Title: Ultimate Explanations, Turtles and the Nature of the Laws of Physics

Date: Sep 02, 2008 08:30 AM

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Abstract:

A DEBATE IN COSMOLOGY
THE MULTIVERSE

PI

PERIMETER INSTITUTE FOR THEORETICAL PHYSICS
SEPTEMBER 2 - 4, 2008

The purpose of this meeting is to provide a forum for scientists from various fields to discuss, debate, and stimulate progress on one of the emerging fundamental areas of theoretical physics - the idea that our observable universe is part of a multiverse.

This conference is a collaborative effort between Columbia University, Perimeter Institute and University of North-Carolina-Chapel Hill, and is the second of a series of meetings aimed at stimulating progress in outstanding topics in theoretical physics. The first meeting in this series focused on the Origin of the Arrow of Time and was held at the New York Academy of Sciences last October.

www.perimeterinstitute.ca/multiverse

ORGANIZERS

Brian Greene, Columbia University

Justin Khoury, Perimeter Institute

Laura Mersini-Houghton, University of North Carolina-Chapel Hill

SPEAKERS

David Albert, Columbia University

Andy Albrecht, UC Davis

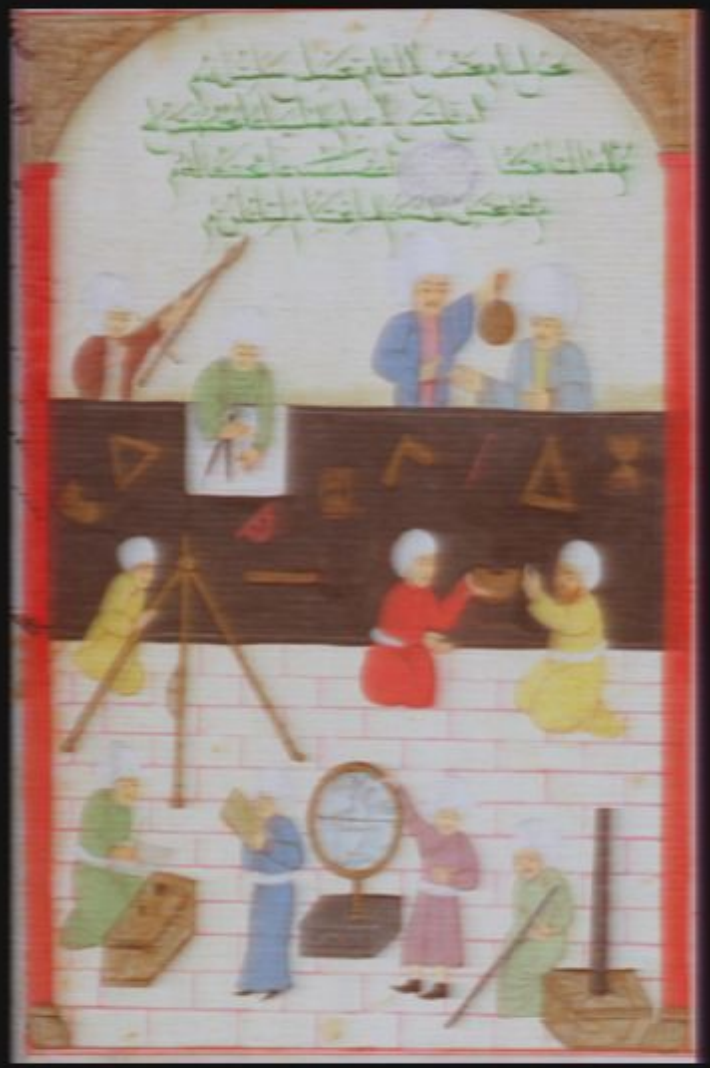
A Debate in Cosmology: The Multiverse

Perimeter Institute
June 2-4, 2008
Schedule

Tuesday, September 2nd

Time	Event or Speaker	Topic	Location
8:15	Registration		Atrium
8:30 – 10:00	**Paul Davies**	Ultimate Explanations, Turtles and the Nature of the Laws of Physics	Bob Room
10:00 – 10:30	Coffee Break		Black Hole Bistro
10:30 – 12:00	**James Hartle**	Science in a Very Large Universe	Bob Room
12:00 – 2:00	Lunch		Black Hole Bistro
2:00 – 3:30	**Laura Mersini-Houghton**	What is the Multiverse?	Bob Room
3:30 – 4:00	Coffee Break		Black Hole Bistro
4:30 – 6:00	**Lev Kofman**	Collapsing and Expanding Multiverse	Bob Room
6:00	Reception		Black Hole Bistro

