

Physics in 100 Years

Opportunities and Challenges

Unifications

The Grand Tradition

Why seek unification?

Answer 1: Success stories!

space and number; geometry and algebra (Descartes)

celestial and terrestrial law (Galileo, Newton)

mechanics and ray optics (Hamilton)

electricity, magnetism, and wave optics (Maxwell)

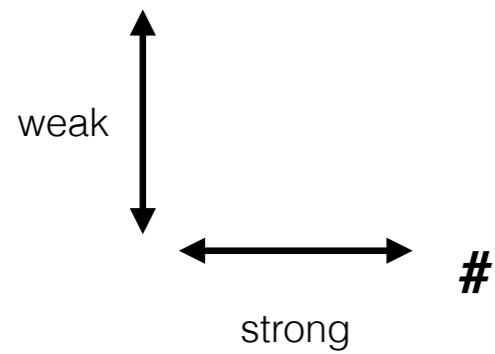
space and time (Einstein, Minkowski)

wave and particle (Einstein, de Broglie)

reasoning and calculation (Boole, Turing)

Answer 2: Isn't it pretty to think so?

Unification I: Forces and Substances (Separately)

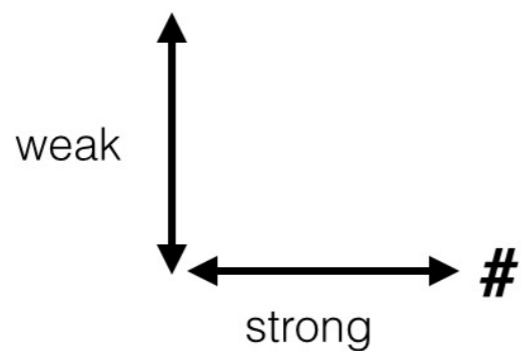


three
fundamental
forces
(plus gravity)

$$\begin{pmatrix} \text{yellow} \\ \text{purple} \end{pmatrix}_{-1/2} \quad \begin{pmatrix} H^0 \\ H^+ \end{pmatrix}$$

Higgs fluid

$\begin{pmatrix} \text{red} & \text{yellow} \\ \text{red} & \text{purple} \end{pmatrix}_{1/6}^L$	$\begin{pmatrix} \text{green} & \text{yellow} \\ \text{green} & \text{purple} \end{pmatrix}_{1/6}^L$	$\begin{pmatrix} \text{blue} & \text{yellow} \\ \text{blue} & \text{purple} \end{pmatrix}_{1/6}^L$	A	$\begin{pmatrix} u \\ d \end{pmatrix}^L$
$(\text{red})_{2/3}^R$	$(\text{green})_{2/3}^R$	$(\text{blue})_{2/3}^R$	B	$(u)^R$
$(\text{red})_{-1/6}^R$	$(\text{green})_{-1/6}^R$	$(\text{blue})_{-1/6}^R$	C	$(d)^R$
$\begin{pmatrix} \text{yellow} \\ \text{purple} \end{pmatrix}_{-1/2}^L$	<p>six fundamental "entities" (plus two repeats)</p>		D	$\begin{pmatrix} \nu \\ e \end{pmatrix}^L$
O_{-1}^R			E	$(e)^R$
O_0^R			F	$(\nu)^R$



three
fundamental
forces

$$\left(\begin{array}{cc} \text{red} & \text{yellow} \\ \text{red} & \text{purple} \end{array} \quad \begin{array}{cc} \text{green} & \text{yellow} \\ \text{green} & \text{purple} \end{array} \quad \begin{array}{cc} \text{blue} & \text{yellow} \\ \text{blue} & \text{purple} \end{array} \right)^L_{1/6}$$

$$\left(\begin{array}{ccc} \text{red} & & \\ & \text{green} & \\ & & \text{blue} \end{array} \right)^R_{2/3}$$

$$\left(\begin{array}{ccc} \text{red} & & \\ & \text{green} & \\ & & \text{blue} \end{array} \right)^R_{-1/6}$$

$$\left(\begin{array}{c} \text{yellow} \\ \text{purple} \end{array} \right)^L_{-1/2}$$

$$\text{O}_{-1}^R$$

$$\text{O}_0^R$$

six
fundamental
"entities"

A

$$\begin{pmatrix} u \\ d \end{pmatrix}^L$$

B

$$(u)^R$$

C

$$(d)^R$$

D

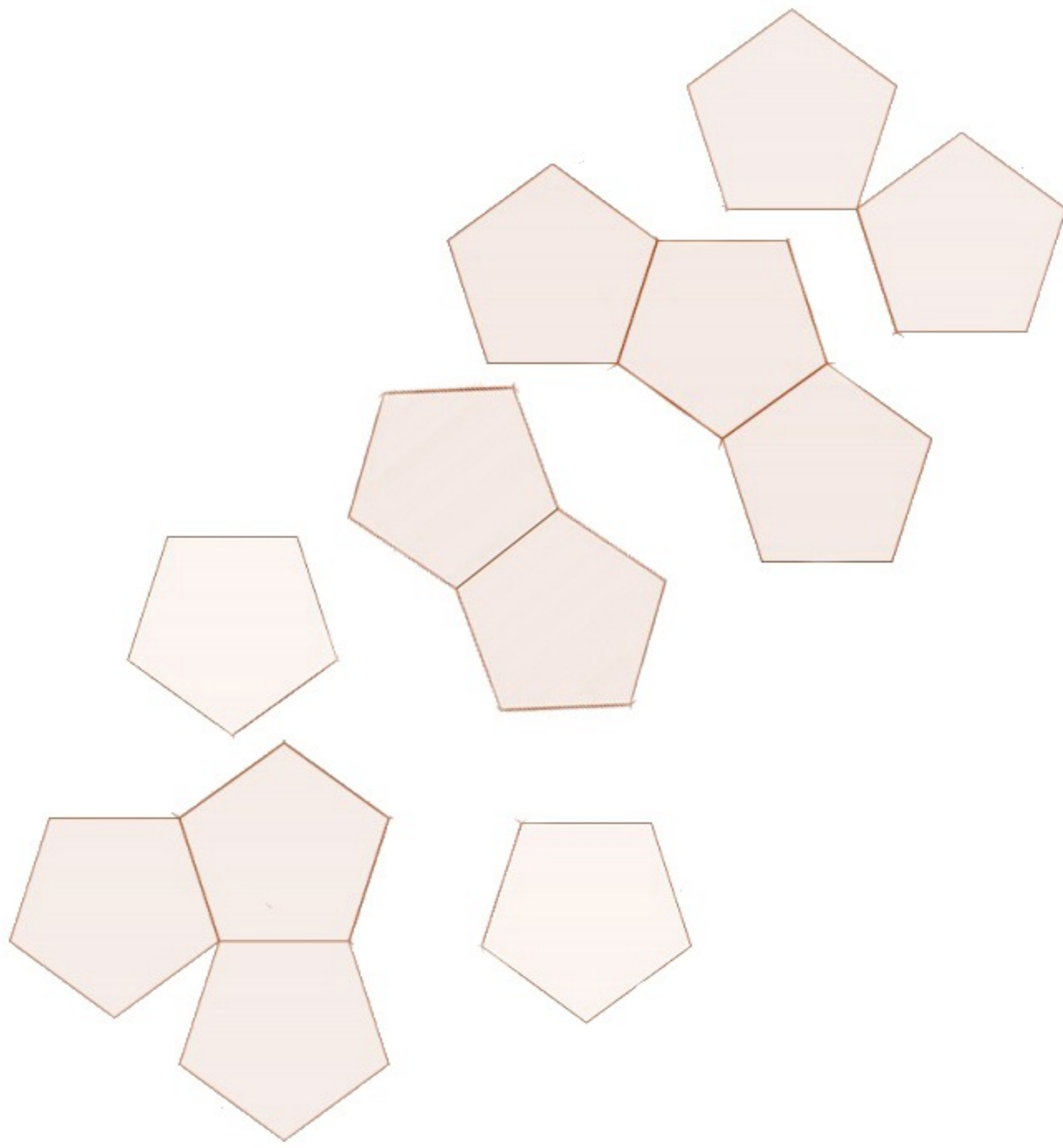
$$\begin{pmatrix} \nu \\ e \end{pmatrix}^L$$

