QC Programming

and all that

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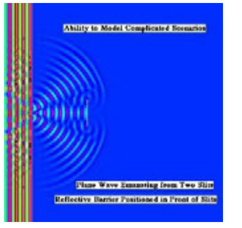
Structure of Speech

- Opening
  - Quantum Computing
  - QC Programming
  - And All That
- Conclusion

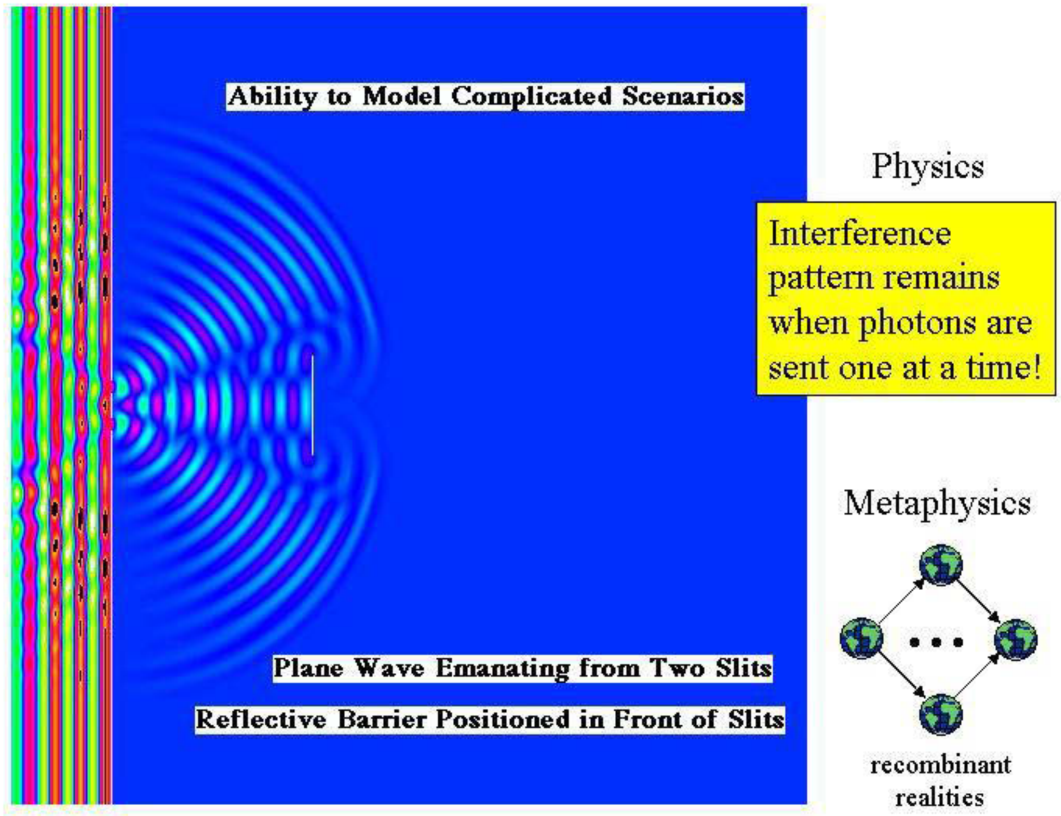
Opening



- Young’s Two-Slit Experiment
- Exponential potential
- Various Limitations
- You need not be a physicist!
- No new computable functions.

Young's Two-Slit Experiment

- Plane wave
- Two slits
- Screen
- Film
- Single photon
- Block a slit, ..

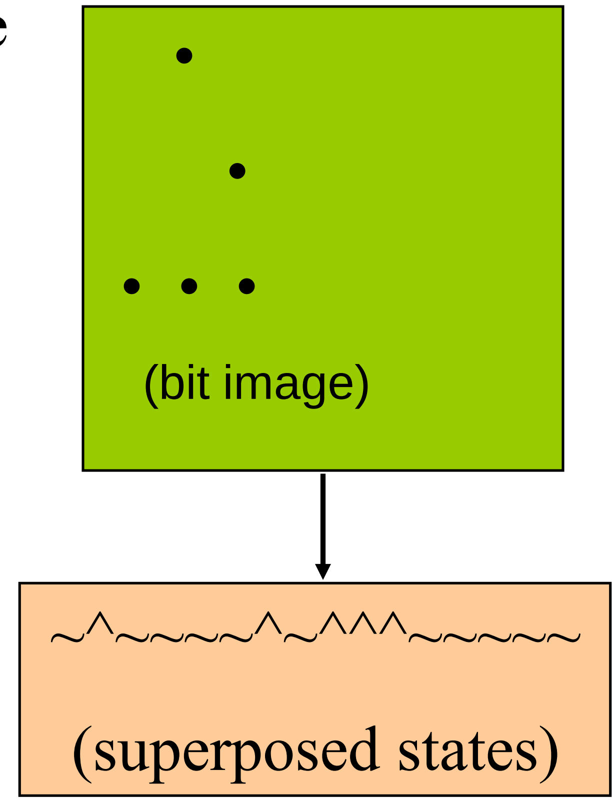


Exponential Potential

- Two places/actions at once
- What’s a qubit? — BC’s Noah
- 2^n simultaneous operations
- A 20-qubit screen image
- A tornado in 60 qubits
- The Universe in 700 Qubits

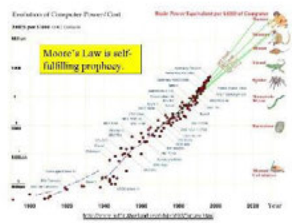
Quantum-Compressed Images

- N qubits store 2^N superposed states, therefore
  - Store $2^A x 2^B$ B&W image in A+B qubits.
  - Store $2^A x 2^B$ gray image in A+B qubits.
  - Can these images be manipulated?
  - Retrieve image from many NMR replicas.
  - How long does it take, say by raster scan?
  - Demonstrate 4x4 images in 2+2 qubits.



- In general, map onto N qubits:
  - a 2^N-bit string,
  - or a 2^N-scalar sequence,
  - or a sequence of 2^{N-2K} quantum states of K qubits?

