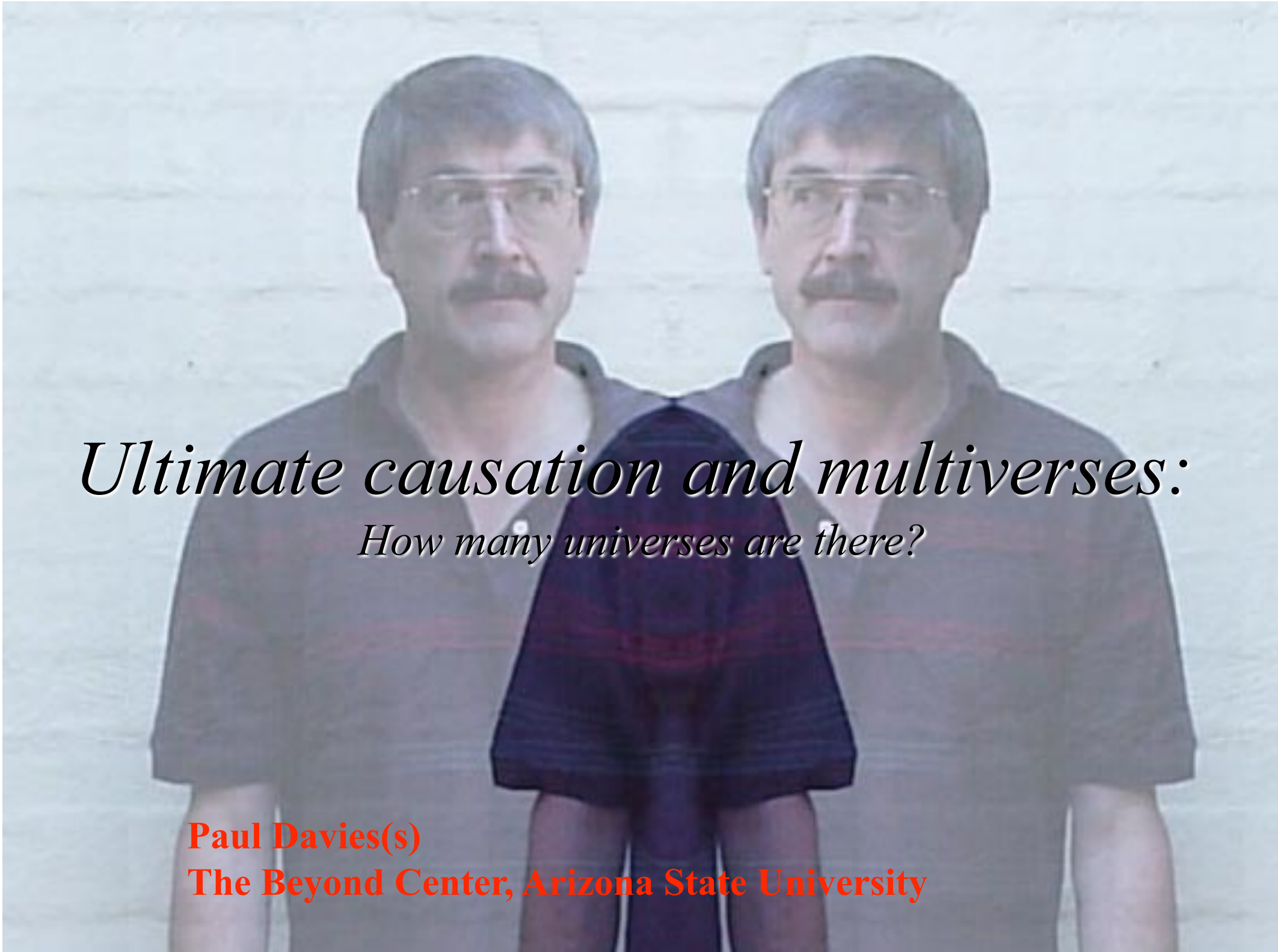
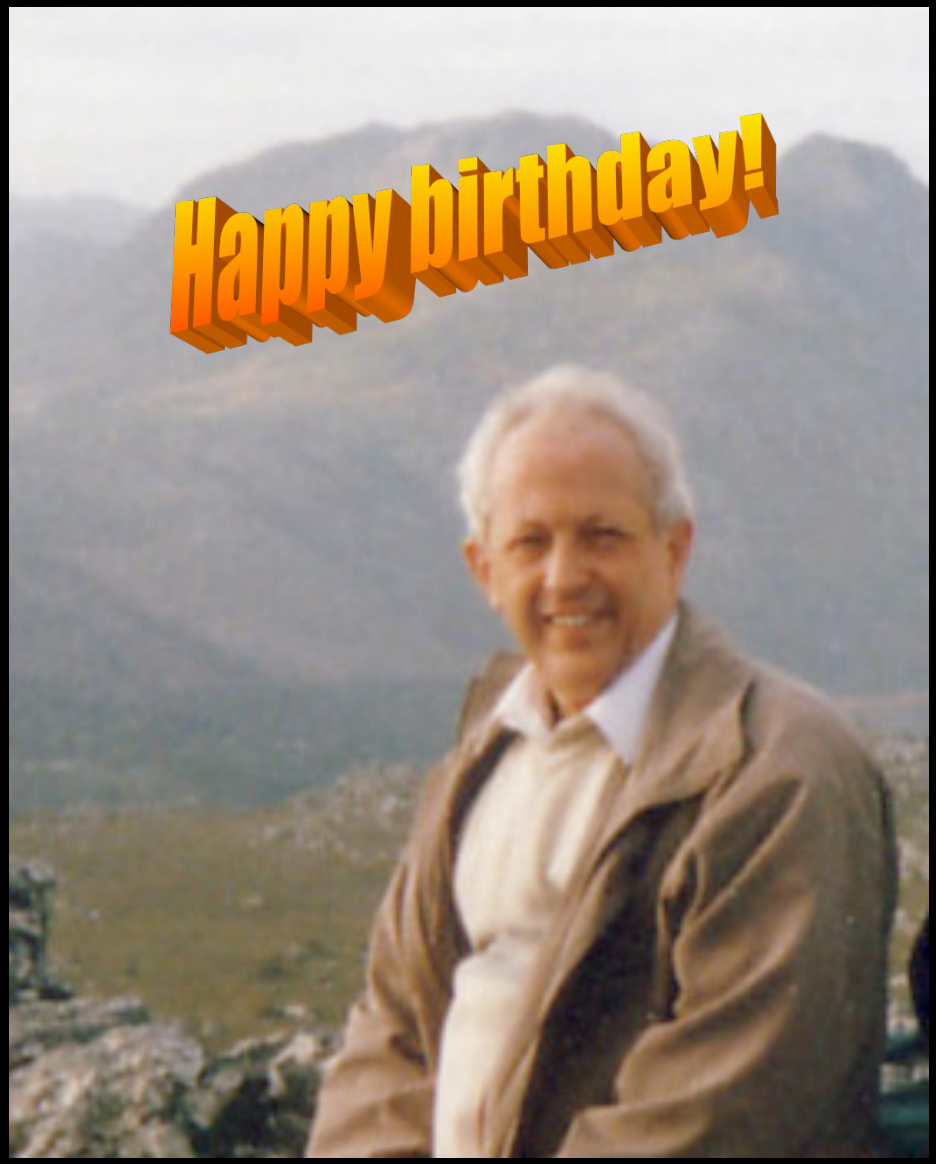


Ultimate causation and multiverses:

How many universes are there?

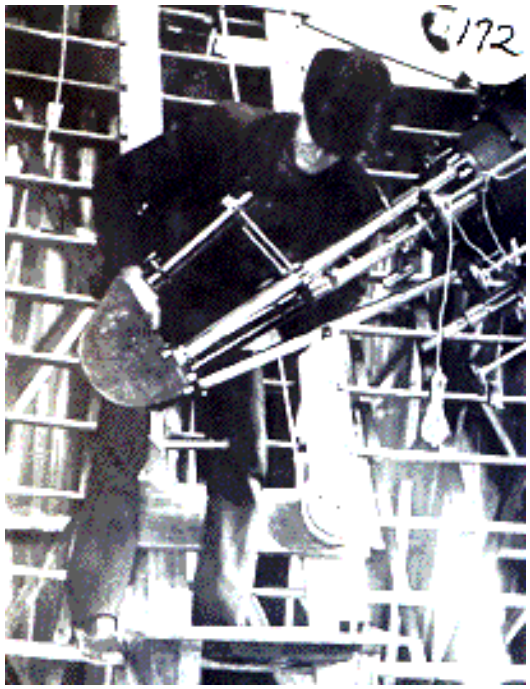
Paul Davies(s)
The Beyond Center, Arizona State University


Happy birthday!