Ultimate explanations, turtles and the nature of the laws of physics

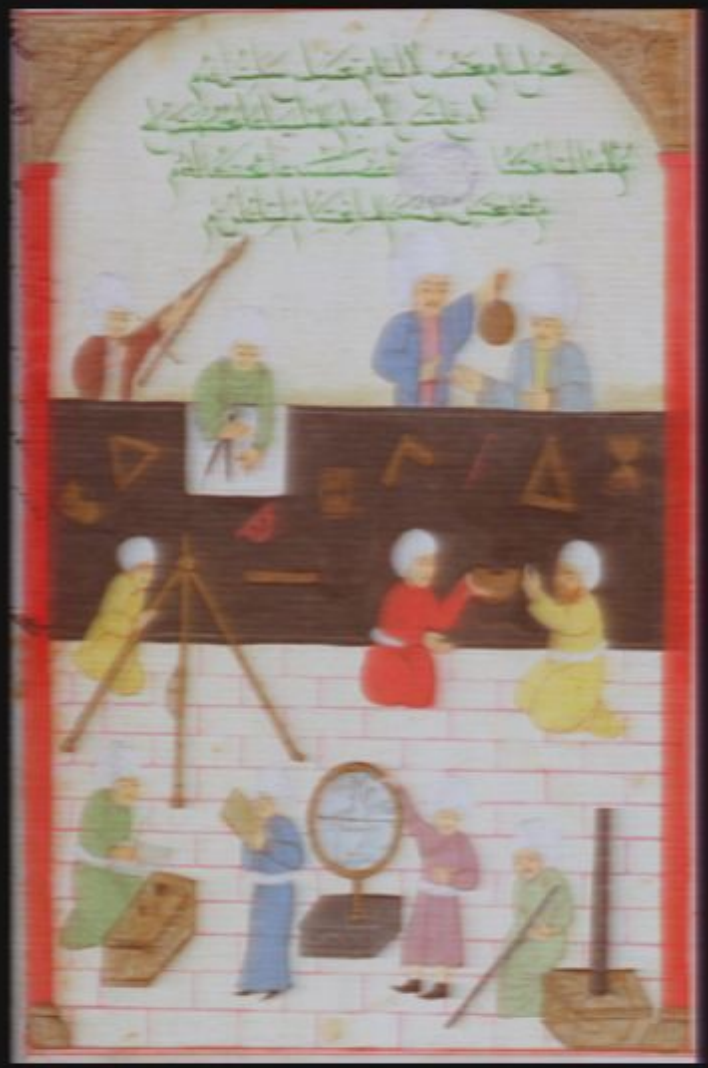


Paul Davies

BEYOND:
Center for Fundamental Concepts in Science

Arizona State University

Ultimate explanations, turtles and the nature of the laws of physics



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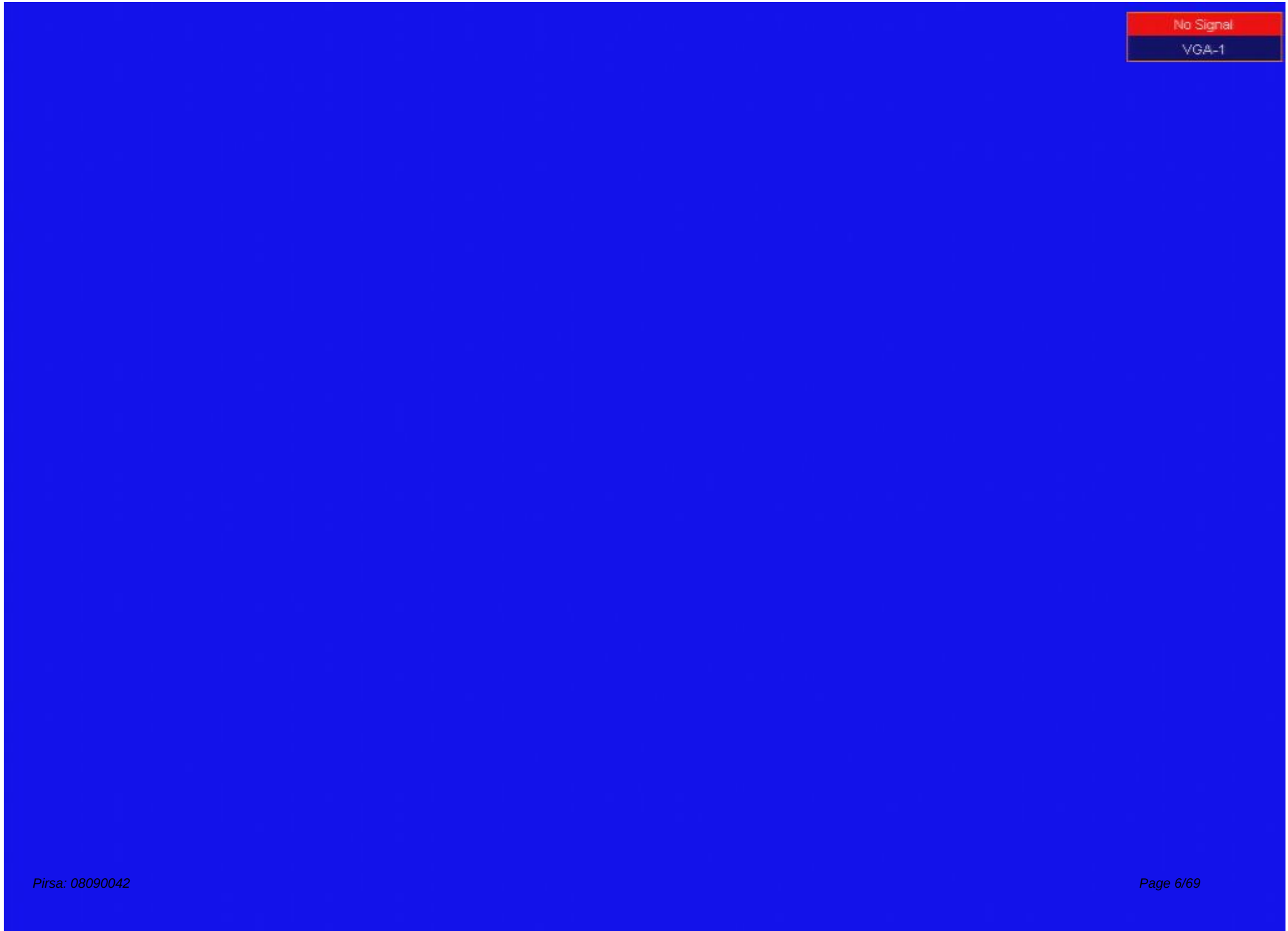
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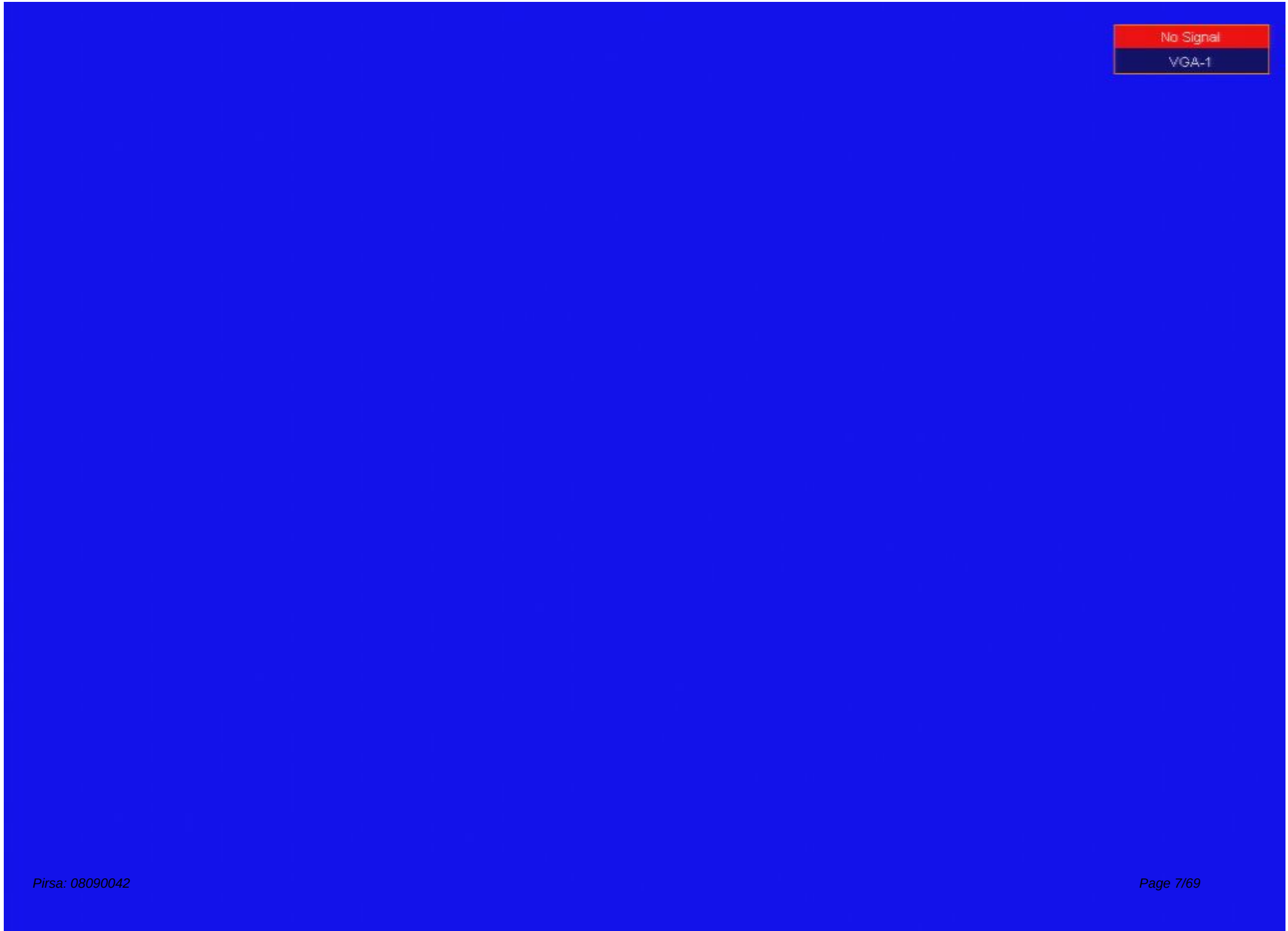
VGA-1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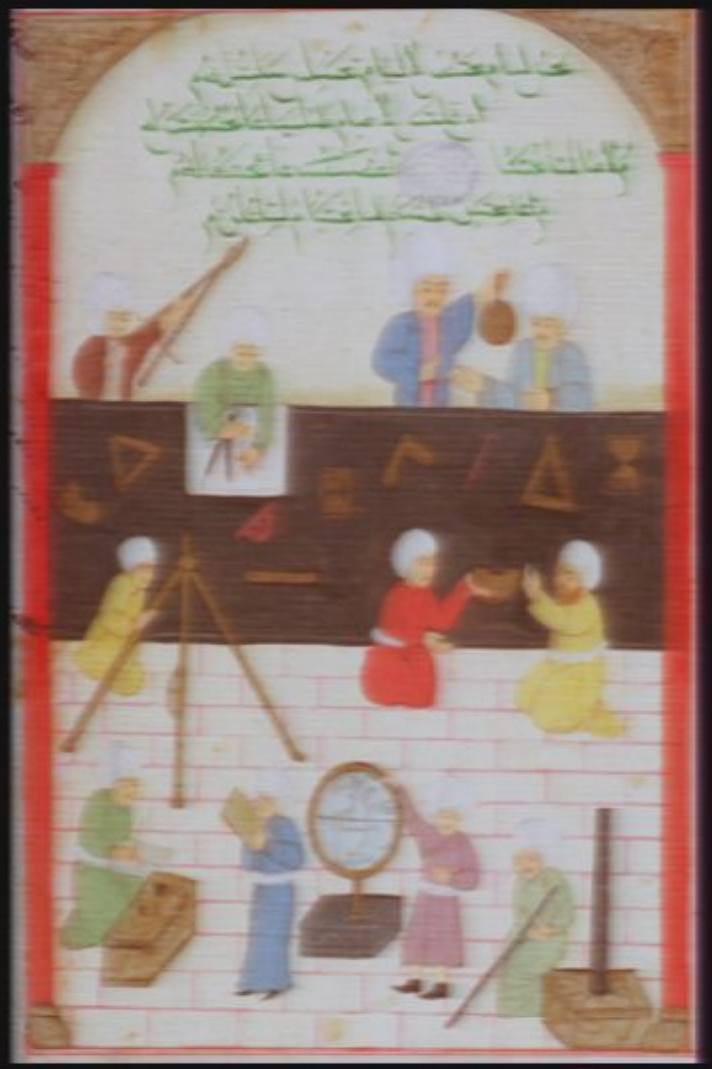
Ultimate explanations, turtles and the nature of the laws of physics



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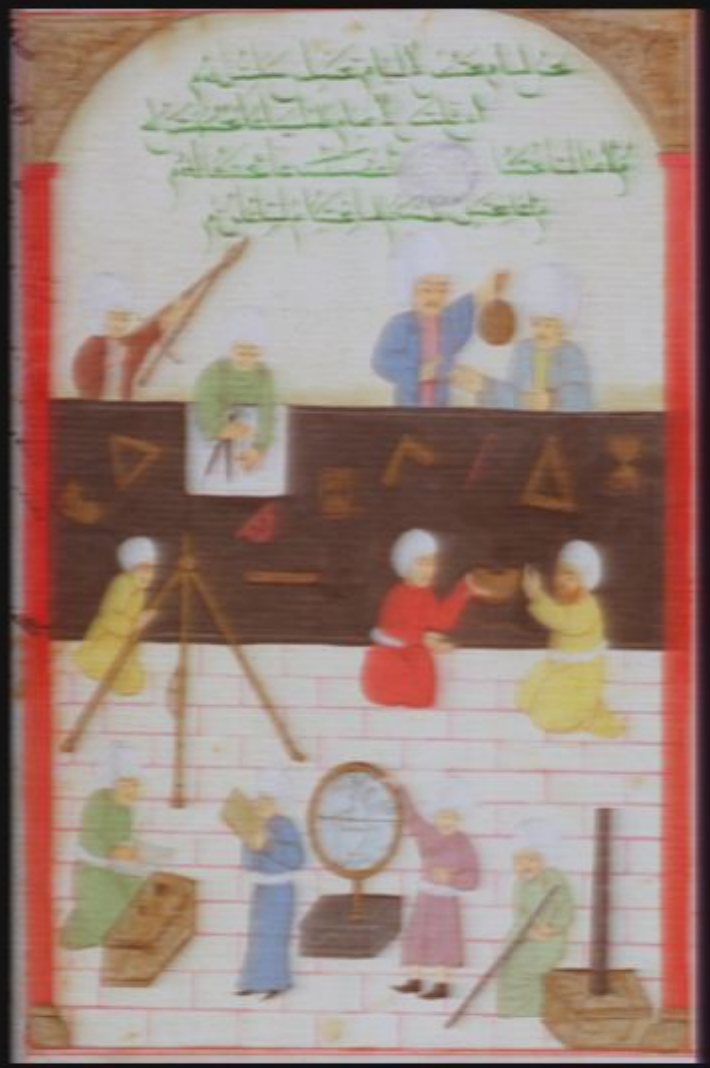