Various Limitations

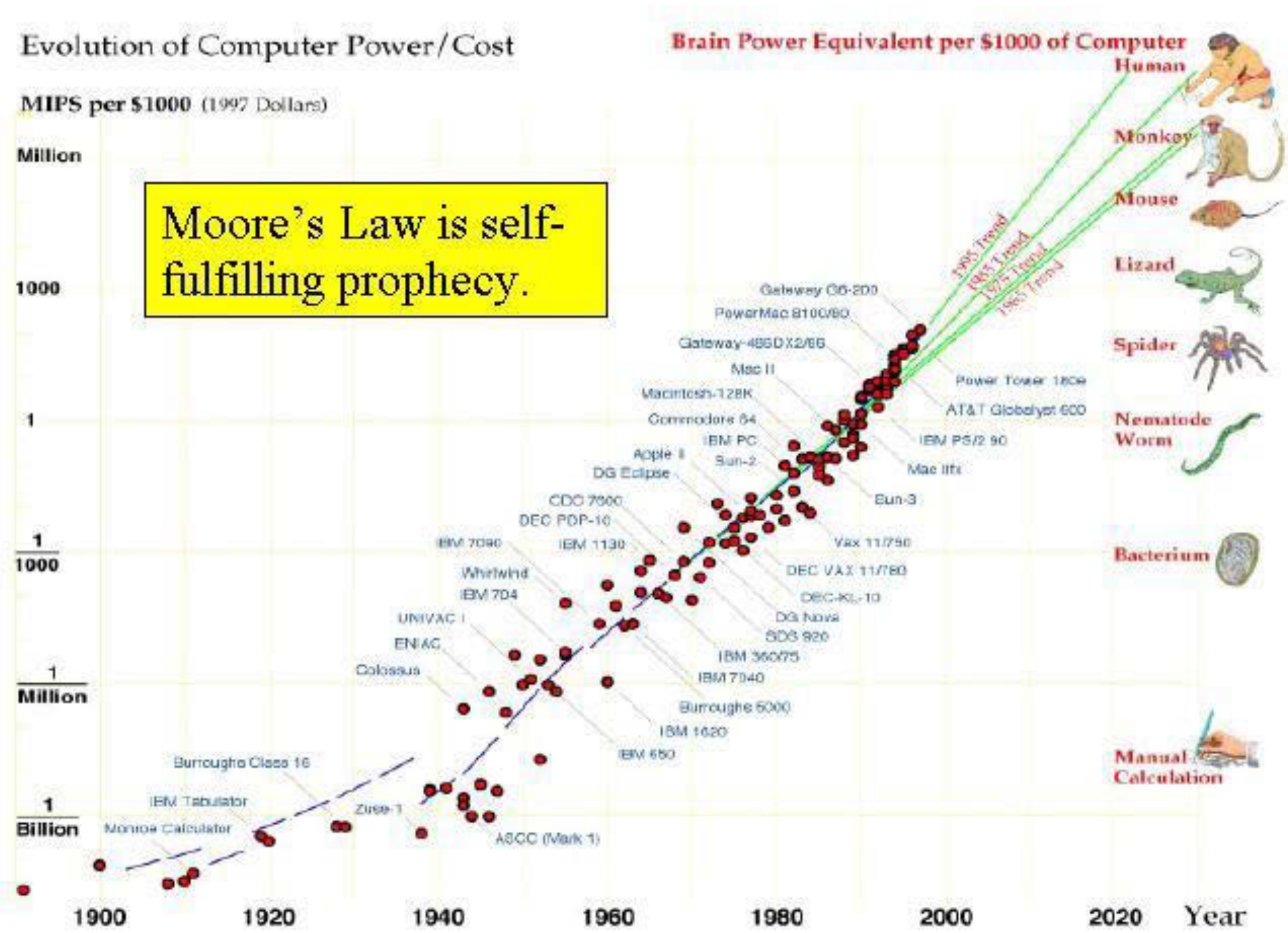


- Moore's Law
- Technological phase lock

- Unitary operations

- Beware the Turing Tar Pit!
- "I'm not smart enough to … "
- Limits on alternate realities?