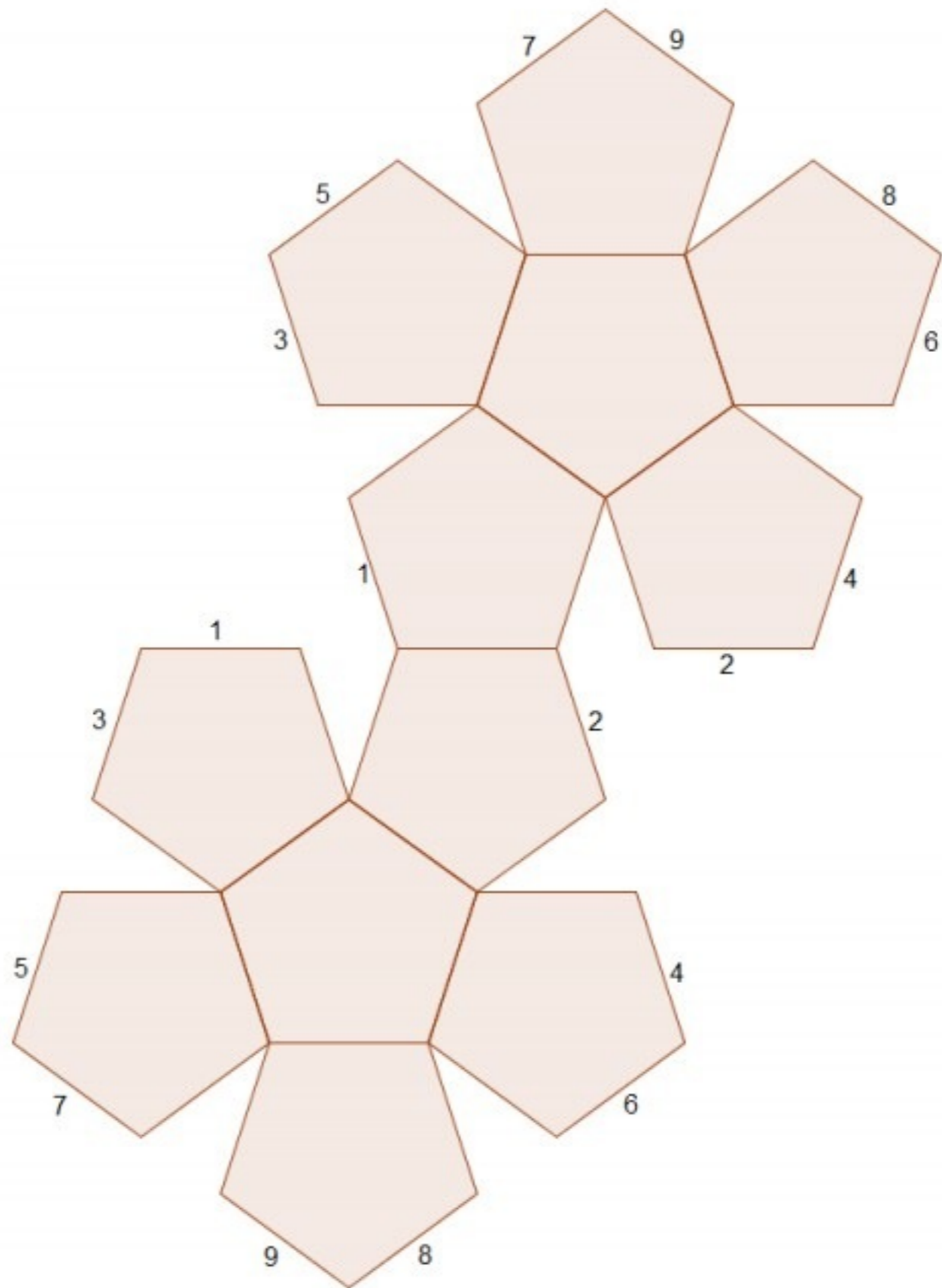
E

$$(e)^R$$

F

$$(\nu)^R$$



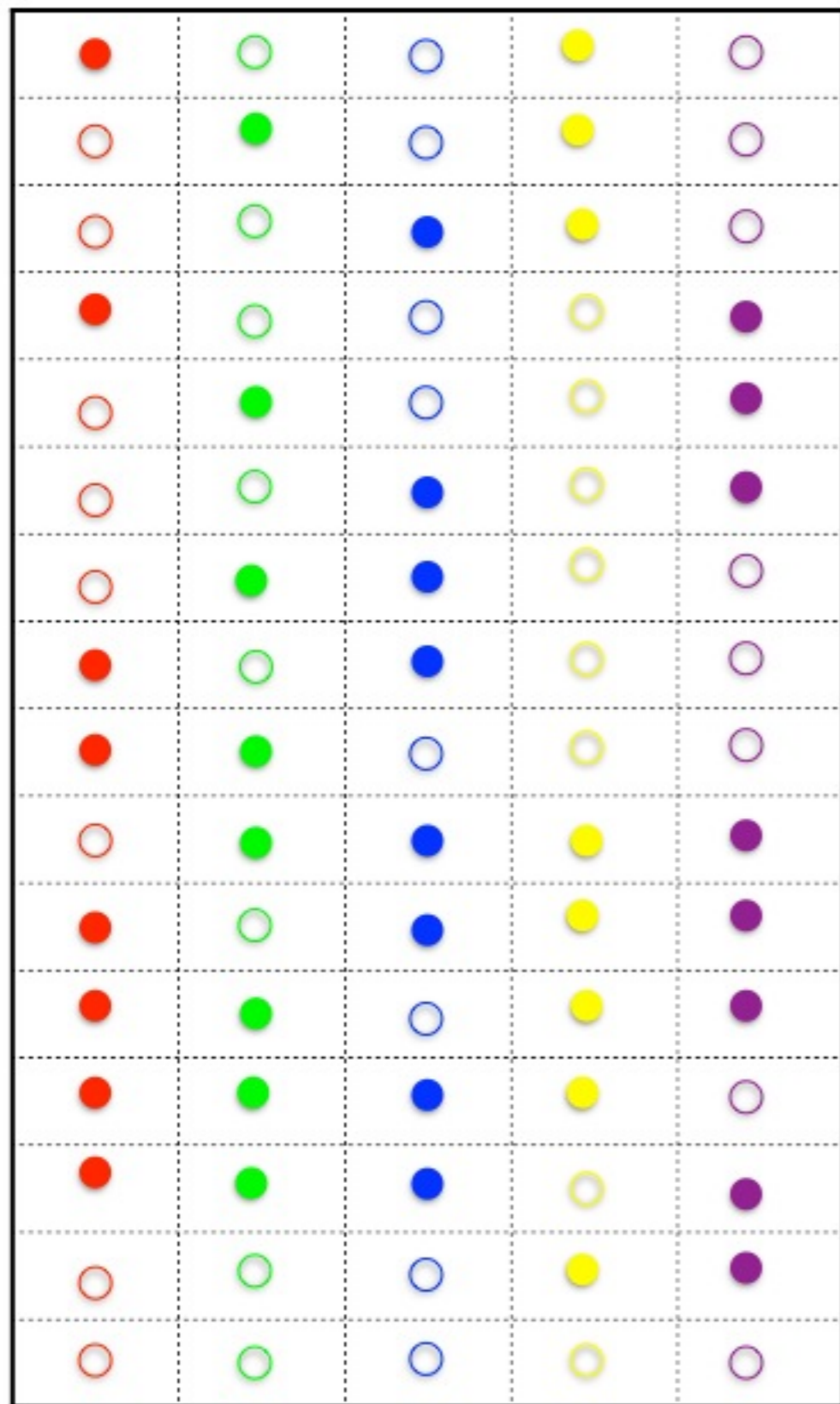


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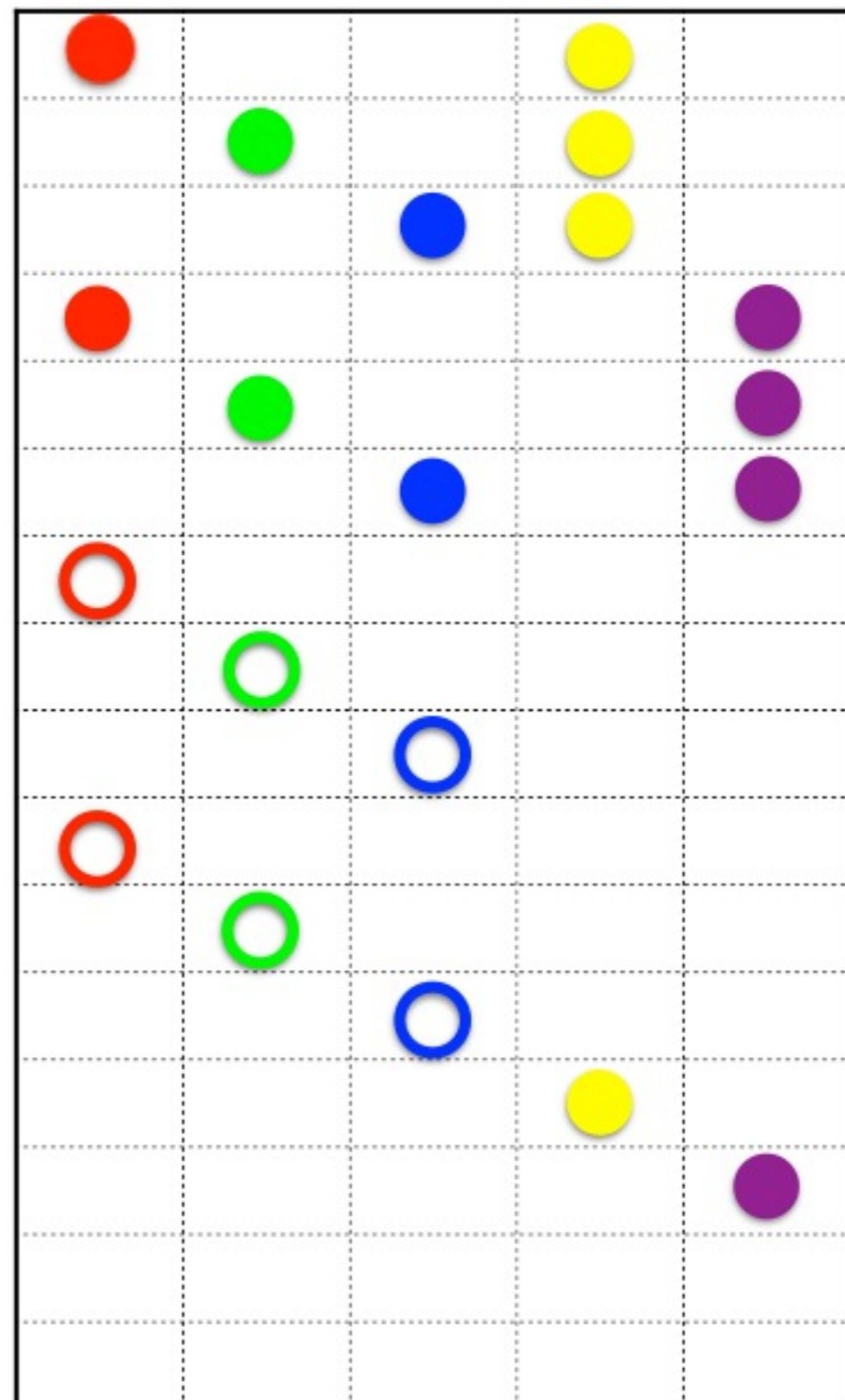
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○	○	○	○	○
○	○	○	○	○

$$Y = -\frac{1}{3}(\text{Red} + \text{Green} + \text{Blue}) + \frac{1}{2}(\text{Yellow} + \text{Purple})$$