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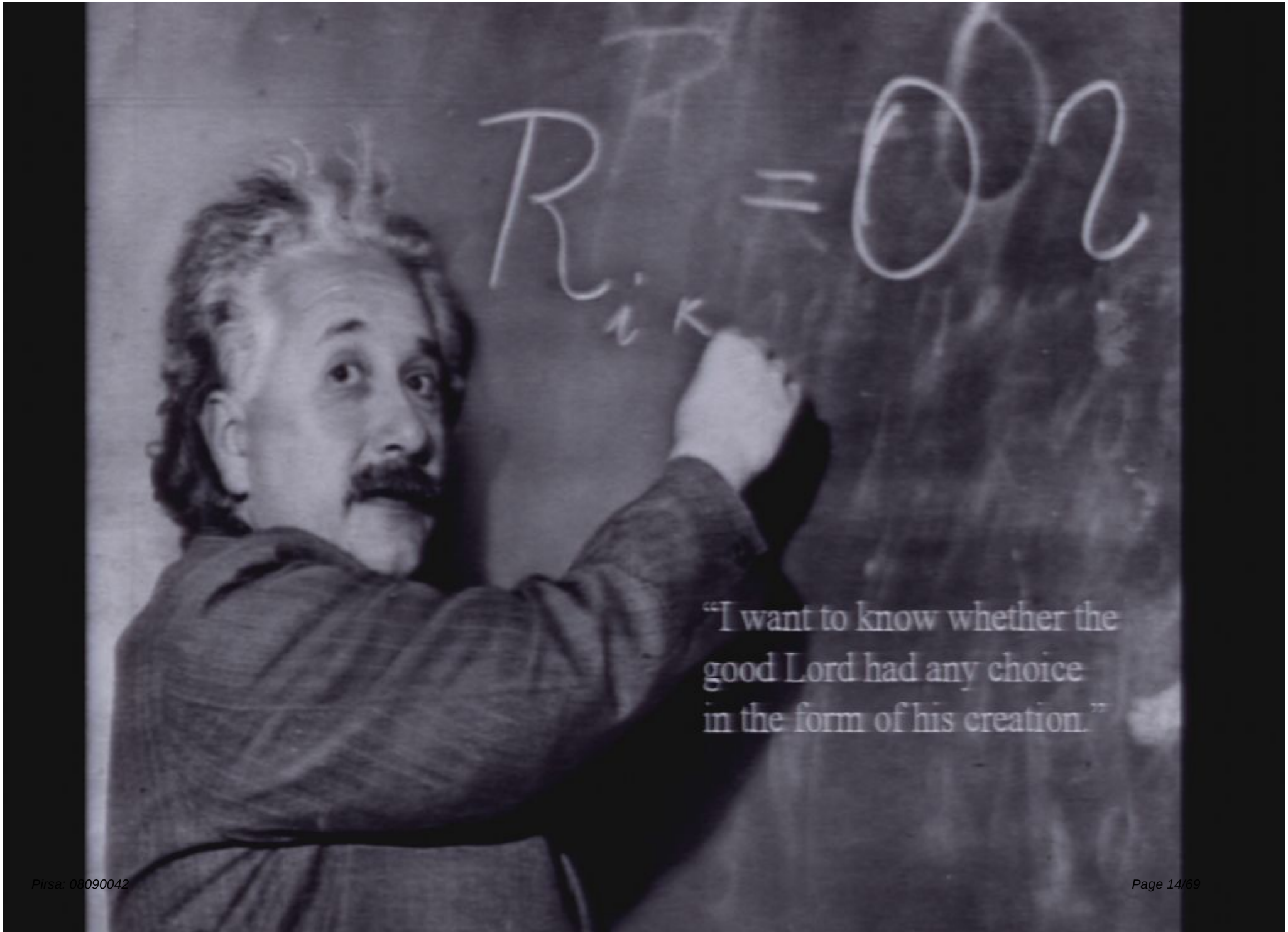
Turtles all the way down...

Superturtle!


Superturtle!
Self-explanatory
or absurd


$R_{ik} = 0?$
"I want to know whether the
good Lord had any choice
in the form of his creation."

* Could the laws of physics have been different?

* If so, why do they have the form that they do?

* Is there anything distinctive about the observed laws?

* Could the laws of physics have been different?

* If so, why do they have the form that they do?

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Can there be a theory of laws?

Subsidiary questions:

Why are they mathematical?

Where does mathematics come from?

How did the universe come to exist? Is it the only one?

Why is the universe comprehensible to humans?

How come existence? Can *science* alone explain it all?

Do the answers lie within the universe or beyond it?

Is the universe ultimately absurd, or is there a reason for it all?

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
- Beyond the scope of physics: "given"

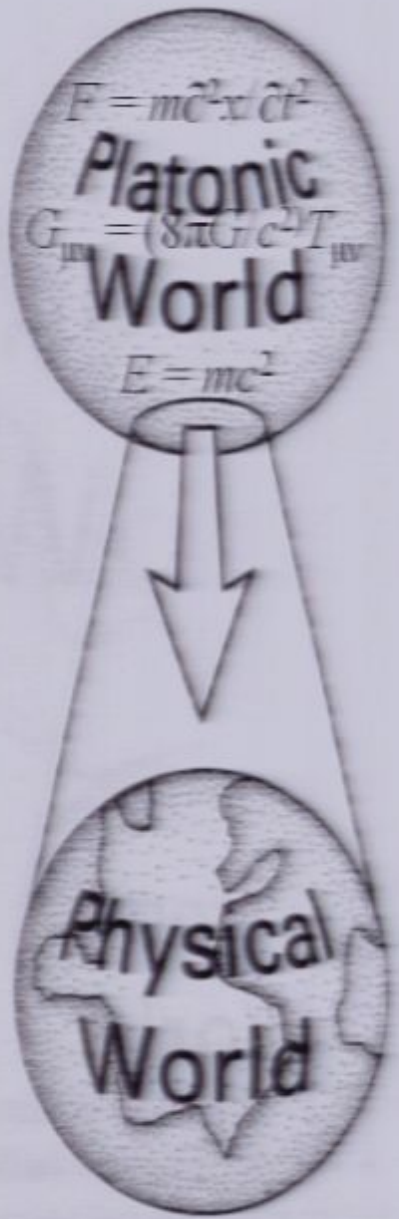
Orthodox view concerning the origin of the laws of nature

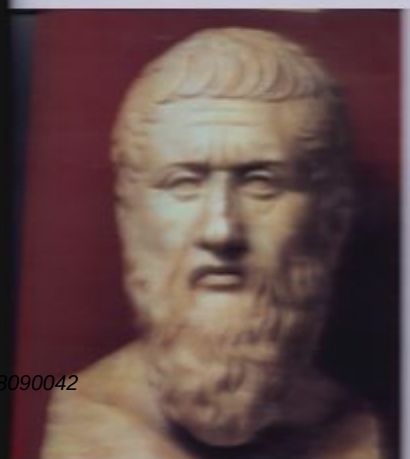
- The laws exist reasonlessly
- They must be accepted as a brute fact, "on faith"
- Their origin is beyond the scope of science
- Asking "why those laws" is not a scientific question and is to be strongly discouraged!

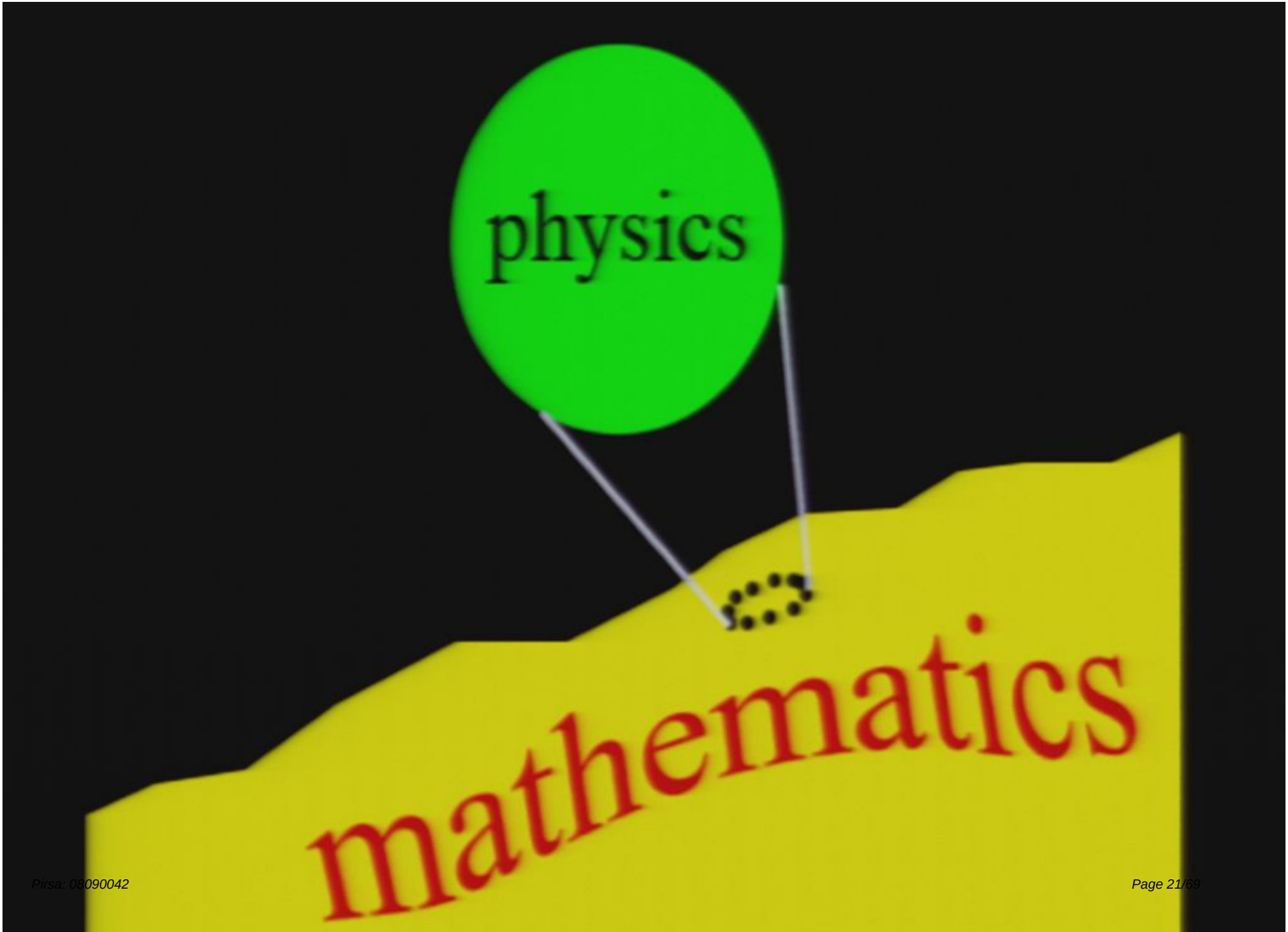
"There is a chain of explanations concerning things that happen in the universe, which ultimately reaches to the fundamental laws of nature and stops… at the end of the day the laws are what they are… that's okay. I'm happy to take the universe just as we find it."

