Title: From the Mathematics of Supersymmetry to the Music of Arnold Schoenberg

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Abstract: The concept of supersymmetry, though never observed in nature, has driven a great deal of research in theoretical physics over the past several decades. Much has been learned through this research, but many unresolved questions remain. This presentation will describe how these questions can lead one down a surprising path: toward the dodecaphony of Austrian composer Arnold Schoenberg.

One Theorist's Bucket List

(a.) **Higgs boson(s),**

(b.) Gravity Waves,

(c.) Super-partner's, and

(d.) Superstring/M-Theory

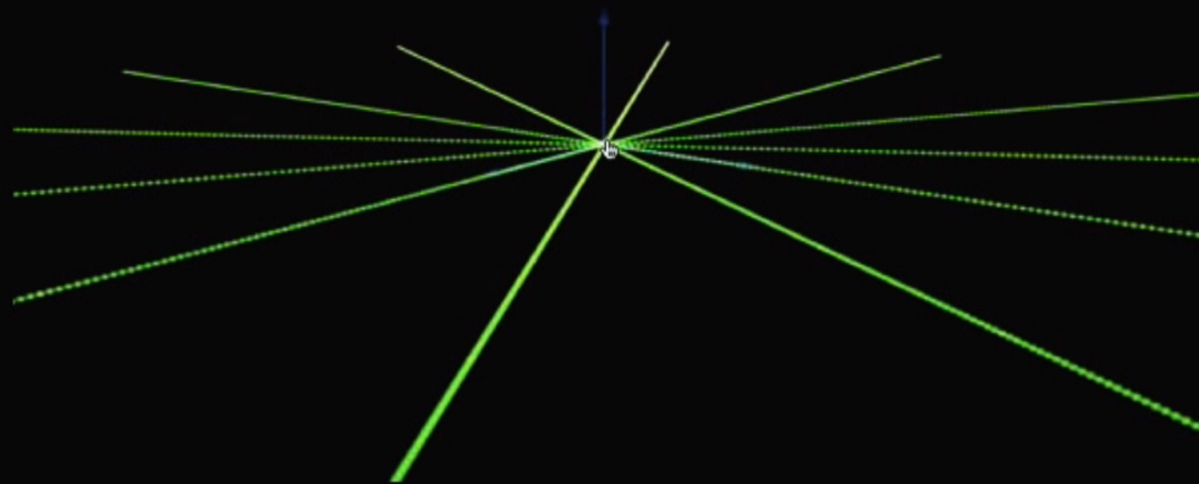
Maxwell's Equations and Conservation Law

(Beeper/Cell Phone Equations)

$$\vec{\nabla} \cdot \vec{D} = 4\pi\rho \quad , \quad \vec{\nabla} \cdot \vec{B} = 0 \quad ,$$

$$\vec{\nabla} \times \vec{H} - \frac{1}{c}\frac{\partial \vec{D}}{\partial t} = \frac{4\pi}{c}\vec{J} \quad , \quad \vec{\nabla} \times \vec{E} + \frac{1}{c}\frac{\partial \vec{B}}{\partial t} = 0$$

$$\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot \vec{J} = 0 \quad .$$



Electric Field of an Oscillating Charge

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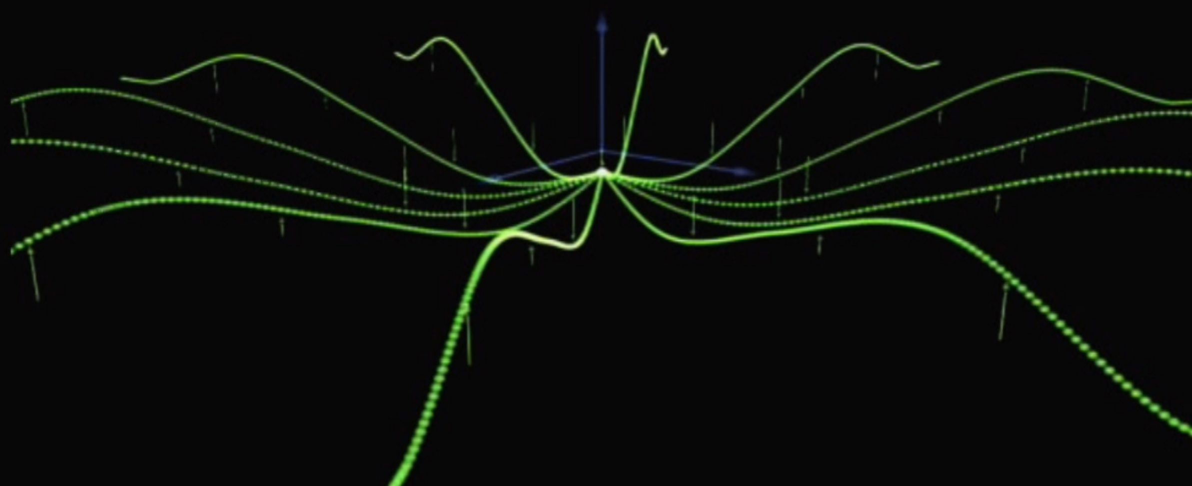
ELECTRIC FIELD OF AN OSCILLATING CHARGE



When Dmitri Mendeleev first presented the Periodic Table of Elements, there were ‘holes’ in it, i.e. elements that were not known at the time he conceived it. The result was an image that is highly asymmetrical.

I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Cs 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Tl 204	Pb 207	Bi 209					
			Th 232		U 238				

The modern Periodic Table, by contrast, is highly symmetrical in its appearance.

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
*Lanthanoids			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
**Actinoids			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

The Standard Model (SM)

FERMIONS
matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2

Flavor		Mass GeV/c^2	Electric charge
ν_e	electron neutrino	$<1\times10^{-8}$	0
e	electron	0.000511	−1
ν_μ	muon neutrino	<0.0002	0
μ	muon	0.106	−1
ν_τ	tau neutrino	<0.02	0
τ	tau	1.7771	−1

Quarks spin = 1/2

Flavor		Approx. Mass GeV/c^2	Electric charge
u	up	0.003	2/3
d	down	0.006	−1/3
c	charm	1.3	2/3
s	strange	0.1	−1/3
t	top	175	2/3
b	bottom	4.3	−1/3

BOSONS
force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1

Name	Mass GeV/c^2	Electric charge
γ photon	0	0
W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1

Name	Mass GeV/c^2	Electric charge
g gluon	0	0

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at: 10^{-18} m	10^{-41}	0.8	1	25	Not applicable to quarks
Strength relative to electromag for two u quarks at: 3×10^{-17} m	10^{-41}	10^{-4}	1	60	
for two protons in nucleus	10^{-36}	10^{-7}	1	Not applicable to hadrons	20

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force carriers
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Unified Electroweak spin = 1

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W^-	80.4	−1
W^+	80.4	+1
Z^0	91.187	0
H^0	125	0

Strong (color) spin = 1

Name	Mass GeV/c^2	Electric charge
g gluon	0	0

PROPERTIES OF THE INTERACTIONS

Property \ Interaction	Gravitational	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong: Fundamental	Strong: Residual
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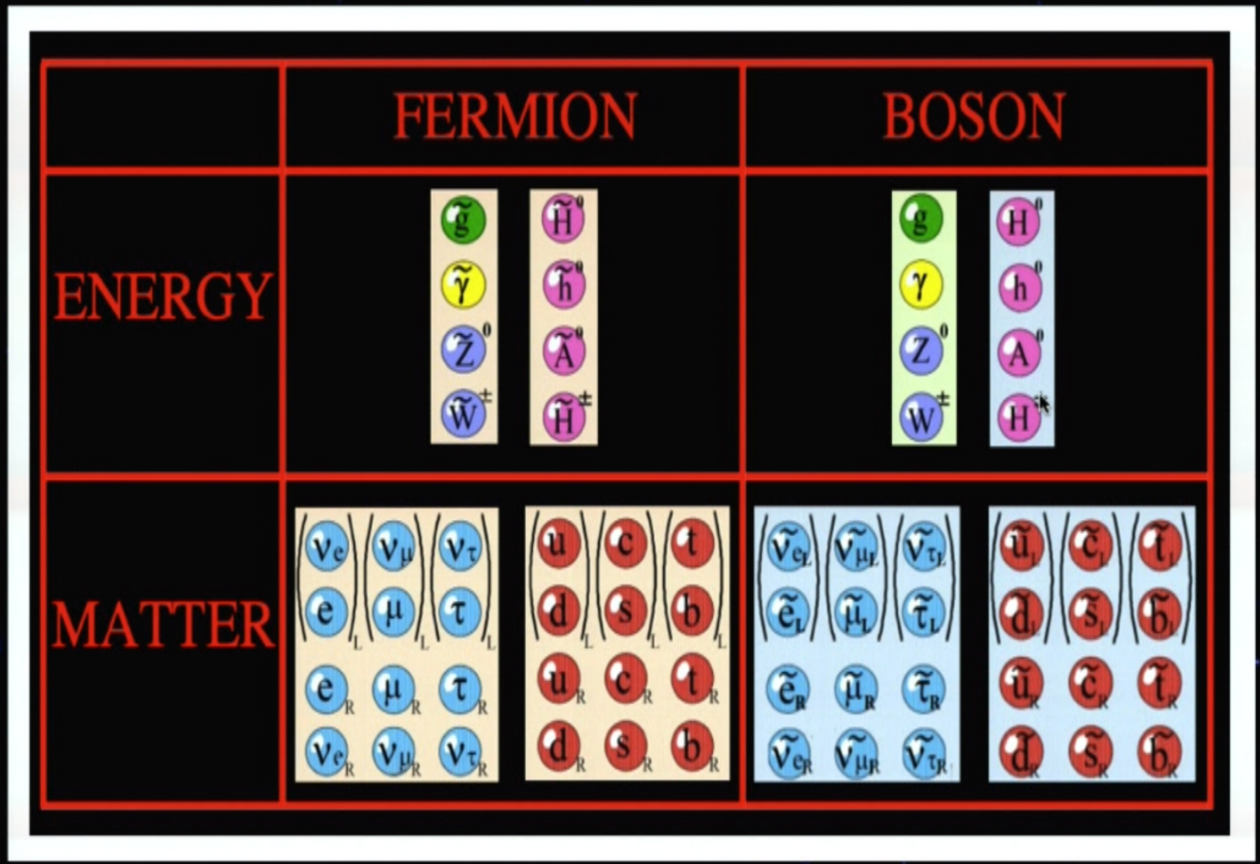
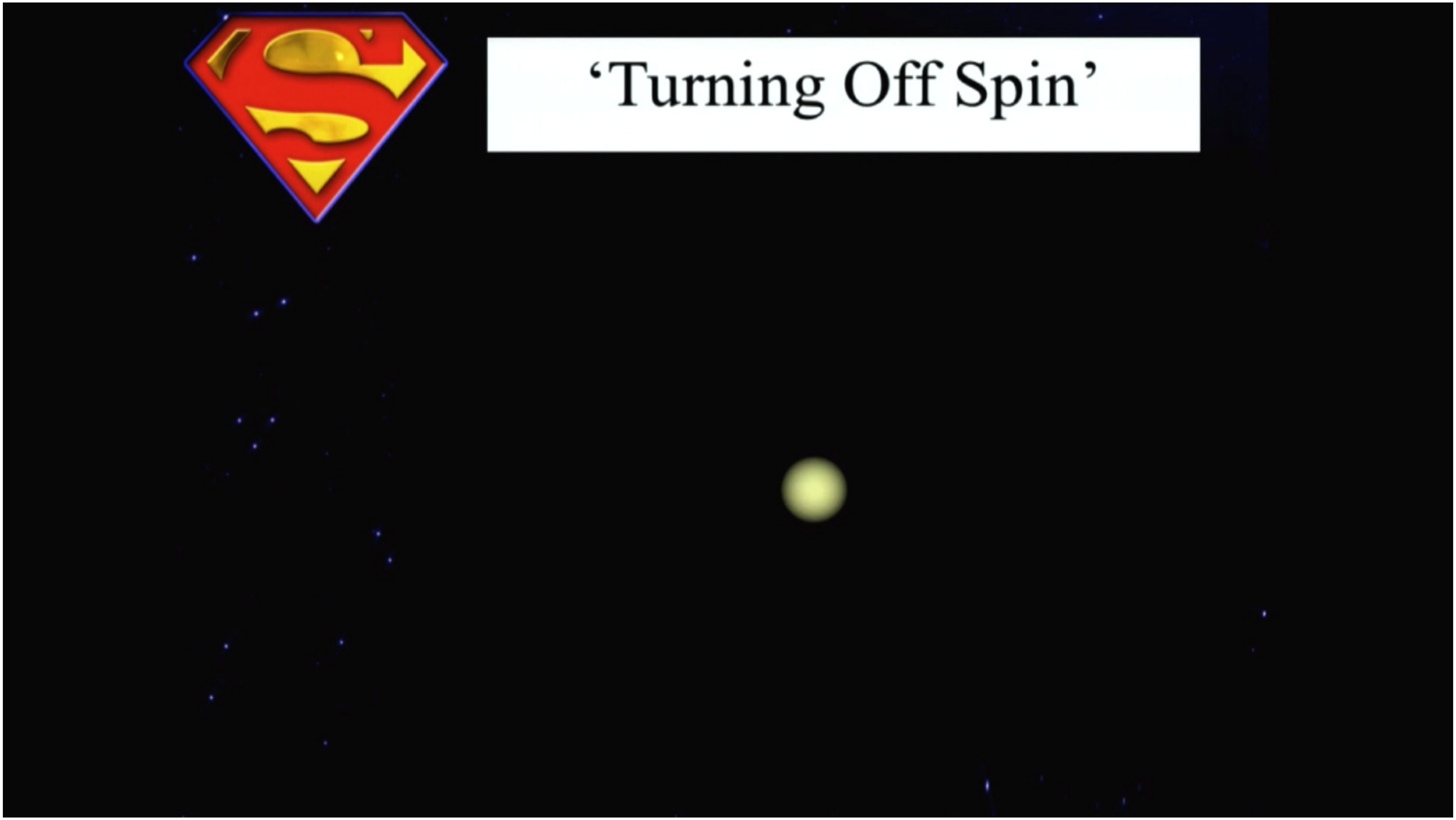
When all the particles of today's Standard Model are classified according to their spins (bosons or fermions) and matter/energy properties, the image is highly asymmetrical.