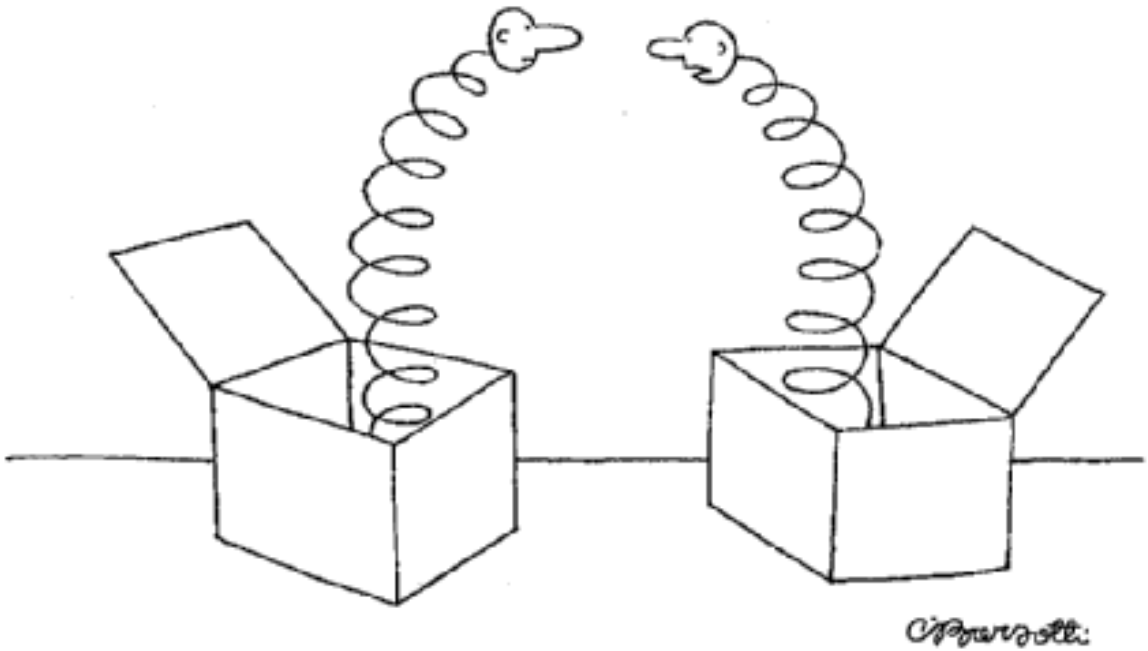
Vesto Melvin Slipher

1909

Flagstaff, Arizona



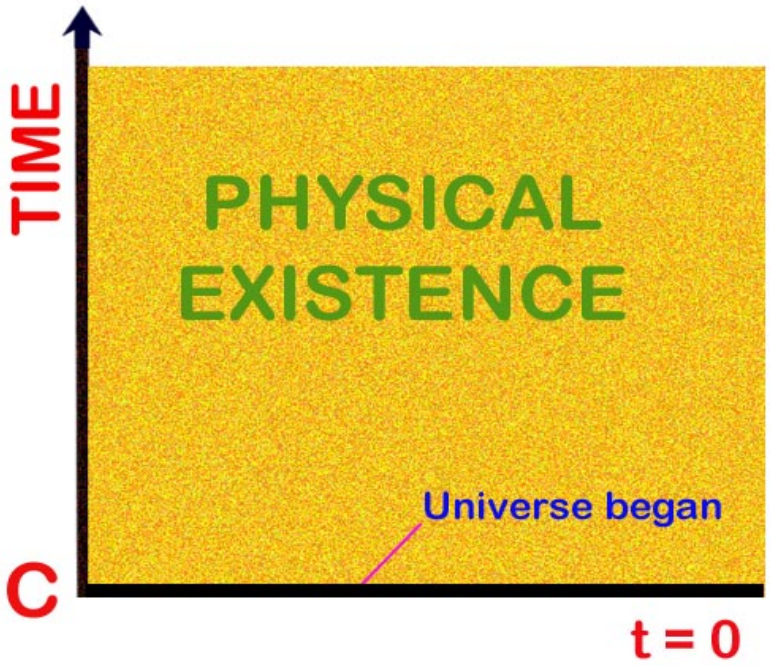

Big bang!
What happened before?



"*But before the big boing, what was there?*"

AUGUSTINE

"The world was made *with* time,
not *in* time."



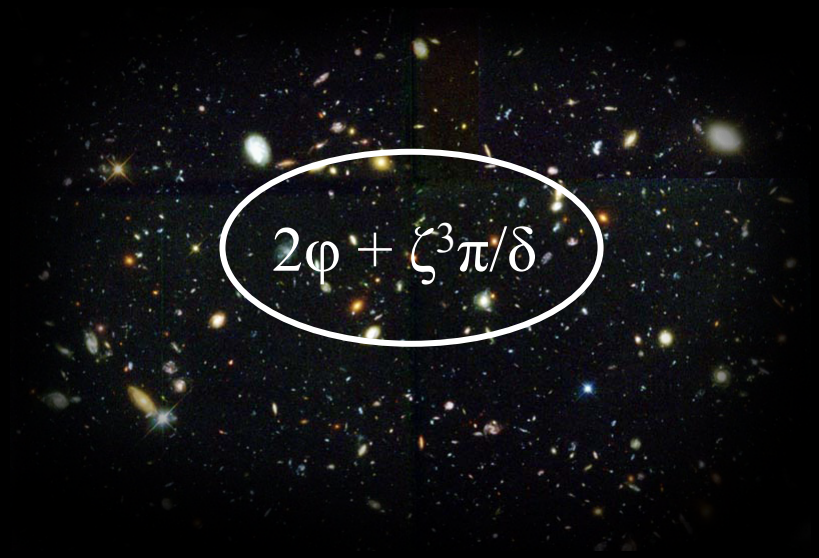
"NOTHING"

The founding assumption that underlies all science

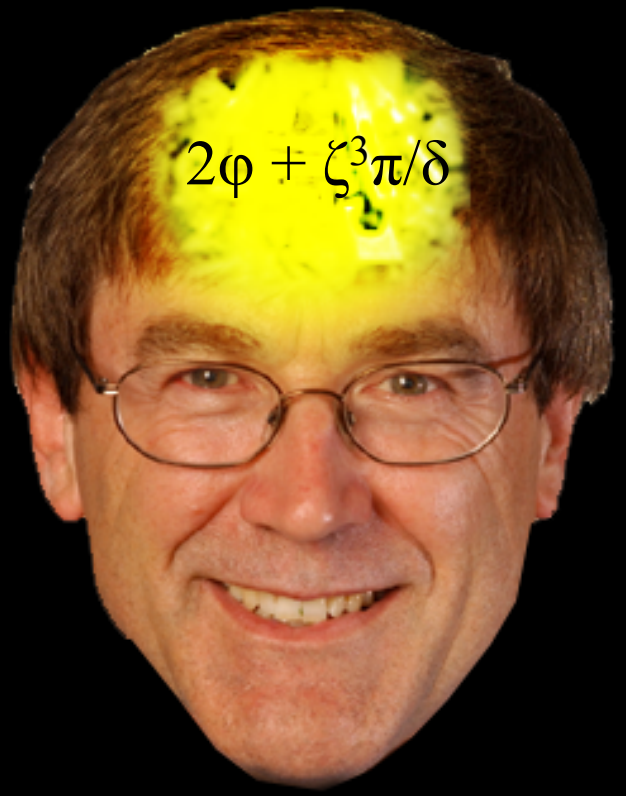
The universe is ordered in a rational and intelligible way – *there are "laws of nature"*

There is a "scheme of things" that human beings can discover and come to understand, albeit imperfectly, using mathematics and experiment – *laws are mathematical relationships*

What is mathematics?

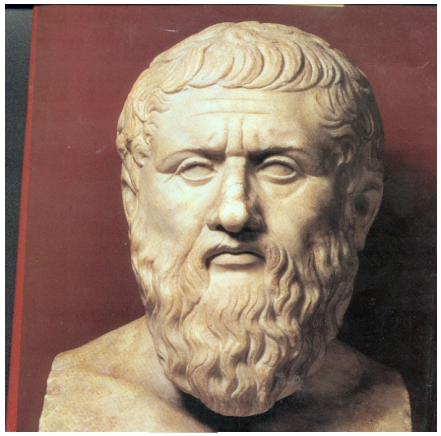


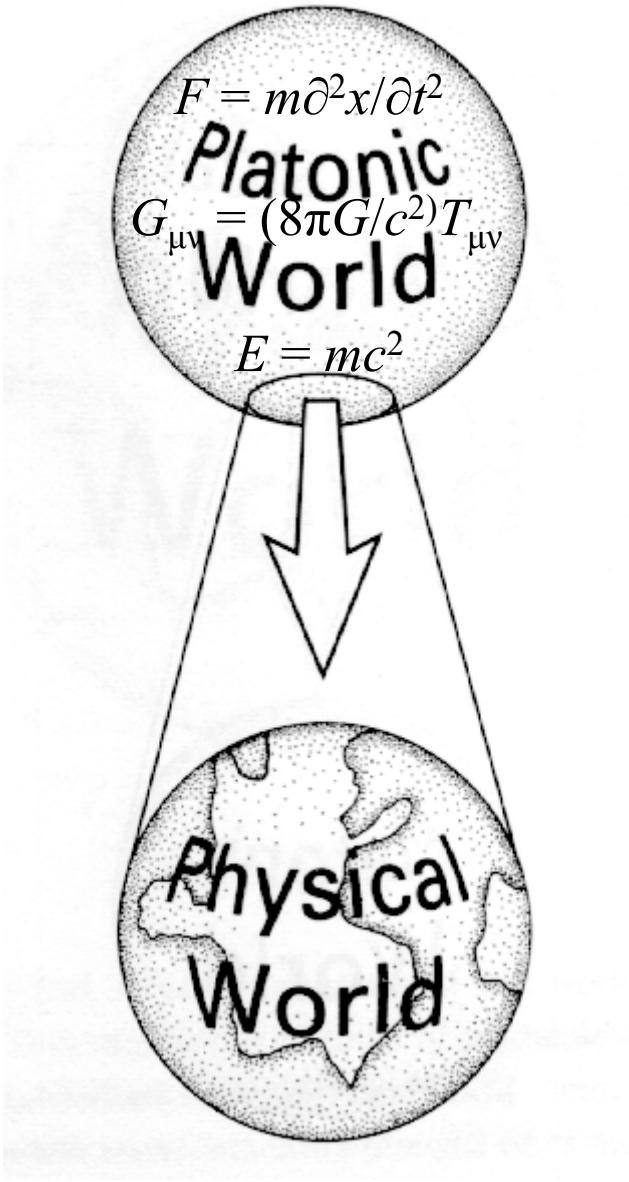
Mathematics is "out there"
to be discovered



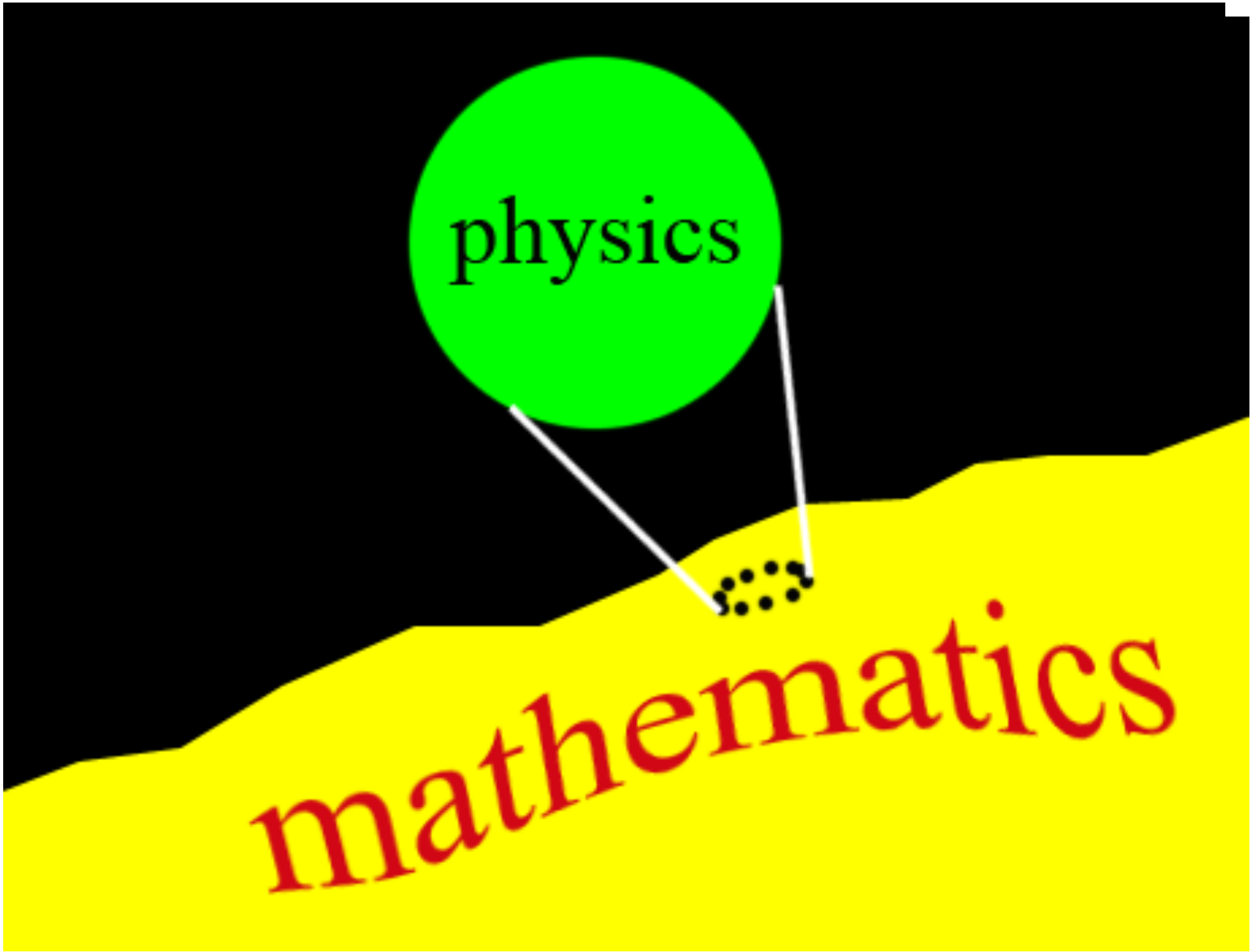
Mathematics is a construction
of the human mind