Sean Carroll

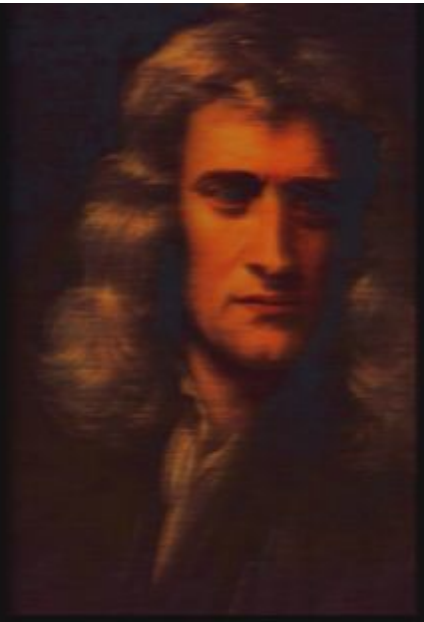
The nature of physical law

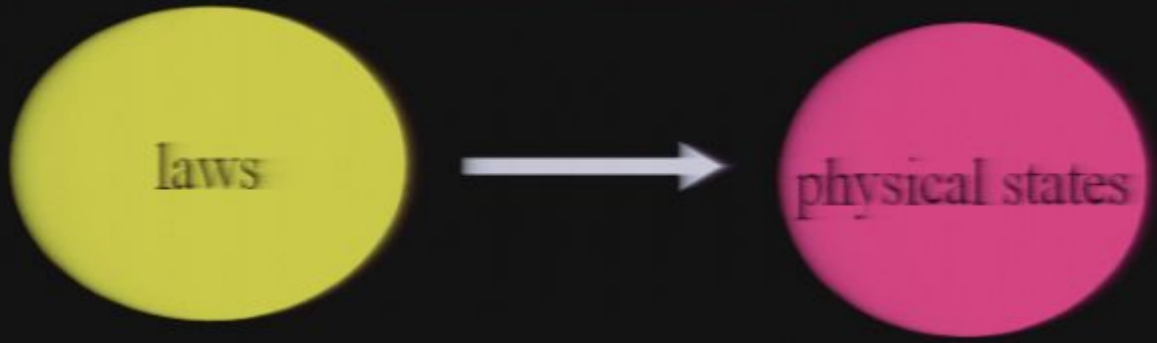




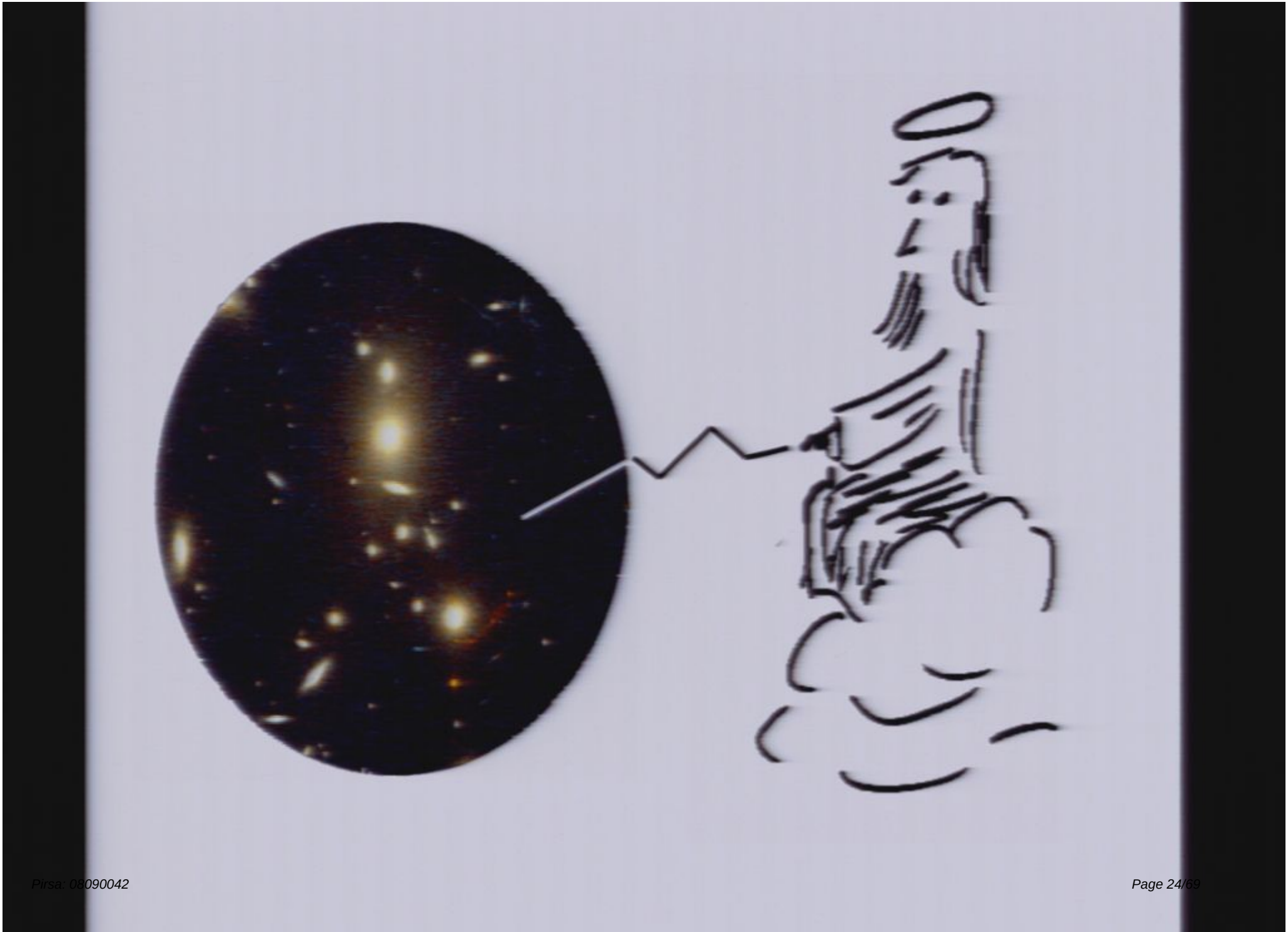

physics
mathematics


Mother
Nature

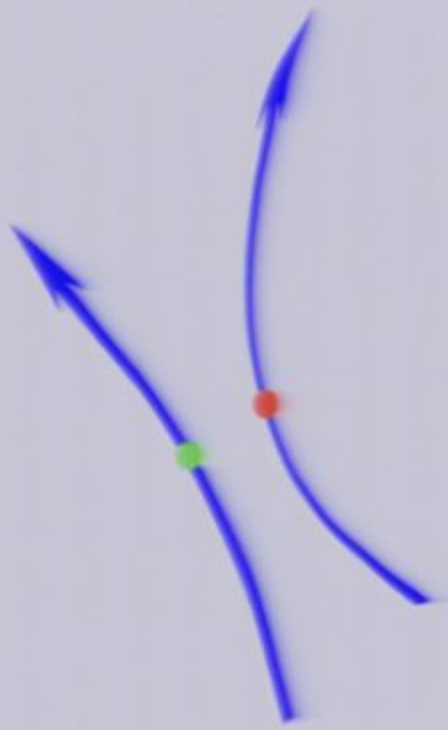




Newtonian dualism



Pierre Laplace



"An intellect which at any given moment knew all of the forces that animate nature and the mutual positions of the beings that compose it, if this intellect were vast enough to submit the data to analysis, could condense into a single formula the movement of the greatest bodies of the universe and that of the lightest atom; for such an intellect nothing could be uncertain and the future just like the past would be present before its eyes."

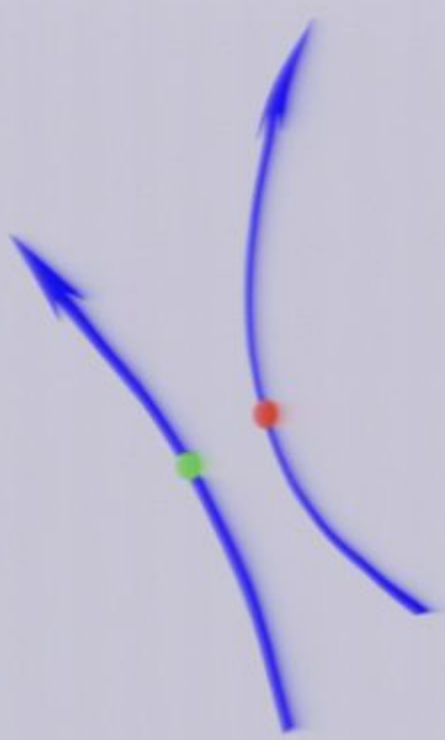
[I]t is God who has established the laws of nature, as a King establishes laws in his kingdom. . . . You will be told that if God has established these truths, he could also change them as a King changes his laws. To which it must be replied: yes, if his will can change. But I understand them as eternal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

Pierre Laplace



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Take home message

- After 300 years, the time has come to challenge this "theological" formulation of the laws of physics as immutable, eternal, infinitely-precise, transcendent truths, and to explore alternative models of physical law

A rational universe?

Bring the laws within the scope of physics

Instead of accepting the laws as "given", try to find a mechanism to explain them. Won't explain them so long as they are fixed, and imprinted from without

Treat laws as inherent in, and emergent with, the universe

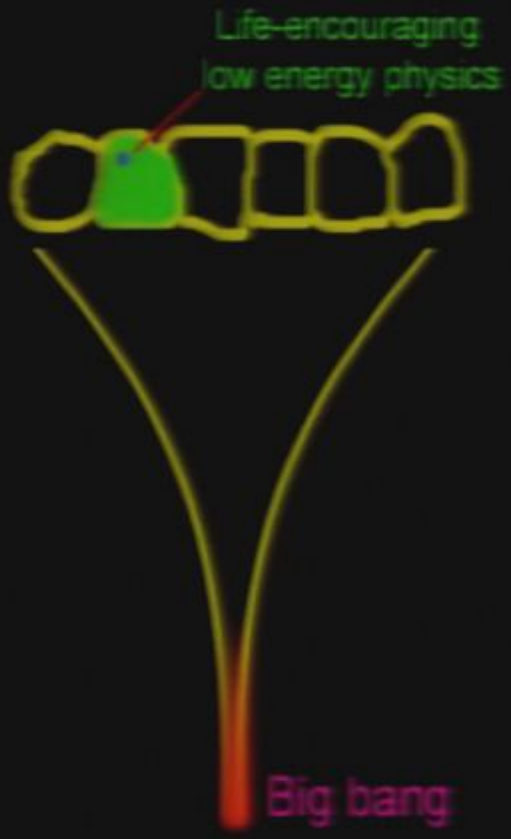
Restore the symmetry between laws and states

The Goldilocks Enigma

Why is the universe just right for life?