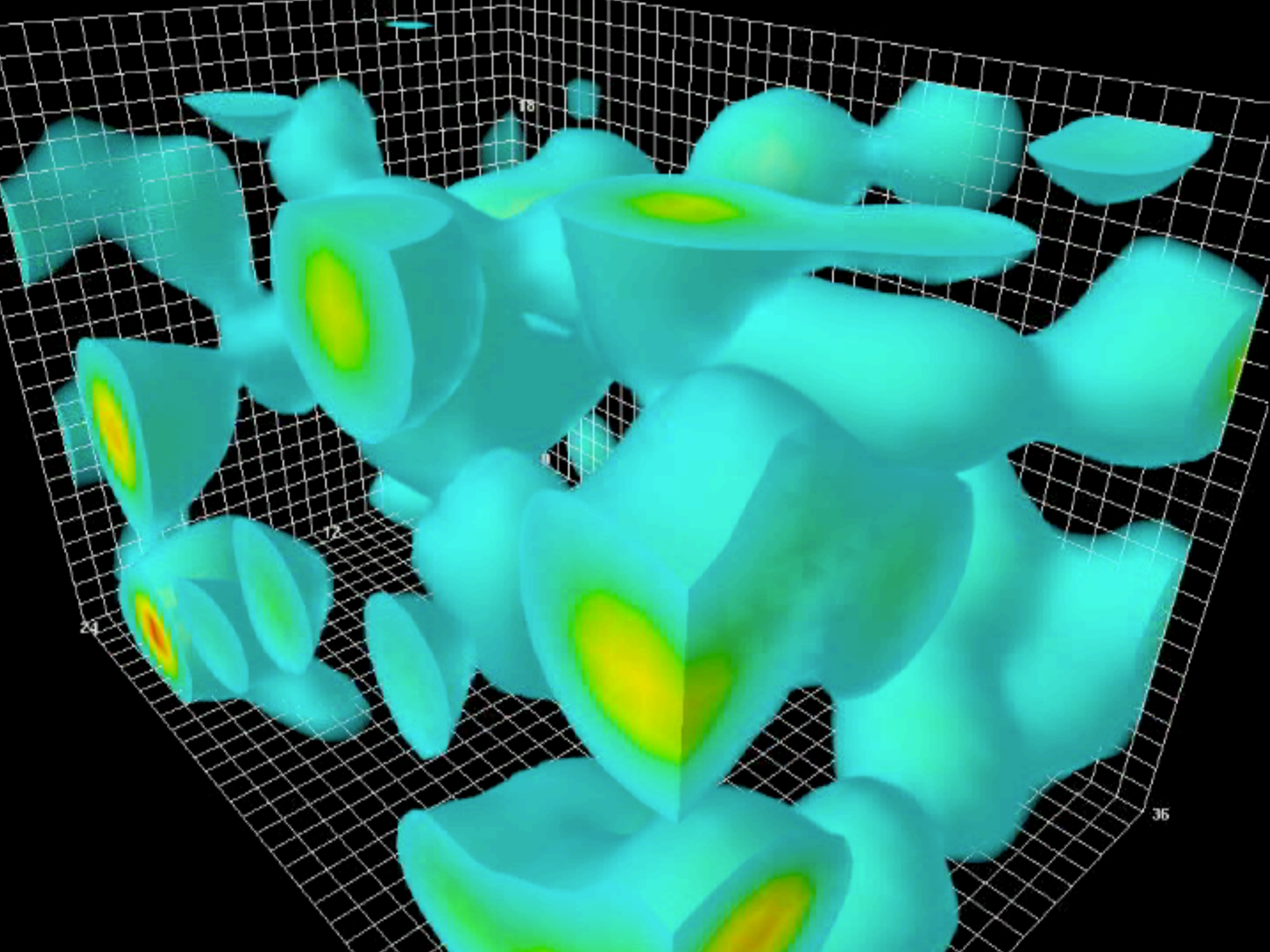
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One Entity, One Force (?)

