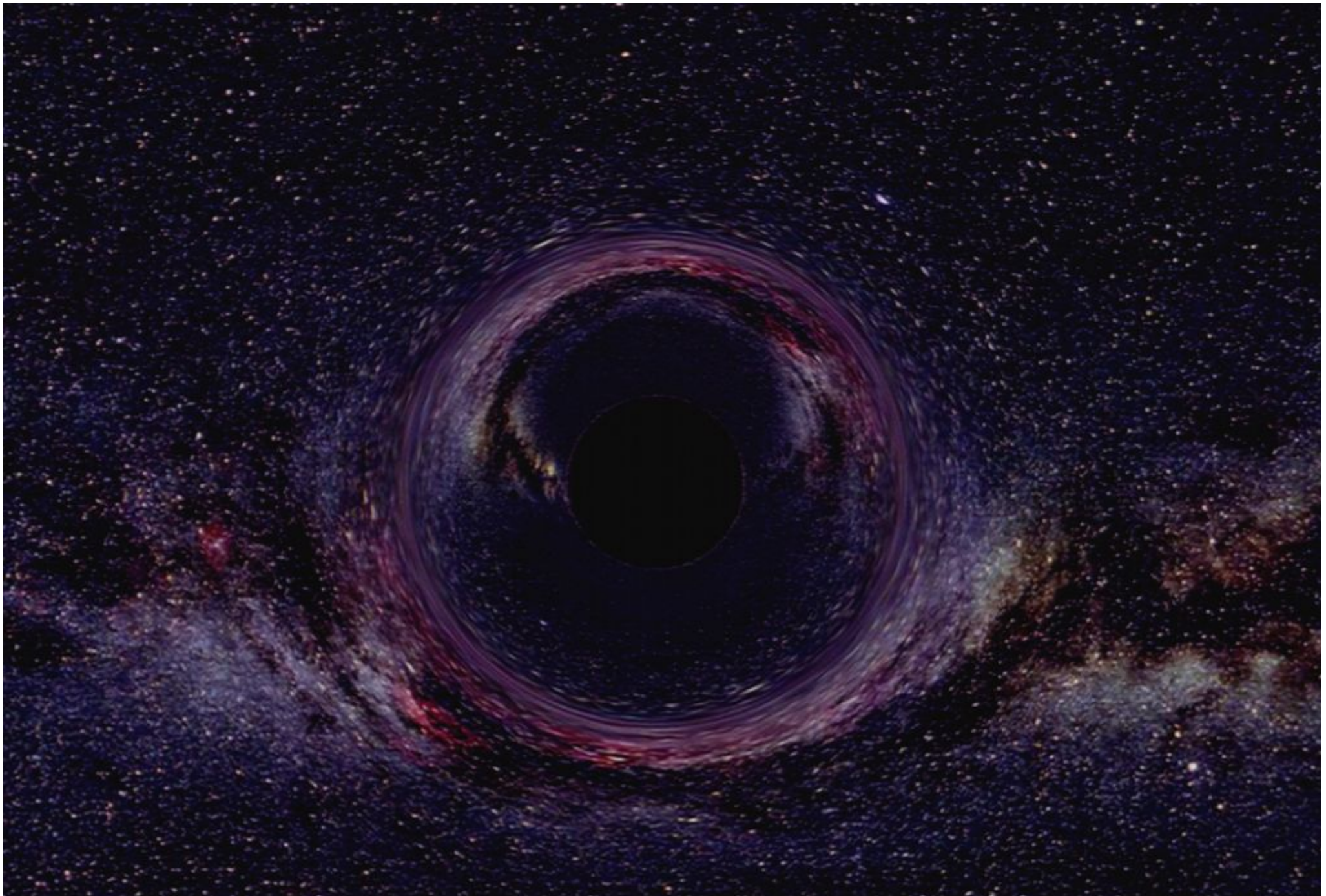


Title: The World as a Hologram?