Moore’s Law

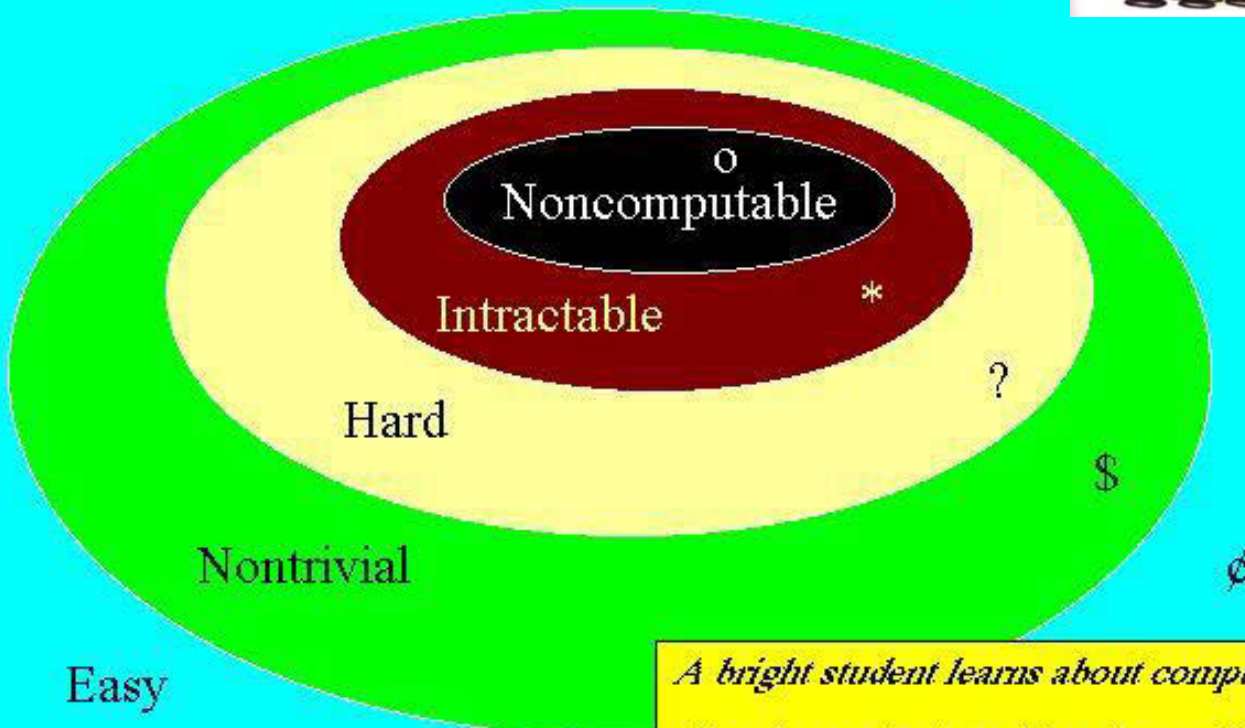


http://www.jeffsutherland.org/objwld98/future.html

Not a physicicist?

- Qubits are fungible! 
- Any implementation will do
- Qubit physics is hard
- Metaphysics helps
- Qubit math is easy

Perlis's Turing Tarpit



A bright student learns about computability,
then does not attempt to solve problems
that he recognizes as noncomputable,
even though partial results may be valuable.

Quantum Computing

- Quantum mechanics is weird?
- QC makes some problems tractable.
- Particles do not get entangled!
- Their quantum states do.

Quantum mechanics is weird?

A single particle can:

- follow many paths at a time
- spin in many directions at once
- entangle its state with another

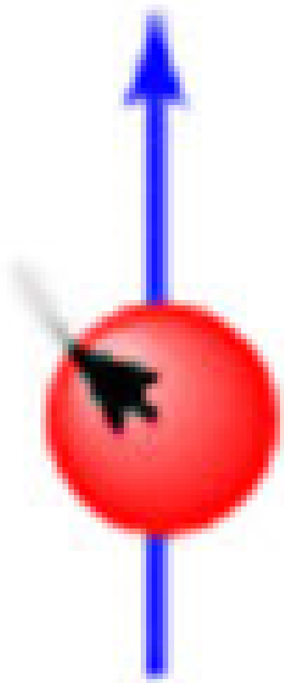
QC Programming

- Why is it hard?
- Unscalable Bloch Sphere
- Relax the tensor product.
- Time goes down the page.
- Similarities to Prolog
- QC Applications

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

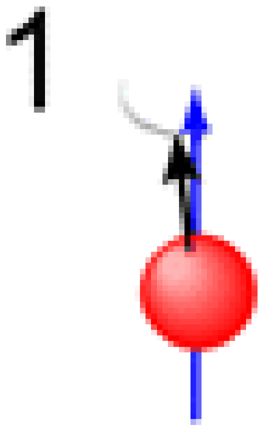
Bloch Sphere

- Longitude => phase
- Latitude => probability
- Bearing => missing phase



Unscalable Bloch Sphere

- Meant to suggest quantum state
- Exposes my coin trick
- Does not scale,
- Even to two qubits
- Useless for QC insight



Bullseye Icon

- Single Qubit Bullseye
- Basic Qubit Ops
- Quaternions $\rightarrow$ Pauli Matrices
- Polar Quaternion Product
- Quaternion Rotations
- Hadamard Transform

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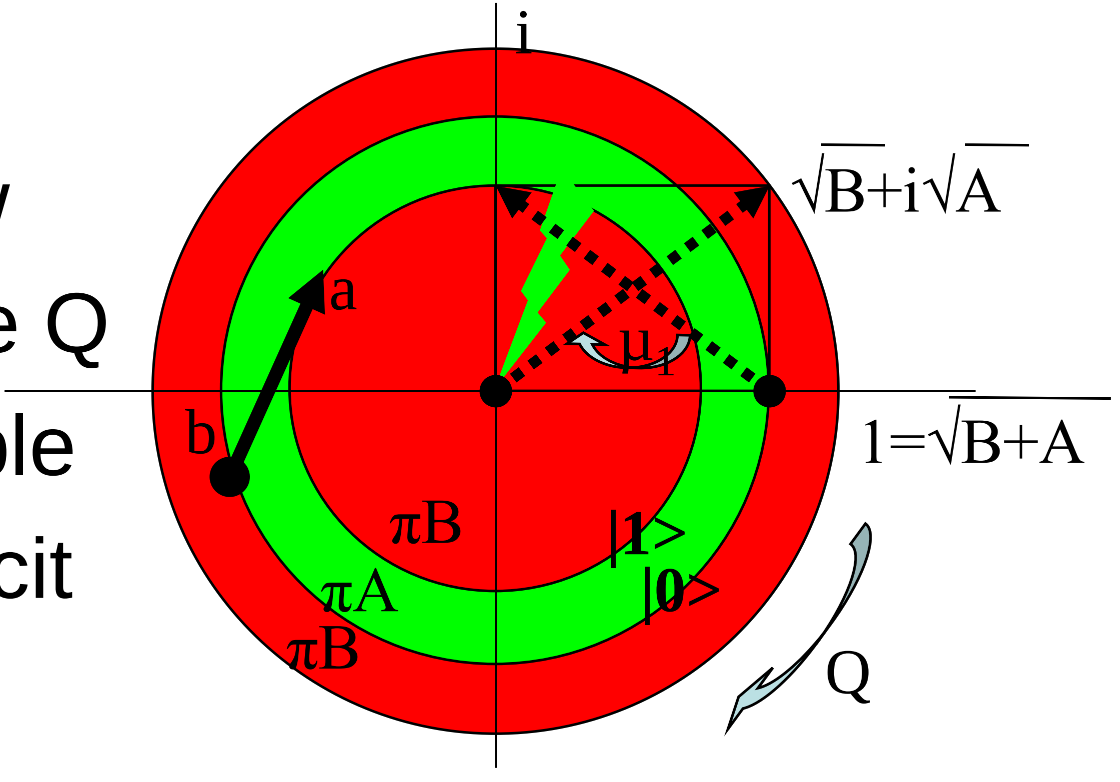
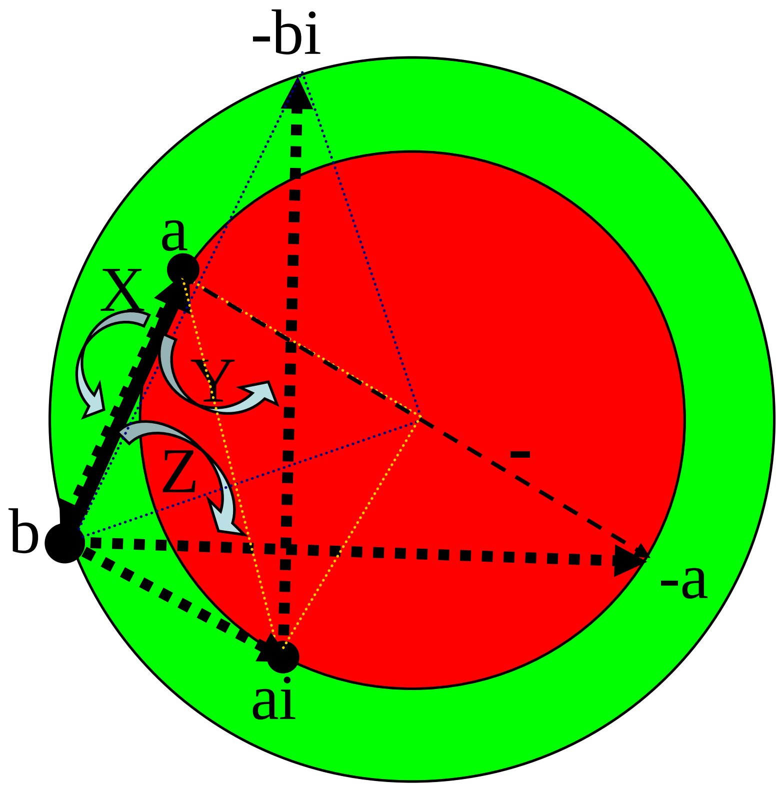
Single Qubit Bullseye