Unification 2: Force and Substance



coupling strength
↓

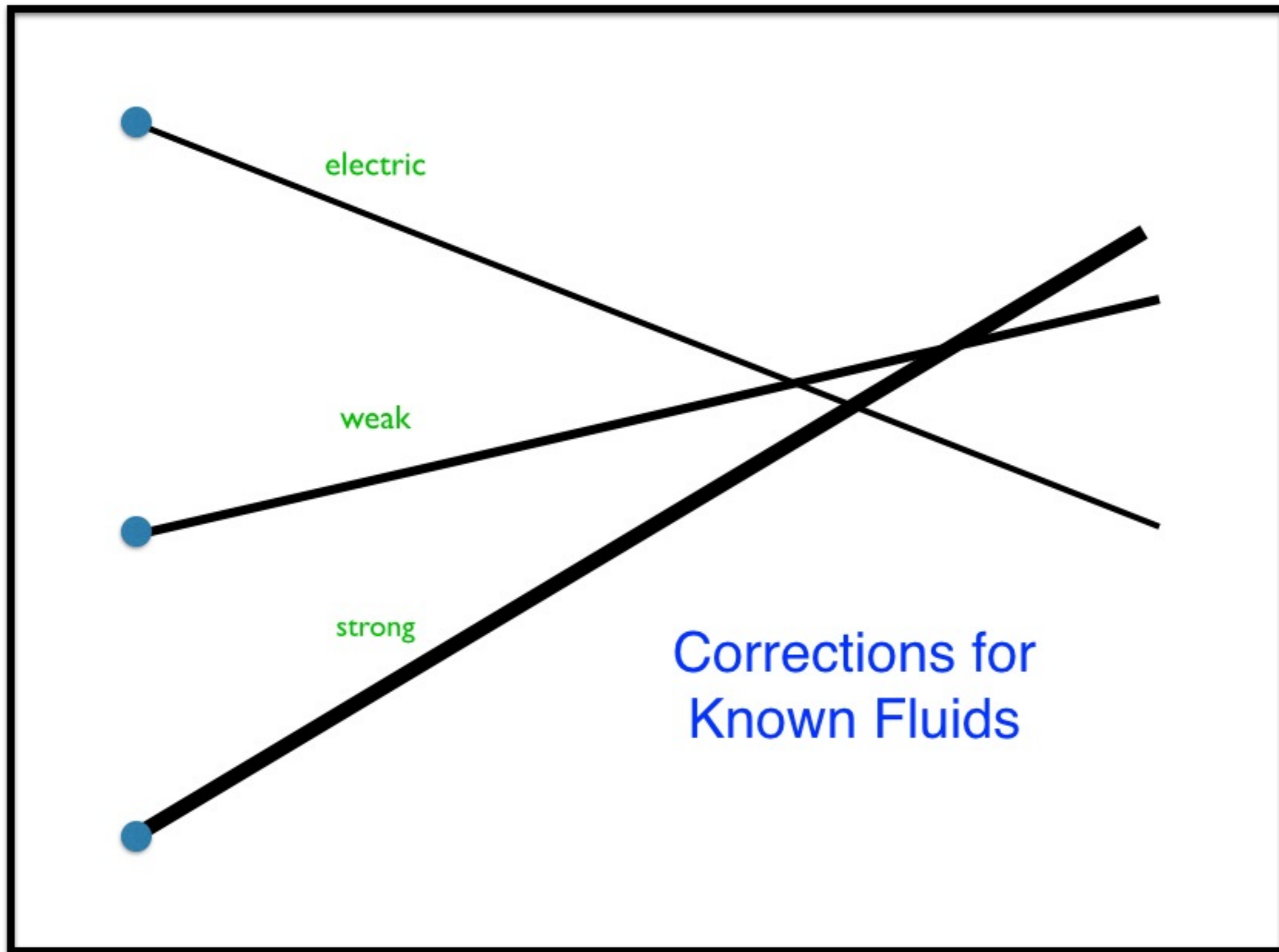
electric

weak

strong

Corrections for
Known Fluids

large energy, short distance →

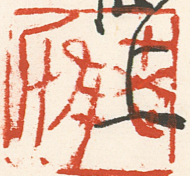




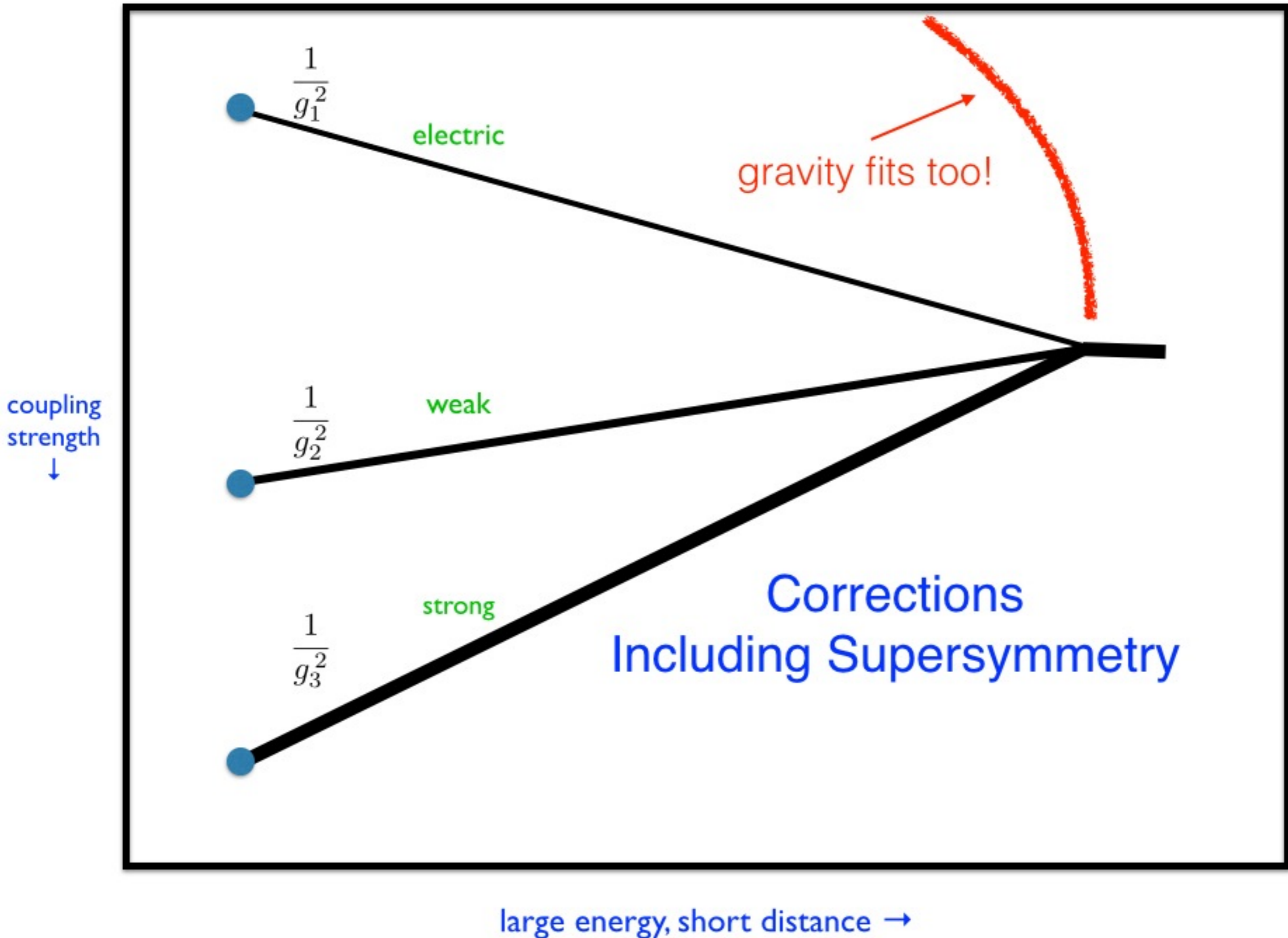
太極淺魚乃中華

文化之精髓今以之為考

寫照 甲午冬初何壯

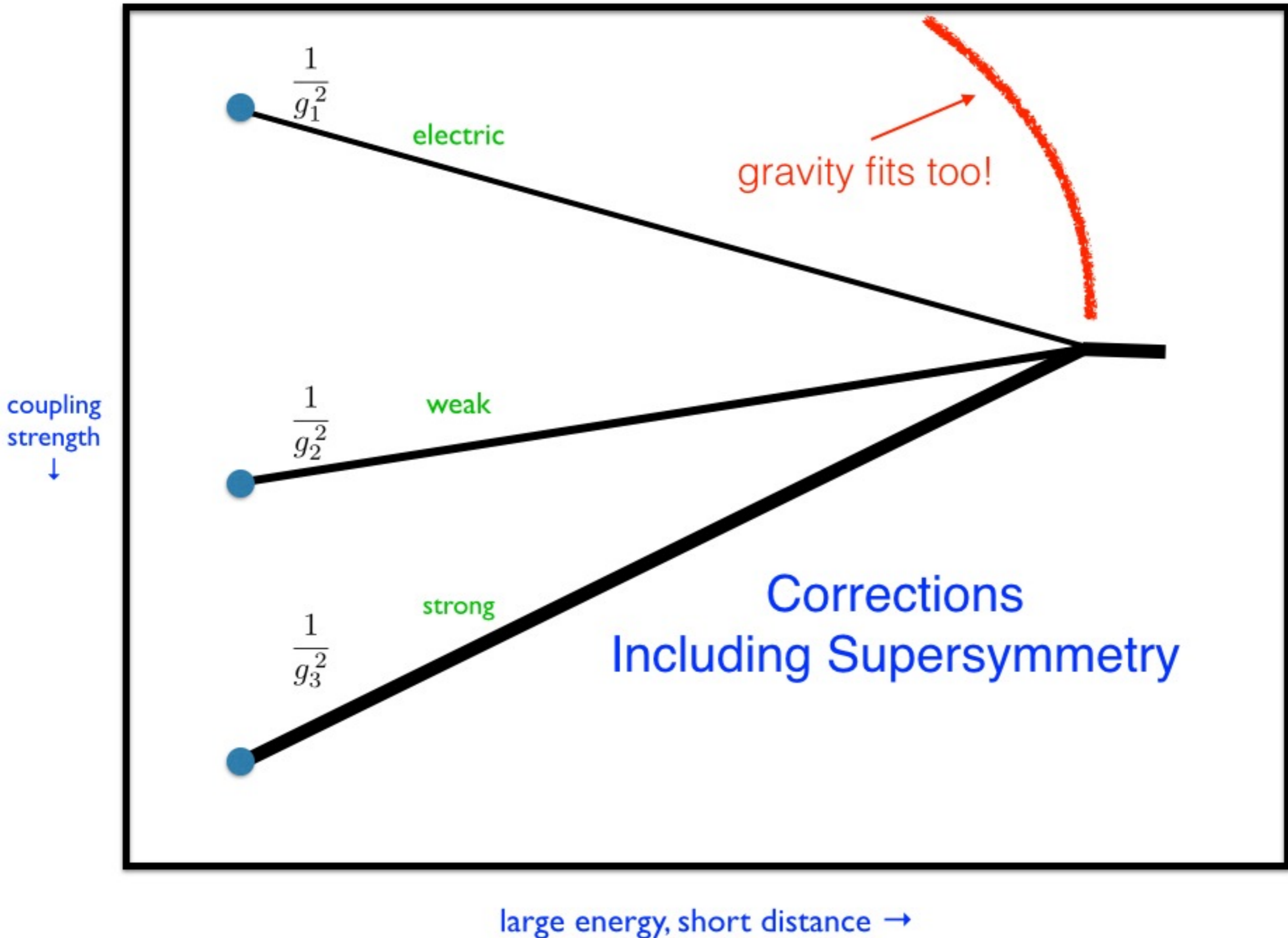


Why I ♥ SUSY



Unification 3: Space- Time and Matter

Why I ♥ SUSY



quantum gravity - more material?

infinitesimals

- why not?

gravity waves: a new window

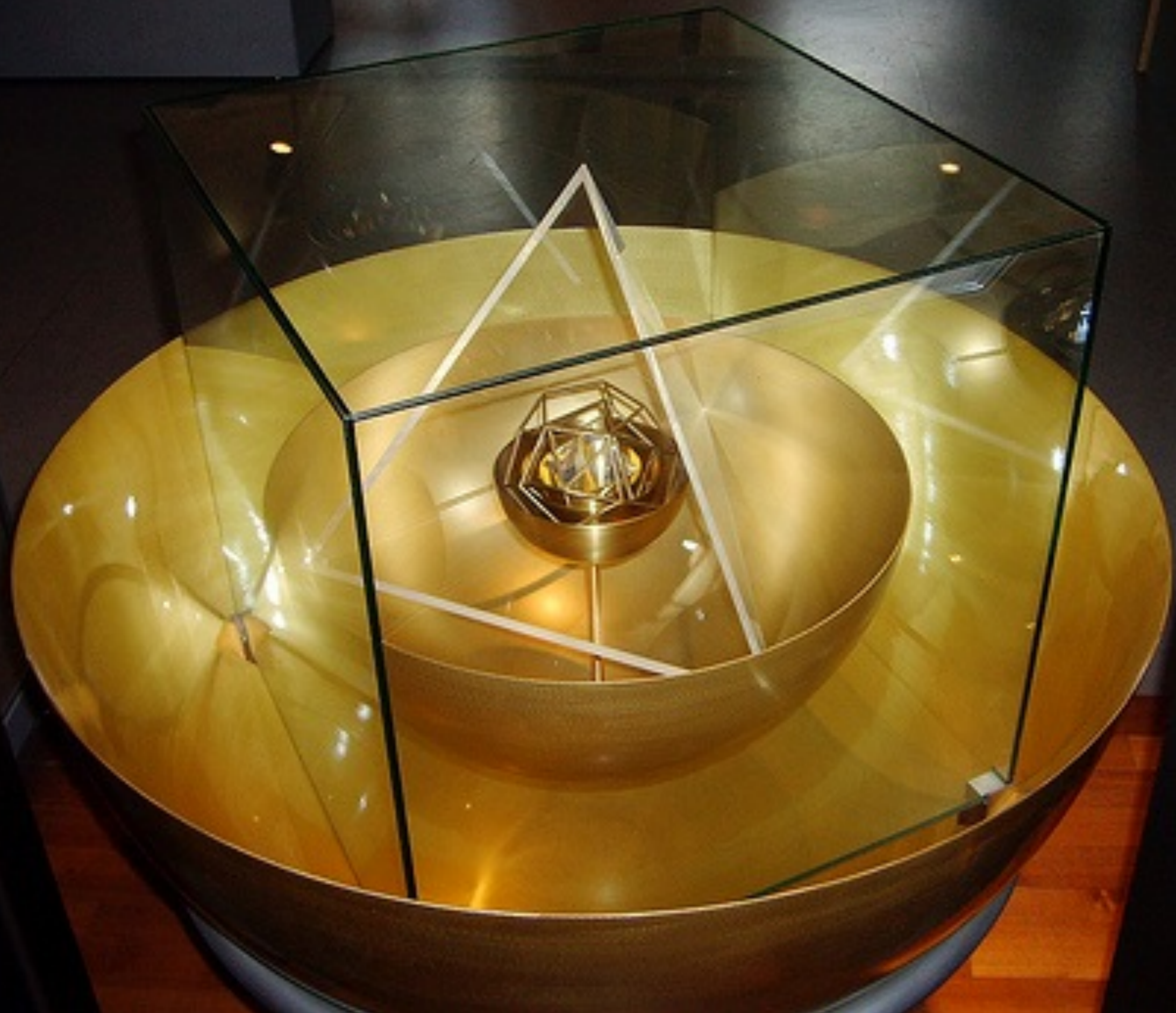
or several

Unification 4: Evolution and Origin

How could what is perish? How could it have come to be? For if it came into being, it is not; nor is it if ever it is going to be. Thus coming into being is extinguished, and destruction unknown. - Parmenides