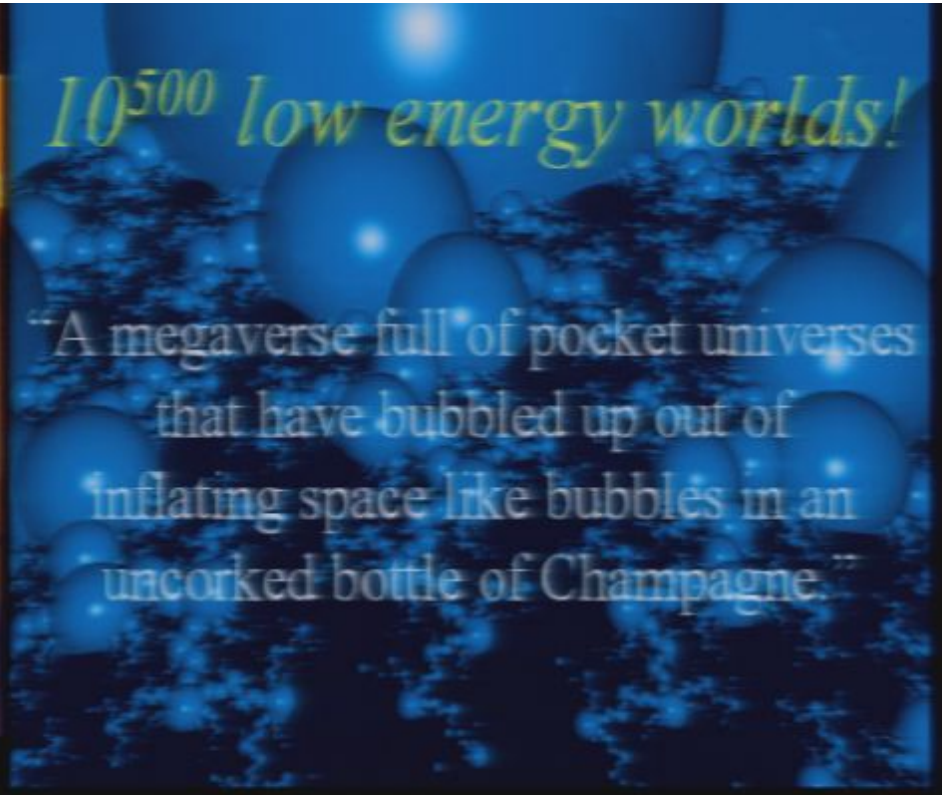
Martin Rees PRS

Cosmic domain structure



"The laws of physics
are just local by-laws"

Leonard Susskind

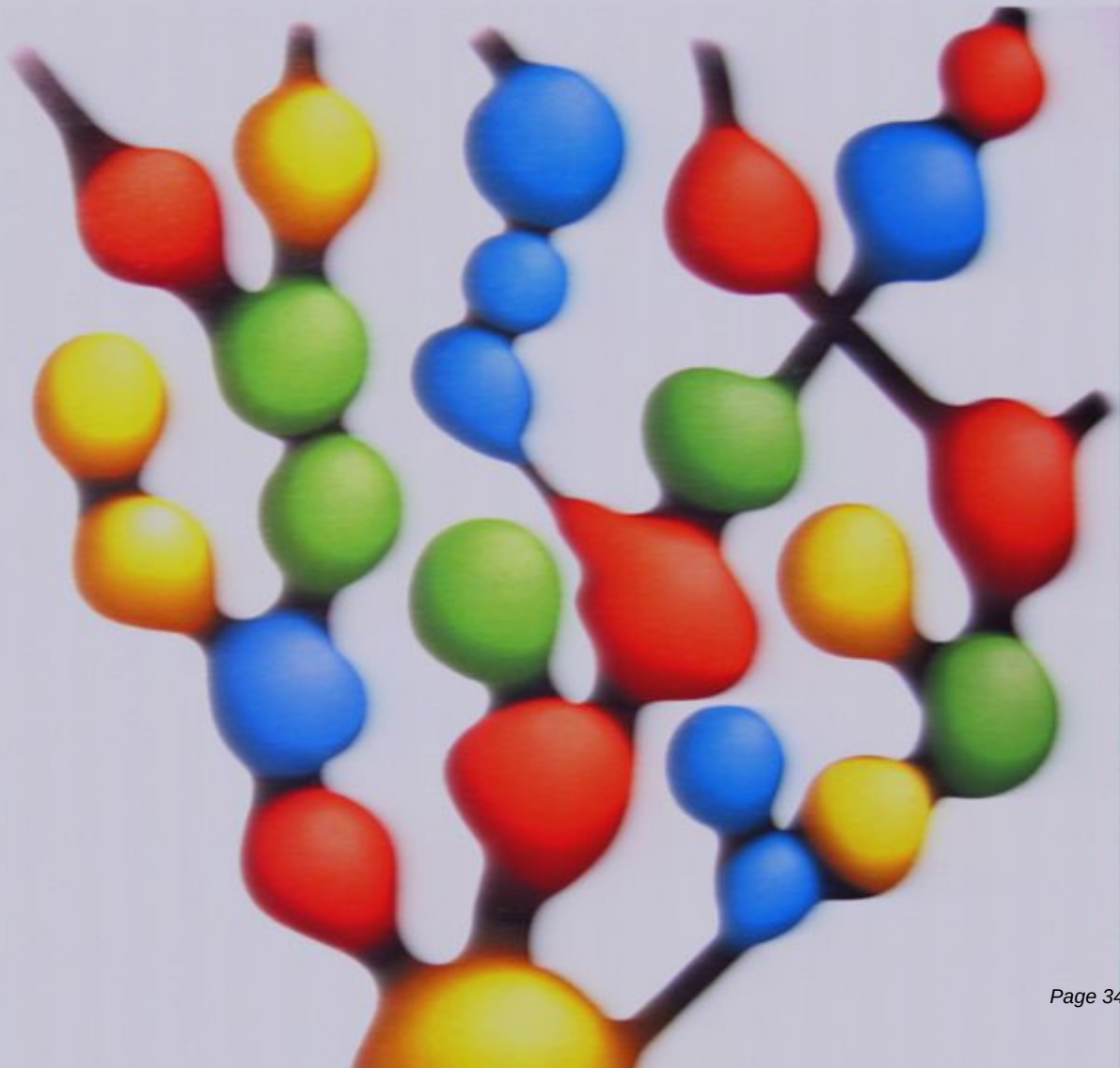


Landscape

Eternal inflation

Andrei Linde

TIME



This explanation is *incomplete*

Meta-laws

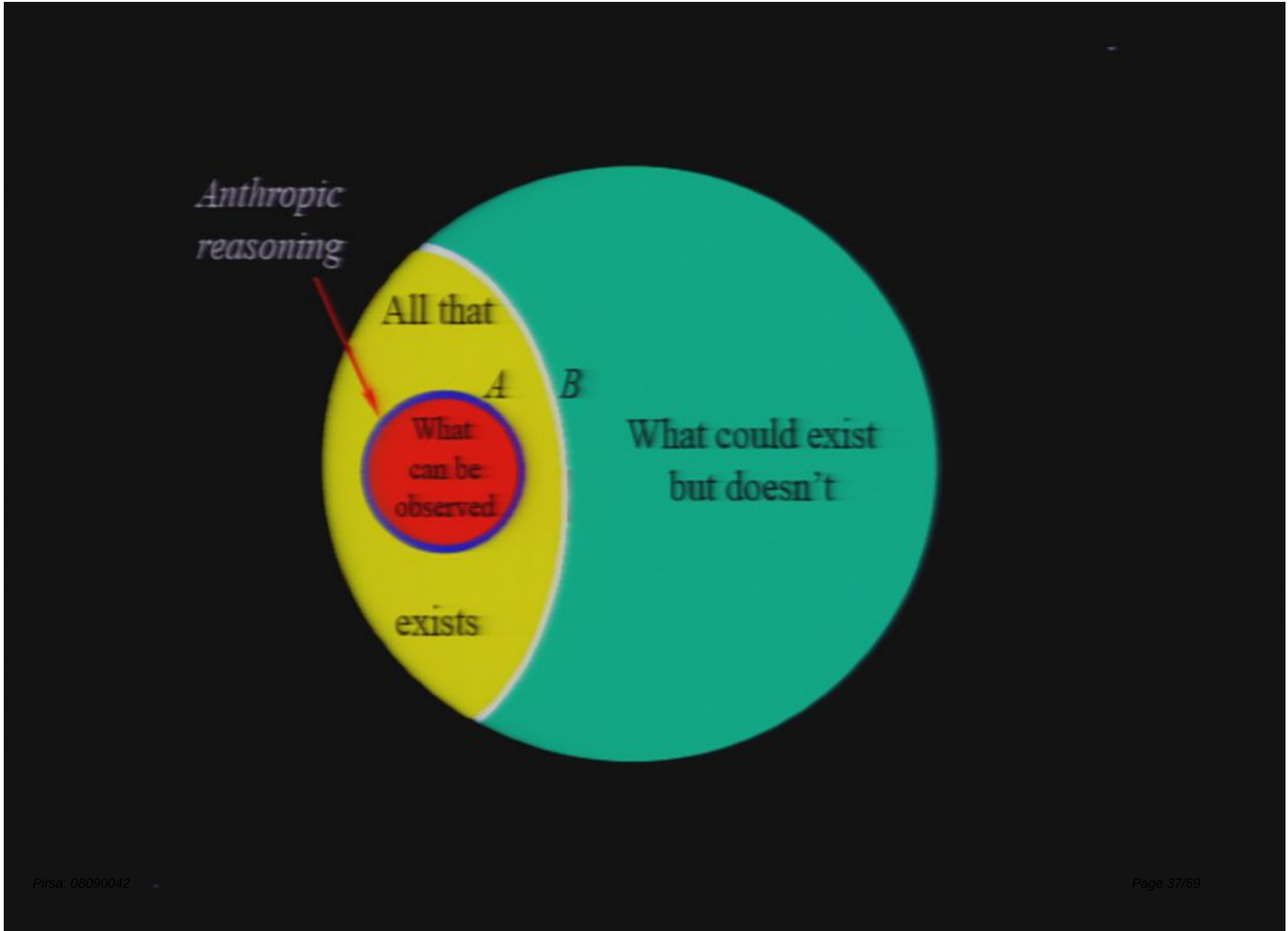
Universe-generating mechanism
(quantum mechanics, relativistic causality, etc.)