Date: Feb 19, 2009 09:00 AM

URL: <http://pirsa.org/09020042>

Abstract: Our universe has a split personality: quantum and relativity. Understanding how the two can coexist, i.e. how our universe can exist, is one of the greatest challenges facing theoretical physicists in the 21st century. Join us for a simple but mind-bending thought experiment that hints at some fascinating new ways of thinking that may be required to unravel this mystery. Could the world be like a hologram? This half hour multimedia presentation provides refreshing insight into how science works – how theoretical physicists search for the ultimate nature of reality, and is followed by a half hour question and answer session with a leading scientist in the field.



018



PERIMETER **PI** INSTITUTE

Black Hole Science Café

The logo for Perimeter Institute, featuring a stylized white 'PI' with a small roof-like shape above the 'I'.

PERIMETER INSTITUTE

Black Hole Science Café
The World as a Hologram?



Black Hole Science Café
The World as a Hologram?



Guest: Robert Myers
Faculty, Perimeter Institute

ence Café

The World as a Hologram?

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The World as a Hologram?

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Faculty, Perimeter Institute

What do we know about our Universe?



What do we know about our Universe?



What do we know about our Universe?

What do we know about our Universe?

Quantum

Relativity

What do we know about our Universe?

Quantum

Relativity

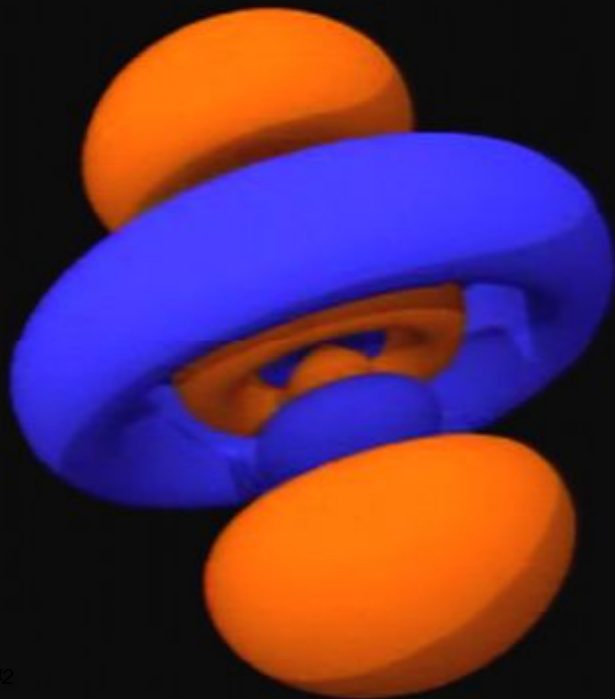
How atoms
can exist

What do we know about our Universe?