This world, which is the same for all, no one of gods or men has made. But it always was and will be an ever-living fire, with measures of it kindling, and measures going out. - Heraclitus

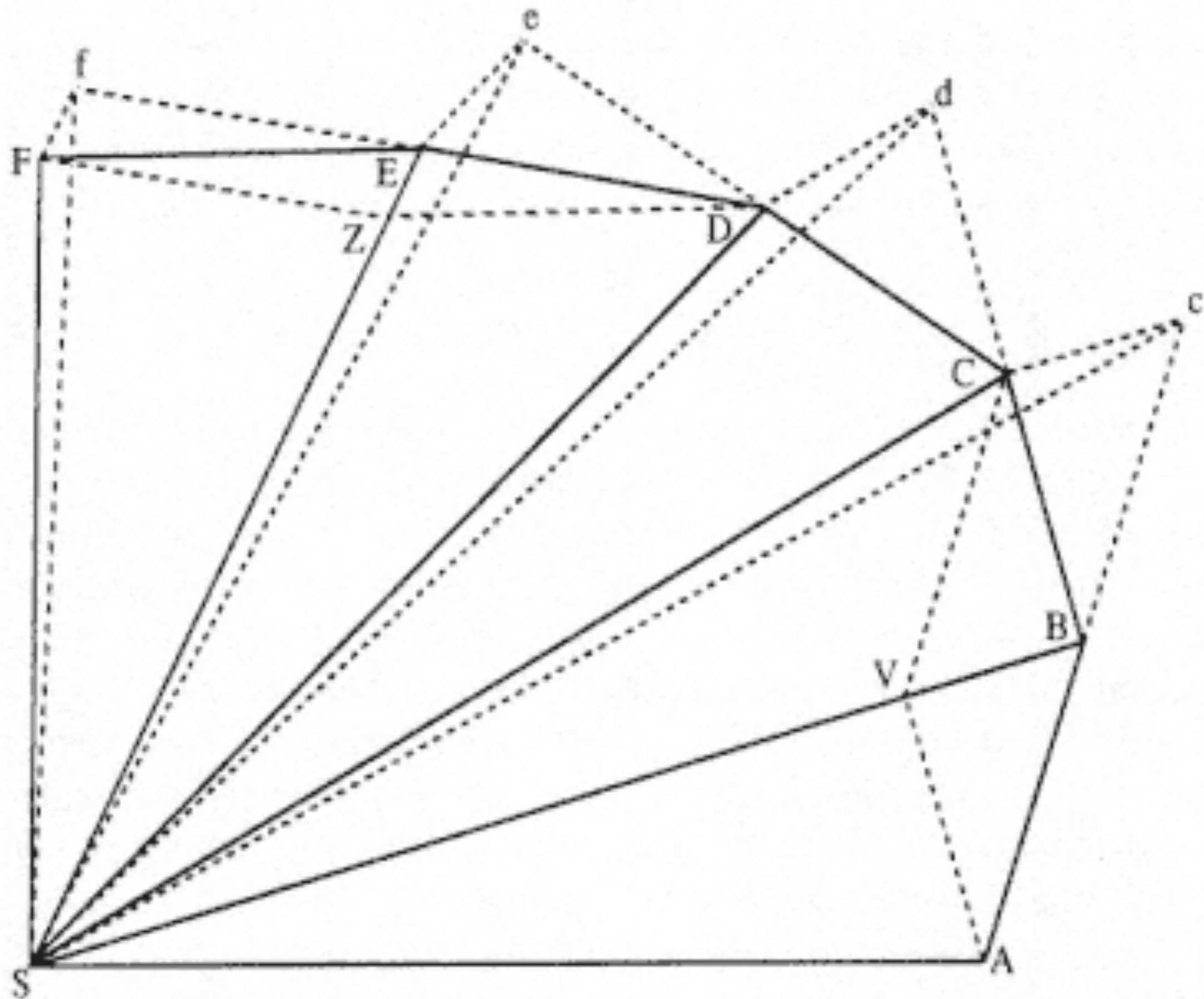
Kepler (Parmenides) versus Newton (Heraclitus)



Kepler's Darstellung des Kepler's Depiction of the

Kepler's heliocentric system was first described in his 1609 work *De Revolutionibus Astronomiacum*. In this work, Kepler described the orbits of the planets as elliptical, a revolutionary idea at the time. He also described the laws of planetary motion, which are still used today.

According to the Ptolemaic system, the Earth was at the center of the universe. The planets were thought to move in circular orbits around the Earth. Kepler's heliocentric system, on the other hand, placed the Sun at the center. The planets were thought to move in elliptical orbits around the Sun.



Relativity: space + time \rightarrow space-time

More comfortable with Parmenides!

The world simply is.

In my consciousness

Tethered to my brain and body

Fleeting images come to life -

Of the world, samples only.

The world simply is,

It does not happen.

Unification 5: Information and Action



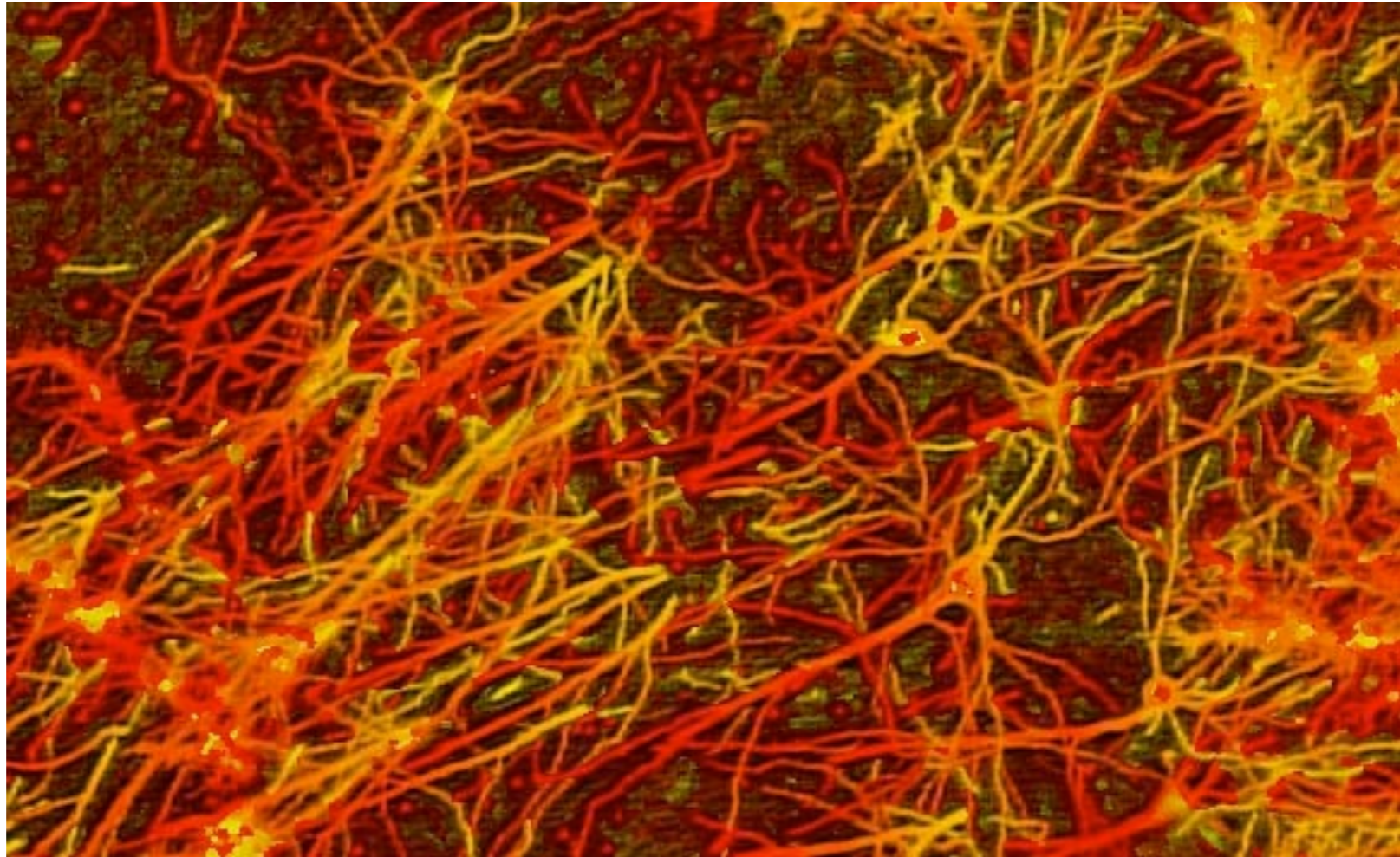


Unification 6: Quantum and Symmetry

$$[x_j, p_k] = i\hbar \delta_{jk}$$

$$[T^a, T^b] = if_c^{ab} T^c$$

Unification 7: Mind and Matter





Baryon decay will be observed, and lead to a rich phenomenology.

Supersymmetry will be observed, and lead to a rich phenomenology.

The nature of the dark matter will be revealed. axions

Tangible consequences of quantum gravity will be identified, and observed.

New kinds of numbers, including some form of infinitesimals, will be used to describe space and time.

Gravity waves will be observed, and become a powerful tool in astrophysics and cosmology.

The fundamental laws will no longer separate into initial conditions and dynamics.

Information will appear as a primary ingredient of physical law.

Quantum mechanics be formulated as a fundamental symmetry principle, and integrated together with other such principles.

Biological memory, cognitive processing, and emotion will be understood at the molecular level, comparable to our understanding of heredity and metabolism today.