	FERMION	BOSON
ENERGY		g, γ, Z^0, $W^\pm$; H^0
MATTER	$\begin{pmatrix}\nu_e \\ e\end{pmatrix}_L$ $\begin{pmatrix}\nu_\mu \\ \mu\end{pmatrix}_L$ $\begin{pmatrix}\nu_\tau \\ \tau\end{pmatrix}_L$ e_R μ_R τ_R ν_{eR} $\nu_{\mu R}$ $\nu_{\tau R}$; $\begin{pmatrix}u \\ d\end{pmatrix}_L$ $\begin{pmatrix}c \\ s\end{pmatrix}_L$ $\begin{pmatrix}t \\ b\end{pmatrix}_L$ u_R c_R t_R d_R s_R b_R	

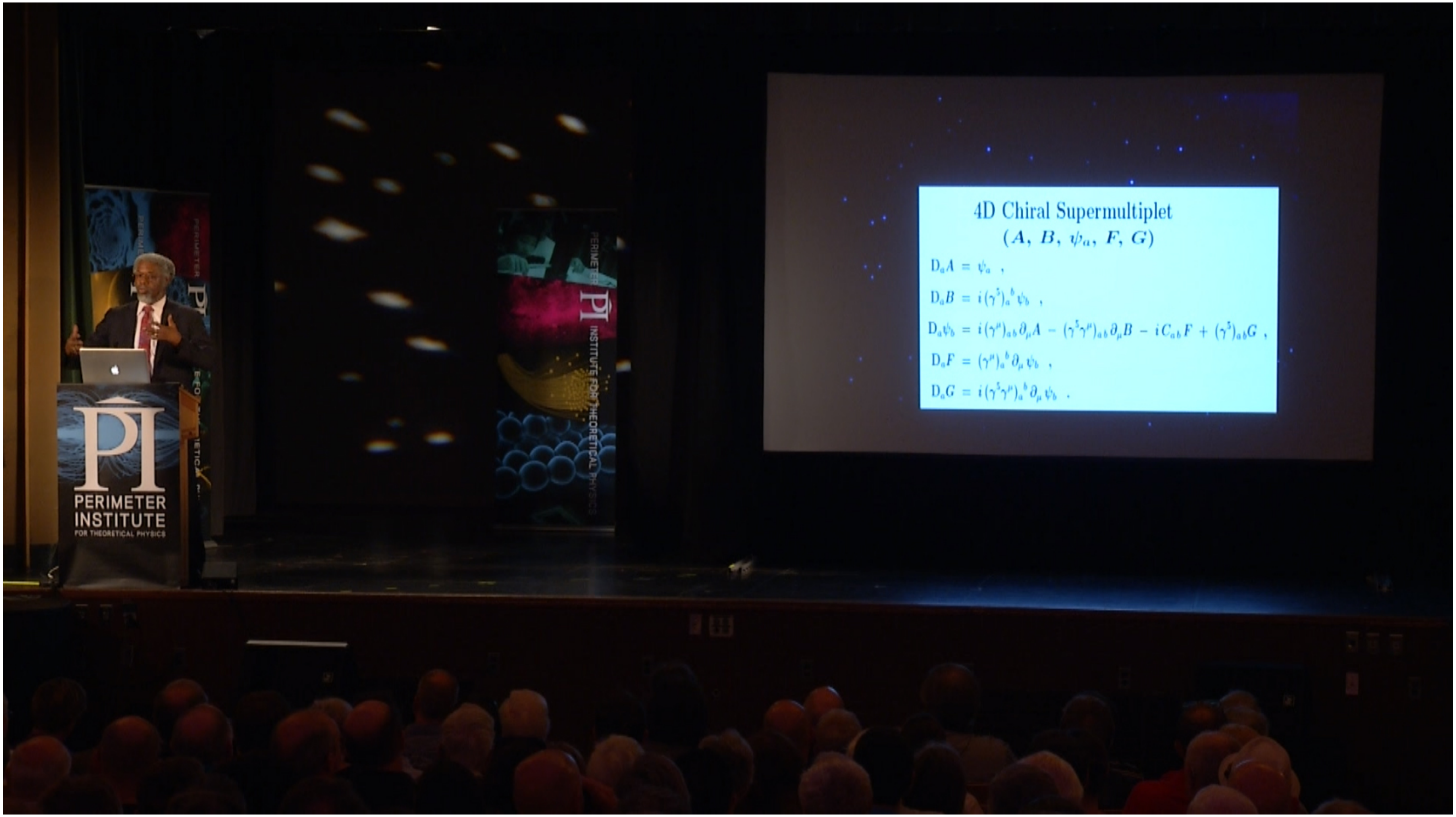
Should ‘sparticles’ or ‘superpartners’ be later observed in laboratories, once more there would he a high symmetrical table to describe physical reality.



‘Turning Off Spin’


‘Turning Off Spin’


10 00
m


4D Chiral Supermultiplet
$(A,\, B,\, \psi_a,\, F,\, G)$
$\mathrm{D}_a A = \psi_a \ ,$
$\mathrm{D}_a B = i\,(\gamma^5)_a{}^b \psi_b \ ,$
$\mathrm{D}_a \psi_b = i\,(\gamma^\mu)_{ab}\partial_\mu A - (\gamma^5\gamma^\mu)_{ab}\partial_\mu B - i\,C_{ab} F + (\gamma^5)_{ab} G \ ,$
$\mathrm{D}_a F = (\gamma^\mu)_a{}^b \partial_\mu \psi_b \ ,$
$\mathrm{D}_a G = i\,(\gamma^5\gamma^\mu)_a{}^b \partial_\mu \psi_b \ .$
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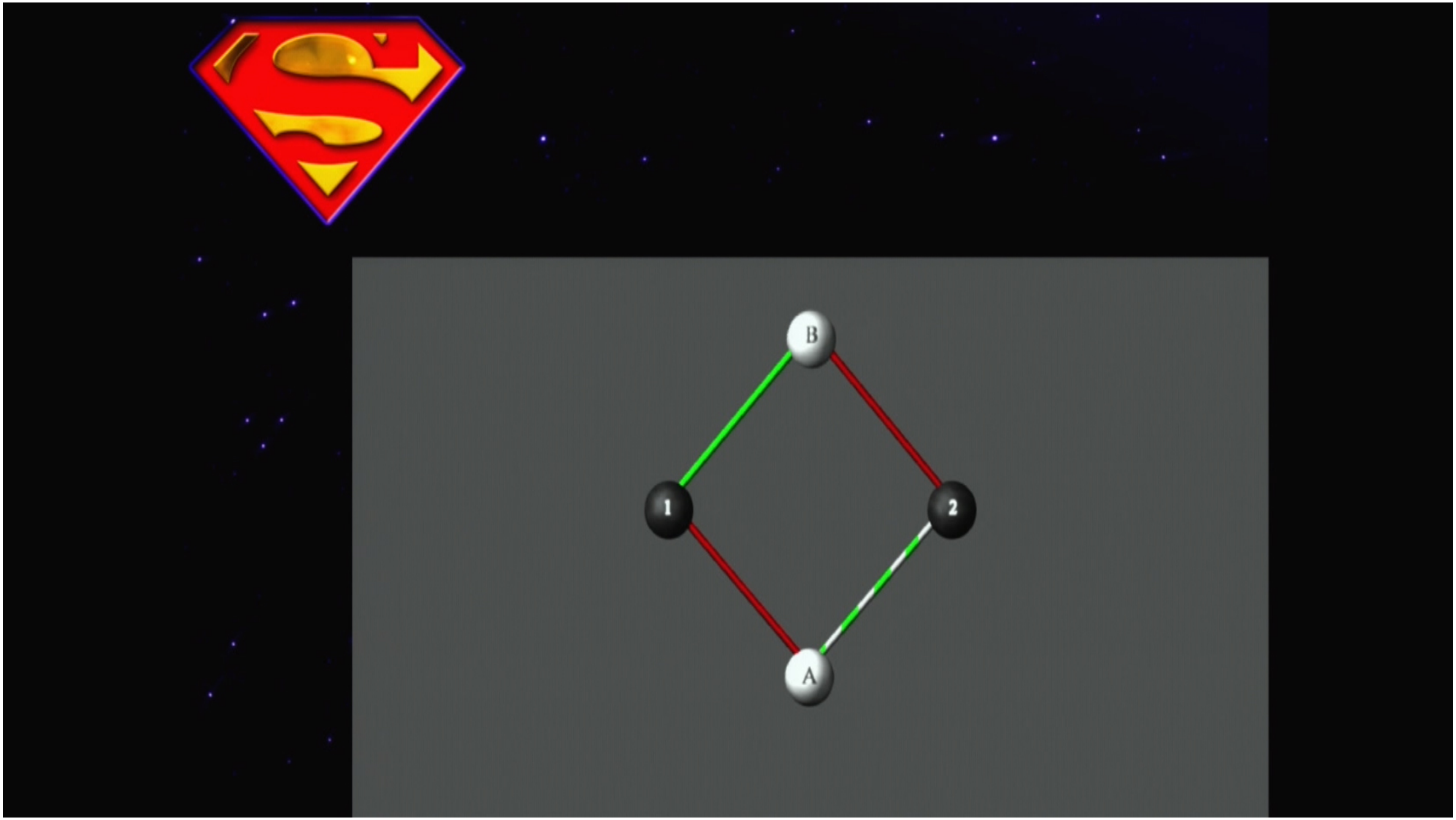
B
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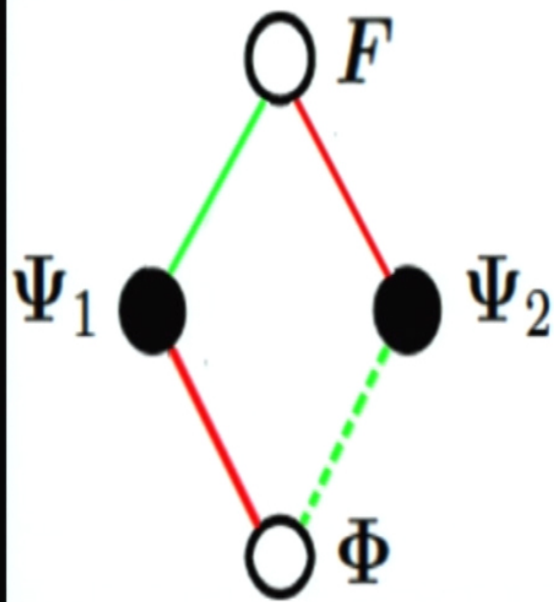


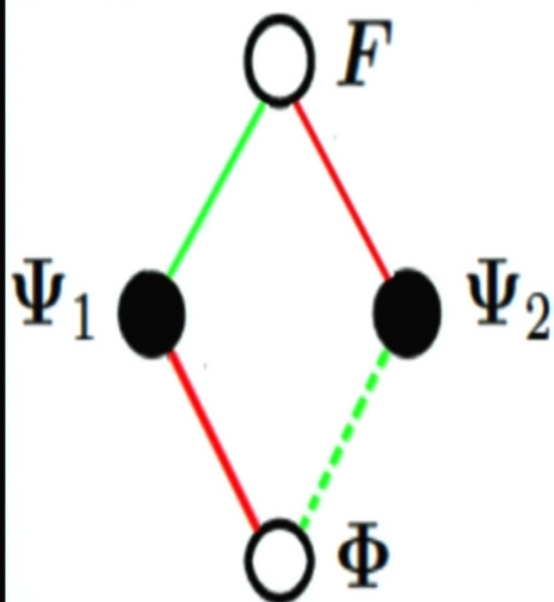
$$\mathrm{D}_1\Phi = i\,\Psi_1\,, \quad \mathrm{D}_2\Phi = -i\,\Psi_2\,,$$

$$\mathrm{D}_1\Psi_1 = \dot{\Phi}\,, \quad \mathrm{D}_2\Psi_1 = F\,,$$

$$\mathrm{D}_1\Psi_2 = F\,, \quad \mathrm{D}_2\Psi_2 = -\,\dot{\Phi}\,,$$

$$\mathrm{D}_1 F = i\dot{\Psi}_2\,, \quad \mathrm{D}_2 F = i\,\dot{\Psi}_1\,.$$

Color indicates direction,
Height indicates engineering dimension,
Solid lines indicate positive coefficients,
Dashed lines indicate negative coefficients.



$$\mathrm{D}_1\Phi = i\,\Psi_1\,, \quad \mathrm{D}_2\Phi = -i\,\Psi_2\,,$$

$$\mathrm{D}_1\Psi_1 = \dot{\Phi} \quad , \quad \mathrm{D}_2\Psi_1 = \boldsymbol{F} \quad ,$$

$$\mathrm{D}_1\Psi_2 = \boldsymbol{F} \quad , \quad \mathrm{D}_2\Psi_2 = -\,\dot{\Phi} \quad ,$$

$$\mathrm{D}_1\boldsymbol{F} = i\dot{\Psi}_2\,, \quad \mathrm{D}_2\boldsymbol{F} = i\,\dot{\Psi}_1 \quad .$$

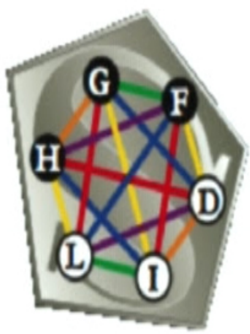
Color indicates direction,
Height indicates engineering dimension,
Solid lines indicate positive coefficients,
Dashed lines indicate negative coefficients.