Quantum

Relativity

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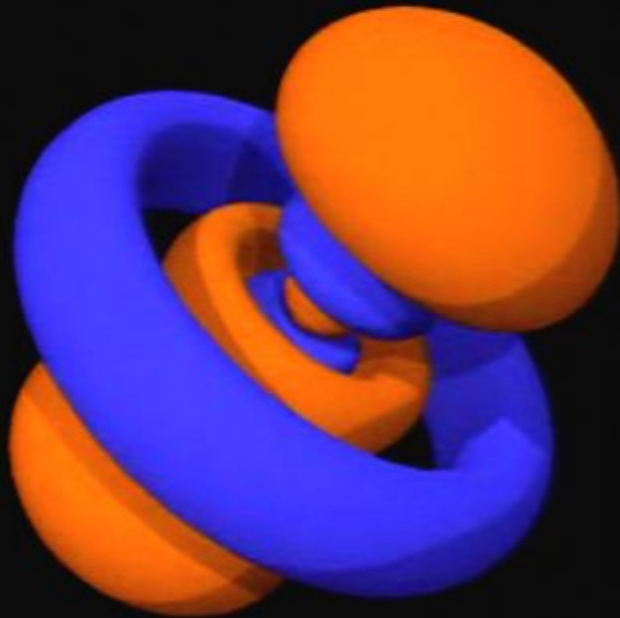
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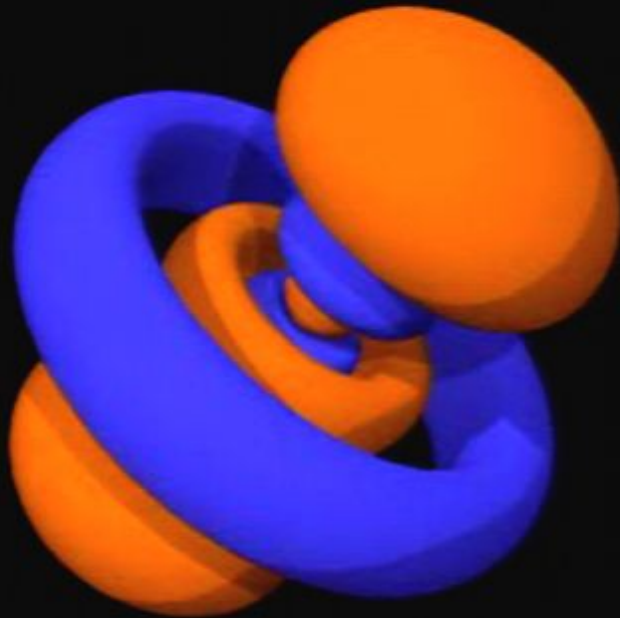
How gravity
works