The nature of physical law (orthodox view)

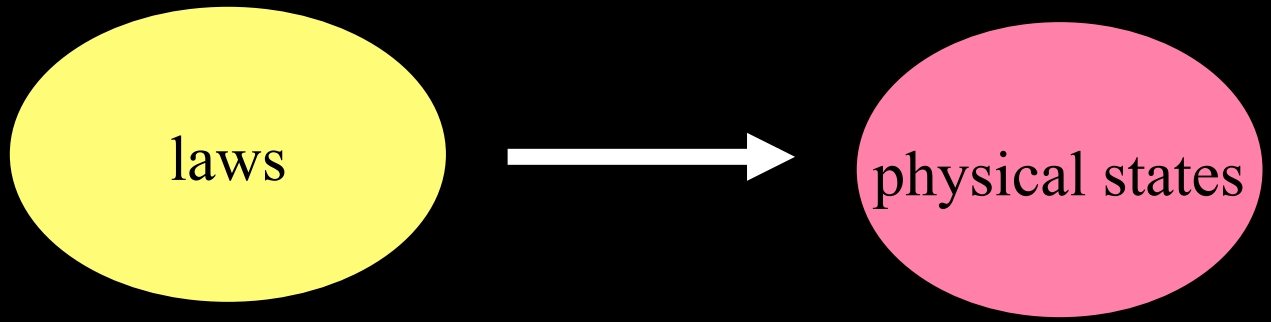

Bust of Plato



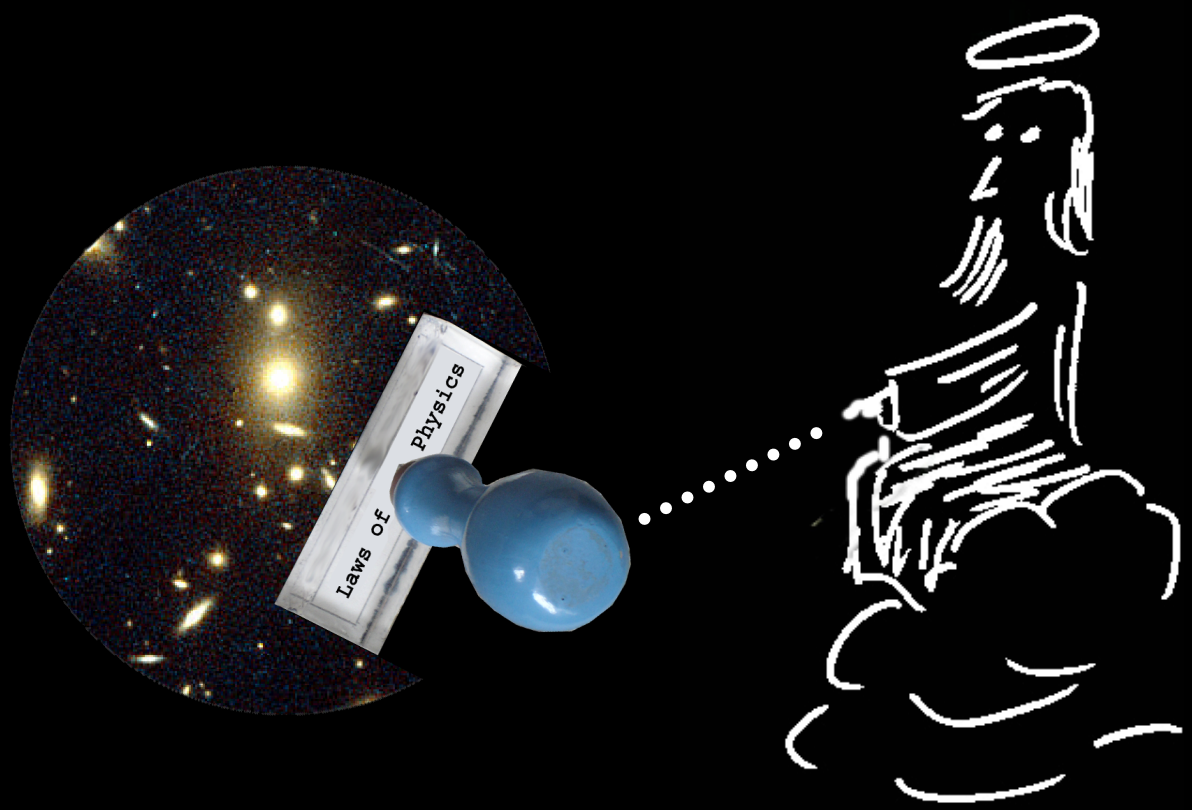
The laws are not "in" space and time – they are "transcendent"


physics
mathematics


$(F_1, F_2) = \frac{1}{2}\int_{\text{over } M} (\epsilon \mathbf{E}_1^* \cdot \mathbf{E}_2 + \mu \mathbf{H}_1^* \cdot \mathbf{H}_2)\, dV$
Mother
Nature



Newtonian dualism: the laws are *immutable*



The laws are imprinted on the universe at the moment of its birth

[I]t is God who has established the laws of nature, as a King establishes laws in his kingdom. . . . You will be told that if God has established these truths, he could also change them as a King changes his laws. To which it must be replied: yes, if his will can change. But I understand them as eternal and immutable. And I judge the same of God.

Rene Descartes (1630)

"Now, as nothing is necessarily true save only by Divine decree, it is plain that the universal laws of nature are decrees of God following from the necessity and perfection of the Divine nature….; nature, therefore, always observes laws and rules which involves eternal necessity and truth, although they may not all be known to us, and therefore she keeps a fixed and immutable order."

Spinoza, *Tractatus Theologico-Politicus* (1670), p. 83

Where do the laws "come from"?

The laws exist reasonlessly

They must be accepted as a brute fact

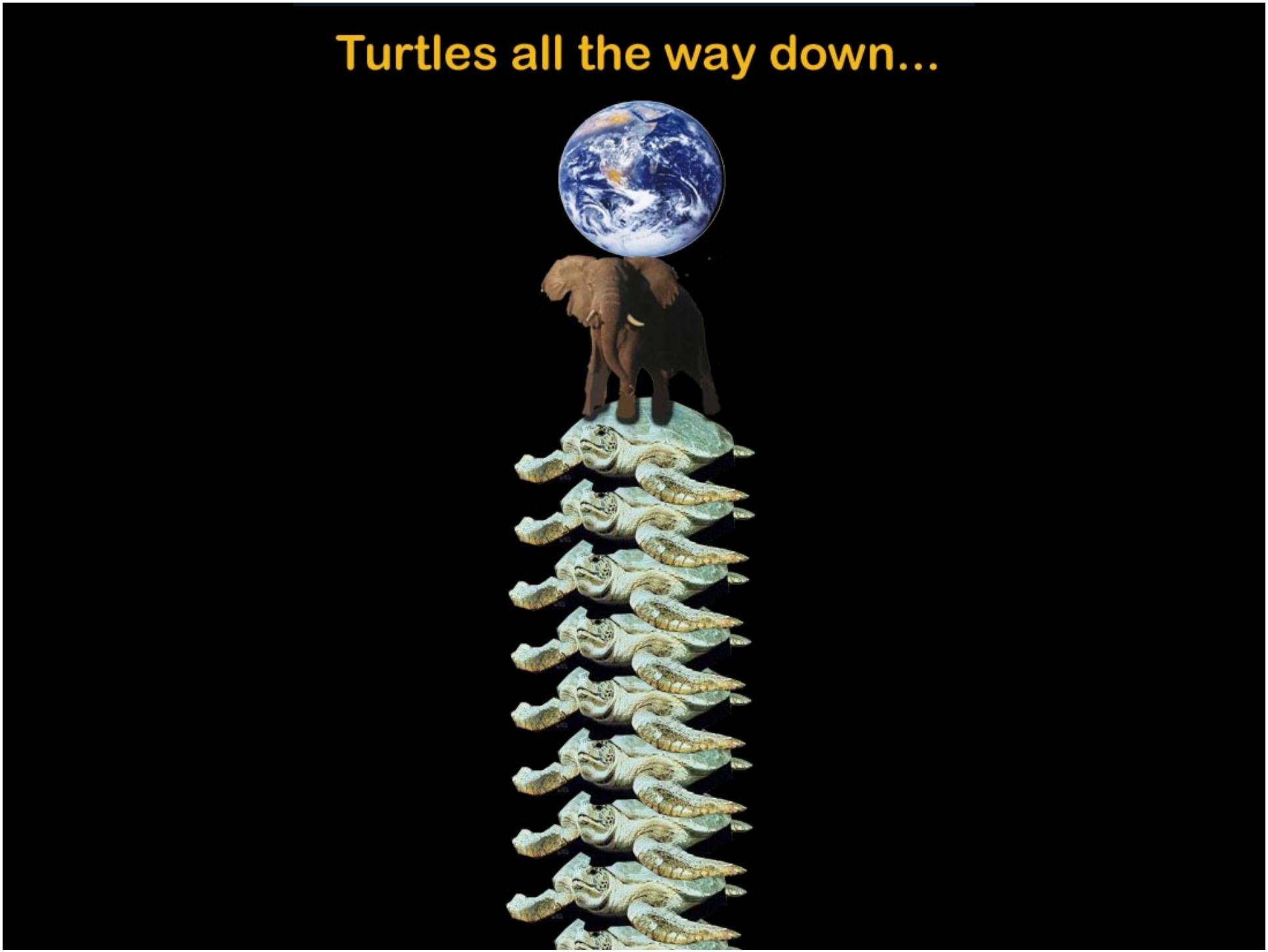
Their origin is beyond the scope of science

Asking "why those laws" is not a scientific question
and is to be strongly discouraged!

