y])(z)$
- Axioms: **A1** $:U_x V_{y,x} = V_{x,y} U_x$, **A2** $:U_{U_x y} = U_x U_y U_x$
- Jordan pair: $x, y |$ **A1** & **A2** & $V_{U_x y, y} = V_{x, U_y x}$

REF:

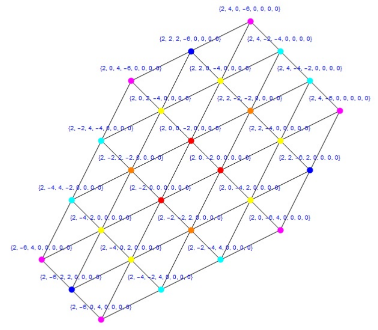
3 H. Freudenthal. Beziehungen der E7 und E8 zur oktavenebene, i, ii. Indag. Math., 16:218, 1954

4 Gürsey, Feza, and Chia-Hsiung Tze. On the Role of Division, Jordan and Related Algebras in Particle Physics. World Scientific, 1996.

4B McCrimmon, Kevin. A Taste of Jordan Algebras. Universitext. New York: Springer, 2004.

4C JACOBSON, N. “Exceptional Lie Algebras,” n.d., 14.

Discrete Jordan Matrix

- Each octonion in J can be encoded by its $9D$ coordinates in a 3x3 matrix
- Induced by lattice coordinates they can be restricted to integer [5]
- 

$$J' = \begin{pmatrix} t - x_8 & \psi_+ & \bar{o} \\ \overline{\psi_+} & \phi - 2t & \psi_- \\ o & \overline{\psi_-} & t + x_8 \end{pmatrix}$$

REF:

5 Catto, Sultan, Yasemin Gürcan, Amish Khalfan, and Levent Kurt. “Root Structures of Infinite Gauge Groups and Supersymmetric Field Theories.” Journal of Physics: Conference Series 474 (November 29, 2013): 012013.

F_4 action

F_4 action is a derivation [6] on $\mathfrak{M}_8^3$:

- An element of 52D algebra F_4 is represented by two traceless H_+ and H_-
- Its action [7] on J=$H + \Phi$ is $F_4(H_+, H_-)(J) = \delta J = [H_+, J, H_-]$
- Invariants are $I_1 = Tr(J)$, $I_2 = Tr(J^2)$, $I_3 = Det(J) = \frac{1}{3}Tr(J \cdot J \times J)$

REF:

6 Chevalley, Claude, and R. D. Schafer. “The Exceptional Simple Lie Algebras F4 and E6.” Proceedings of the National Academy of Sciences of the United States of America 36, no. 2 (February 1950): 137–41.

7 Catto, Sultan, Yoon S. Choun, and Levent Kurt. “Invariance Properties of the Exceptional Quantum Mechanics (F_4) and Its Generalization to Complex Jordan Algebras (E_6).” In Lie Theory and Its Applications in Physics, 469–75. Springer Proceedings in Mathematics & Statistics. Springer, Tokyo, 2013.

E_6 action

E_6 action is a derivation [6] on $\mathfrak{M}_8^3 \otimes \mathbb{C}$:

- An element of 78D algebra E_6 is represented by H_1, H_+ $H_- \in Tr_O(\mathfrak{M}_8^3)$
- Its action [7] on J is $E_6(H_1, H_+, H_-)(J) = \delta J = [H_+, J, H_-] + e_1 H_1 \cdot J$
- Invariants are $I_2 = Tr(J^2)$, $I_3 + \imath I_3' = 3Det(J) = Tr(J \cdot (J \times J)^*)$, $I_4 = Tr((J \times J) \cdot (J^* \times J^*)^*)$

$E_6(-26)$ action

An action on the reduced structure group is proposed in [8]

- $J = \Xi + \Psi + \Phi$
- $S = \frac{1}{8\pi} Tr \int d\sigma d\tau (\delta_\alpha \overline{\Xi} \delta^\alpha \Xi + \delta_\alpha \overline{\Psi} \delta^\alpha \Psi + \delta_\alpha \overline{\Phi} \delta^\alpha \Phi)$

REF:

8 Foot, R., and G. C. Joshi. “Space-Time Symmetries of Superstring and Jordan Algebras.” International Journal of Theoretical Physics 28, no. 12 (December 1, 1989): 1449–62.