- Complex plane
- Qstate by arrow
- Unknown phase Q
- Axes unknowable
- Outer ring implicit
- Random tosses



Basic Qubit Ops

- Basic ops
- X reverses arrow
- Y rotates b,a $\pm 90°$
- Z negates a



Pilot Terms

- $R_Z(t)$ = pitch
- $R_X(t)$ = roll
- $R_Y(t)$ = yaw

¶: Quaternions → Pauli Matrices

$$I = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad Y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

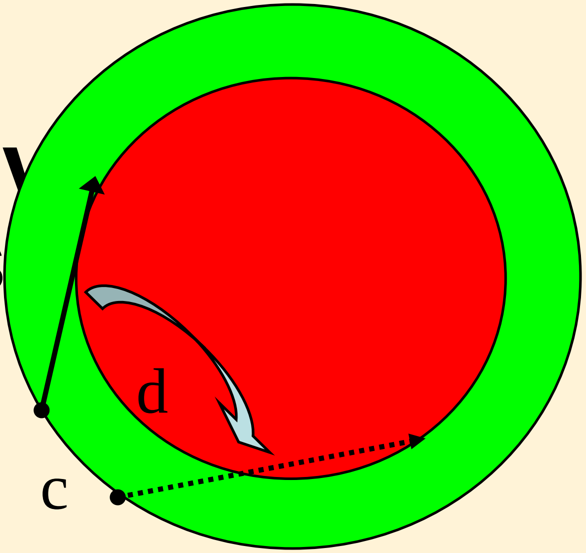
$$\P\boldsymbol{1} = I = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad \P\boldsymbol{i} = -Xi = \begin{pmatrix} 0 & -i \\ -i & 0 \end{pmatrix} \quad \P\boldsymbol{j} = -Yi = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \quad \P\boldsymbol{k} = -Zi = \begin{pmatrix} -i & 0 \\ 0 & i \end{pmatrix}$$

Polar Quaternion Product

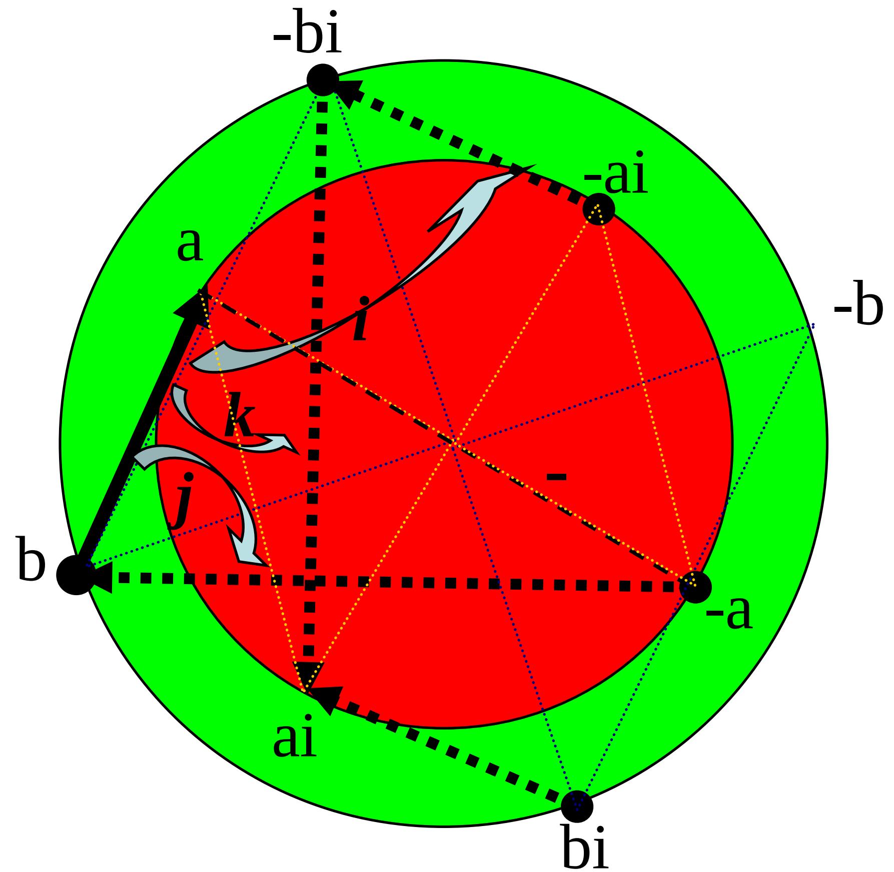
- Given $\mathbf{u}^2 = \mathbf{v}^2 = (\mathbf{uv})^2 = -1$
- $e^{(c+d)\mathbf{u}/2} \, (Re^{b\mathbf{u}}+Se^{a\mathbf{u}}\mathbf{v}) \, e^{(c-d)\mathbf{u}/2}$