"There is a chain of explanations concerning things that happen in the universe, which ultimately reaches to the fundamental laws of nature and stops…at the end of the day the laws are what they are…that's okay. I'm happy to take the universe just as we find it."

Sean Carroll

Turtles all the way down…



Superturtle!

Self-explanatory
or absurd

The laws of physics c 1965

- **Immutable/absolute**
- **Universal**
- **Eternal**
- **Infinitely precise**
- **Transcendent/Platonic**
- **Imprinted on the universe from without**
- **Immune to change in the physical world**

Transcendent laws could explain how the universe came into existence "from nothing"

laws

But….

It would be a funny sort of “law” that acted only once

Laws 1

Laws 4

Weak anthropic principle

Brandon Carter, 1969

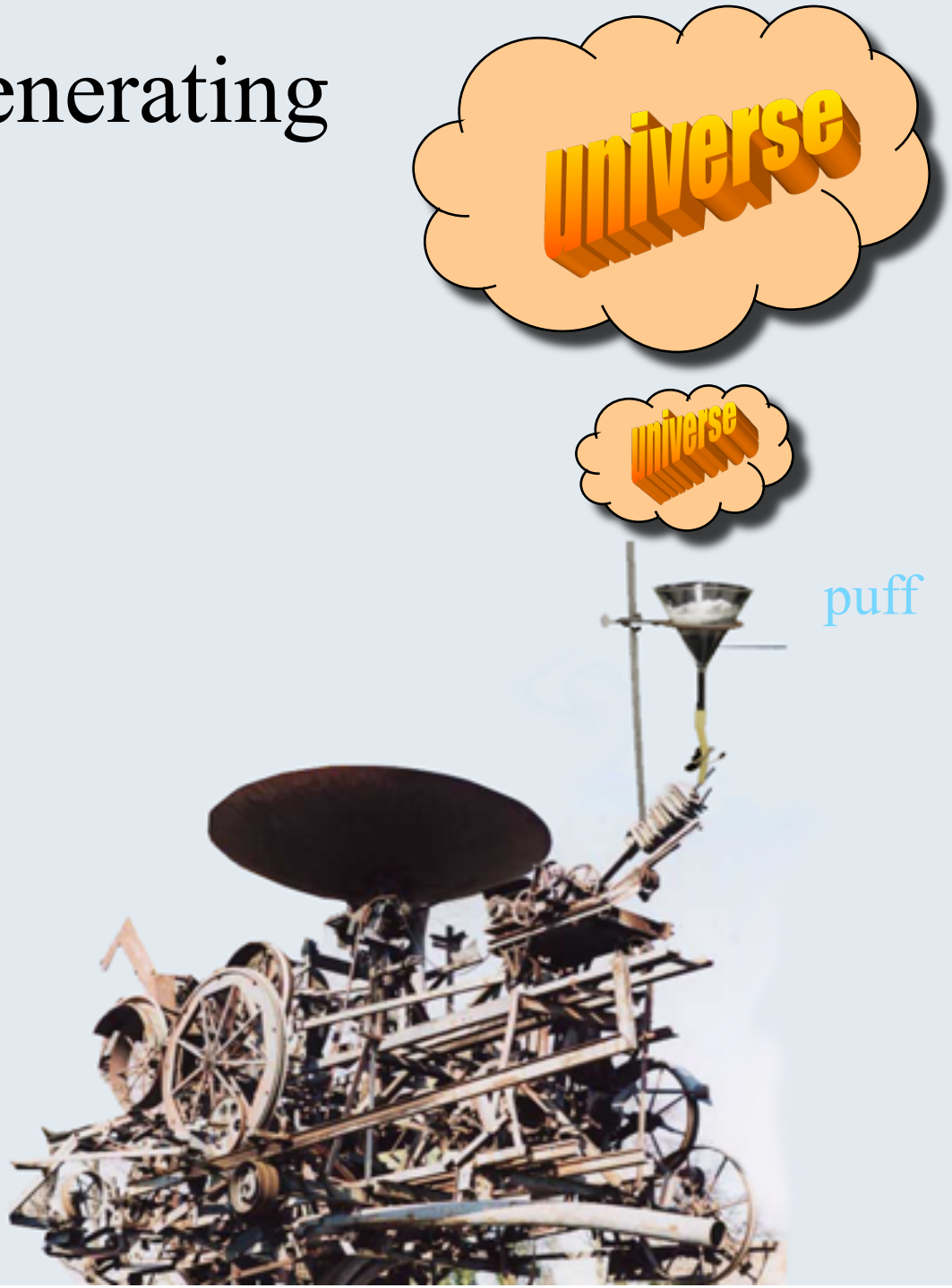
Laws 7

Laws 5

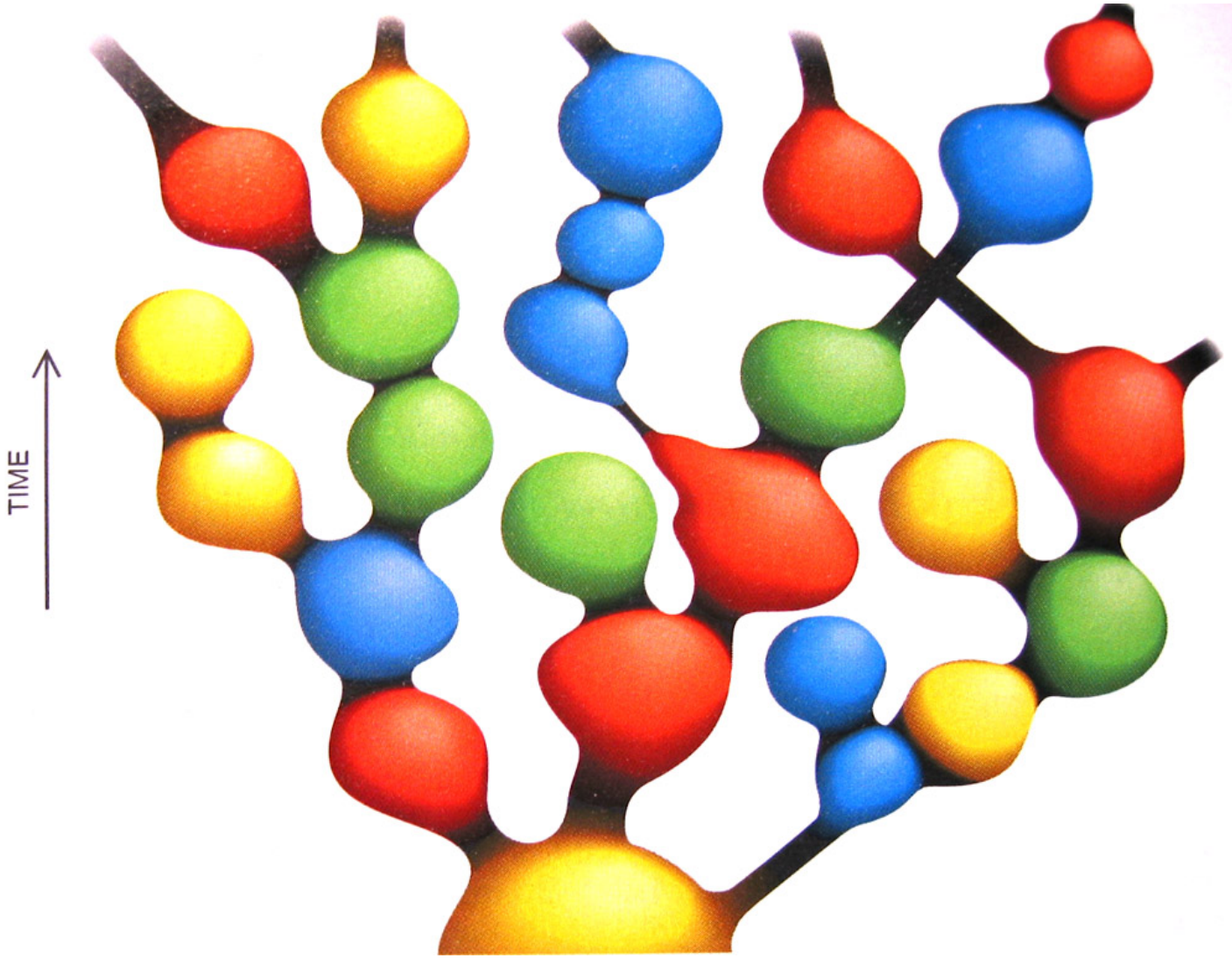
End of story?

NO! The multiverse theory
is *not* a complete explanation of
existence!

Universe generating mechanism



Eternal inflation



Meta-laws

Universe-generating mechanism
(quantum mechanics, relativistic causality, etc.)

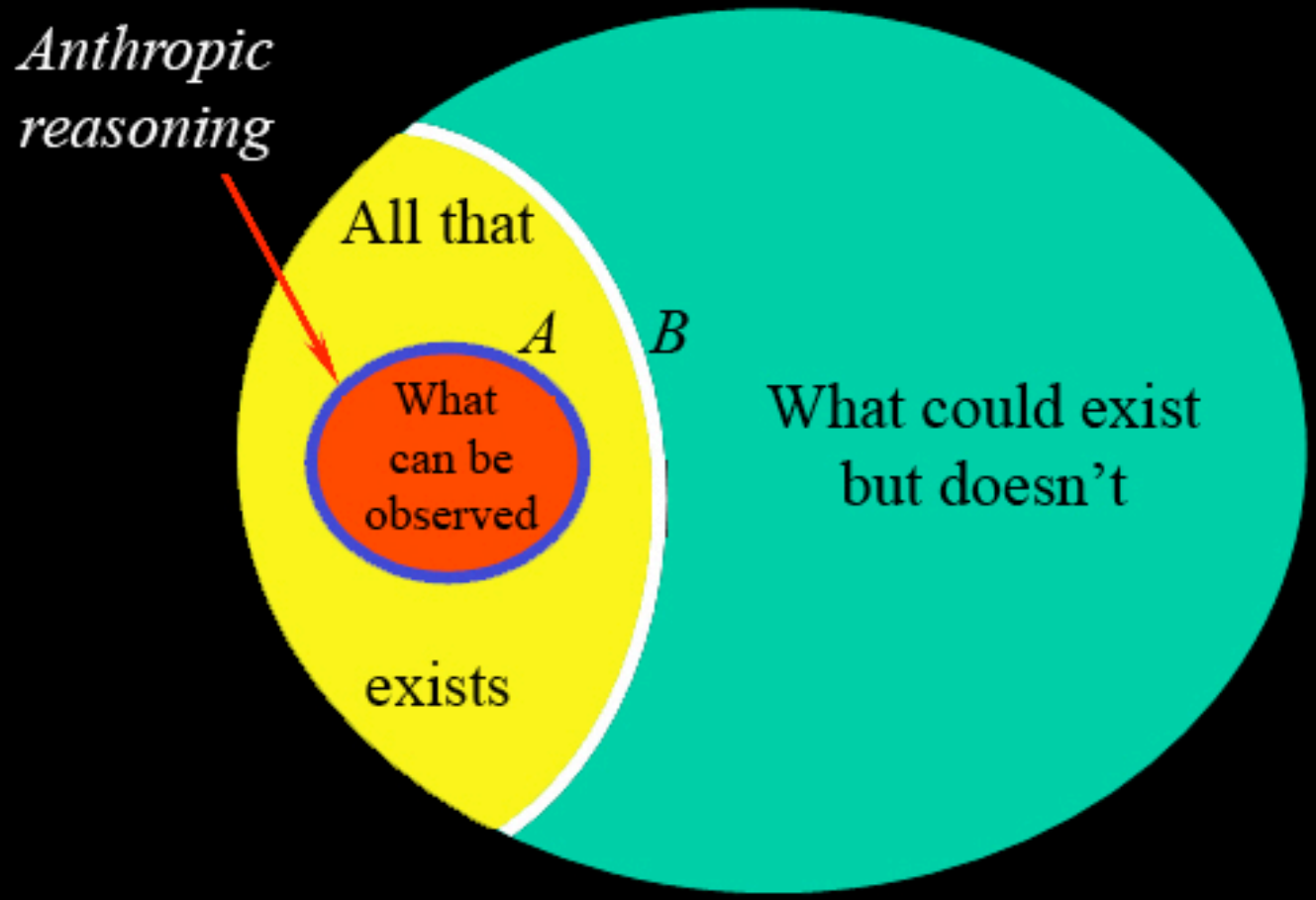
Superlaw + symmetry-breaking
(String theory Lagrangian, spacetime manifold,…)