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 universe absurd?


Anthropic
reasoning
All that
A
B
What
can be
observed
What could exist
but doesn't
exists

The problem of "The Rule"

Only two "natural" states of affairs:

The problem of "The Rule"

Only two "natural" states of affairs:

Nothing exists

Everything exists (Tegmark)

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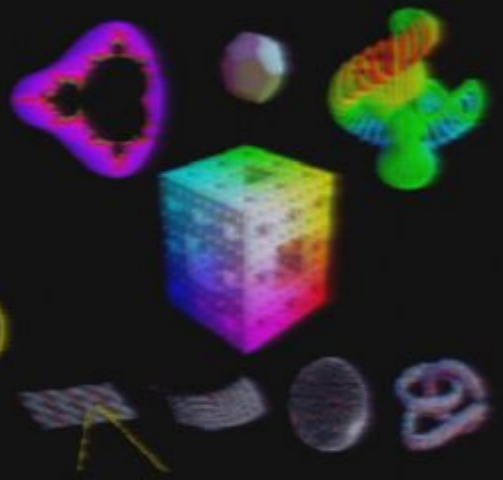

The problem of "The Rule"

Only two "natural" states of affairs:

Nothing exists

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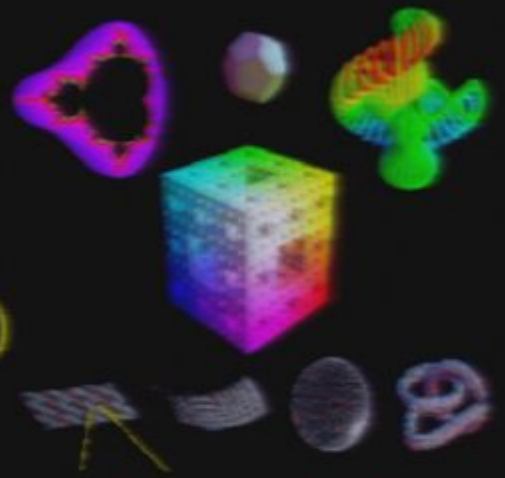

If less-than-everything exists then there must be a rule that divides "what exists" from "what can exist but doesn't"

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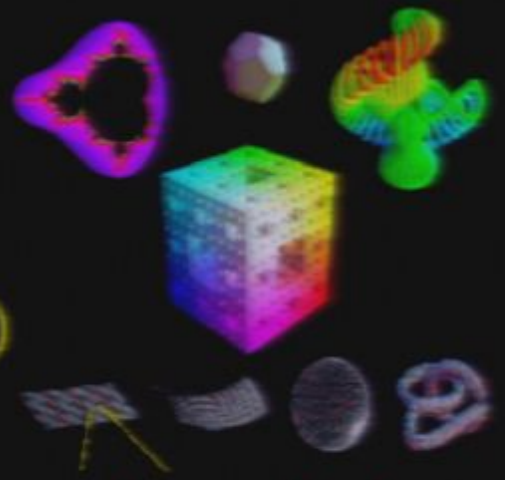

If less-than-everything exists then there must be a rule that divides "what exists" from "what can exist but doesn't"

Where does the rule come from?

What *that* rule?

The problem of "The Rule"

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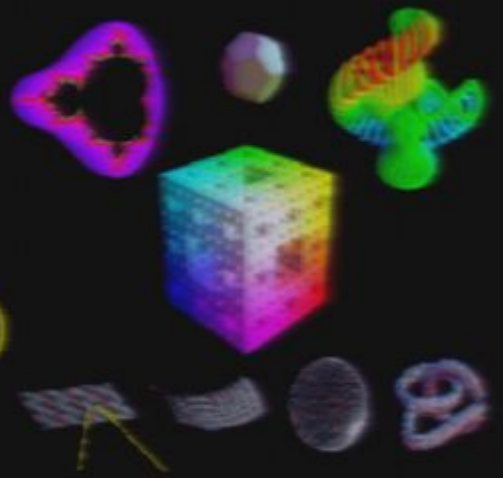


What is it that breathes fire into the equations and makes a universe for them to govern? …

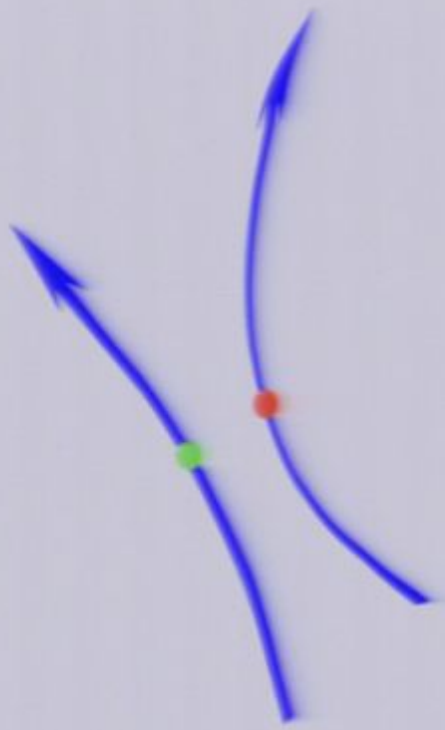
Weird laws

- Time-dependent laws (Peirce, Smolin)
- Non-local laws (Aharonov)
- Global principles (Mach, Penrose)
- Laws not derivable from an action principle (Robert Rosen)
- Time-asymmetric laws (Prigogine)
- Emergent laws (Wheeler, Ellis)
- Finite accuracy laws (Landauer, Benioff)
- Statistical laws (Nielson)
- Laws of initial conditions (Hartle & Hawking, Gell-Mann)
- State-dependent laws (weak – Susskind, strong – Davies)
- Acausal laws (Pauli & Jung)
- Teleological laws (Aristotle, d'Alambert)
- No laws! (Sciama, Wheeler)

Challenging the orthodox 300 year-old (theological) notion of physical law

- 1. Infinite precision
- 2. Immutability
- 3. Transcendence

Pierre Laplace



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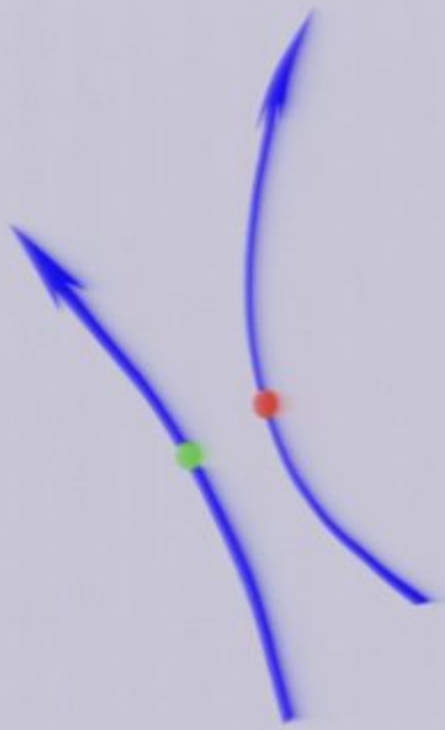

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Absurd extrapolation,

totally unjustified idealization

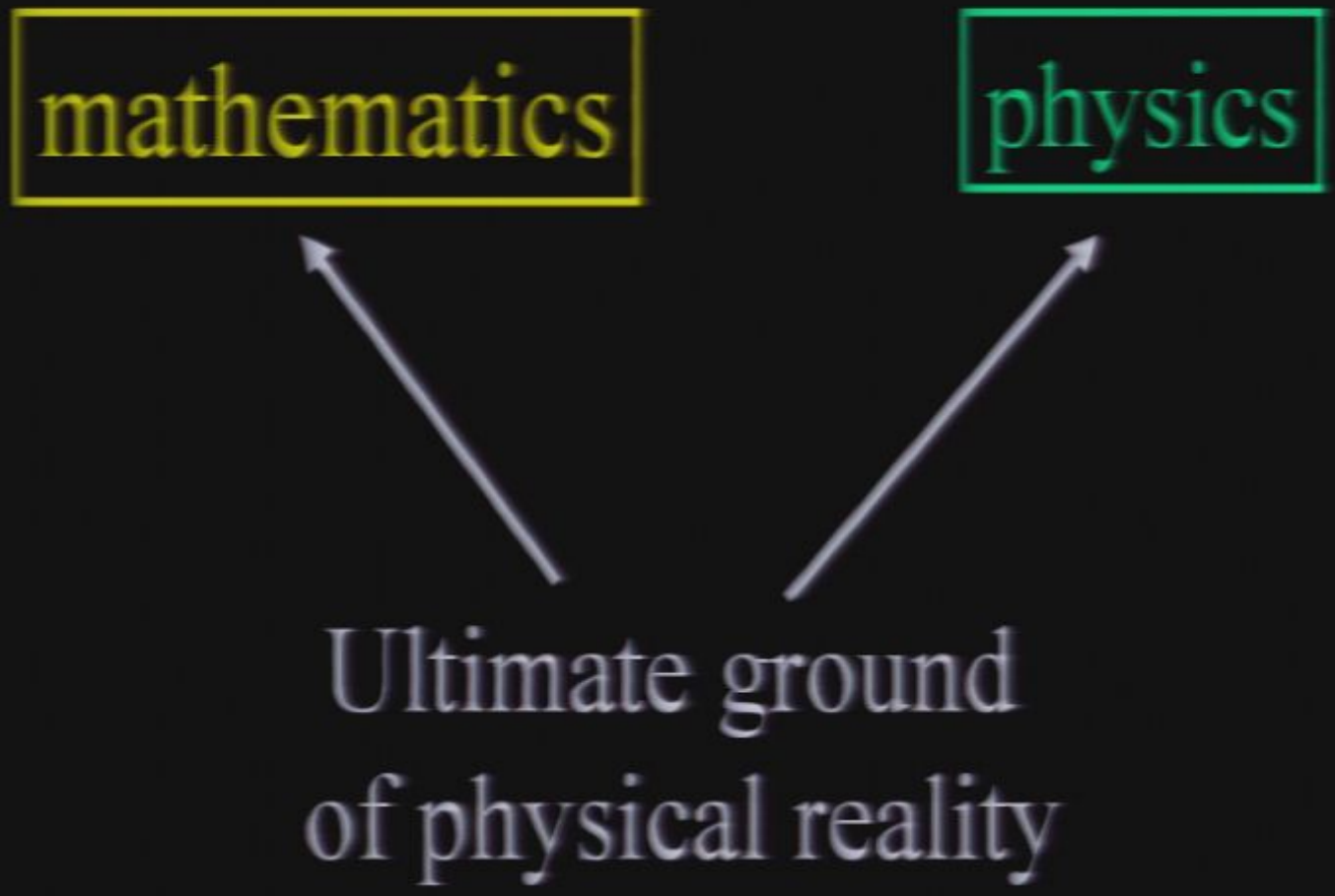
Rolf Landauer

The fundamental laws of nature are *mathematical statements*

$$-(\hbar^2/2m)\partial^2\psi/\partial x^2 + V(x)\psi = i\hbar\partial\psi/\partial t$$

$$F = m\partial^2 x/\partial t^2$$

"The calculative process, just like the measurement process, is subject to some limitations. A sensible theory of physics must respect these limitations, and should not invoke calculative routines that in fact cannot be carried out."