http://www.kaleidoscope.net/greg/math/The%20Adinkramat.html

https://code.google.com/p/adinkramat/

The Adinkramat

COHOMOLOGY.COM BIBDESK SCRIPTS THE LINEAR ALGEBRATOR THE ADINKRAMAT

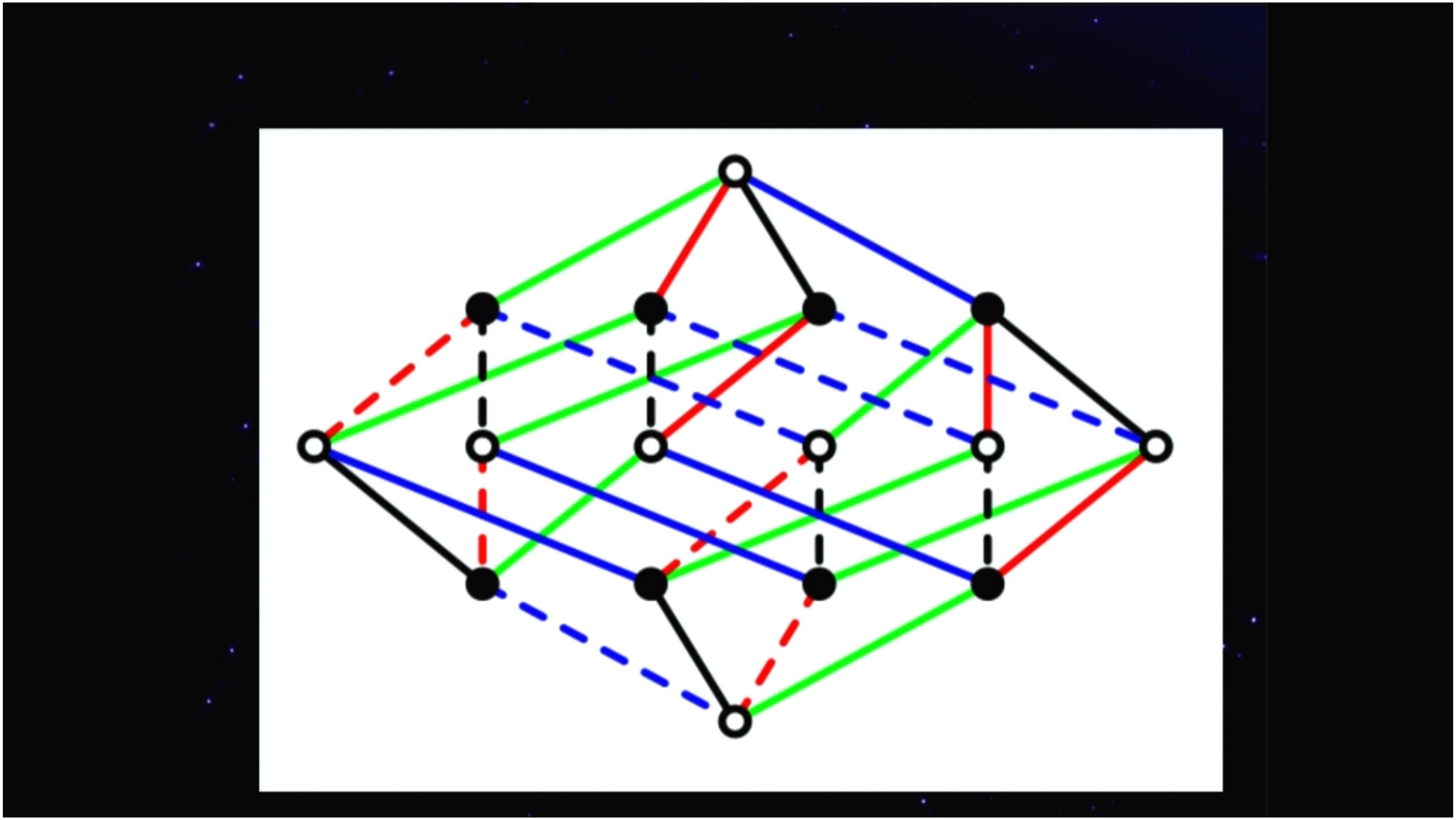


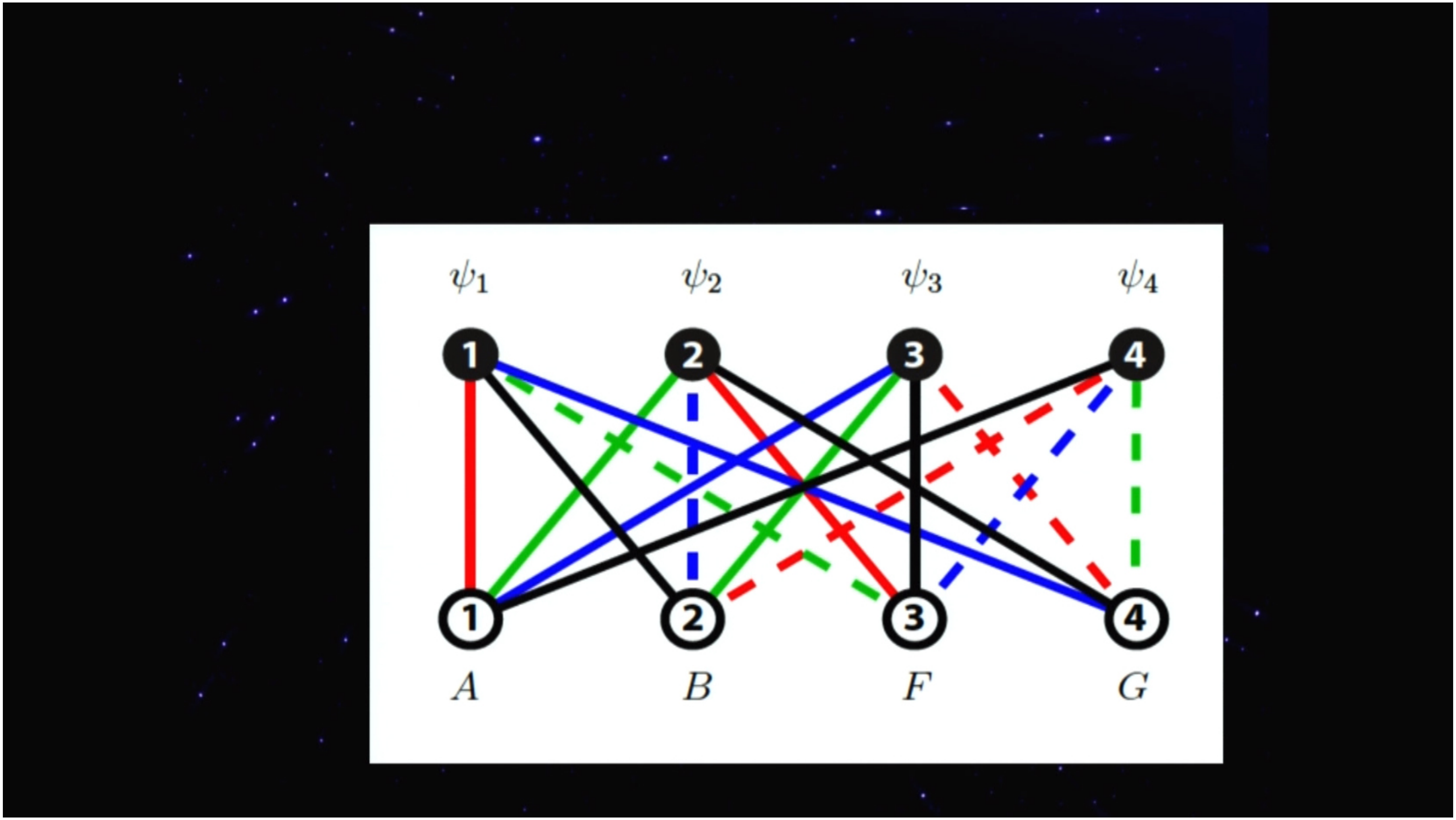
Have you ever tried to understand off-shell supermultiplets and thought that it might be interesting to describe the component fields and supersymmetry actions in terms of diagrams? If so, you're probably one of my research collaborators, Chuck Doran, Mike Faux, Jim Gates, Tristan Hübsch, or Kevin Iga. **Adinkras** are graphs which encapsulate representation of d=1, N-extended off-shell supersymmetry. Such representations are used in supersymmetric quantum mechanics, and they also arise as the dimensional reductions of higher dimensional supersymmetric field theories.

The **Adinkramat** is a document-based multi-threaded Mac OS X application for exploring Adinkras, which automatically generates the standard Adinkras, lets you rearrange the vertices, and exports the results as PDF and Encapsulated PostScript.

Download Adinkramat 1.1 (November 14, 2006)

If you have any questions, comments, or suggestions, please e-mail Greg Landweber.