Where do these meta-laws come from?

Why do they have the form that they do?

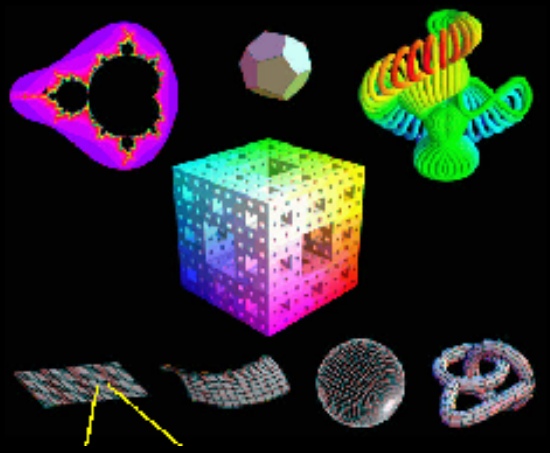
Do they exist reasonlessly? Is the *multiverse* absurd?

The outer limits of existence



The problem of "The Rule"

Only two "natural" states of affairs:



Nothing exists

Everything exists
(including all possible gods)

If less-than-everything exists then there must be a rule that divides "what exists" from "what can exist but doesn't"

Where does the rule come from?

What *that* rule?

What is it that breathes fire into the equations and makes a universe for them to govern? …

Problems with multiverses

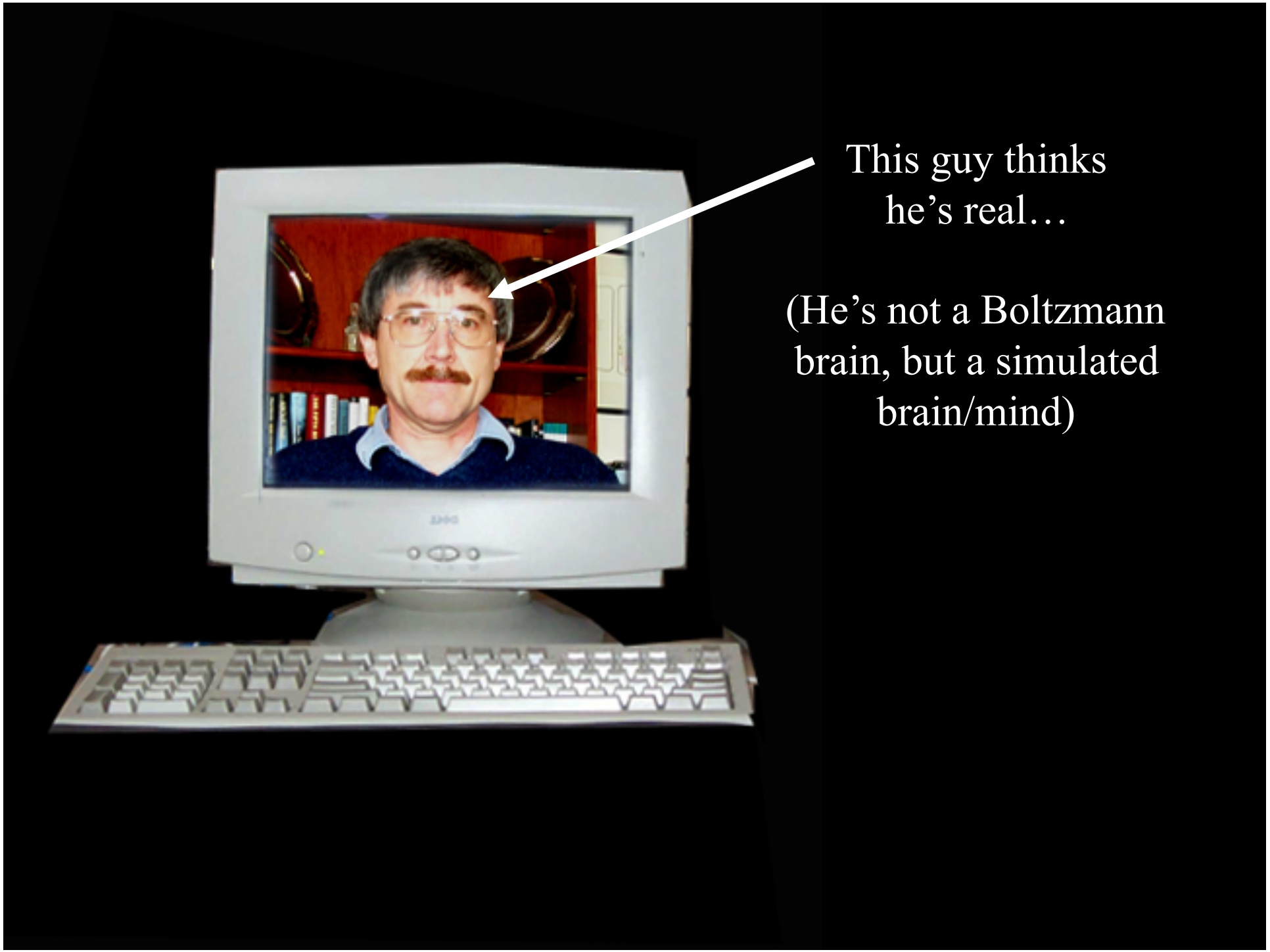
Duplicate beings

$10^{10^{29}}$ m

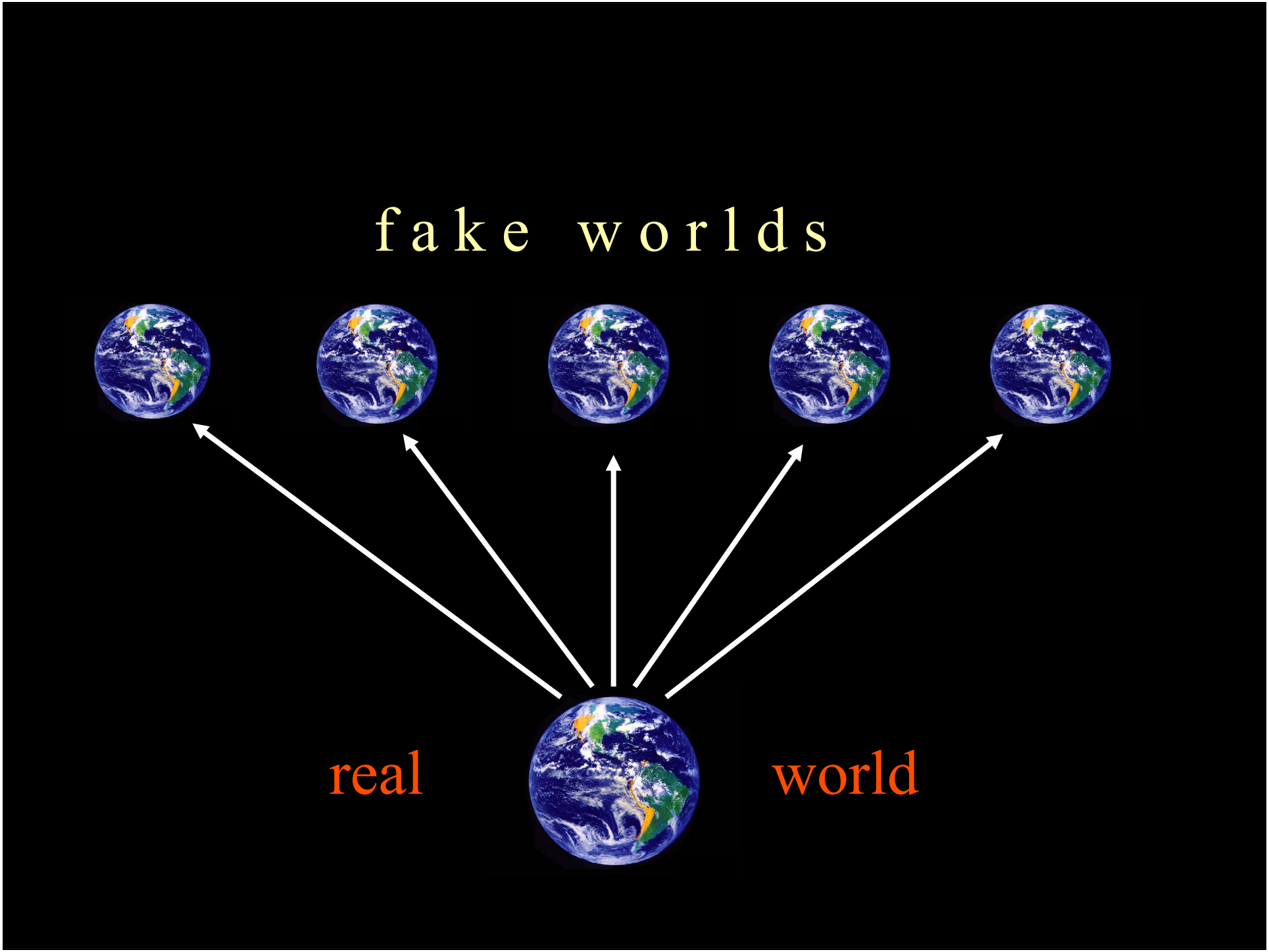
Duplicate universes

$10^{10^{120}}$ m

it gets worse...