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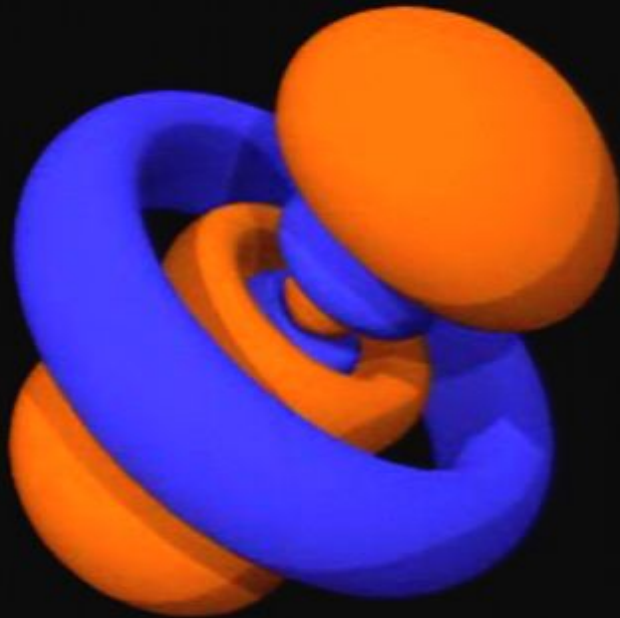
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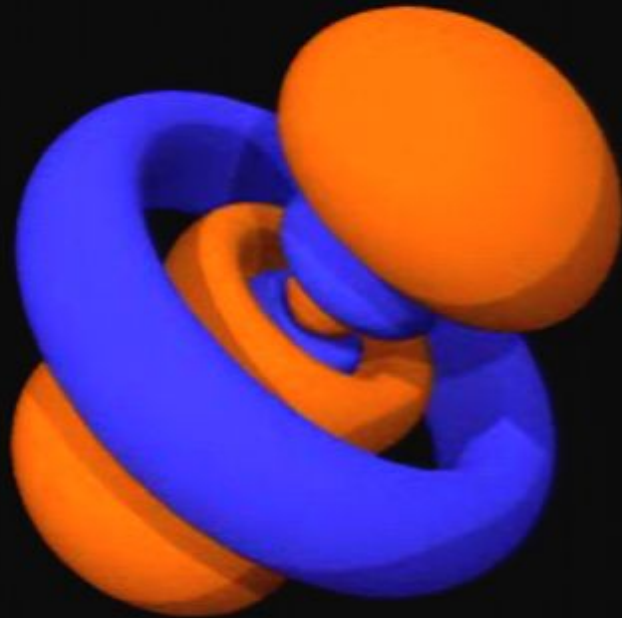
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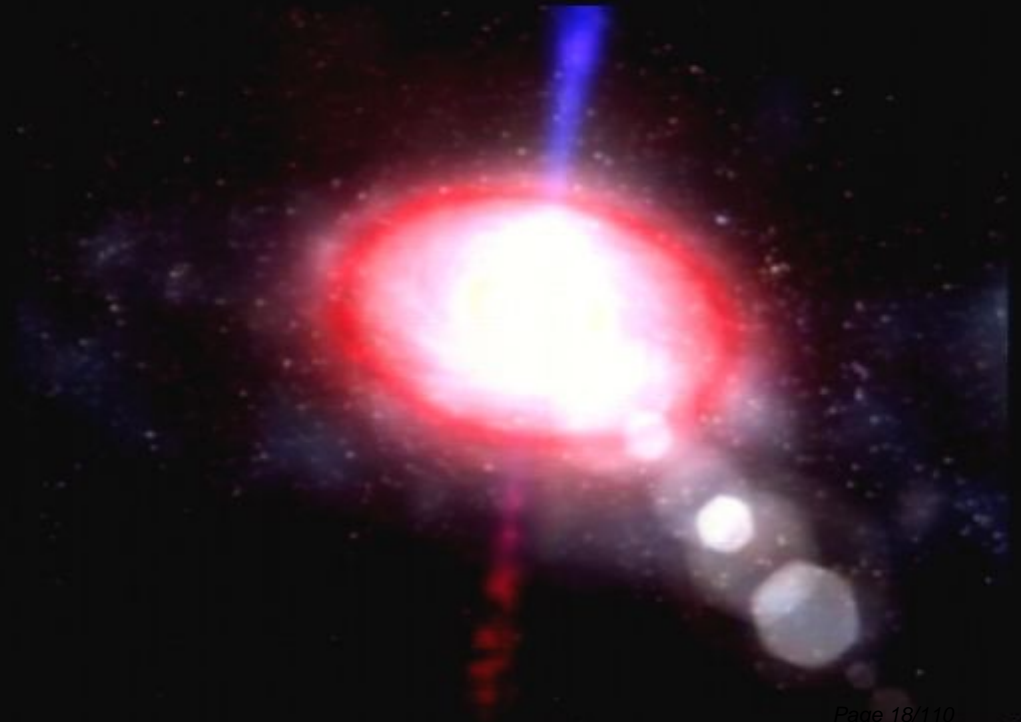
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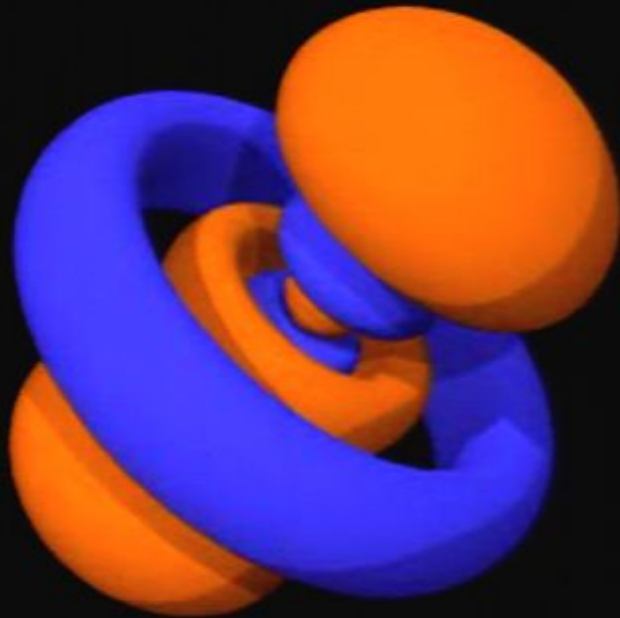
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What do we know about our Universe?