$$= Re^{(b+c)\mathbf{u}} + Se^{(a+d)\mathbf{u}}\mathbf{v}$$

- which rotates two planes independently.

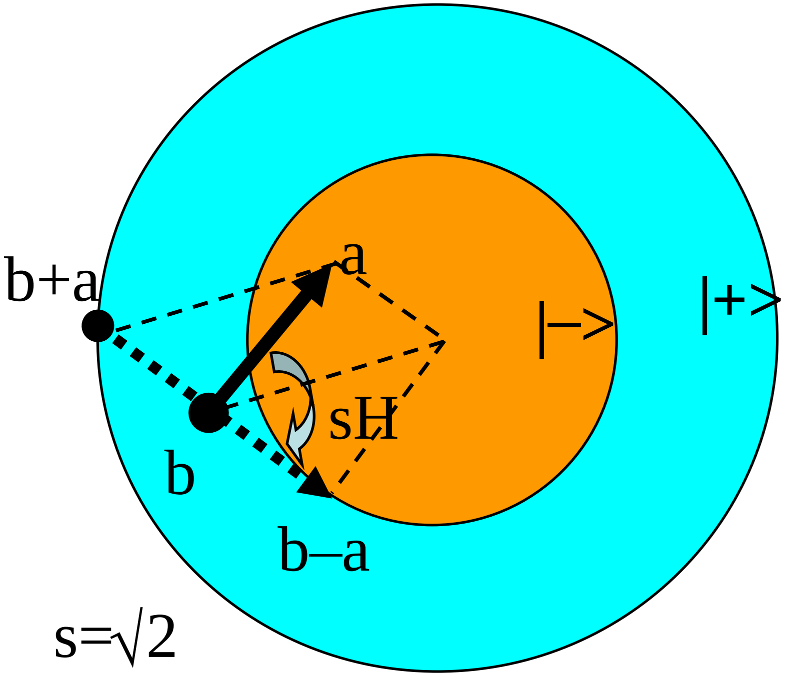


Quaternion Rotations



Hadamard Transform

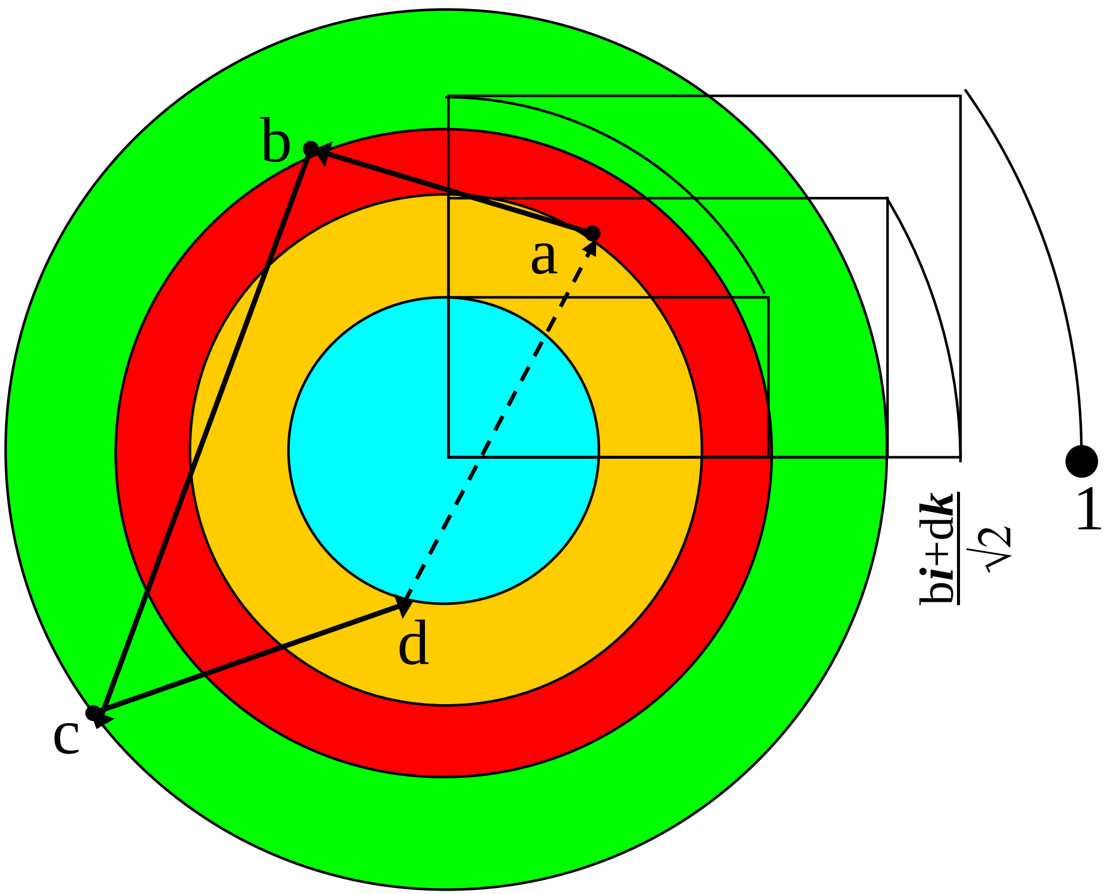
- Changes probabilities
- Sum and difference
- Implicit frame