E_7 action

An action of E_7 by a Freudenthal triple system on E_8 was proposed in [9]:

- 56D representation of E_7 as $\mathfrak{M}^2_{27=(\mathfrak{M}^3_8)}$

E_8 action

E_8 proposed action is a derivation on $\mathfrak{M}^3_8 \otimes \mathbb{O}$:

- The action is extrapolated from Tits-Rosenfeld-Freudenthal magic square [10] expressed by Vinberg [10a] as:

$$\mathbb{L}(\mathbb{A}, J^3(\mathbb{B})) = Der(\mathbb{A}) \bigoplus Im(\mathbb{A}) \bigotimes Tr_0(J^3(\mathbb{B})) \bigoplus Der(J^3(\mathbb{B})) \quad (11)$$

REF:

9 Faulkner, John R. “A Construction of Lie Algebras from a Class of Ternary Algebras.” Transactions of the American Mathematical Society 155, no. 2 (1971): 397–408.

10 Tits, Jacques. “Une classe d’algèbres de Lie en relation avec les algèbres de Jordan.” Proceedings of the Koninklijke Nederlandse Academie van Wetenschappen. Series A. Mathematical sciences 65 (1962): 530–35.

10b E. B. Vinberg, A construction of exceptional simple Lie groups (Russian), Tr. Semin. Vektorn. Tensorn. Anal. 13 (1966), 7-9.

Magic star

From three A_8 lattices

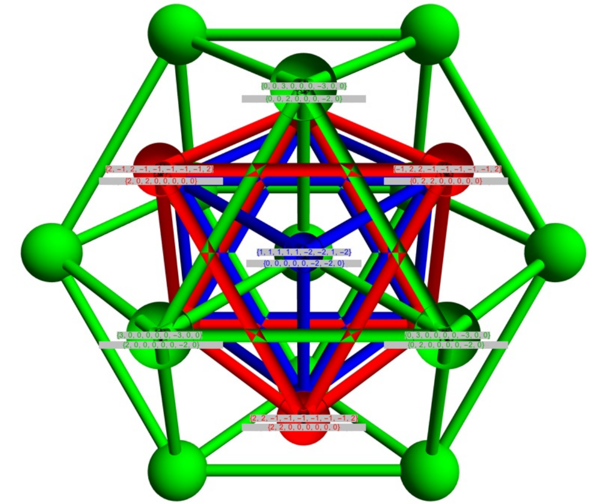


Figure: Three A_8 lattices

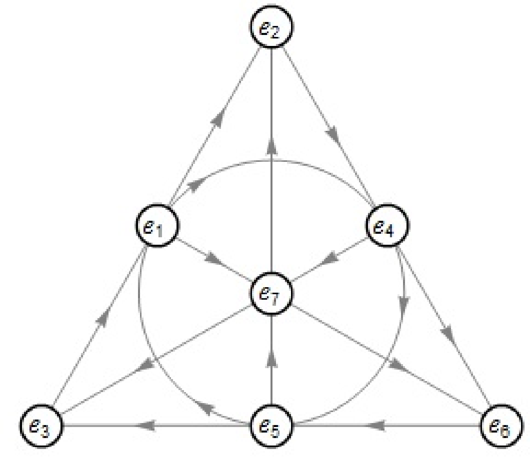


Figure: Induced Fano plane

$E_8 = G_2 \times H_4$?