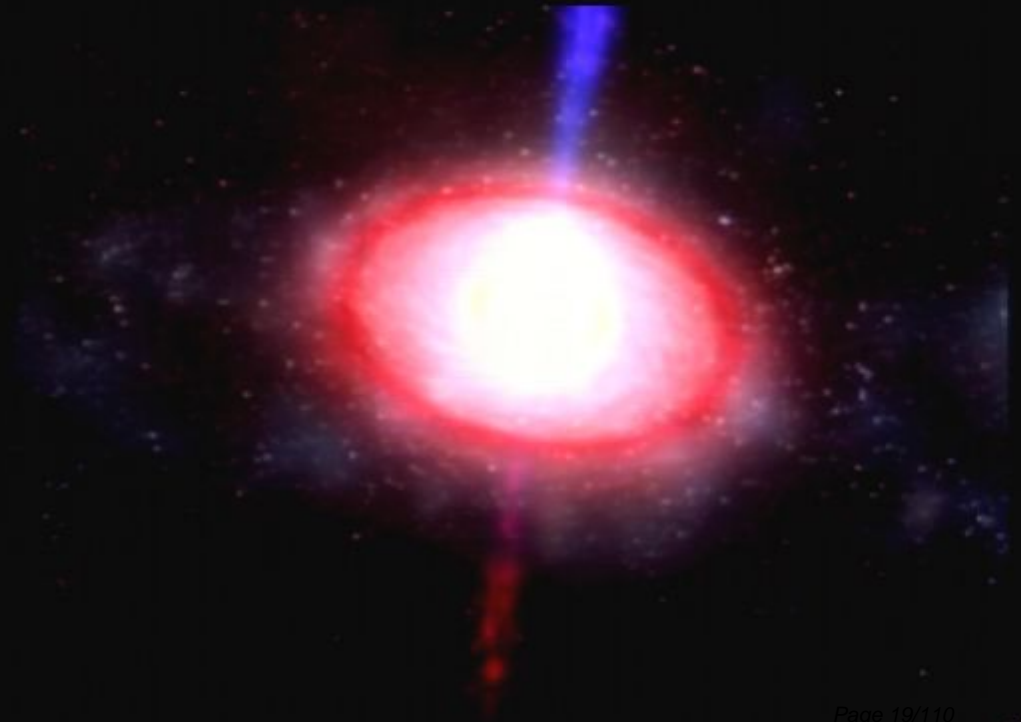
Quantum

How atoms
can exist



Relativity

How gravity
works



Problem: Q & R are incompatible

Problem: Q & R are incompatible

Quantum

Probability



Problem: Q & R are incompatible

Quantum

Relativity

Probability

Geometry



Problem: Q & R are incompatible

Quantum

Relativity

Probability

Geometry

Problem: Q & R are incompatible

Quantum

Relativity

Probability

Geometry



Problem: Q & R are incompatible

Quantum

Relativity

Probability

Geometry



Question: How can our Universe exist?

Question: How can our Universe exist?

Quantum



Relativity



Question: How can our Universe exist?

Quantum



Relativity



Quantum Gravity?

Your Mission: (should you choose to accept it...)



Your Mission: (should you choose to accept it...)



1. Learn: Quantum & Relativity in 60 seconds

Your Mission: (should you choose to accept it...)



1. Learn: Quantum & Relativity in 60 seconds
2. Guess: What are they trying to tell us about the nature of

Your Mission: (should you choose to accept it...)



1. Learn: Quantum & Relativity in 60 seconds
2. Guess: What are they trying to tell us about the nature of our universe?

Step 1: Quantum & Relativity in 60 seconds:

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Step 1: Quantum & Relativity in 60 seconds:

Quantum

Step 1: Quantum & Relativity in 60 seconds:

Quantum

$$E = hf$$

Light = Photons

Photons have Energy

Step 1: Quantum & Relativity in 60 seconds:

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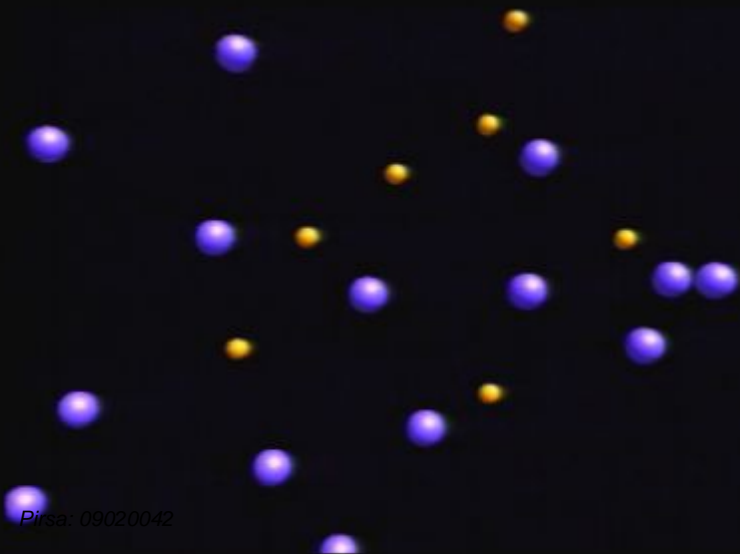
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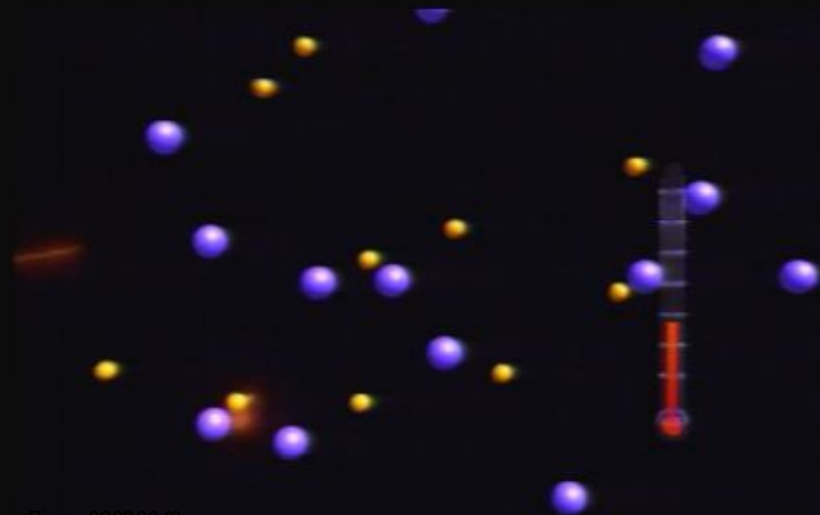
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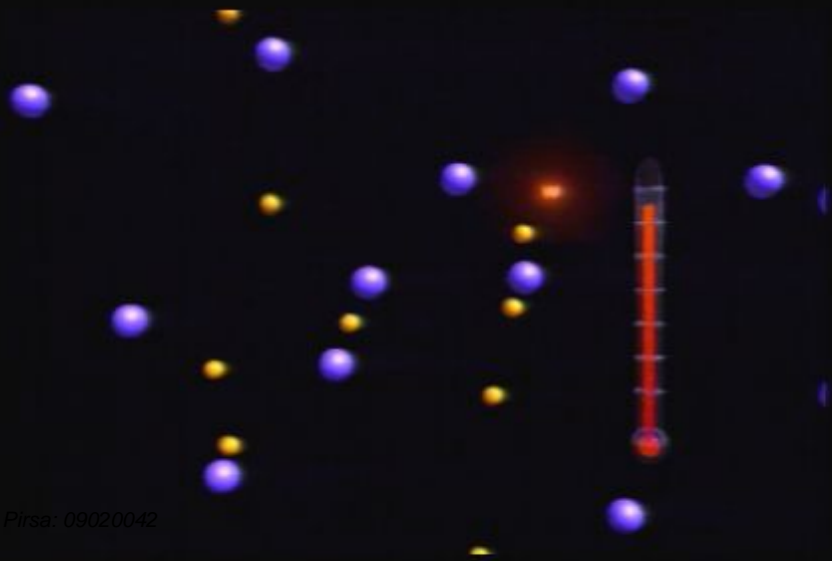