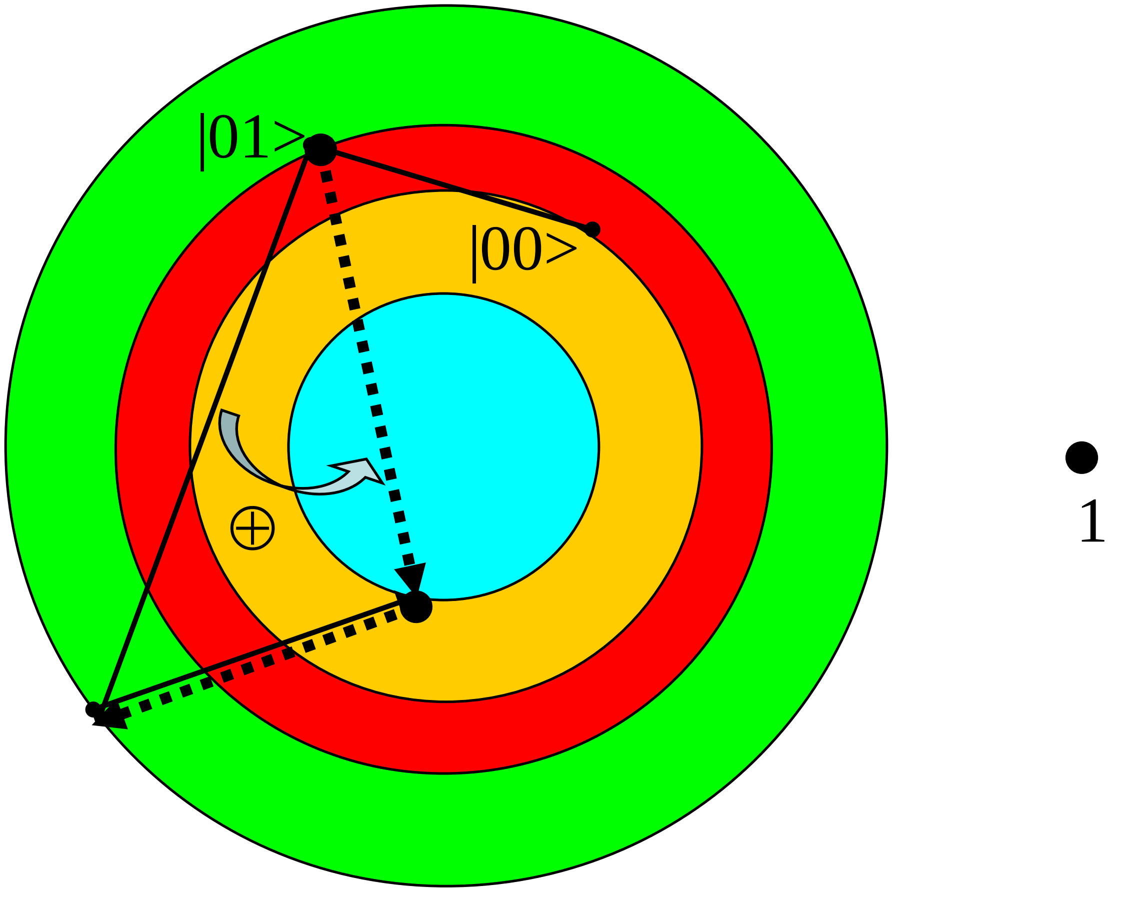
Qubit Registers

- Unit Octonion
- Coupling Two Qubits
- Three Entangled Qubits
- Relax Tensor Product