A golden selective projection operates the H_4 folding

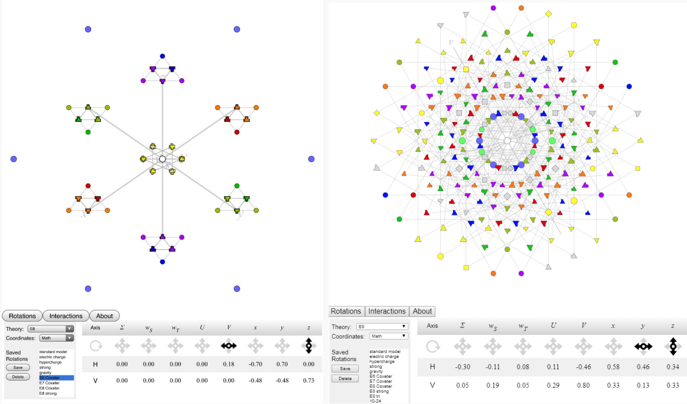


Figure: Rotate E8 projection from G2 to H4 Coxeter plane

Quantum gravity
Quasi-lattice action

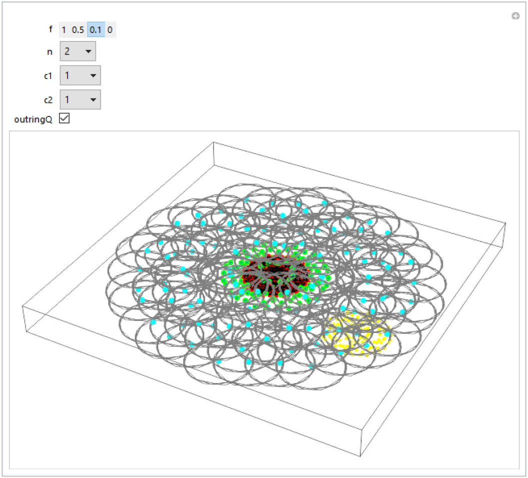


Figure: Elser-Sloane Quasicrystal triacontagonally projected

A the observer

Choose a tetrahedron, select a vertex in it, select an operation

- Operation F_4 involves two E_8 vertices and updates one E_8 vertex
- Operation E_6 involves three vertices and updates two
- Operation E_7 needs choosing a top in the tetrahedron, involves seven vertices
- Operation E_8 involves the full magic star

B the observed

All Jordan matrices affected to lattice vertices are initially blank

P the observation

- Once the observer and its operation choosen, selected vertices, if blank, are initialized
- The operation is performed and vertices are updated