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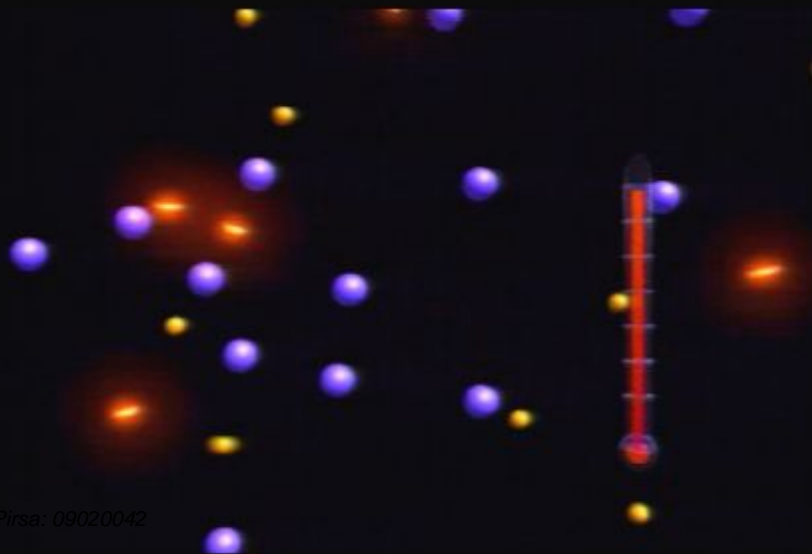
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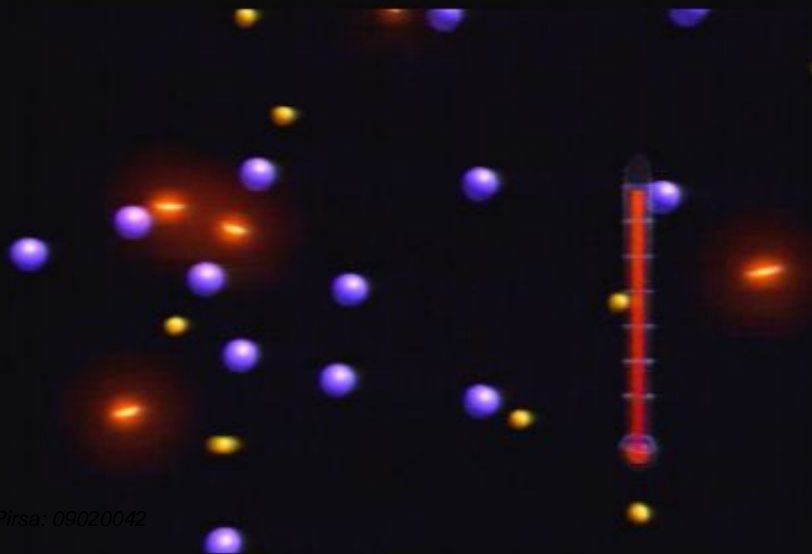
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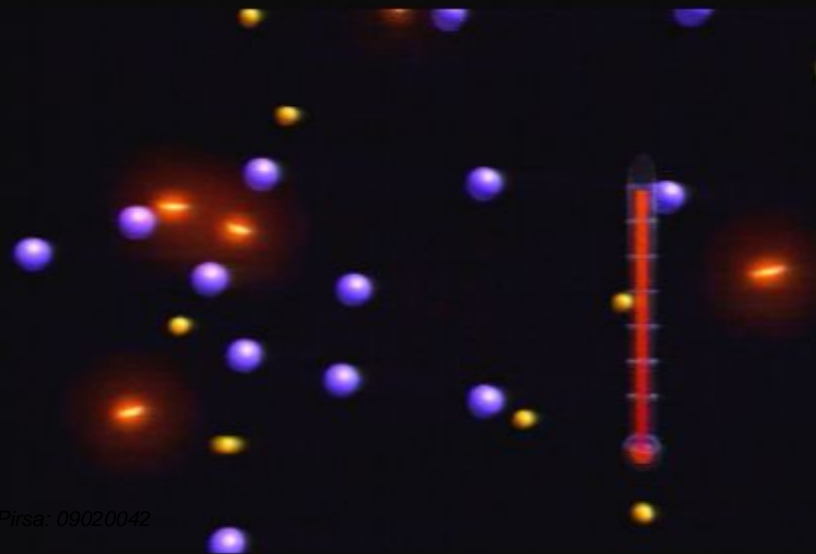
$$E = hf$$