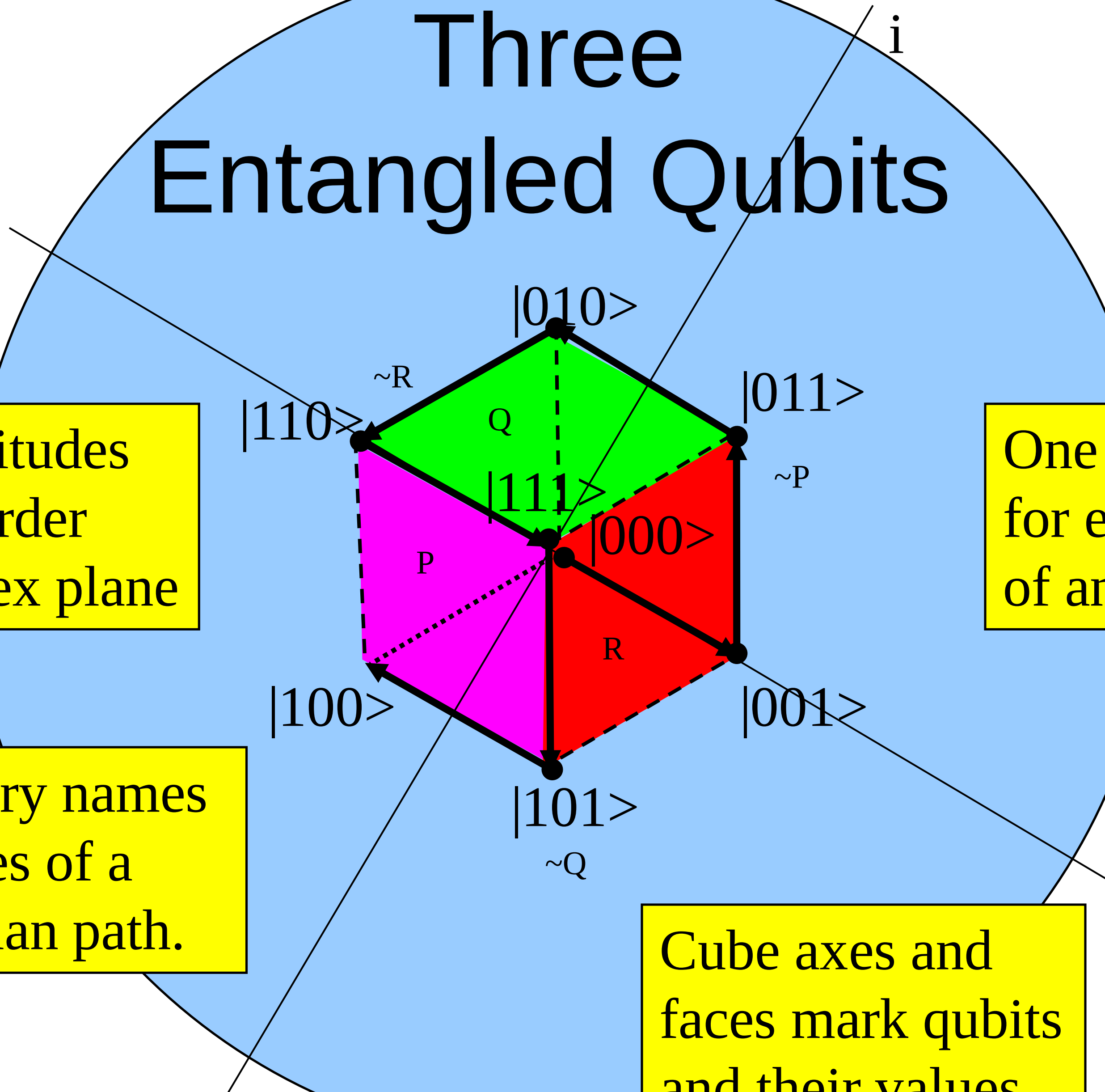
Unit Octonion



Coupling Two Qubits



Three Entangled Qubits



Plot amplitudes in some order on complex plane

One amplitude for each corner of an n-cube.

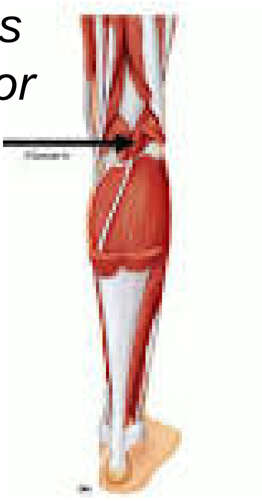
Grey binary names for vertices of a Hamiltonian path.

Cube axes and faces mark qubits and their values.

Relax tensor product

- Used to concatenate two qubit registers
- Assumes sequences of qubits
- Entangle qubits 1 and 3
- Qubit 2 should be separable
- Qreg = names of qubits
- observables : Obs=Qreg→Bit
- quantum states : Obs→Amp
- Catenation: ${}_{q}A^{+}B = {}_{(q}A_{)}^{*}\,{}_{(q}B_{)}$

My 1976 CS was titled "Flexors" for mechanisms to extend or flex a programming system.



QC Applications

- Factoring large numbers
- Quantum crytography
- Modelling weather
- Simulating quantum mechanics

QC Programming Languages

- QCL
- Q Lambda Calculus
- Quipper — extensive libraries
- QML — a functional QC language
- Google's QC Playground
- …
- QLP — my Q Logic Programming

And All That

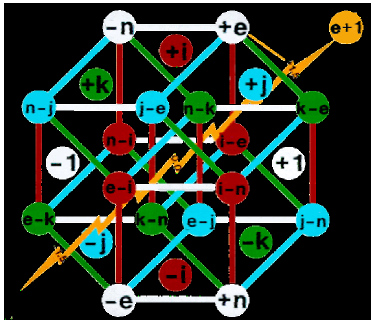
- QKD Kolors
- Music of the Orbs
- Kwarks = Quarks$^{\cup}$Leptons
- Mesons
- Baryons
- Nuclei

Rebuilding the Universe

from the quarks up

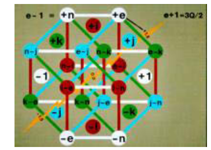
by

R. Krutar



Do you wonder if the Universe is really like they say it is? How can it be? Why halves and thirds? Where is all the antimatter? What are free quarks? What are light and gravity? Why is dark matter dark? How do neutrinos and top quarks decay? What insidious unwarranted assumption is rampant throughout S&T? How can the expansion of the Universe accelerate?