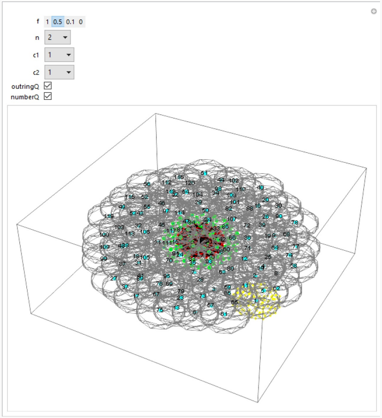


Figure: Elser-Sloane Quasicrystal with numbered 600-cells

Quantum gravity

Quasi-lattice action

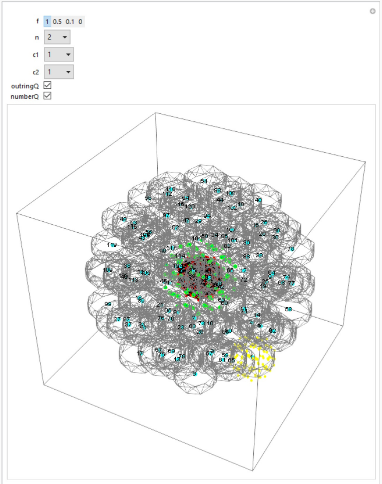


Figure: Elser-Sloane Quasicrystal unflattened

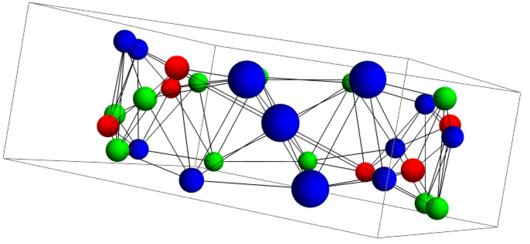


Figure: 30-ring

Quantum gravity
Quasi-lattice action

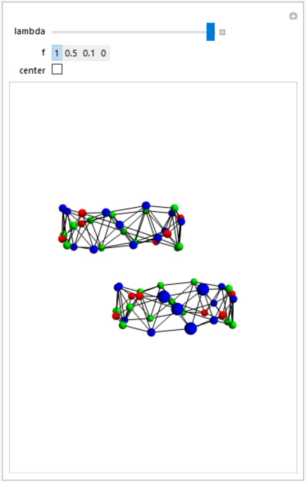


Figure: Two rings

Quantum gravity
Quasi-lattice action

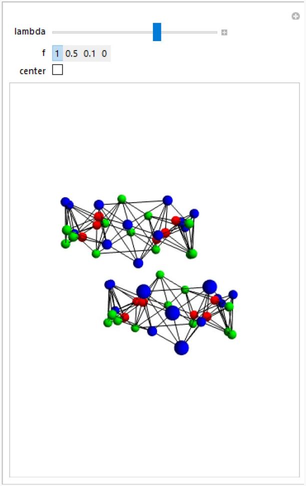


Figure: Two rings

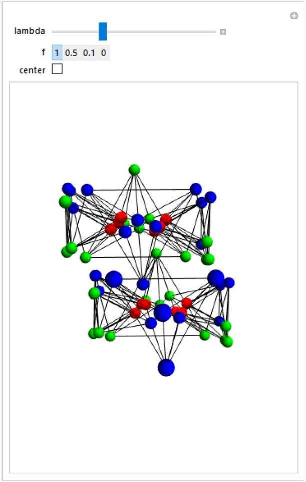


Figure: Two rings

Quantum gravity
Quasi-lattice action

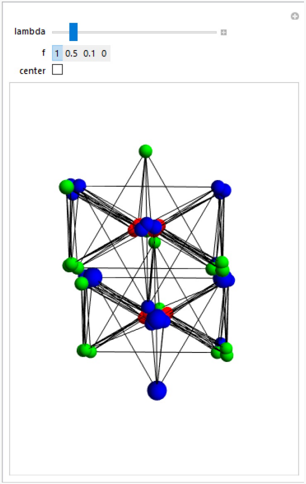


Figure: Two rings

Quantum gravity

Quasi-lattice action

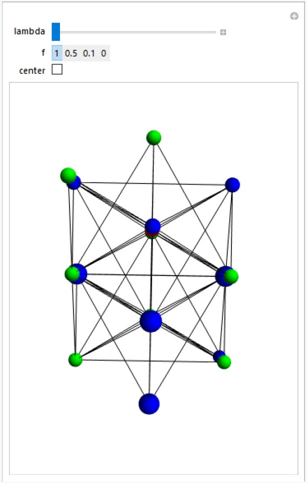


Figure: Two rings

Quantum gravity

Particle Model

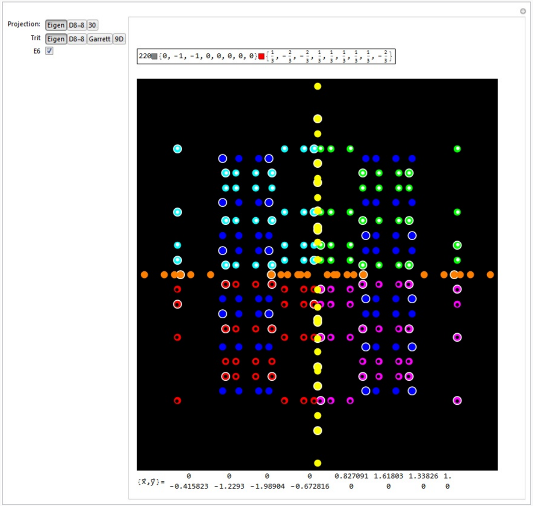


Figure: Gosset polytope projected to Tony's new model

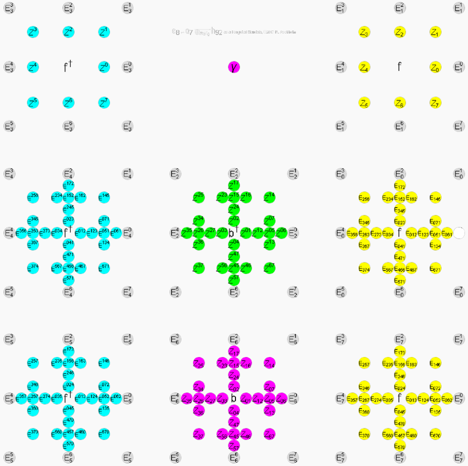


Figure: $\mathfrak{e}_8$ contracted as $\mathfrak{h}_{92} \rtimes \mathfrak{a}_7$.

Thank you !

Quantum gravity

Particle Model

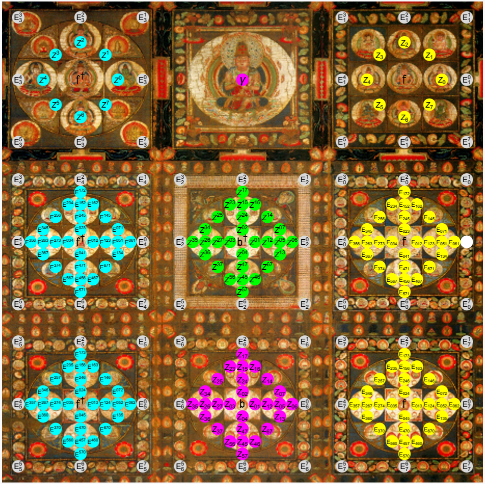


Figure: $\mathfrak{e}_8$ contracted as $\mathfrak{h}_{92} \rtimes \mathfrak{a}_7$, superposed to a Kongokai “Diamond” mandala (Tō-ji, Kyoto, 9th century - Credit https://commons.wikimedia.org/wiki/File:Kongokai.jpg) .“It is like a diamond with tens of thousands of facets,” Bertram Kostant, an emeritus professor of math at M.I.T., said. “It is easy to arrive at the feeling that a final understanding of the universe must somehow involve E8, or, otherwise put, nature would be foolish not to utilize E8.” https://www.newyorker.com/magazine/2008/07/21/surfing-the-universe