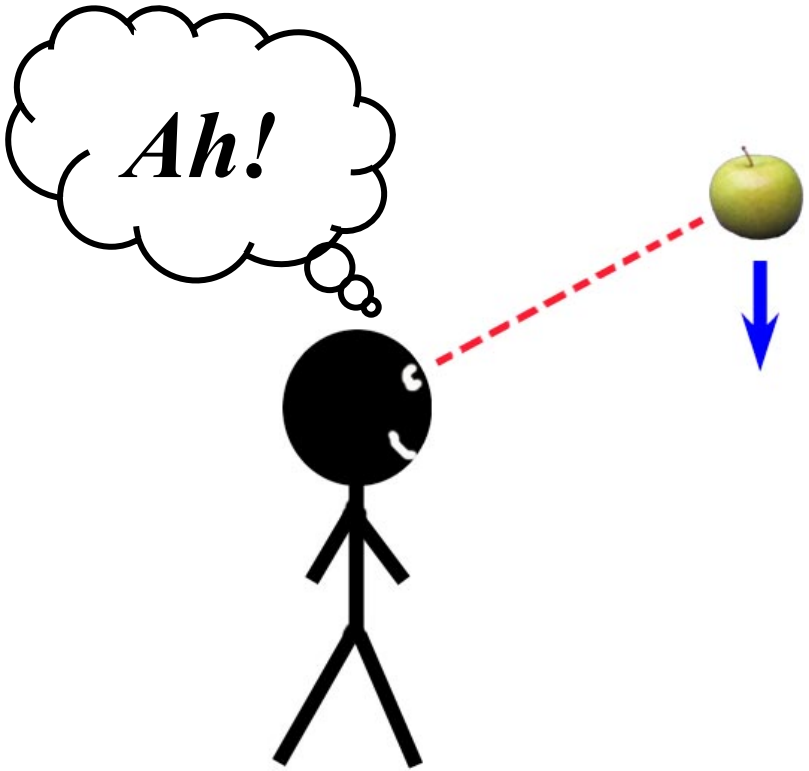

This guy thinks
he's real…
(He's not a Boltzmann
brain, but a simulated
brain/mind)


The Matrix


fake worlds
real
world

Will the real universe please stand up?

Two types of knowledge



1. Direct knowledge

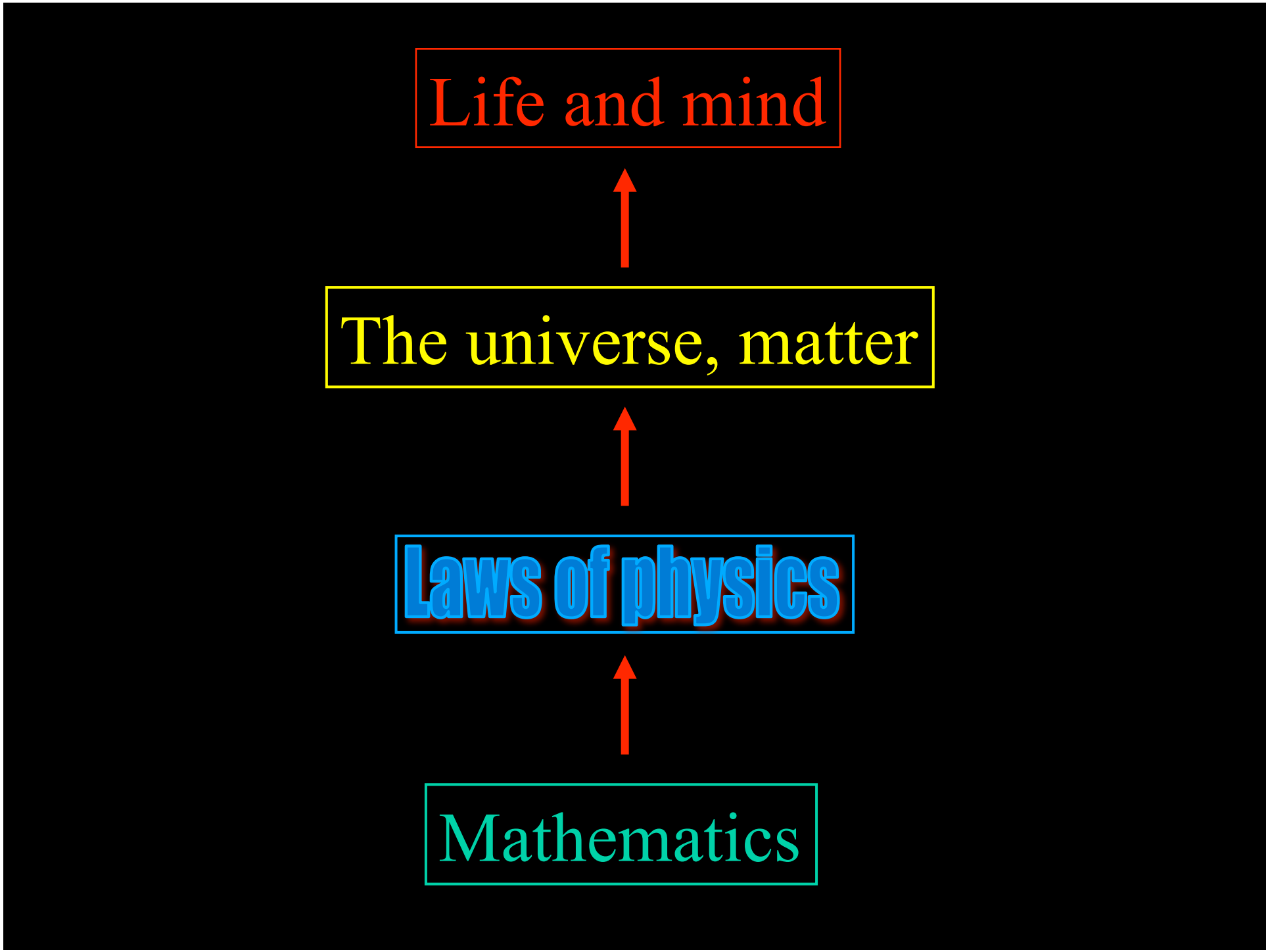
2. Theoretical *understanding*

$$md^2r/dt^2 = - GMm/r^2$$

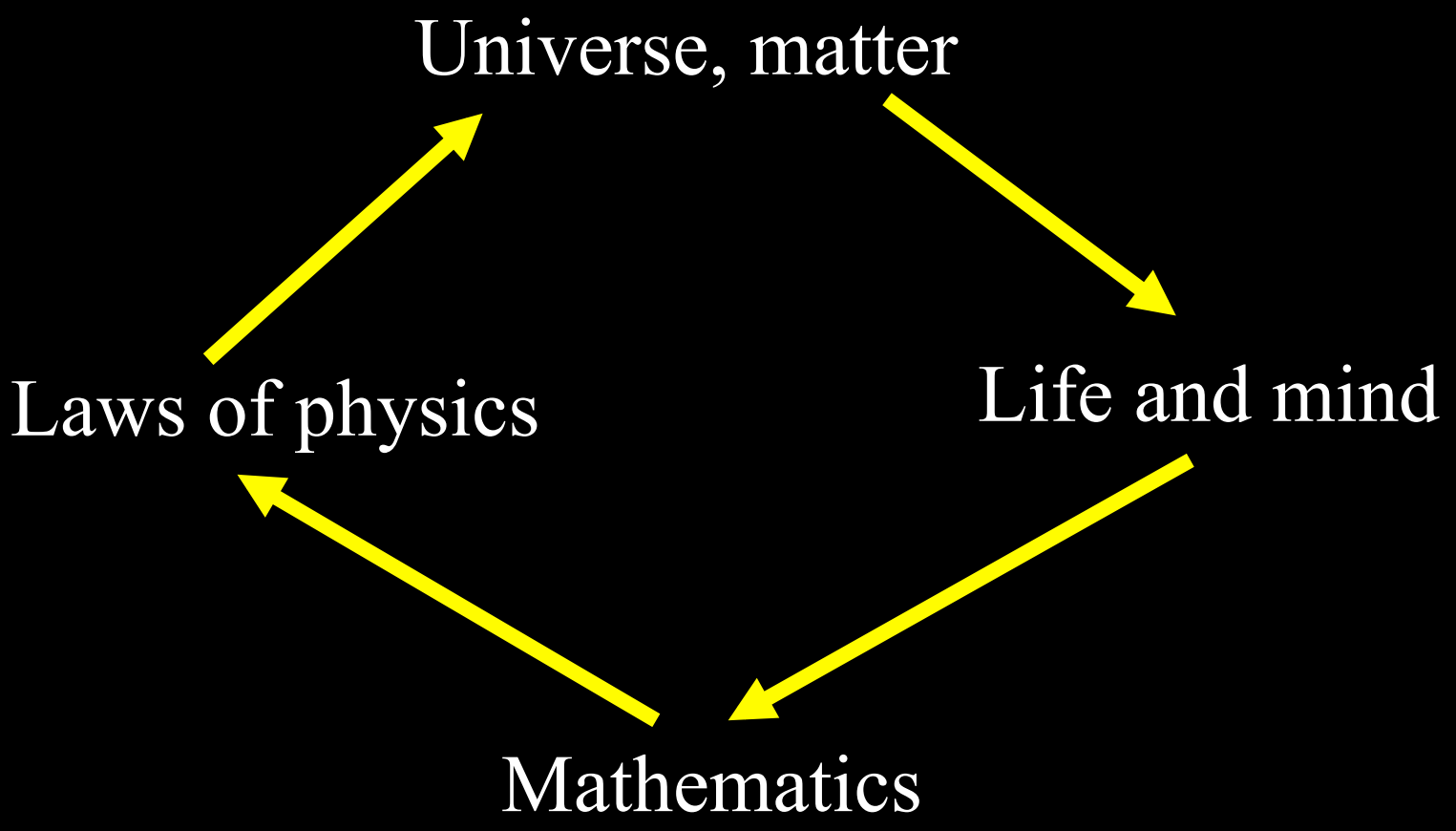
Why can we do cosmology anyway?