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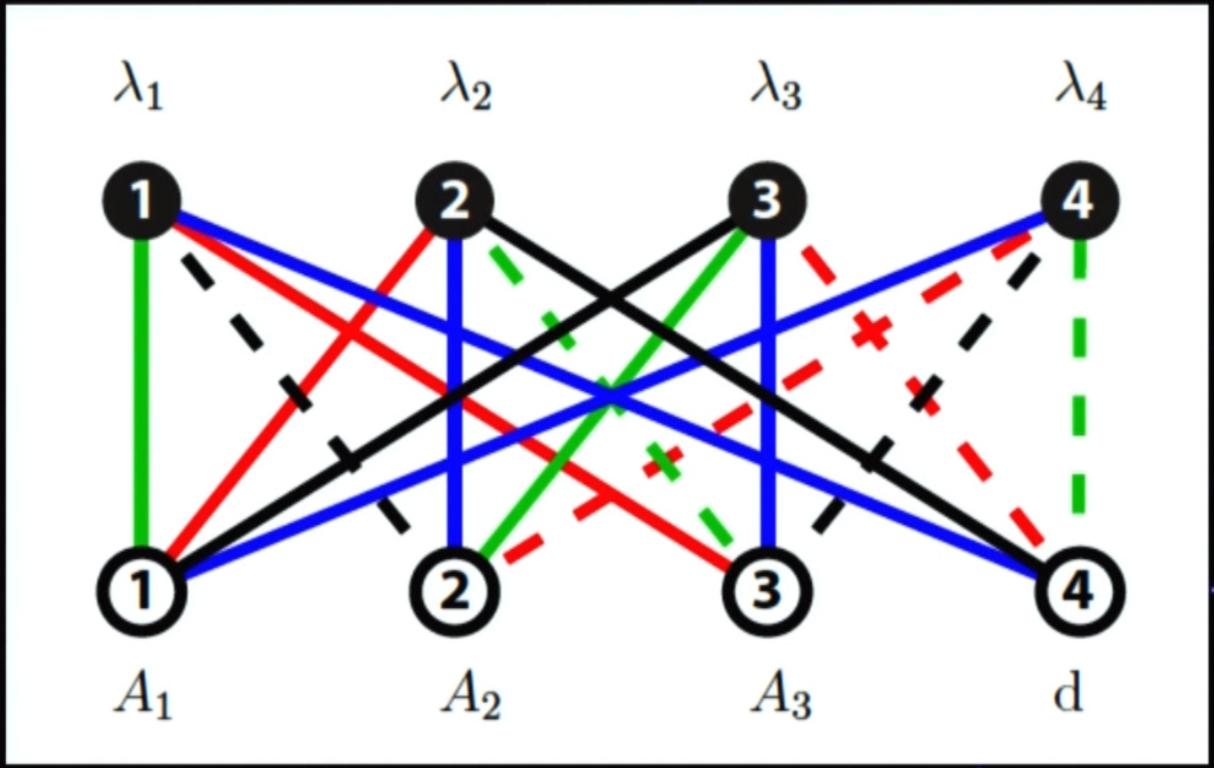
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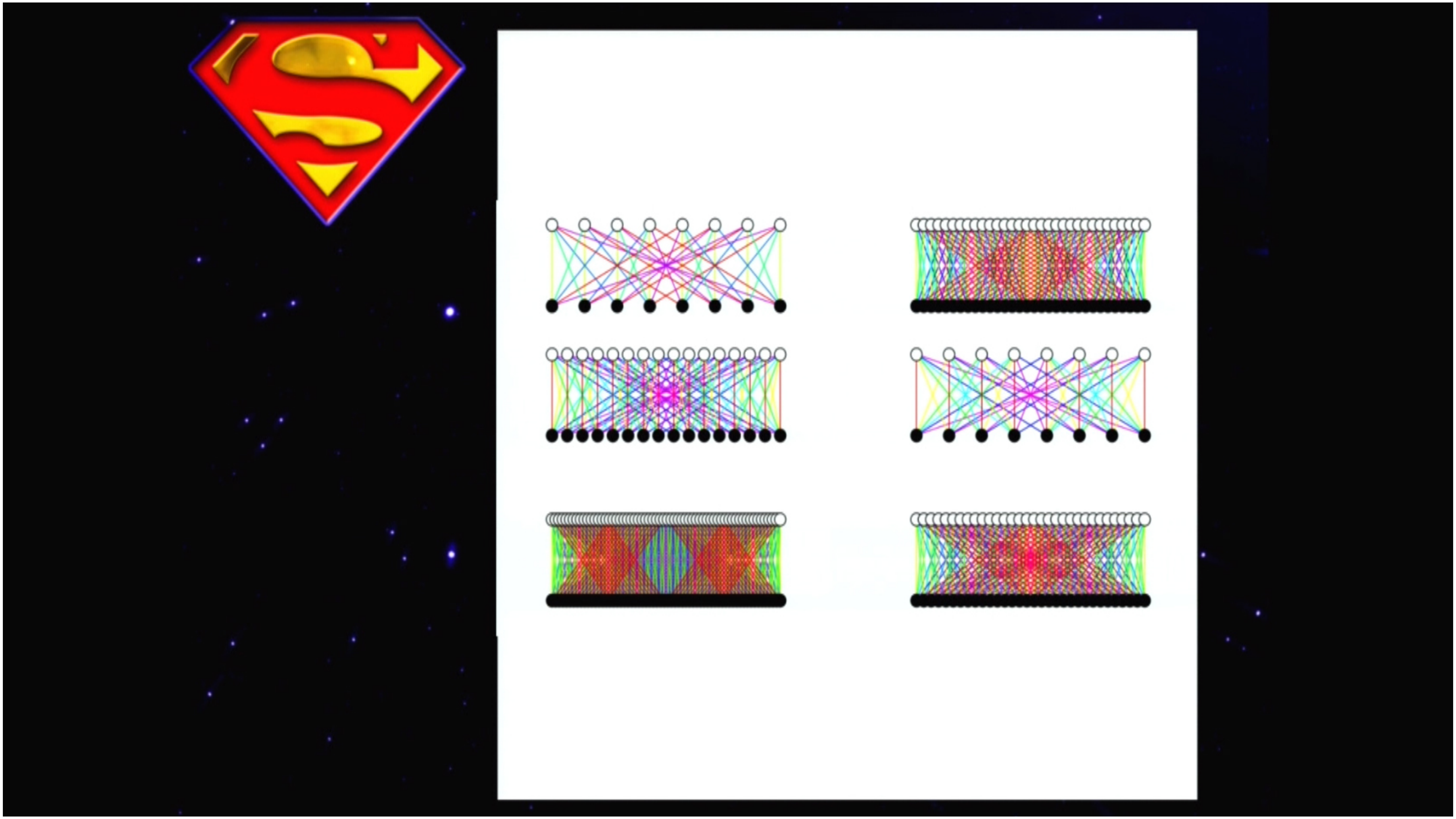
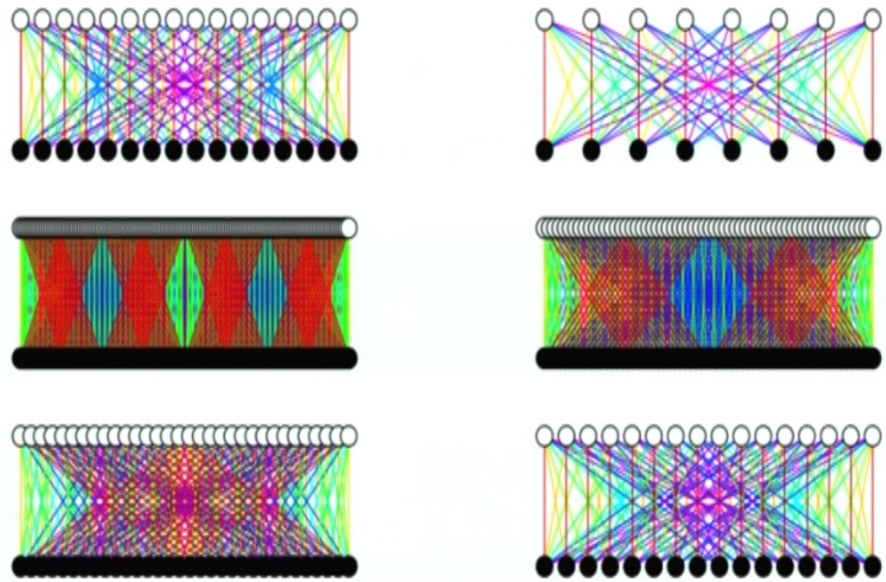
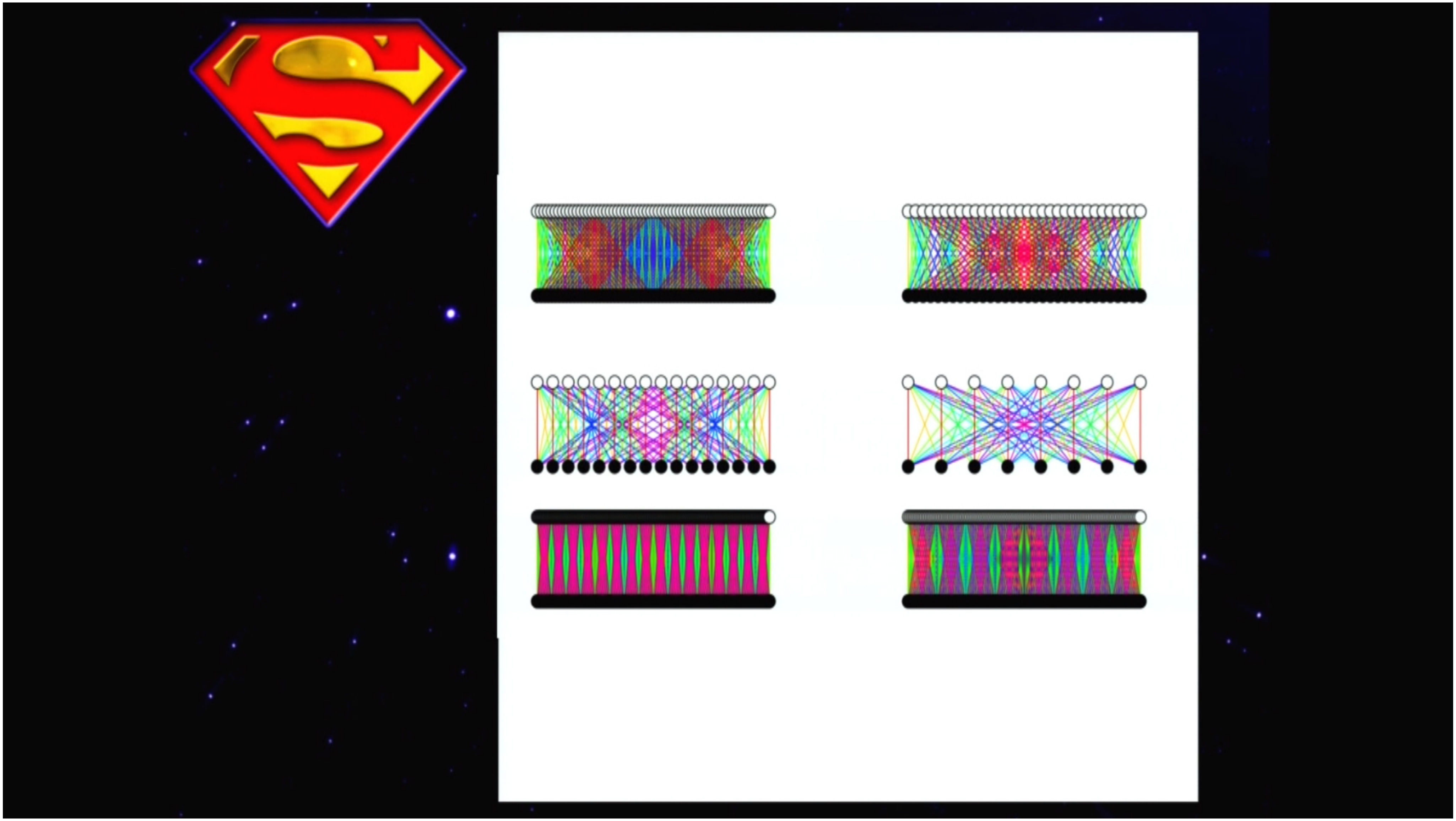
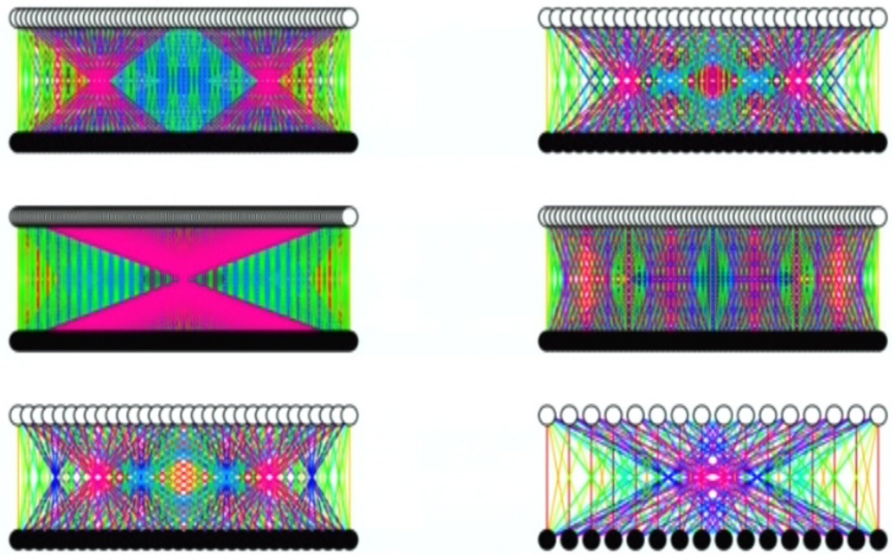
L'Arte Della Fisica

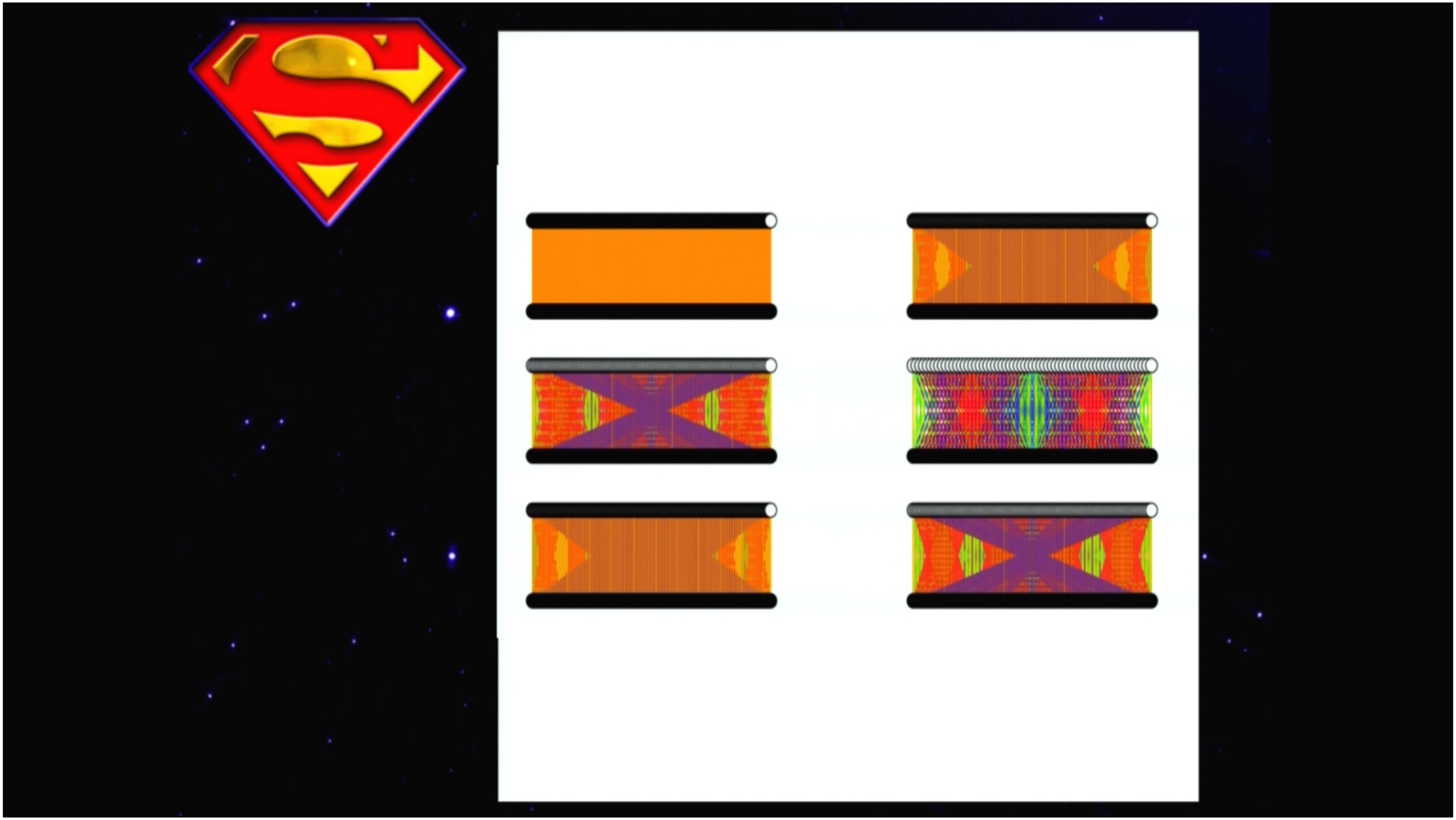
After a certain high level of technical skill is achieved, science and art coalesce in esthetics, plasticity, and form. - A. Einstein