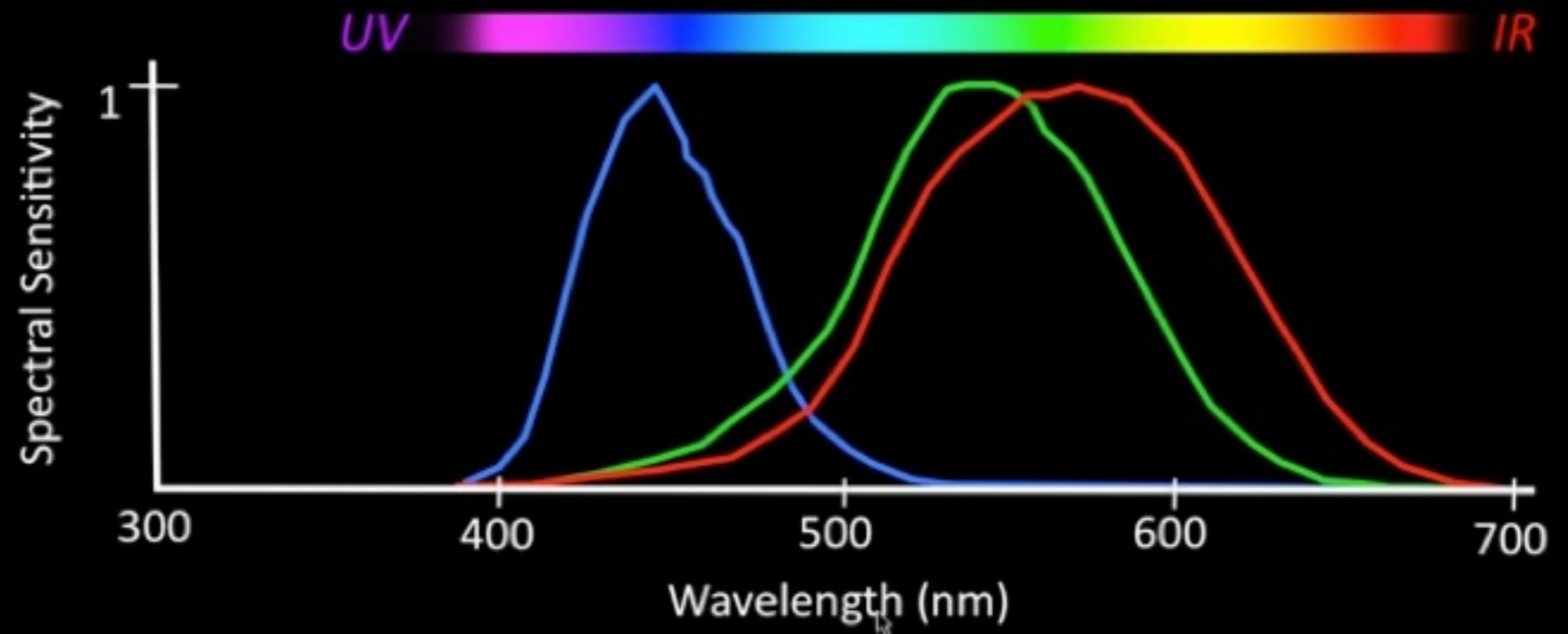
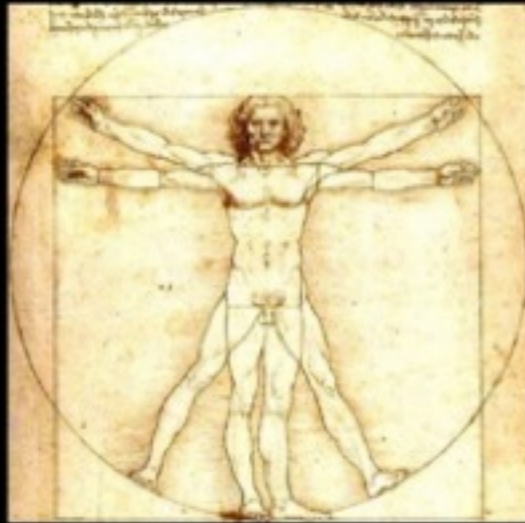
Technologies

“Indistinguishable from Magic”