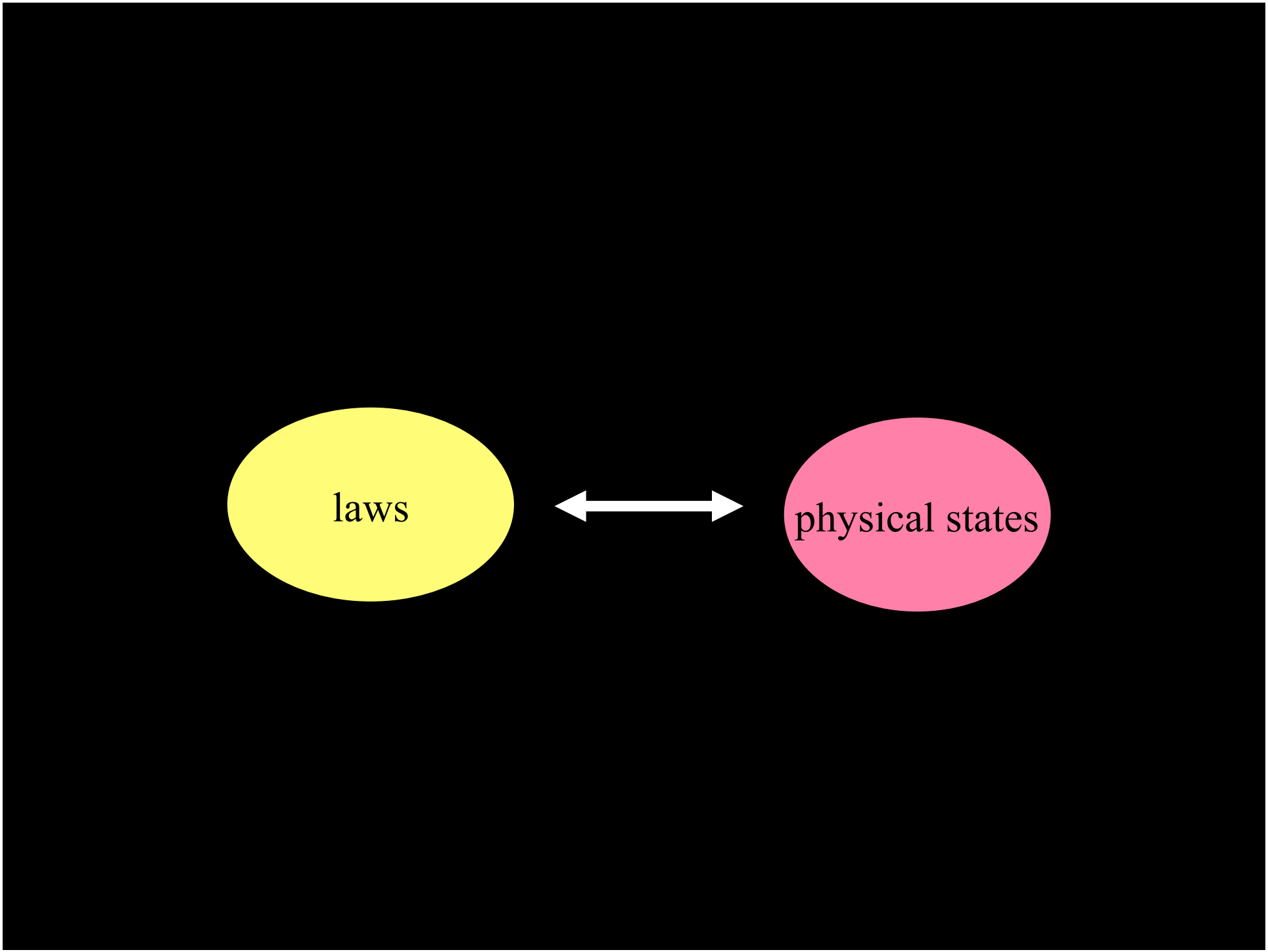
What is the logical structure of a world that permits a subset of itself to comprehend the whole?

“Inference machines” – David Wolpert


Life and mind
The universe, matter
Laws of physics
Mathematics

Self synthesizing, self-explaining reality




laws
physical states

Where do the laws of physics come from?

The universe “self-organizes” its own laws,
just as it self-organizes matter.

The laws are emergent *with* the universe.

Charles Peirce
1839-1914

Natural laws are an evolutionary product

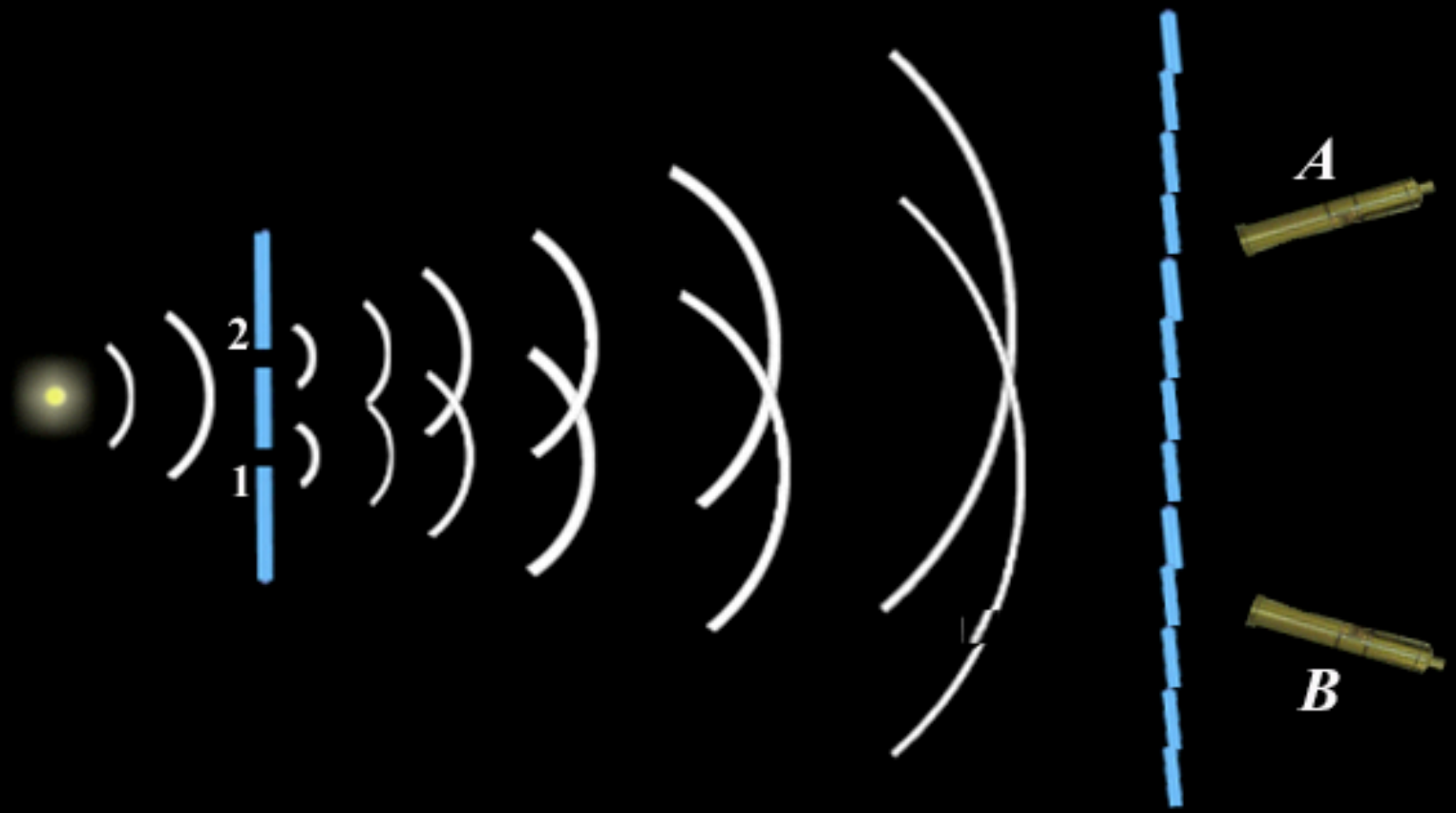
John Wheeler
1911-2008

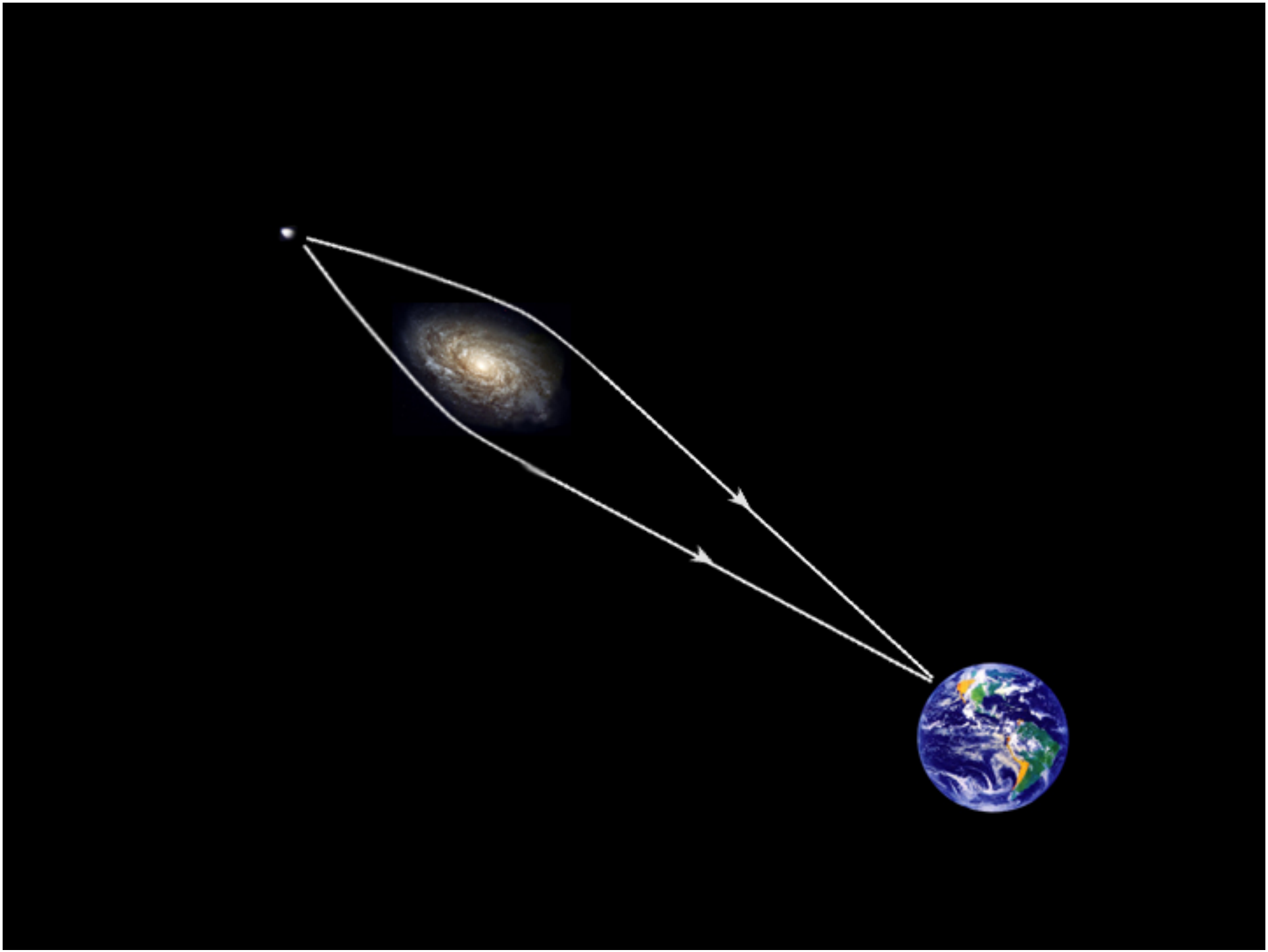
Wheeler's law:

"There is no law except the law that there is no law"

Turtle loop

Delayed choice experiment






"It is feasible and even suggestive to consider an extension of quantum mechanics to include both a wavefunction arriving from the past and a second 'destiny' wavefunction coming from the future."
Yakir Aharonov

Quantum mechanics: Two forms of evolution

- Unitary $U(t_f,t_i)|\psi(t_i)\rangle = |\psi(t_f)\rangle$

(which is reversible)

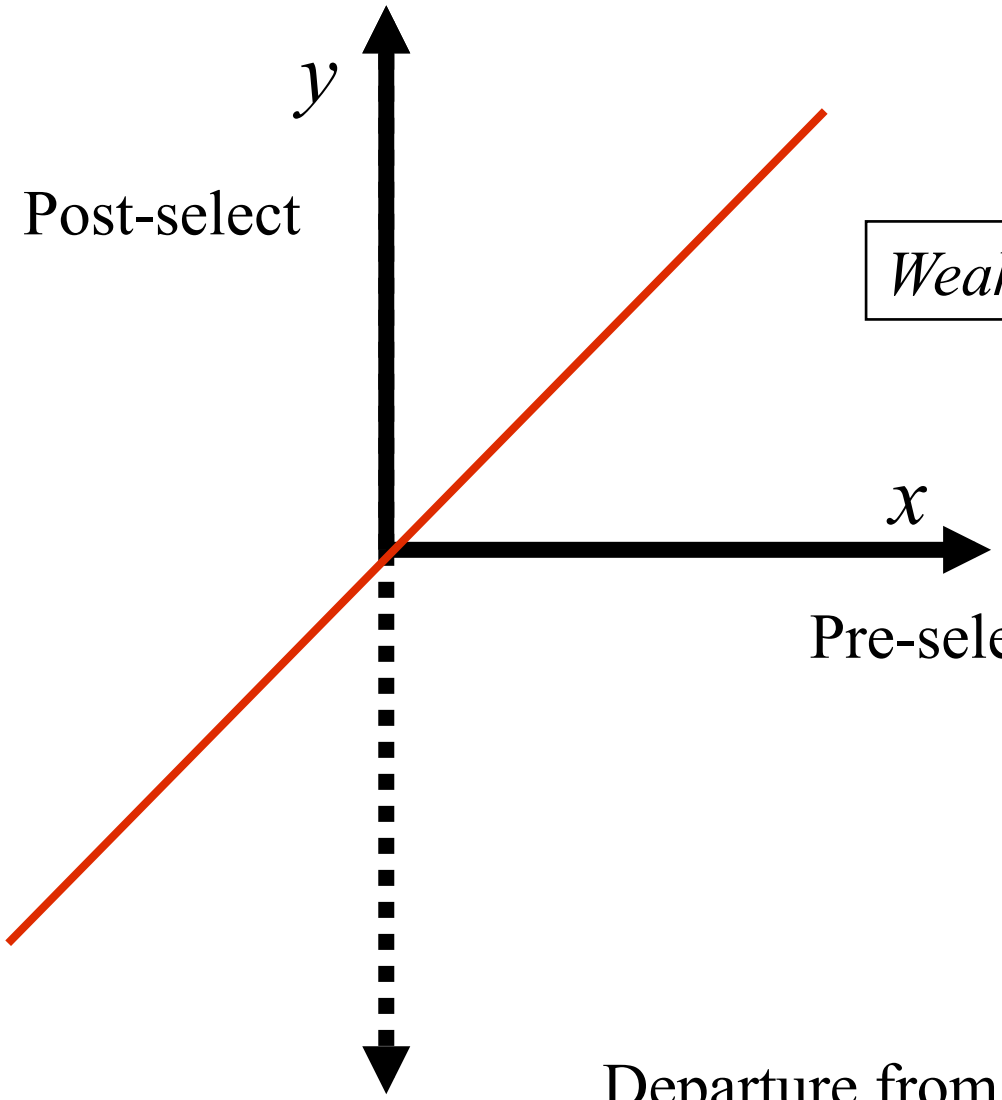
- "Collapse"

$$|\psi\rangle = \Sigma\, c_n|\phi_n\rangle \rightarrow |\phi_i\rangle$$

(which is *irreversible*)

System is incomplete unless both an *initial* and a *final* condition are specified.

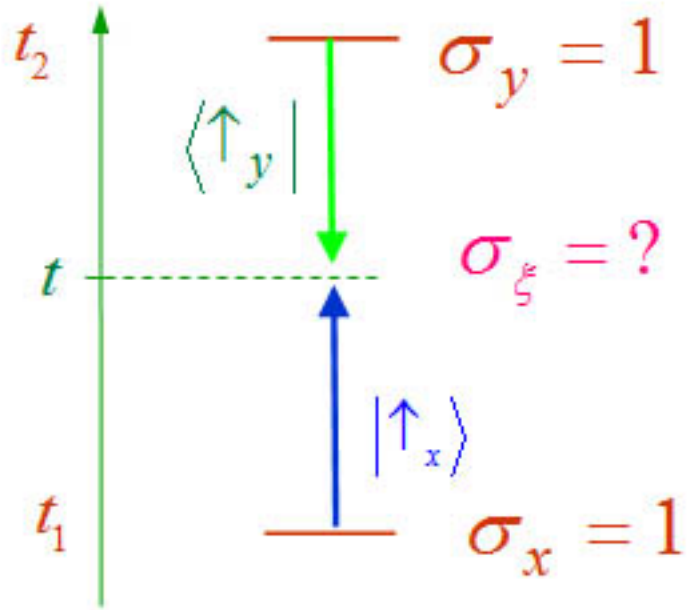
Pre- *and* post-selection



Weak measurement

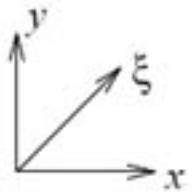
Departure from the Born rule

Weak values with pre- *and* post-selection



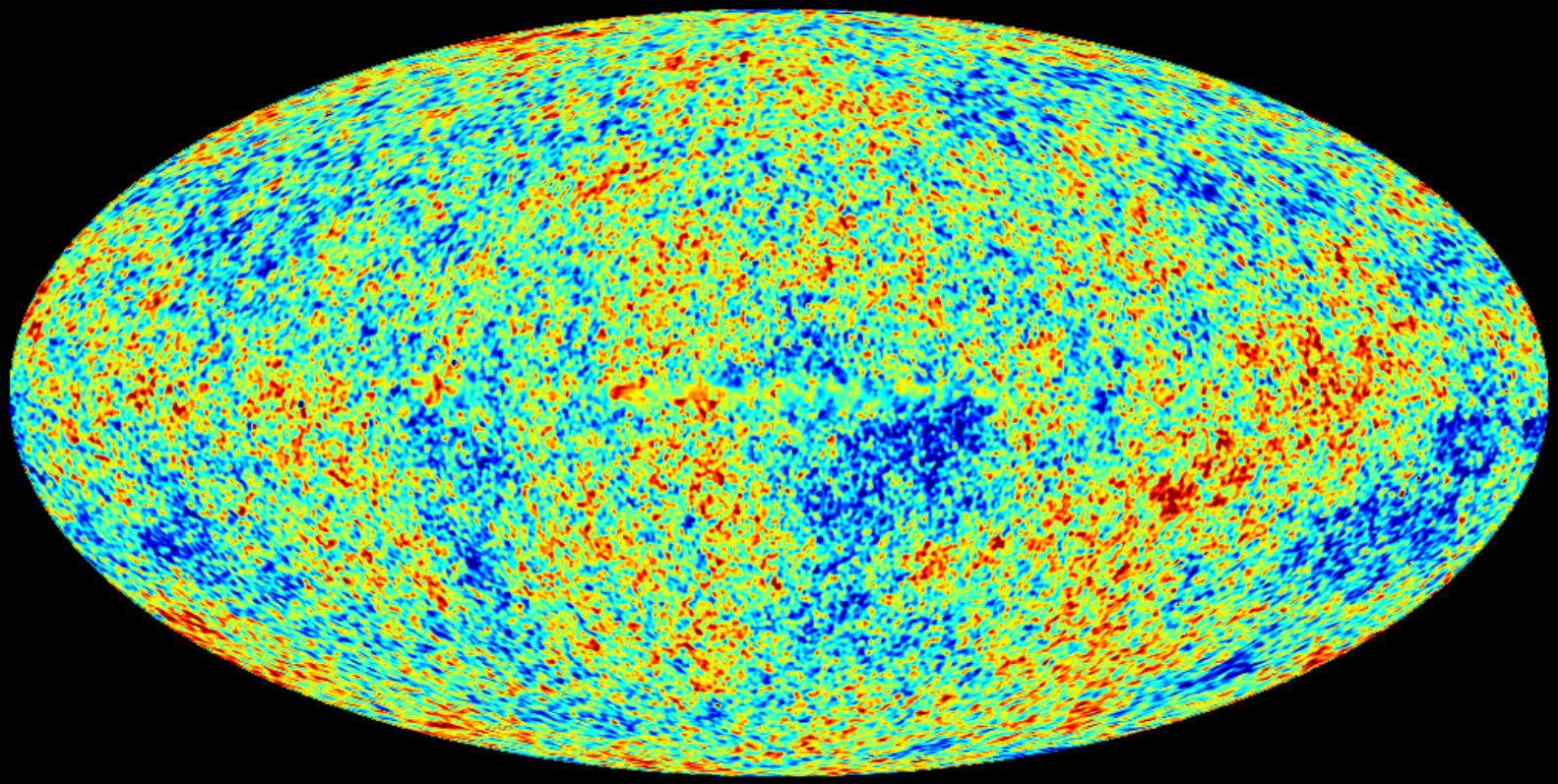
$$C_w \equiv \frac{\langle \Phi | C | \Psi \rangle}{\langle \Phi | \Psi \rangle}$$

$$\sigma_\xi \equiv \frac{\sigma_x + \sigma_y}{\sqrt{2}}$$



$$(\sigma_\xi)_w = \frac{\langle \uparrow_y | \sigma_\xi | \uparrow_x \rangle}{\langle \uparrow_y | \uparrow_x \rangle} = \frac{\langle \uparrow_y | \frac{\sigma_x + \sigma_y}{\sqrt{2}} | \uparrow_x \rangle}{\langle \uparrow_y | \uparrow_x \rangle} = \sqrt{2}$$

compare eigenvalues ±1



CMB contains a relic of quantum fluctuations from inflation

Does it also contain a quantum “relic” from the far future?

Conclusion

The richness and complexity of “our world” is the product of a creative synergy between the forward and backward propagating wave functions. Extend this concept from the domain of quantum states to the domain of underlying laws and principles.