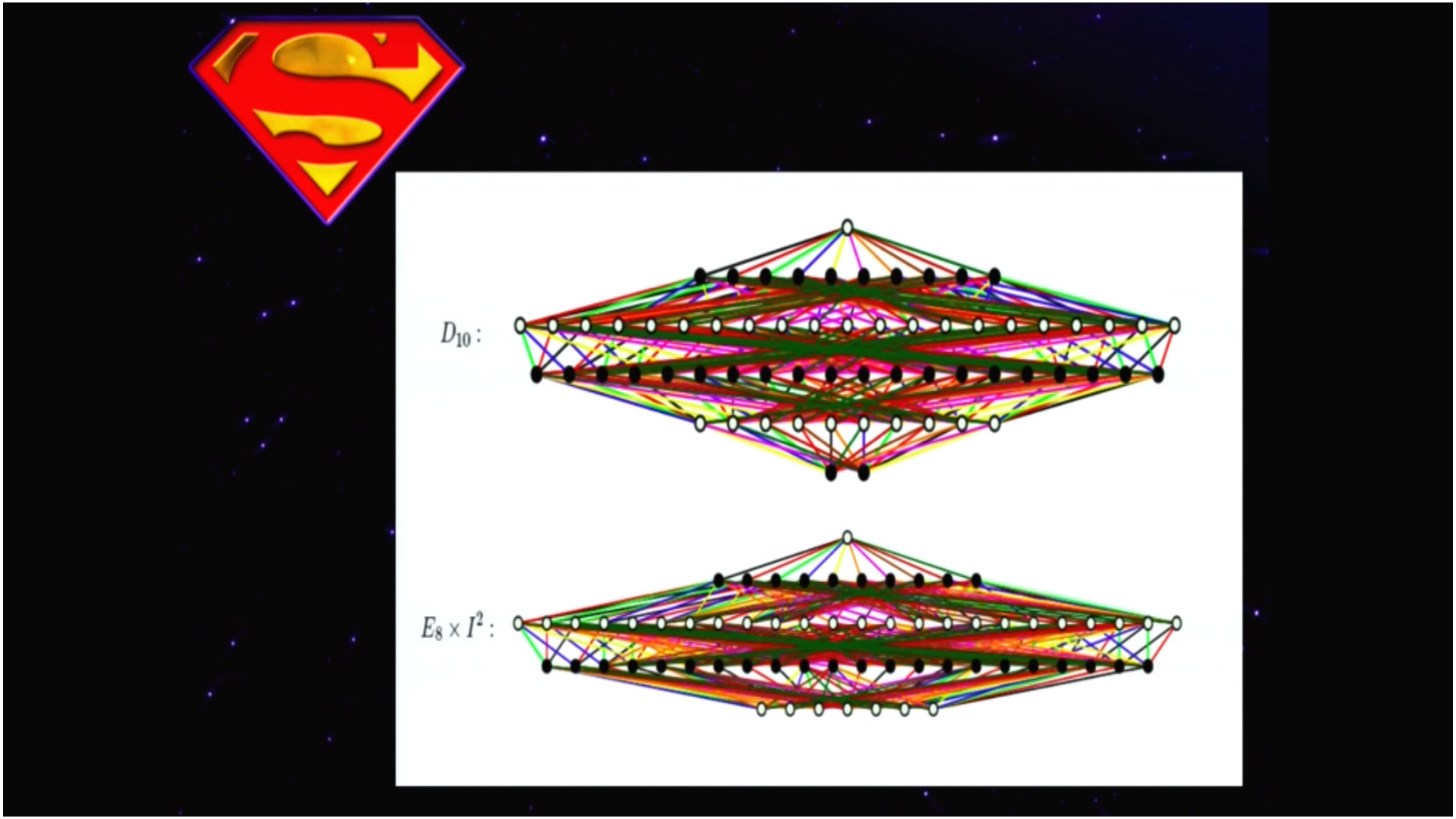




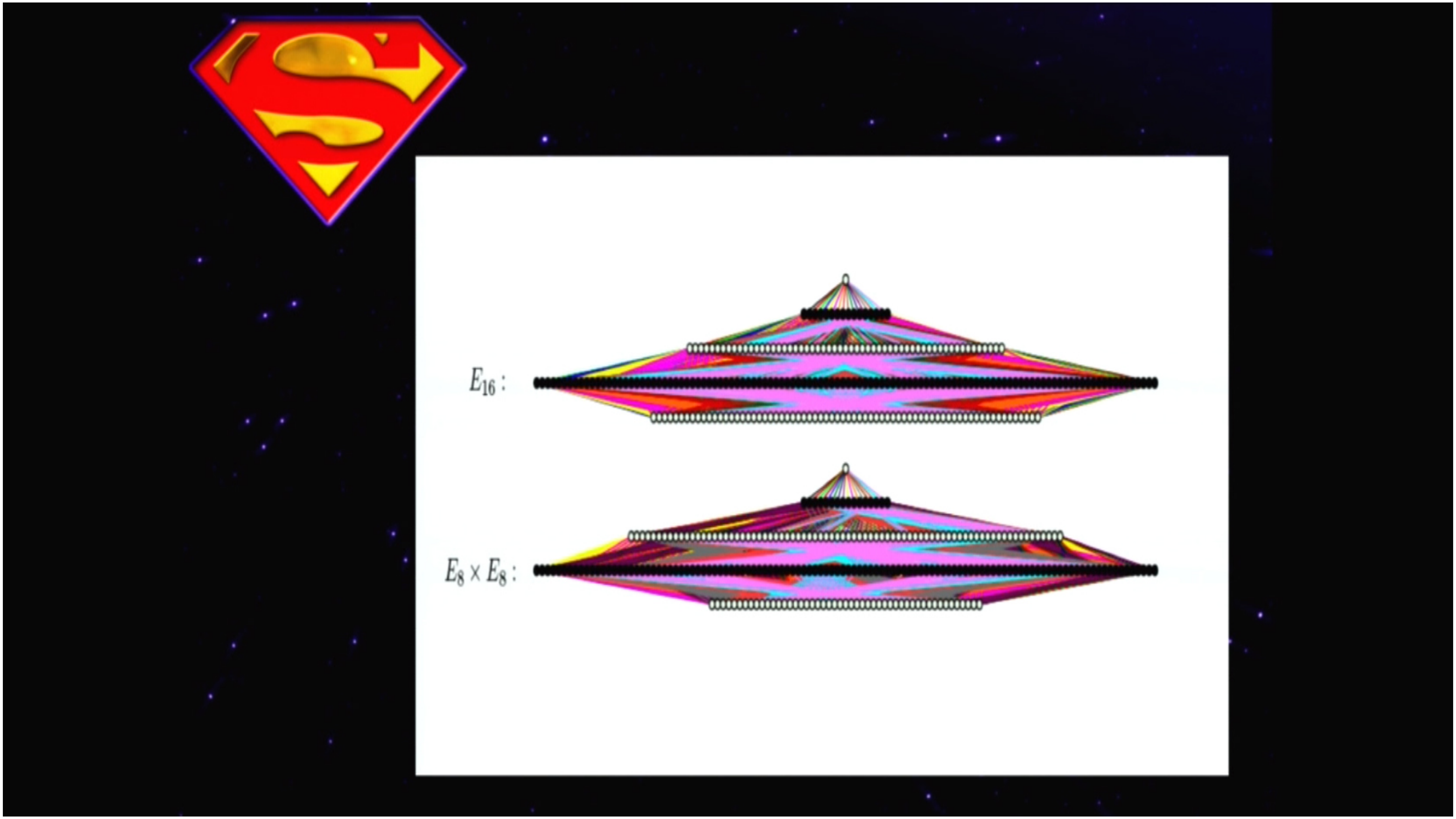




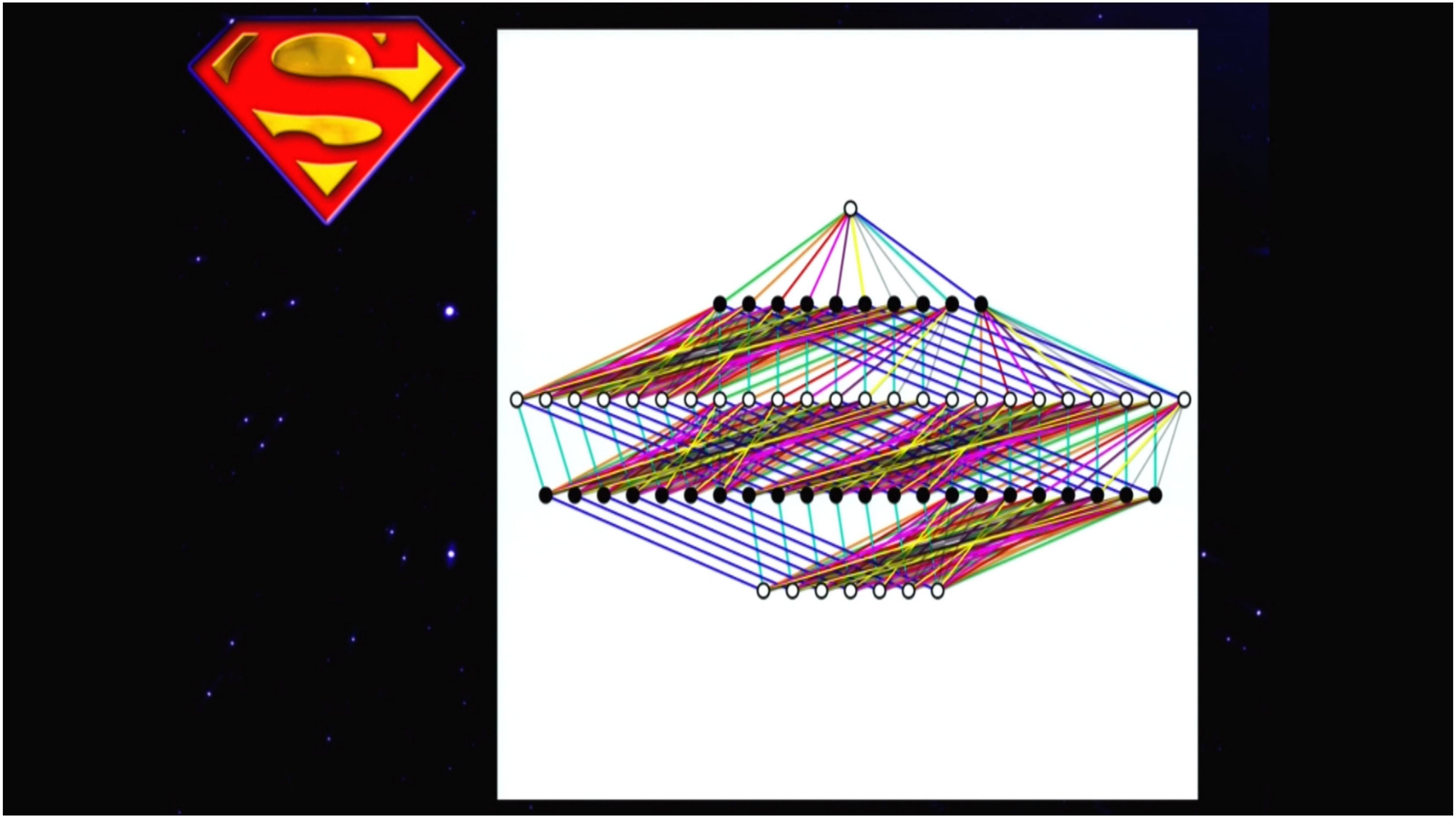


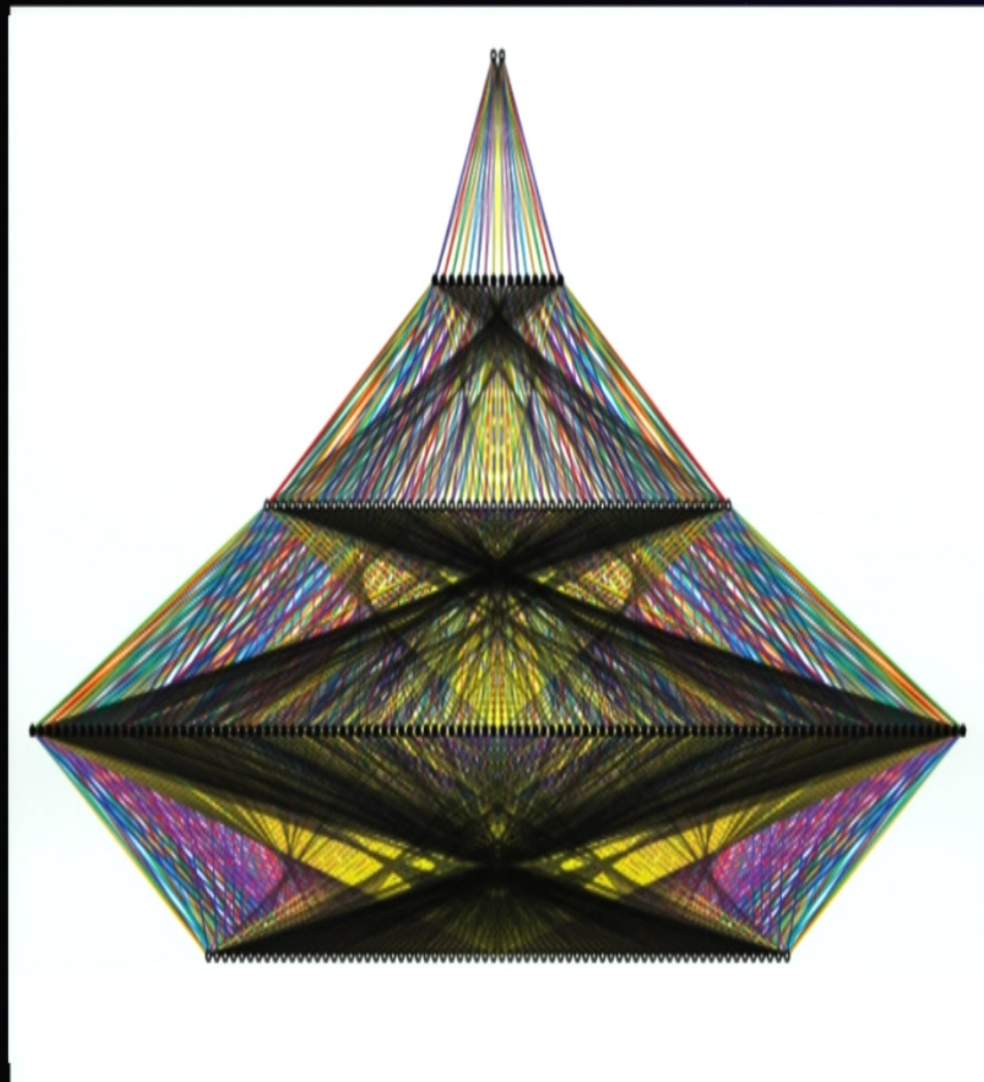


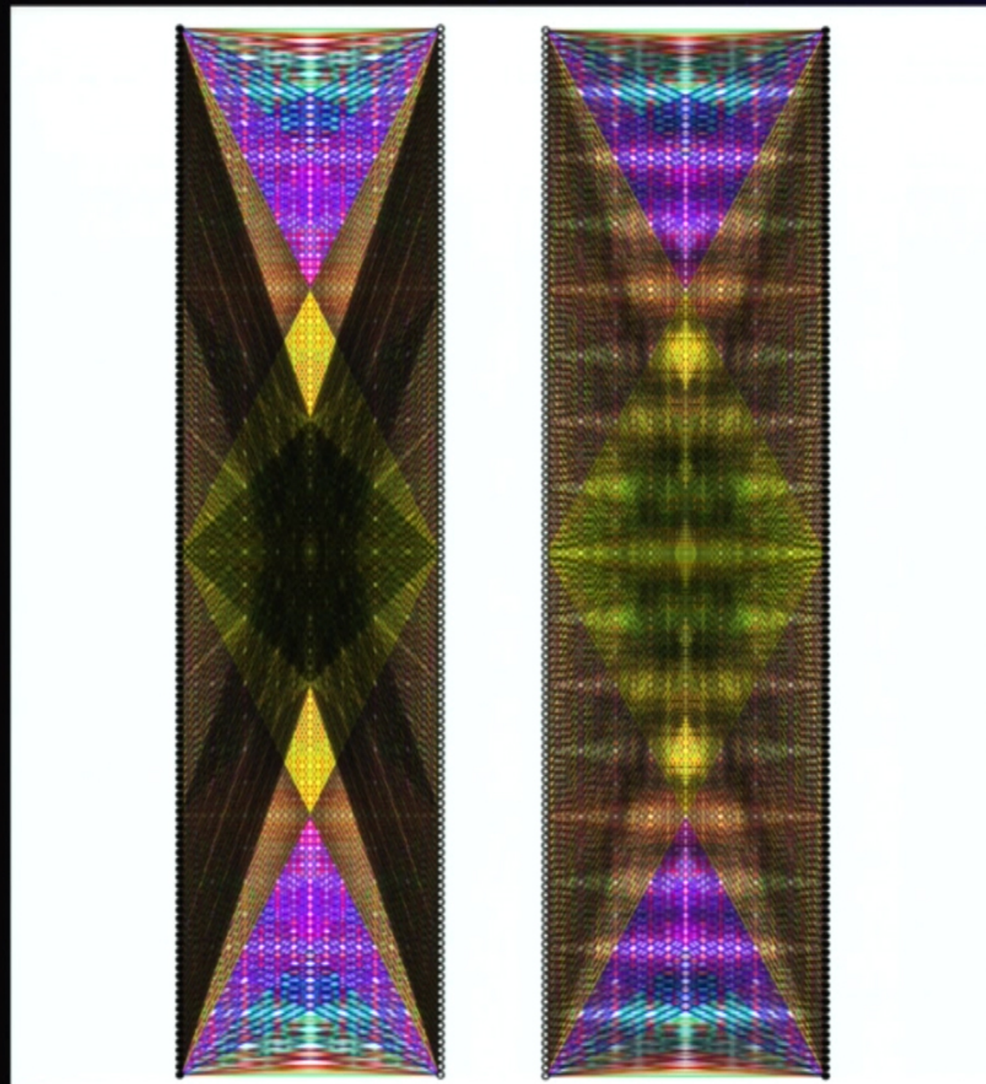
D_{10}:
$E_8 \times I^2$:

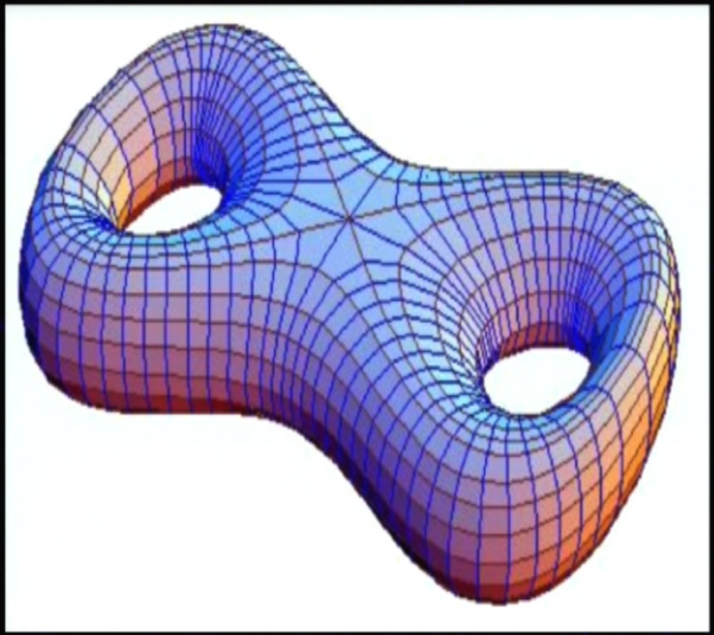


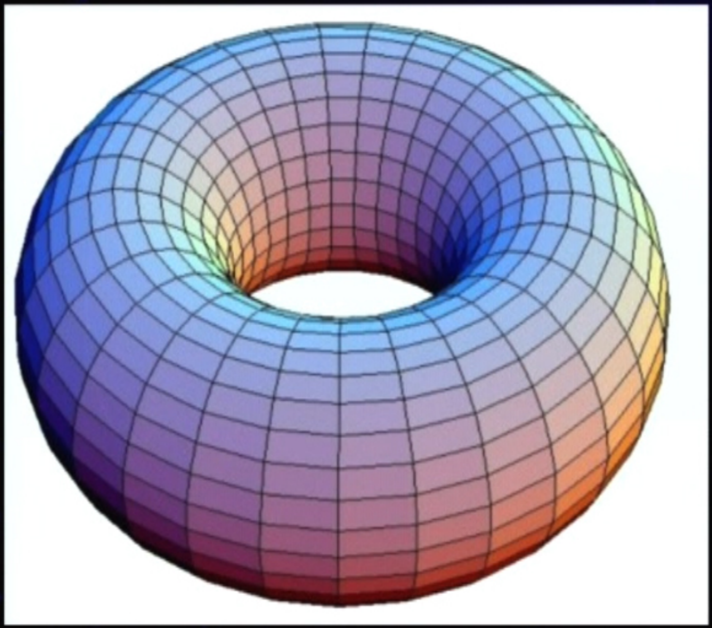
E_{16} :
$E_8 \times E_8$:





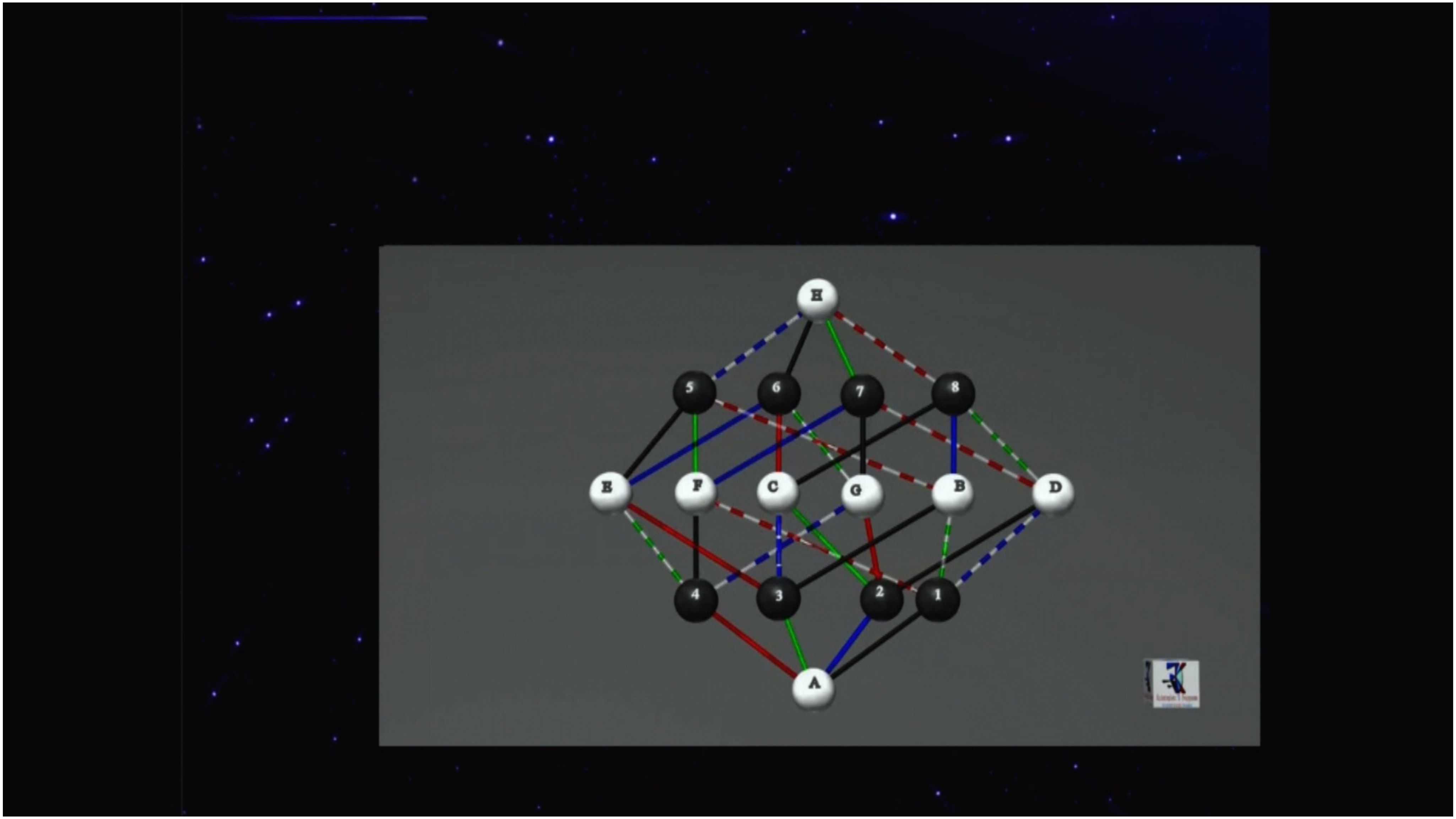






A Beyli pair, $(\mathcal{X}, \beta)$ is a closed Riemann surface X equipped a Belyi map, $\beta : \mathcal{X} \to CP^1$ that is ramified at most over $\{0, 1, \infty\}$. Adinkras induce an integer-valued Morse function on the Riemann surface which is also a divisor.

$$g = 1 + 2^{N-k-3}(N-4)$$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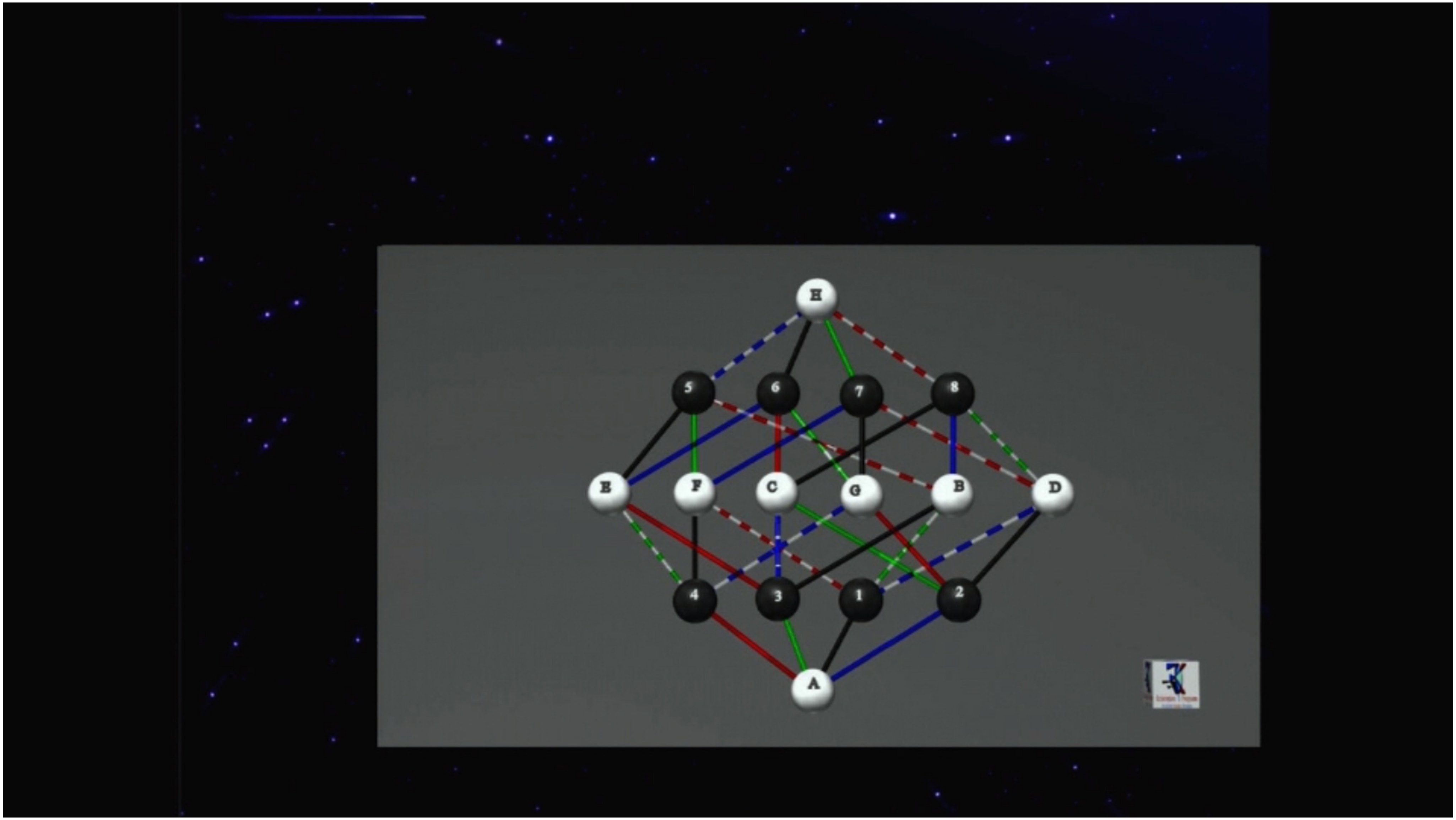