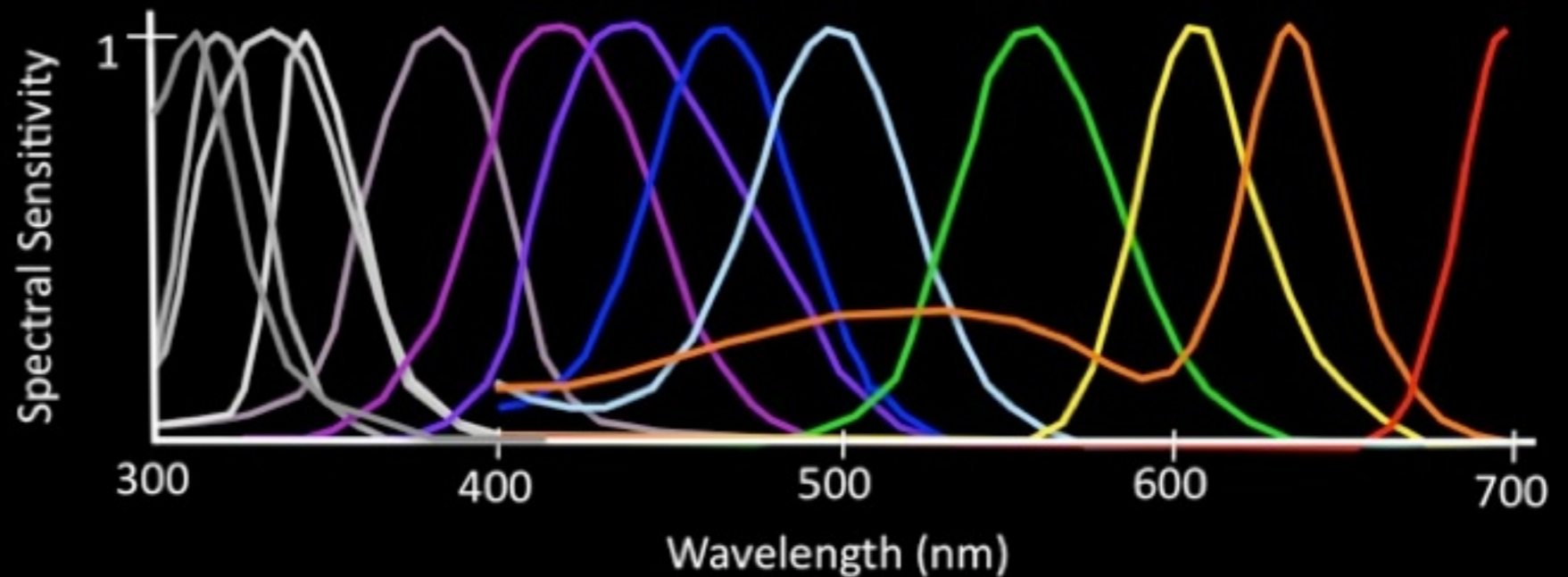
Enhanced Sensoria

Mantis Shrimp: Extraordinary Eyes

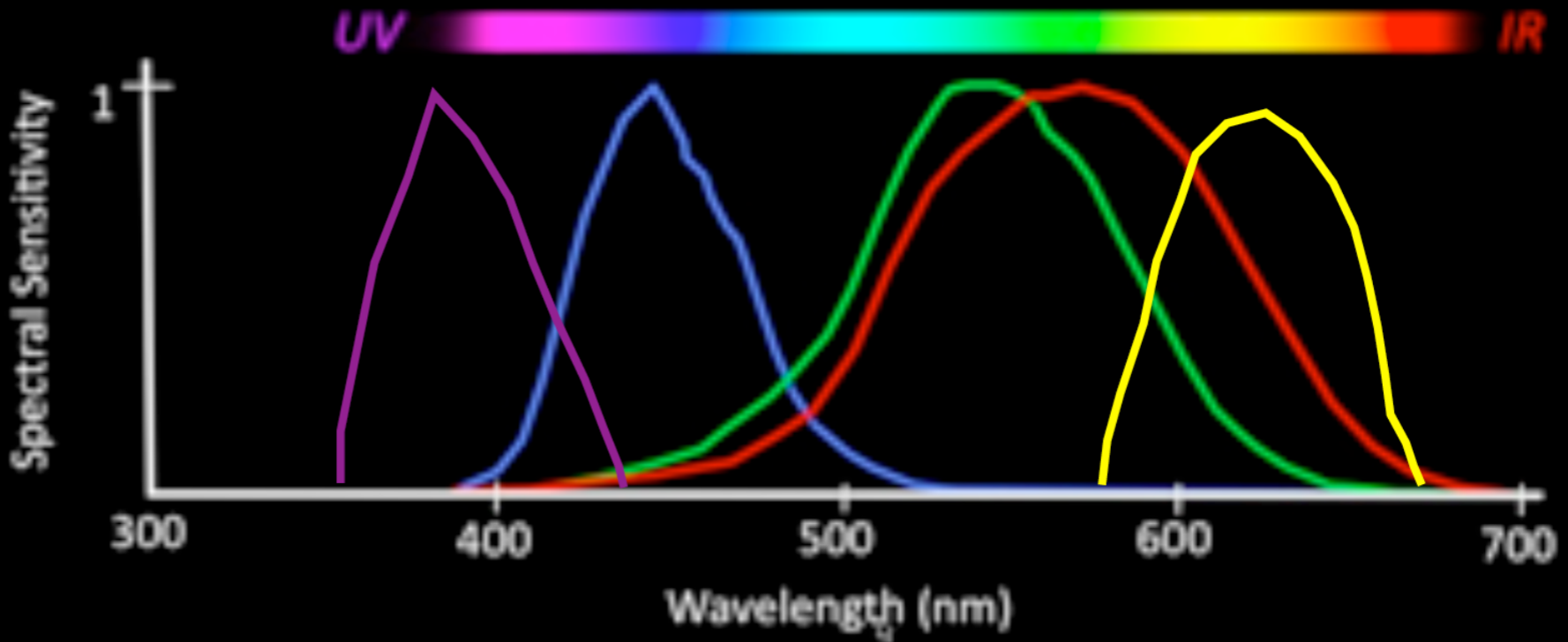
Homo sapiens

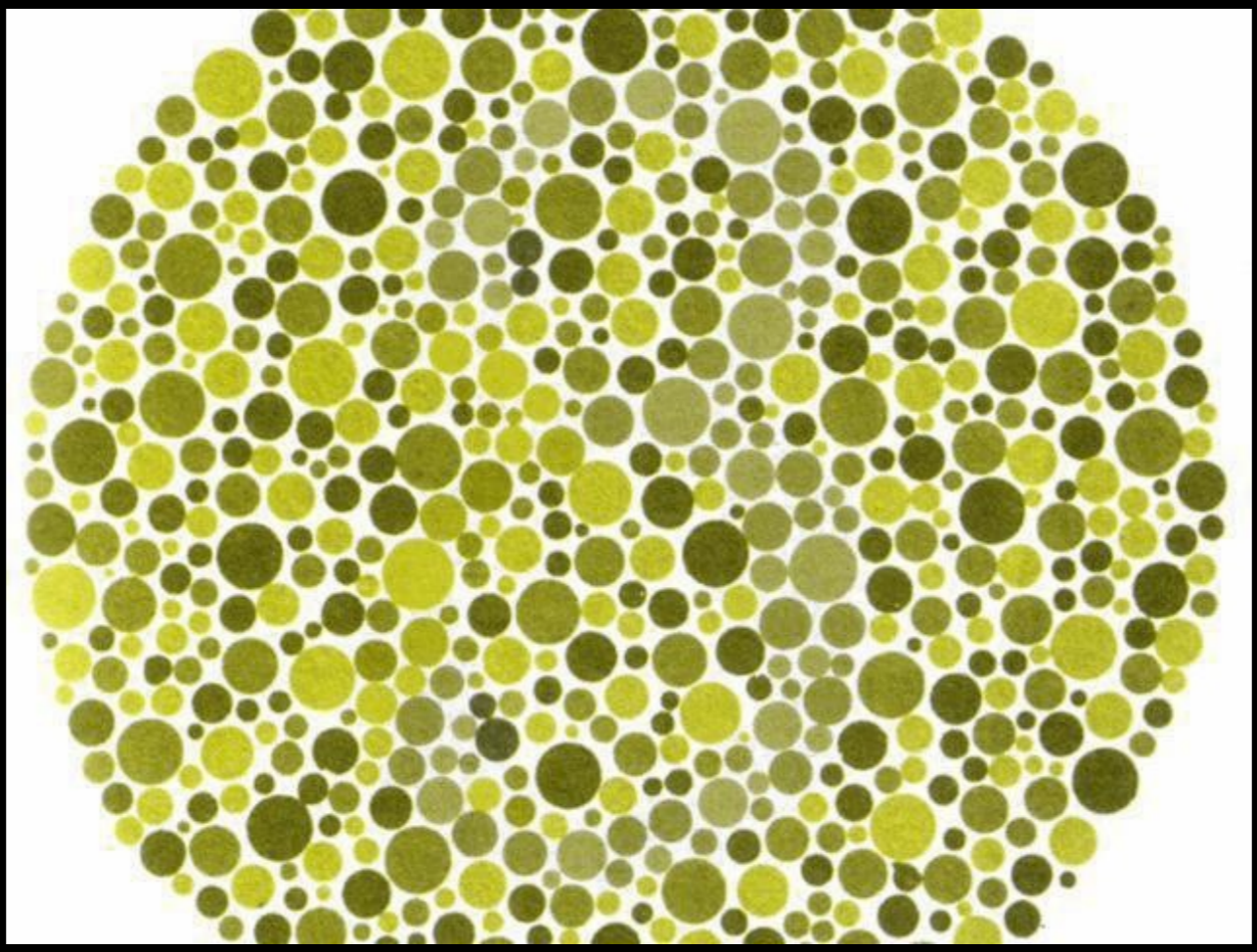
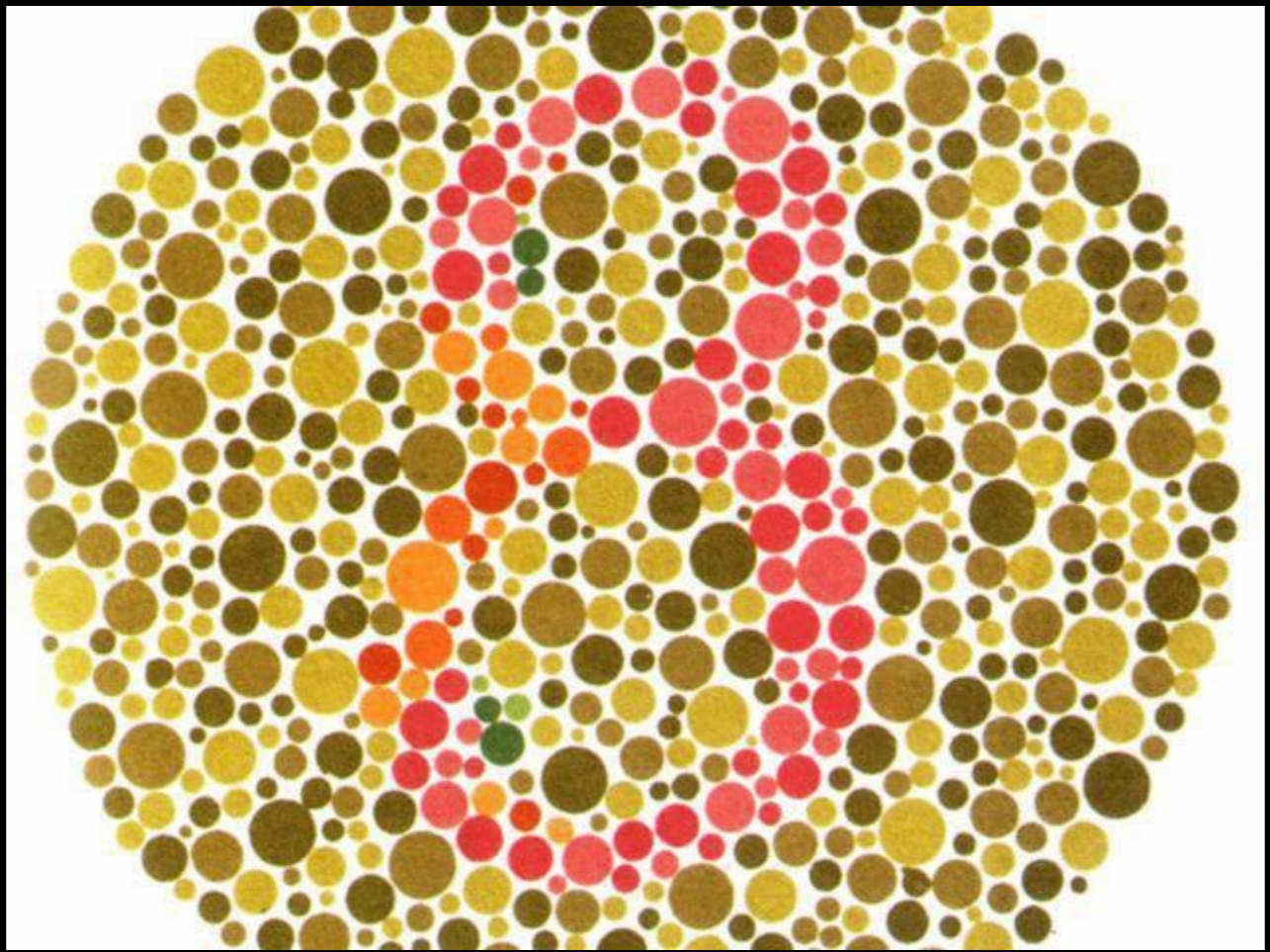