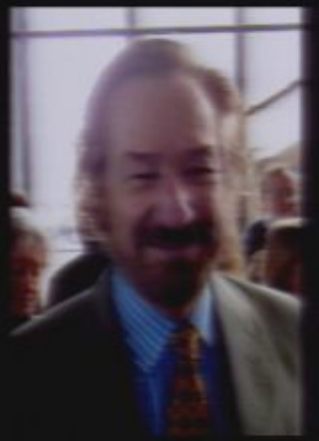

mathematics
physics
Ultimate ground
of physical reality

Universe as computer: laws as software

John Wheeler

Seth Lloyd

David Deutsch



Ed Fredkin

Stephen Wolfram

Seth Lloyd

10^{122} bits

time

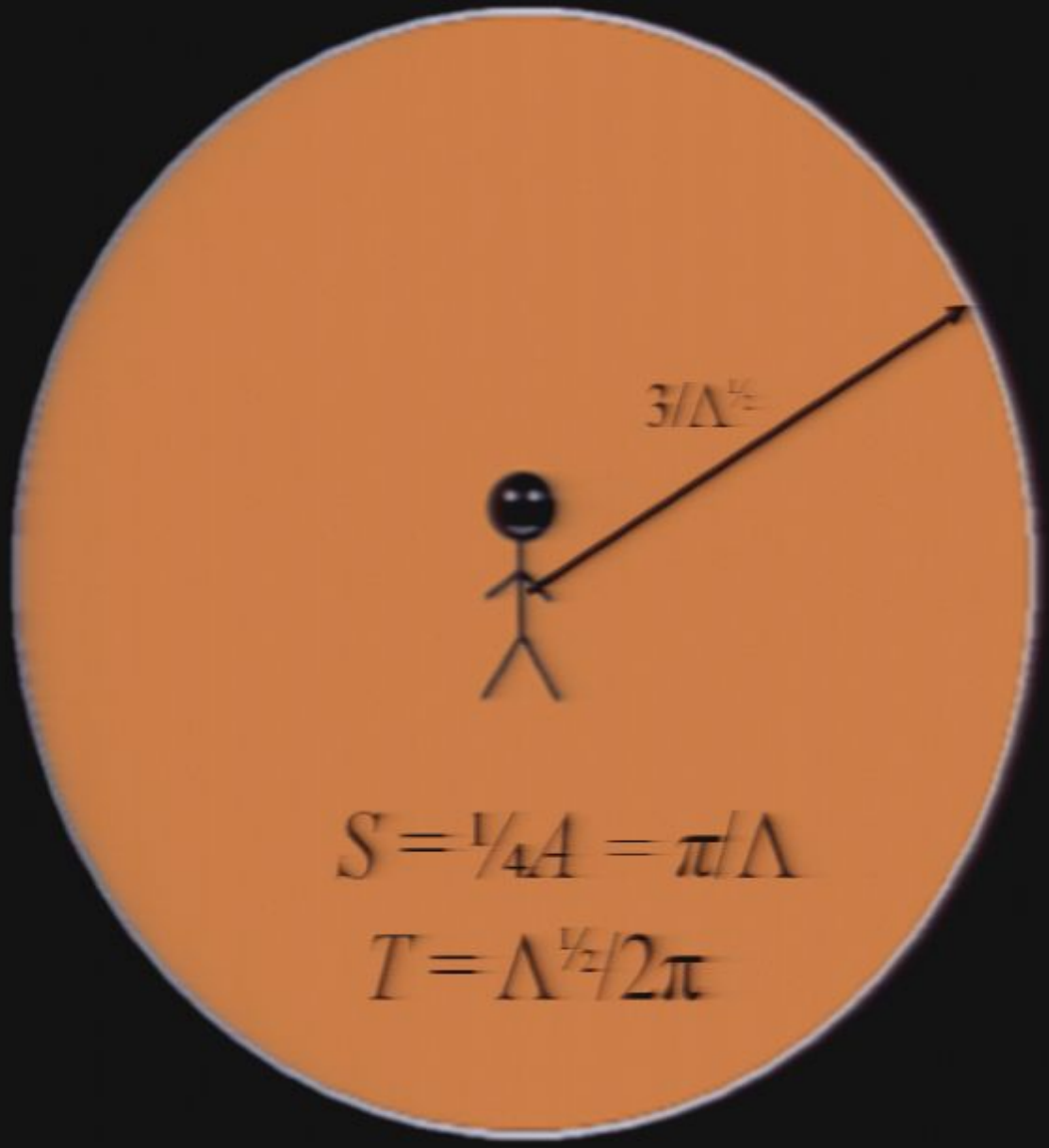
space

The universe has *finite computational resources*

$I \leq 2\pi kER/\hbar c$

10^{122} bits

de Sitter space



Holographic cosmology

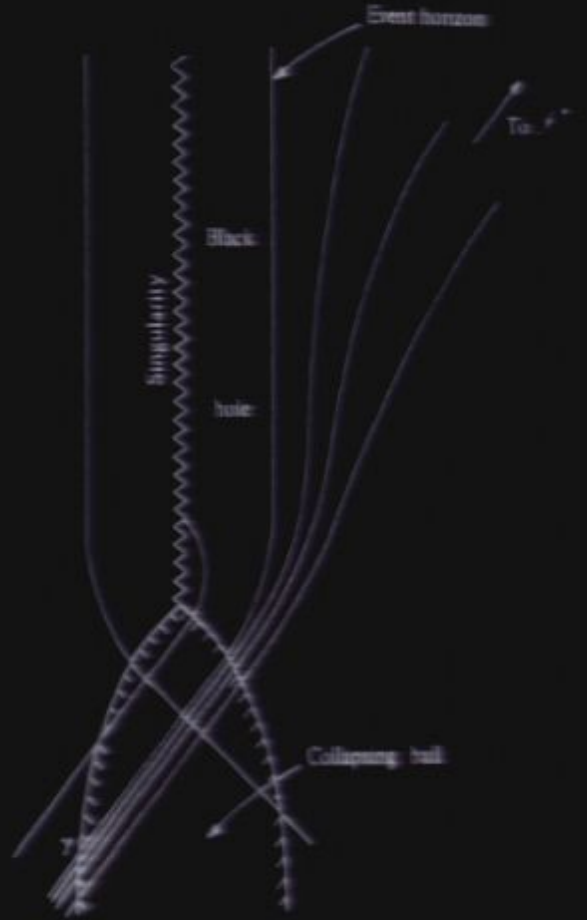
All the physics in a volume of space can be captured
by the information content on the enclosing boundary,
tiled by Planck area patches

$$N_{\mathrm{dof}} \leq A_c / 4L_p^2$$

Conclusion

The finite compuational resources of the universe represents a new fundamental source of unknowability in nature, beyond both quantum uncertainty and Turing uncomputability

The trans-Planckian mode problem

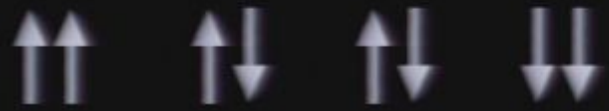


$$\exp(i\omega e^{u/4M})$$

$e^{3.000.000}$ after
1 minute!

$$\bar{u}_j = \sum_{i=0}^{\infty} (\alpha_{ji} u_i + \beta_{ji} u_i^*)$$

A possible experimental test!