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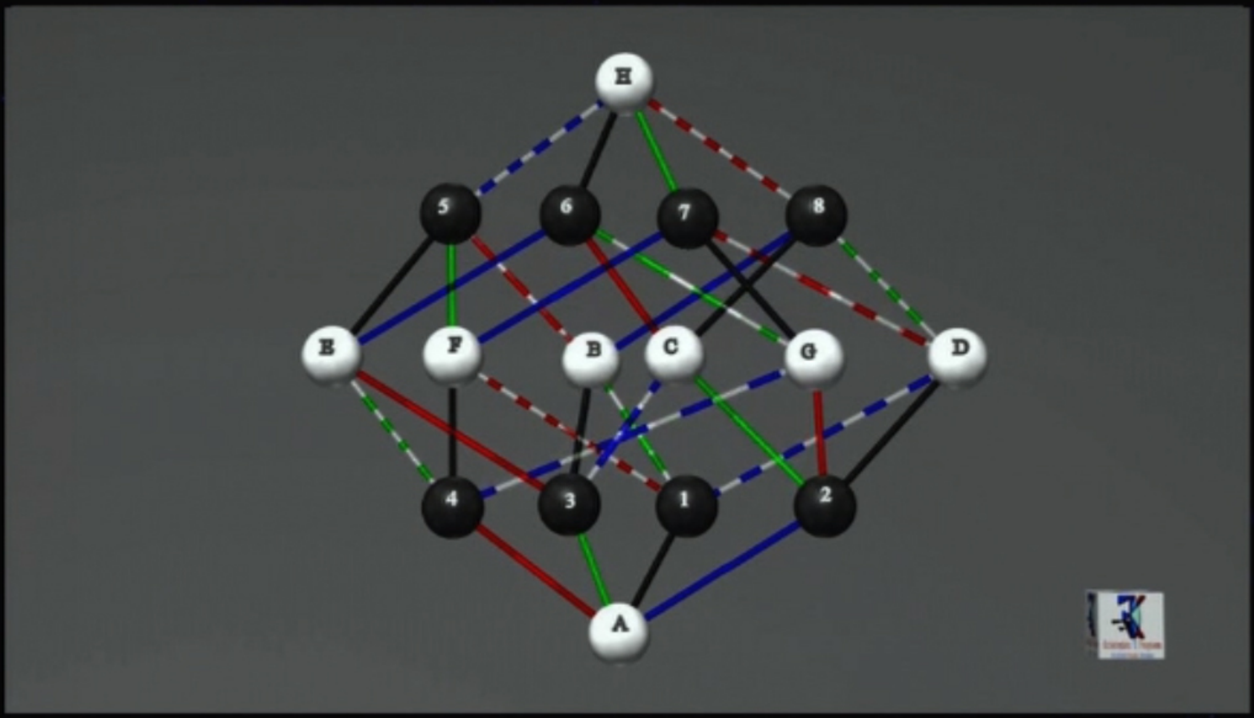
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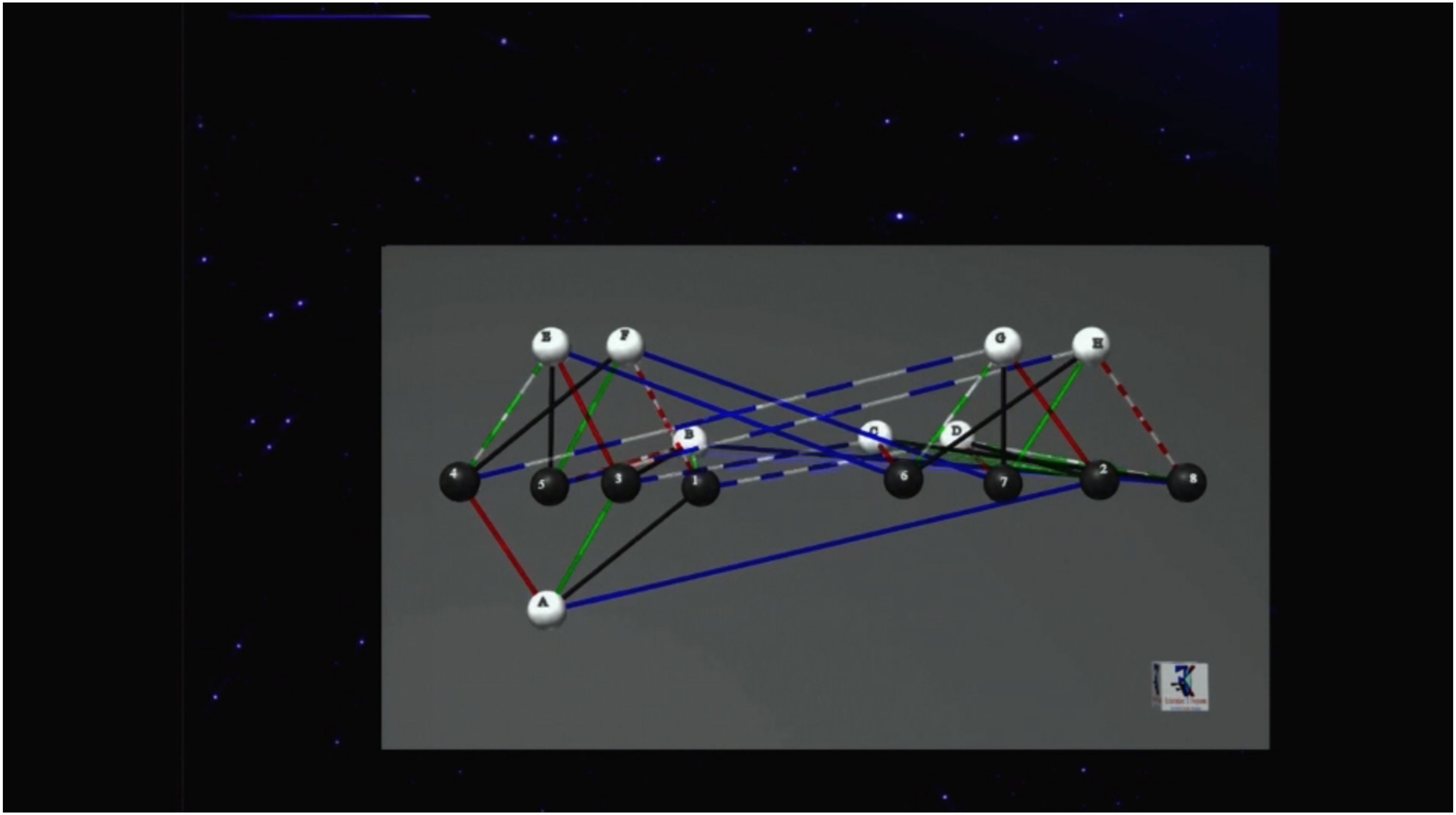

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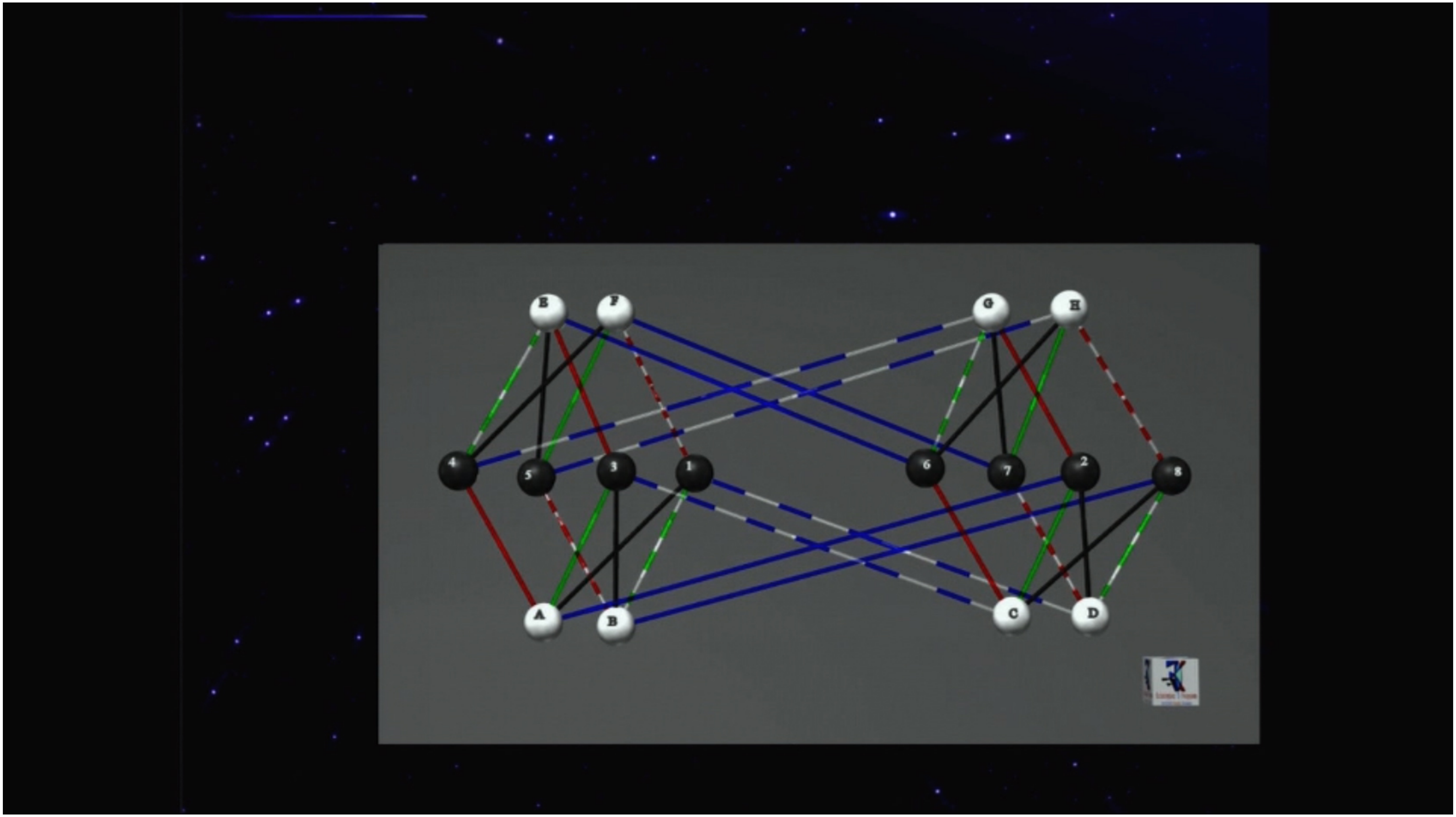
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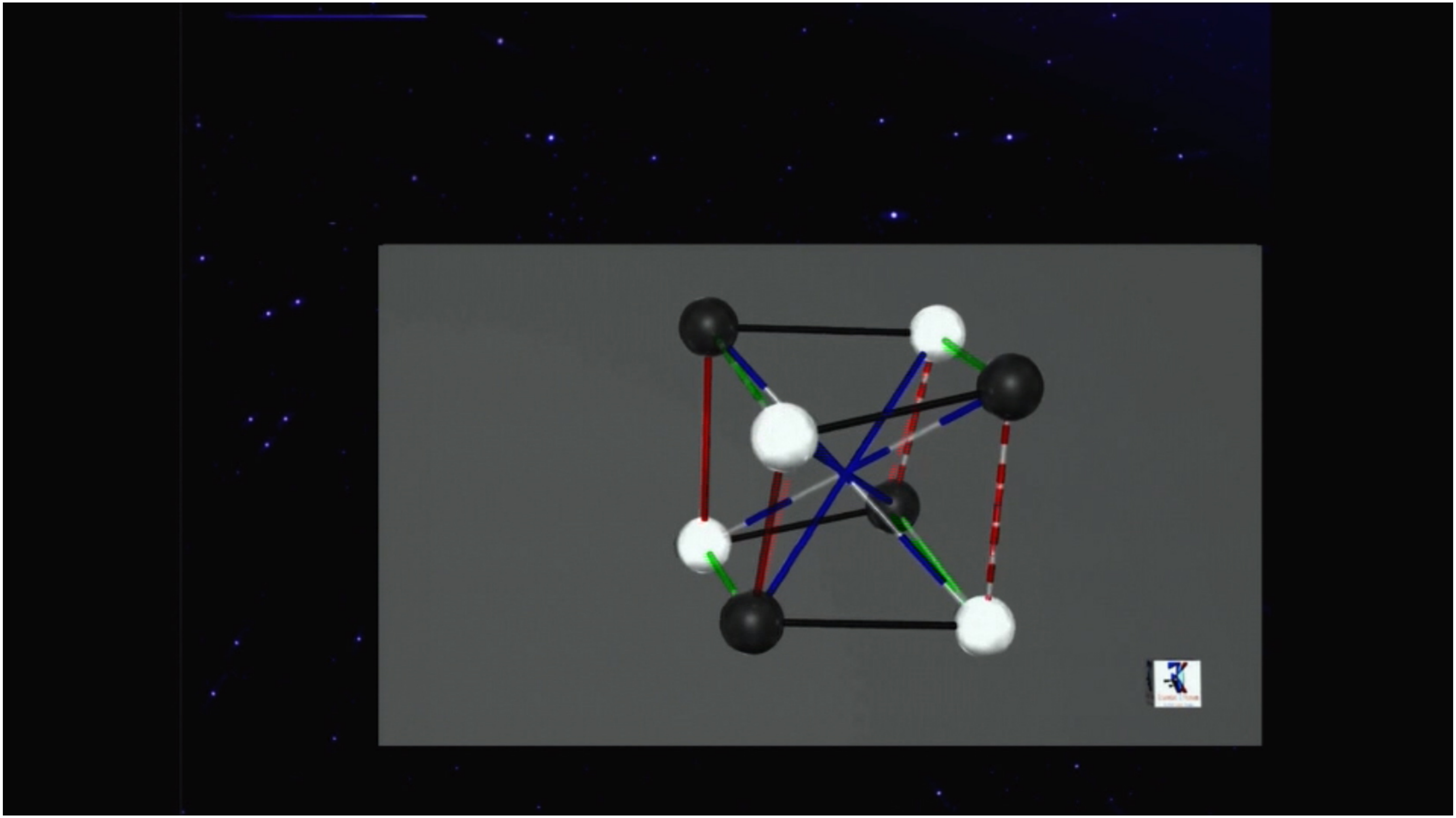