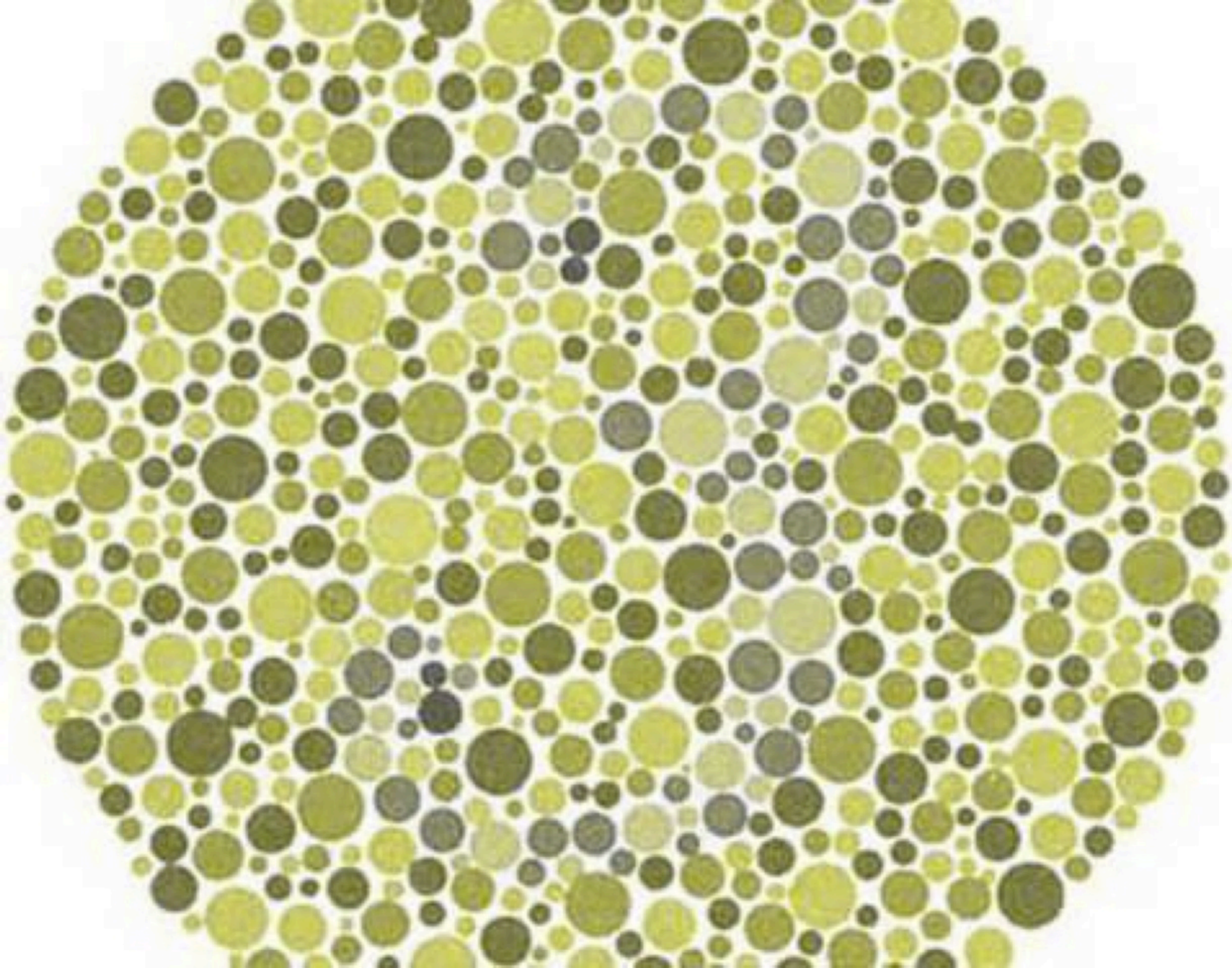
Neogonodactylus oestедii

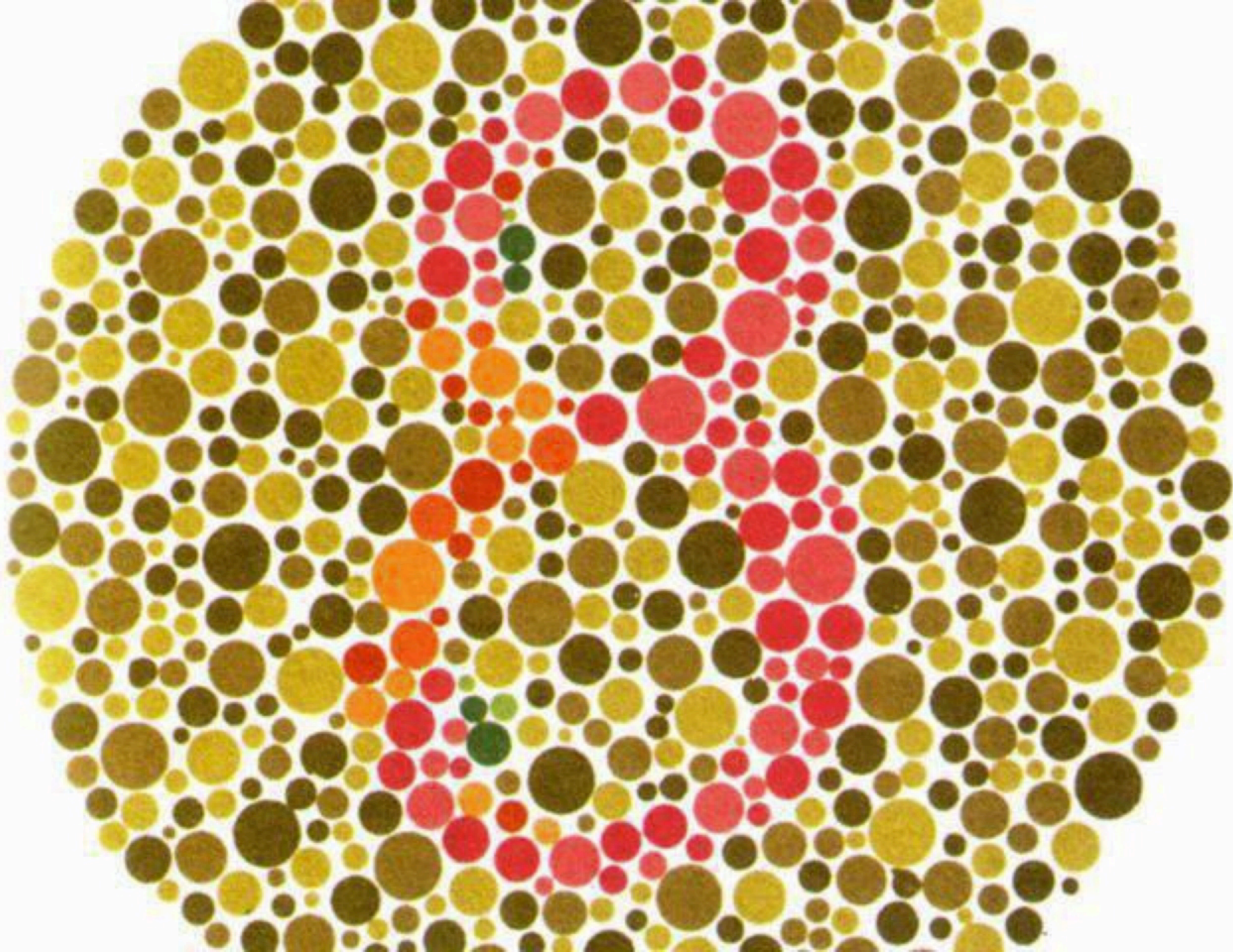


Homo sapiens ++









Making Things (Micro)

molecular design

manipulating nuclei, like atoms

Making Things (Meso)

3D, fault-tolerant, self-repairing computers

self-assembling and self-replicating “bio-machines”

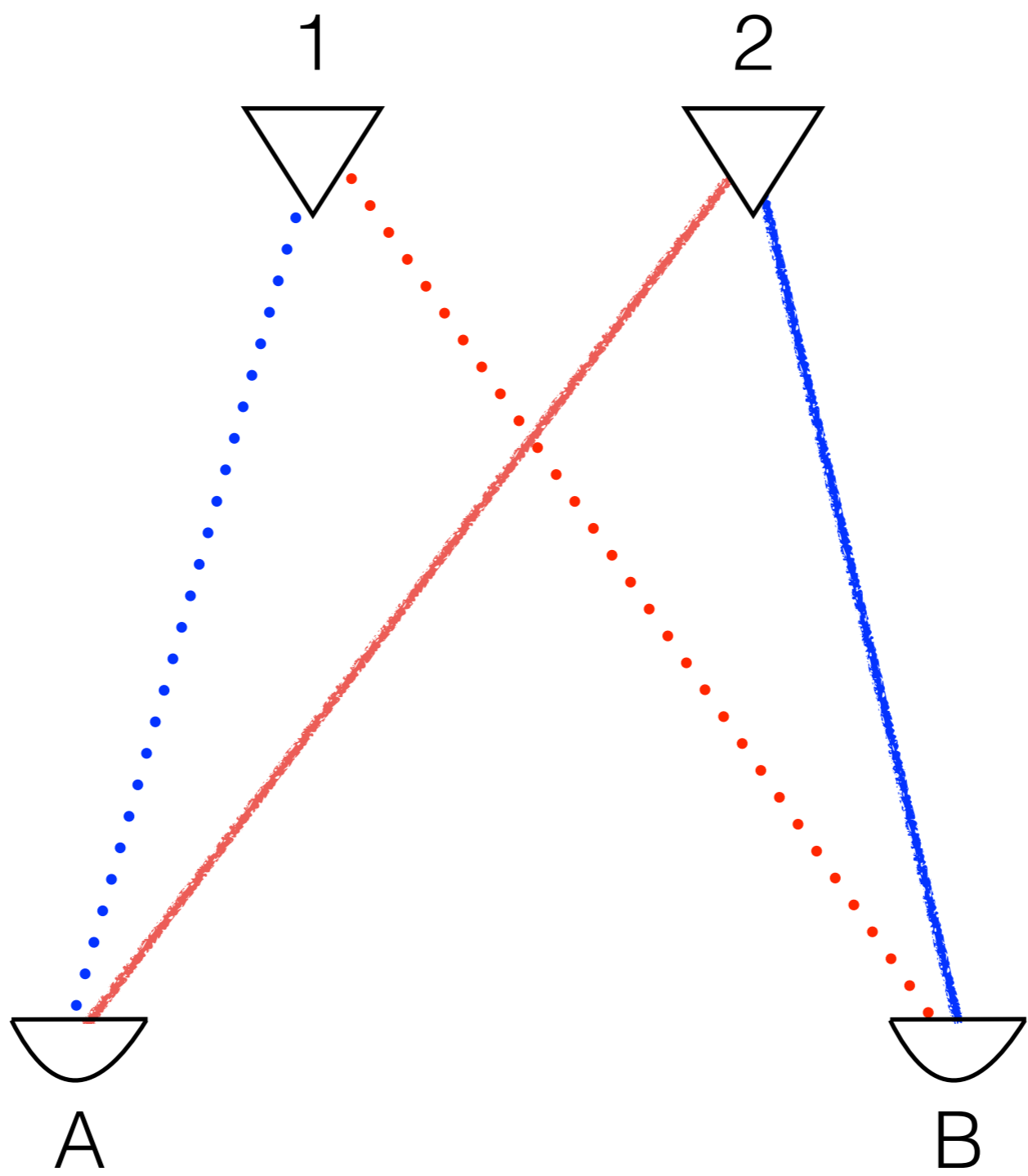
Making Things (Macro)

whole-planet brains (Stapledon)

whole-sun energy gathering (Dyson) [250]

Quantum Minds

expanding the *quantum* sensorium, by exploiting
projection and entanglement



Interference possible when alternative paths can't be distinguished.

So: Erase the evidence!

IGNORANCE

is

STRENGTH



quantum notions of history, inference and causality

quantum AI

embracing contradictions

manipulating time

Changing Minds

distributed intelligence

(spatially) expanding sensorium

With understanding and growing power, perhaps wisdom:

creative humility

complementarity

... to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

— I. Newton

*Do I contradict myself?
Very well, I contradict myself.*

*The world is large –
It contains multitudes.*

*If you're not bedazzled
You're not really looking.*