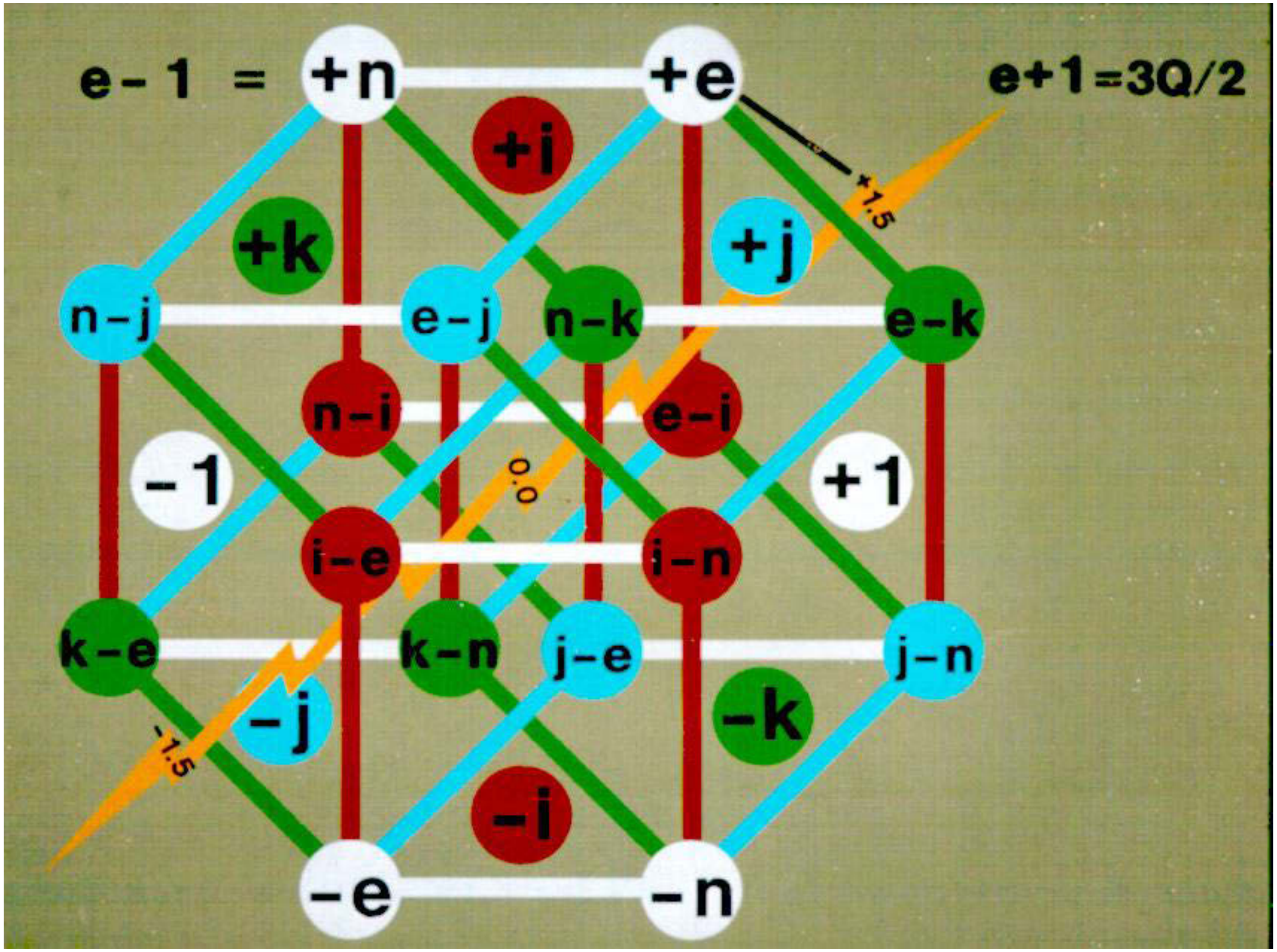
QKD Kolors



- One More QCD Color
- Sixteen QKD kolors
- QKD Kolor Numbers
- Boson Photon
- Particle Families

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

One More QCD Color



Sixteen QKD Gluon Kolors

Only gluons have pure kolors:

- Three *lgt* gluons/kolors **gi,gj,gk**
- One white gluon/kolor **gl**
- Four *drk* gluons/kolors **go,goi,goj,gok**
- Eight anti- gluons/kolors from **-gl**
- One at each corner of a kube

gl
gj goi gk
gok gi goj
go

QKD Kolor Numbers

- Number kolors as shown:
- Multiply mod 120 to add
- Anti-kolors from **-gl=49**

31		*1*	
	41		*-49*
11		*-1*	
	-59		*-29*
-41		*49*	
	-31		*-1*
59		*29*	
	-11		*19*

gj		**gl**	
	gok		**goi**
gi		**gk**	
	go		**goj**

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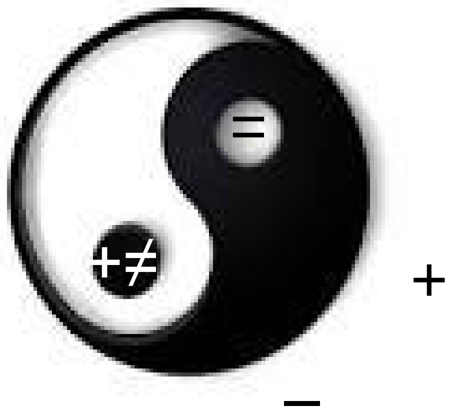
Simulates four-bit $\oplus$ (Bit = ± 1)

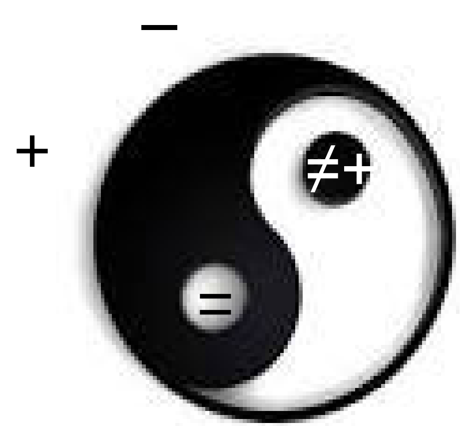
- Mod 5 = -1 for antimatter **-gl,…**
- Mod 4 = -1 for greens **gj,gi,goj,goi, -…**
- Mod 3 = -1 for blues **gk,gi,gok,goi, -…**
- Mod 24 < 0 for *drk* kolors **go,gok,goj,goi, -…**

Boson Photon

- Photon is gl ~ -gl
- Separated by wavelength

Legend:
≠ for +1
\+ for +½
• for 0
− for −½
= for −1
…





Particle Families

- Sixteen gluons
- Three *lgt* families
- Three *drk* families
- ===============
- Seven families
- 7*16=112 particles

Family Album

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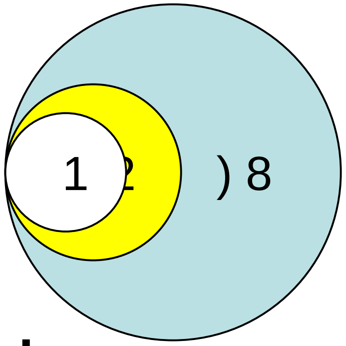
Music of the Orbs



Krutarnion = eight integers on a cube

- orb = sum of their squares
- orb=0: totally balanced O
- orb=1: sixteen unicorn partons
- orb=2: 112 kwarks
- orb=8: unit octonions with 240 integers

Ancient Free & Accepted Mesons

- Leptons are free kwarks
- Quarks are accepted kwarks
- A (free) meson is (up –dn) of same kolor
- An accepted meson (up +dn) not same
- A photon interchanges up and dn

Baryon Superposition

- An accepted meson and
- a quark of the missing kolor
- form a baryon (proton or neutron)
- Which quark is which?
- The baryon spins in ambiguity
- through superposition of states
- without its parts moving!

Nuclear Reactions

- All *lgt* reactions seem to be photonic,
- Neutrino oscillation for n to n'

  n + x = n' for some x,

  x = n' – n obviously,

- which is dn and *drk*.

Conclusion

- QC is fascinating & promising
- You need not be a physicist
- Bottom-up Physics approach is slow
- It needs more minds
- Especially CS approaches
- How would you exploit it?