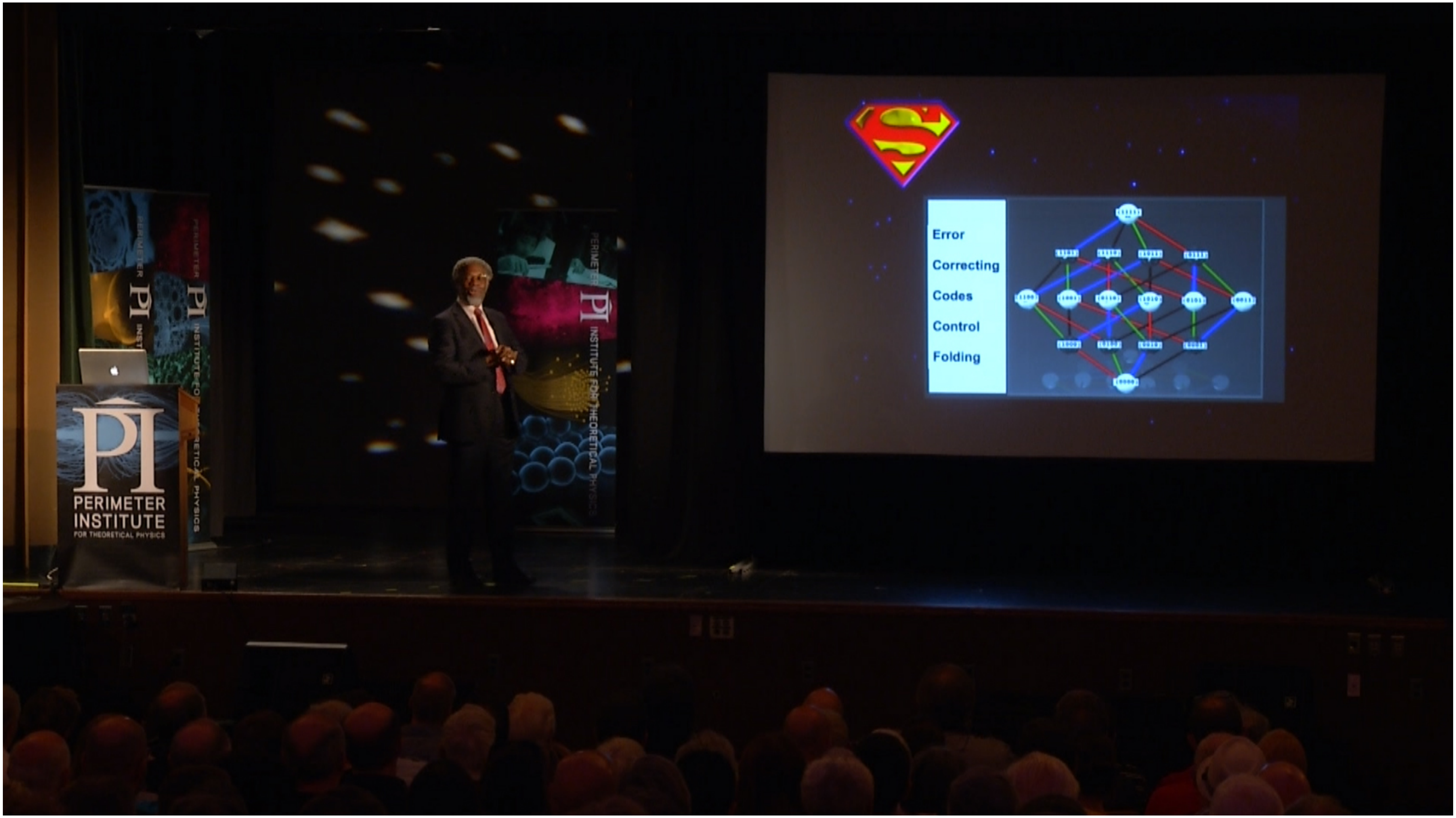
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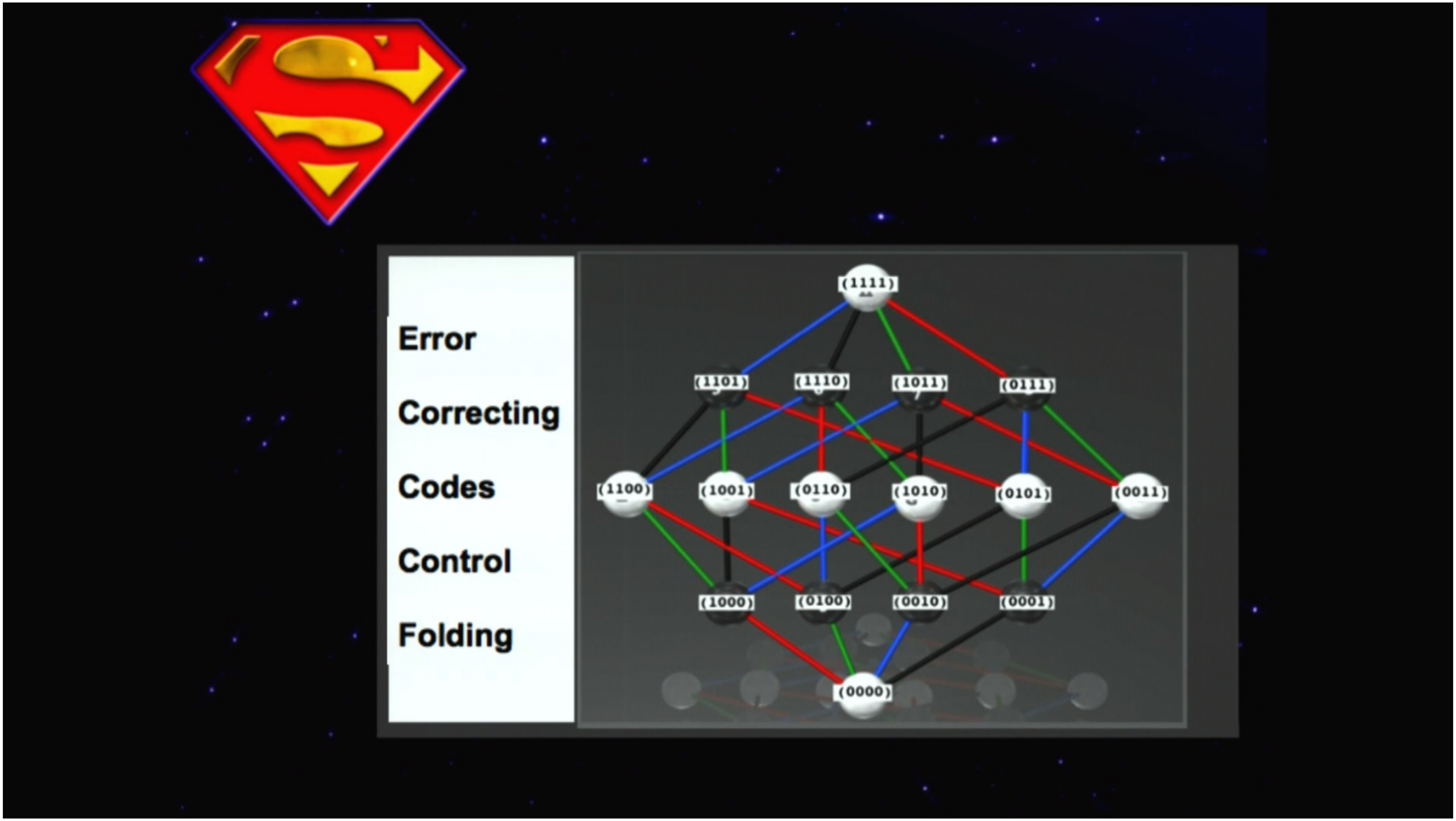
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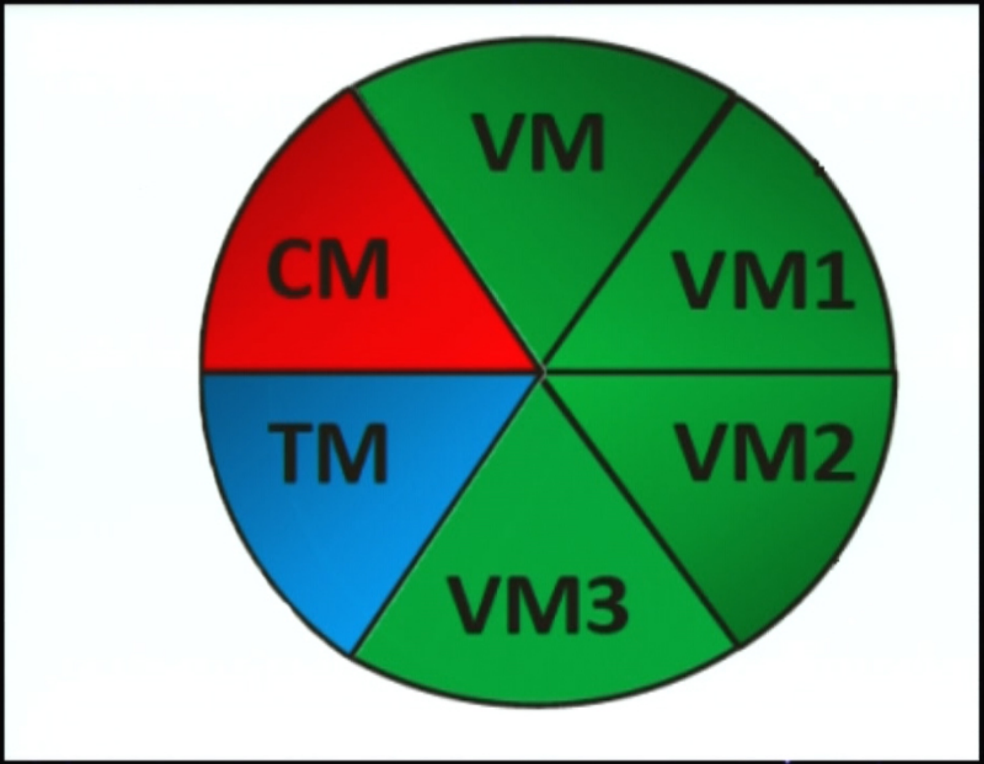
Feynman on Wheeler

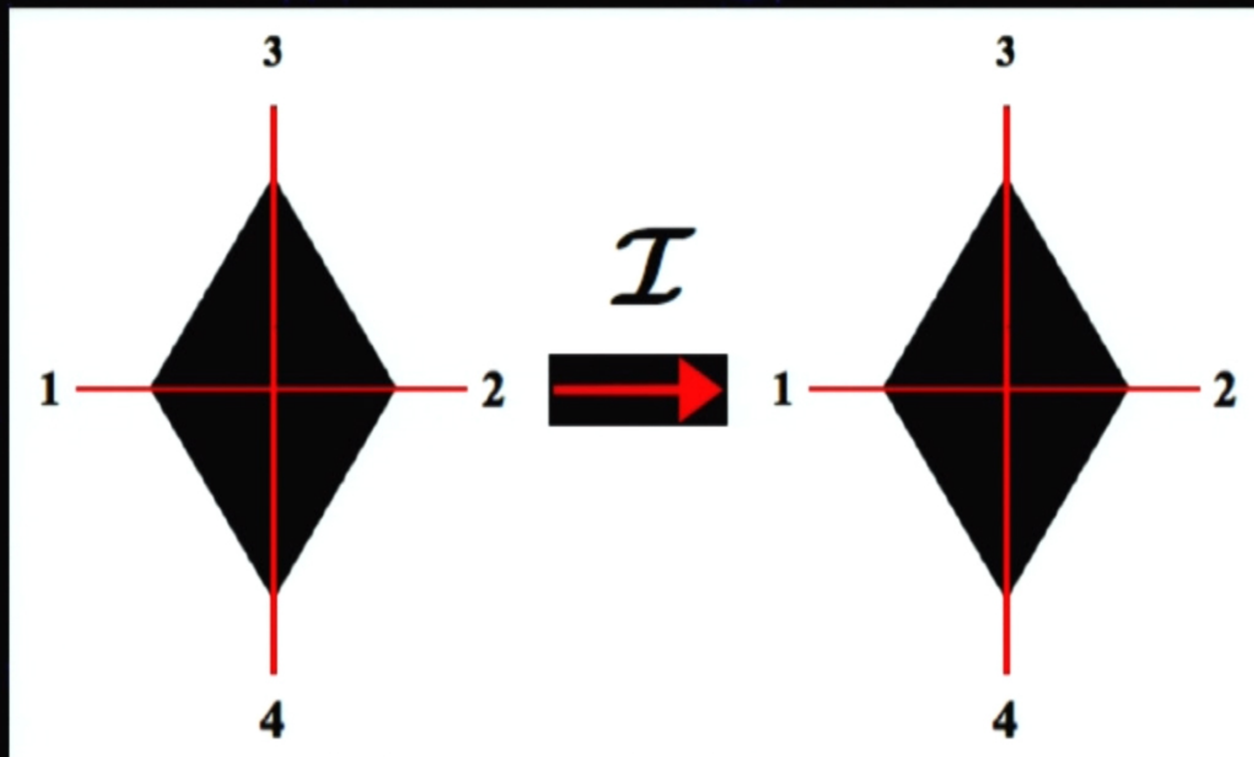
Feynman, Wheeler's student in the 1940s, turned to Thorne, Wheeler's student in the 1960s, and said,

"This guy sounds crazy. What people of your generation don't know is that he has always sounded crazy. But when I was his student, I discovered that if you take one of his crazy ideas and you unwrap the layers of craziness from it one after another like lifting the layers off an onion, at the heart of the idea you will often find a powerful kernel of truth."

SUSY Permutation Quartets Within A Coxeter Algebra



Klein's Vierergruppe Hidden In Four Dimensional SUSY



Notation	$S_3 \times \mathcal{V}_4$ Product	$S_3 \times \mathcal{V}_4$ Elements
VM_3	$()\mathcal{V}_4$	$()$ $(12)(34)$ $(13)(24)$ $(14)(23)$
VM_2	$(12)\mathcal{V}_4$	(12) (34) (1423) (1324)
VM_1	$(13)\mathcal{V}_4$	(13) (24) (1432) (1234)
VM	$(23)\mathcal{V}_4$	(14) (23) (1243) (1342)
TM	$(132)\mathcal{V}_4$	(132) (234) (124) (143)
CM	$(123)\mathcal{V}_4$	(123) (243) (142) (134)

Klein four-group

From Wikipedia, the free encyclopedia
(Redirected from Vierergruppe)

This article is about the mathematical concept. For the four-person anti-Nazi Resistance groups, see Vierergruppe (German Resistance).

In mathematics, the **Klein four-group** (or just **Klein group** or **Vierergruppe** (English: four-group), often symbolized by the letter **V**) is the group $Z_2 \times Z_2$, the direct product of two copies of the cyclic group of order 2. It was named *Vierergruppe* by Felix Klein in his *Vorlesungen über das Ikosaeder und die Auflösung der Gleichungen vom fünften Grade* in 1884.

The Klein four-group is the smallest non-cyclic group. It is given by the group presentation

$$V_4 = \langle a, b \mid a^2 = b^2 = (ab)^2 = 1 \rangle.$$

All non-identity elements of the Klein group have order 2. It is abelian, and isomorphic to the dihedral group of order (cardinality) 4. It is also isomorphic to the direct sum $Z_2 \oplus Z_2$, so that it can be represented as the bit strings {00, 01, 10, 11} under bitwise XOR.

The Klein group's Cayley table is given by:

•	**1**	***a***	***b***	***ab***
1	1	*a*	*b*	*ab*
a	*a*	1	*ab*	*b*
b	*b*	*ab*	1	*a*
ab	*ab*	*b*	*a*	1

An elementary construction of the Klein four-group is the multiplicative group { 1, 3, 5, 7 } with the action being multiplication modulo 8. Here *a* is 3, *b* is 5, and *ab* is $3 \times 5 = 15 \equiv 7 \pmod 8$.

Algebraic structure → Group theory

Group theory

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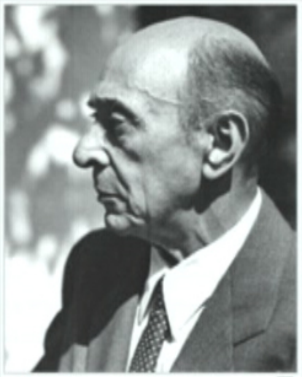
V · T · E

Twelve-tone technique

From Wikipedia, the free encyclopedia

Twelve-tone technique—also known as **dodecaphony**, **twelve-tone serialism**, and (in British usage) **twelve-note composition**—is a method of musical composition devised by Austrian composer Arnold Schoenberg (1874–1951). The technique is a means of ensuring that all 12 notes of the chromatic scale are sounded as often as one another in a piece of music while preventing the emphasis of any one note[3] through the use of tone rows, orderings of the 12 pitch classes. All 12 notes are thus given more or less equal importance, and the music avoids being in a key. The technique was influential on composers in the mid-20th century.



Schoenberg, inventor of twelve-tone technique

Schoenberg himself described the system as a "Method of composing with twelve tones which are related only with one another".[4] It is commonly considered a form of serialism.

Schoenberg's countryman and contemporary Josef Matthias Hauer also developed a similar system using unordered hexachords or *tropes*—but with no connection to Schoenberg's twelve-tone technique. Other composers have created systematic use of the chromatic scale, but Schoenberg's method is considered to be historically and aesthetically most significant.[5]

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Josef Matthias Hauer's "athematic" dodecaphony in *Nomos* Op. 19[1] (Play (help·info))