n particles $\rightarrow 2^n$ possible states

$2^n \sim 10^{122} \rightarrow n \sim 400$ particles

Immutability & Newtonian dualism

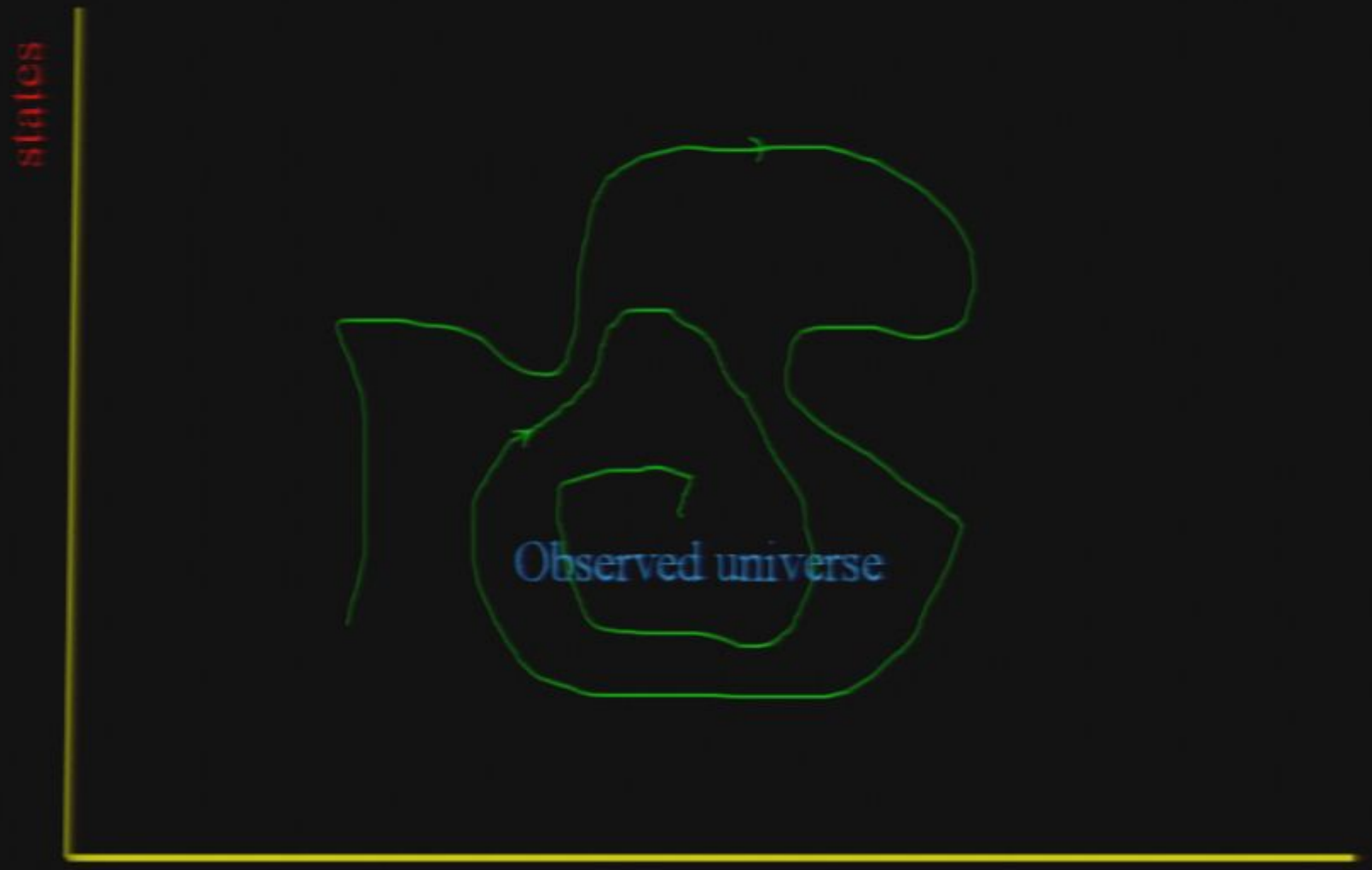
The founding dualism
of physical science

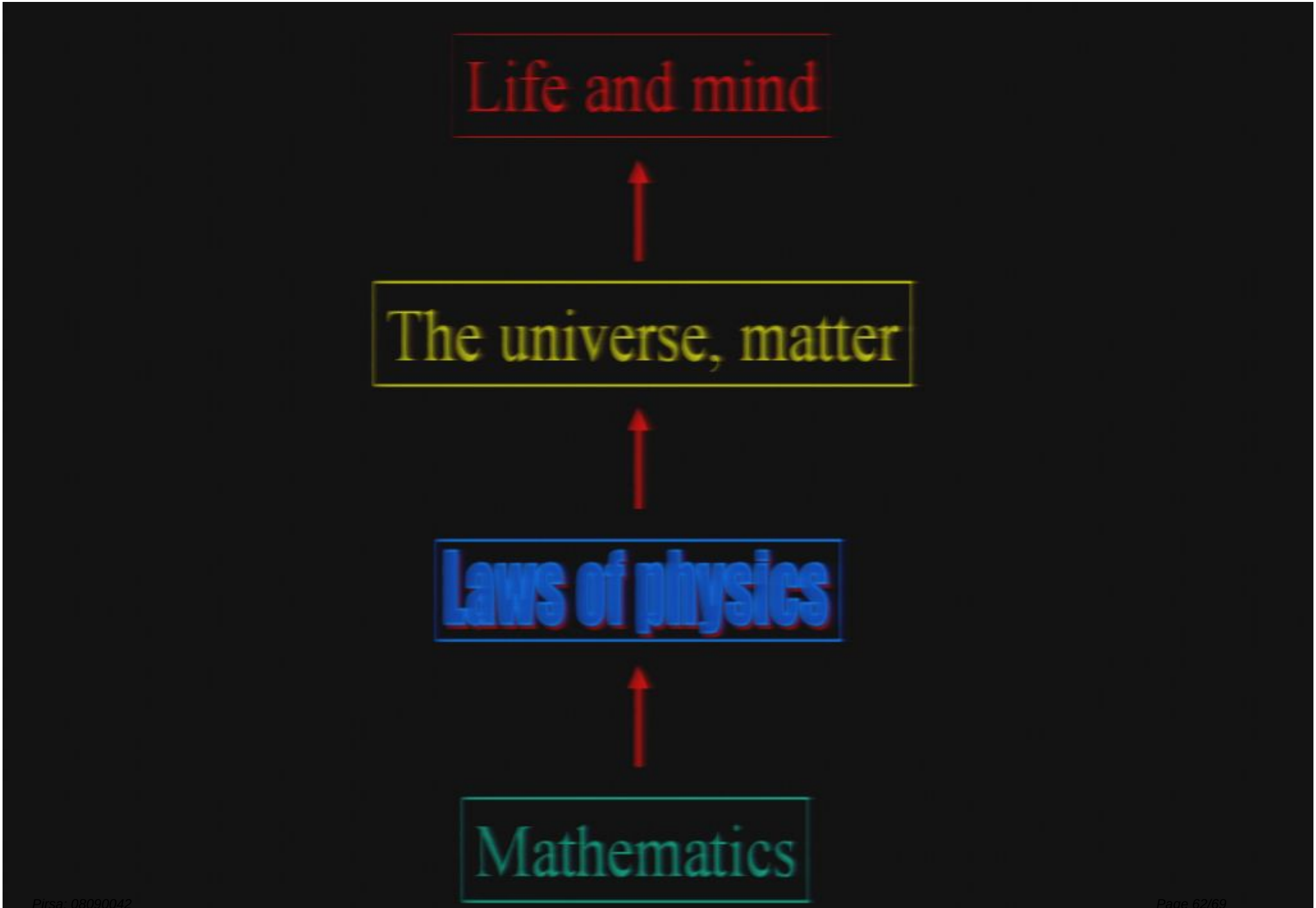
S → S → S → S → S

L A W S

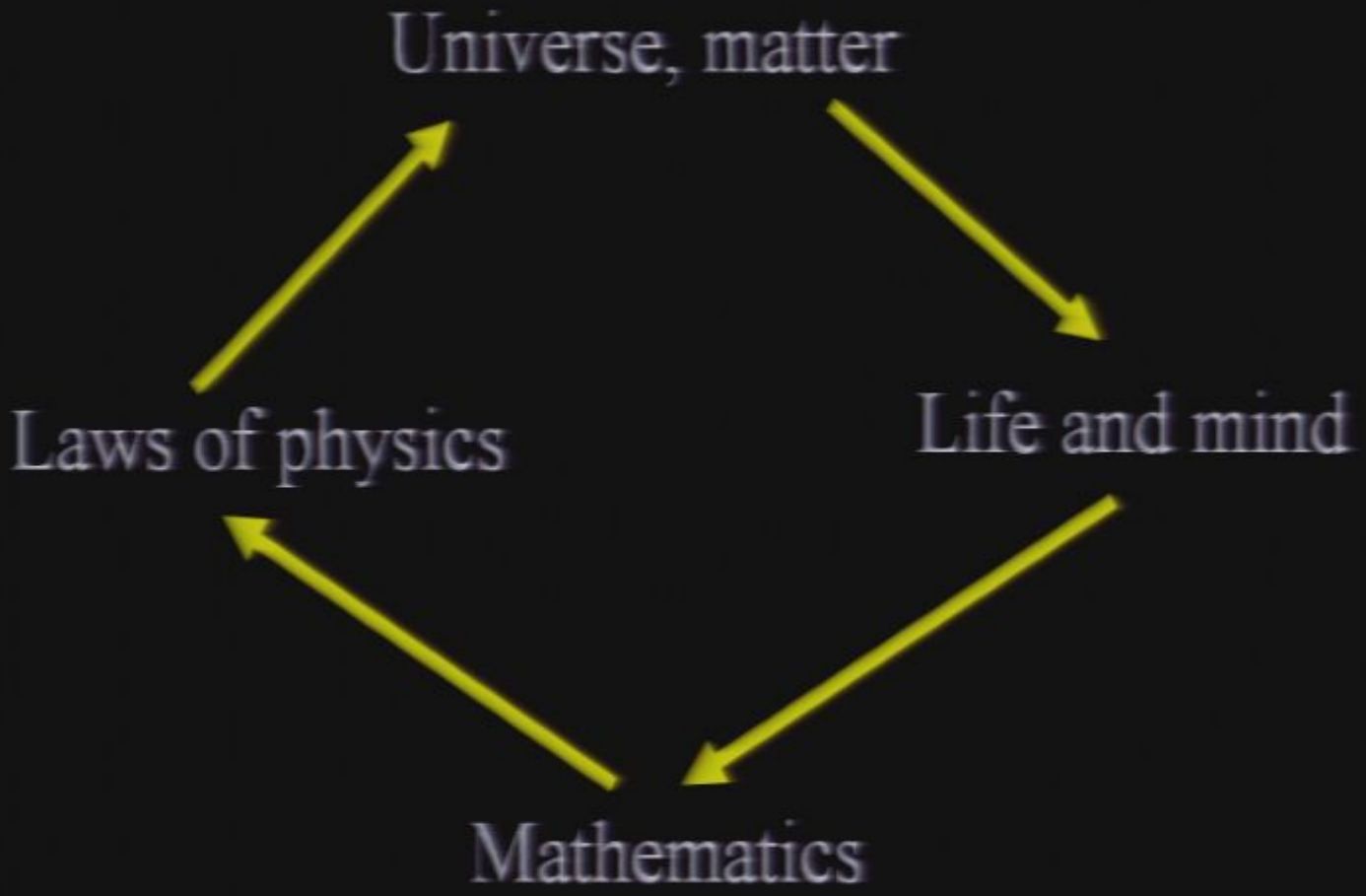
Suppose we remove the duality between *states* of the world and *laws* of physics!

Emergent laws, emergent states




Life and mind
The universe, matter
Laws of physics
Mathematics

Self synthesizing, self-explaining reality



Turtle loop

Transcendence of the laws

- Transcendent?
- Inherent?

"The laws we discover about nature do not already exist as 'Laws of Nature' in the outside world."

Anton Zeilinger

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"

Superturtle!

Turtle loop