Light = Photons
Photons have Energy

Relativity

$$E = Mc^2$$

Energy & Mass
Interchangeable



Step 1: Quantum & Relativity in 60 seconds:

Quantum

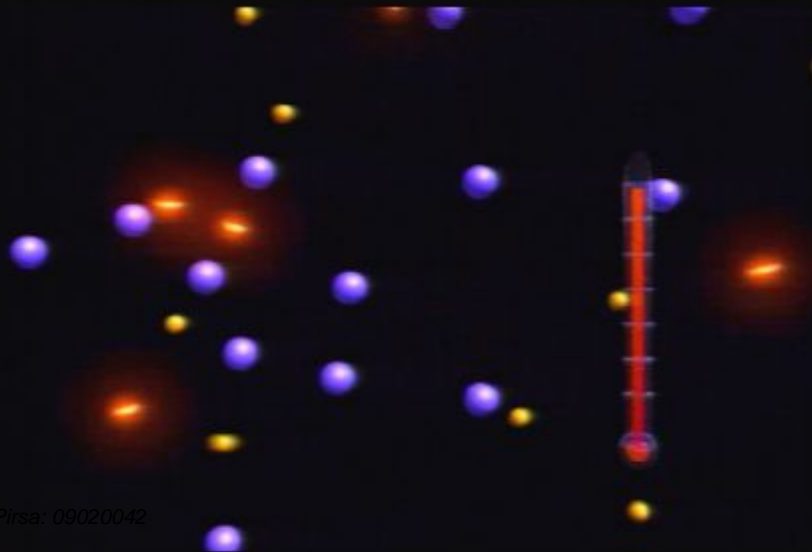
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Pirsa: 09020042

NASA/CXC/SAO/D. Berry



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NASA/Goddard Space Flight Center



Step 1: Quantum & Relativity in 60 seconds:

Quantum

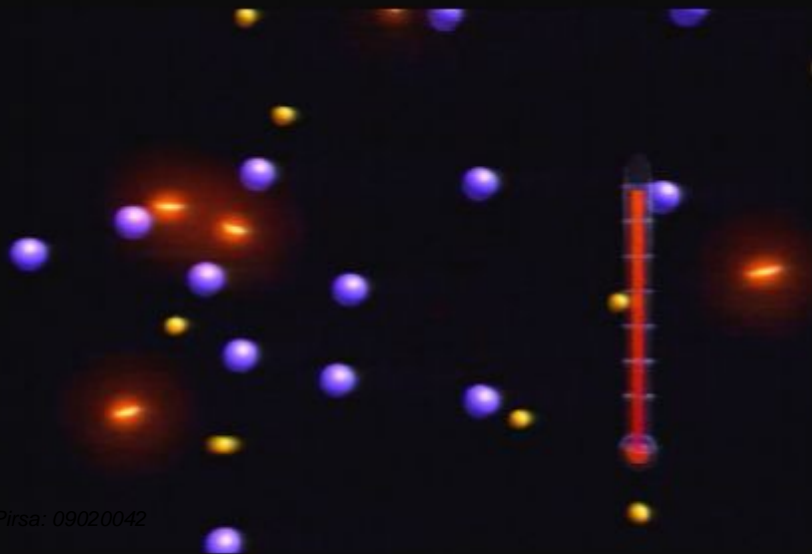
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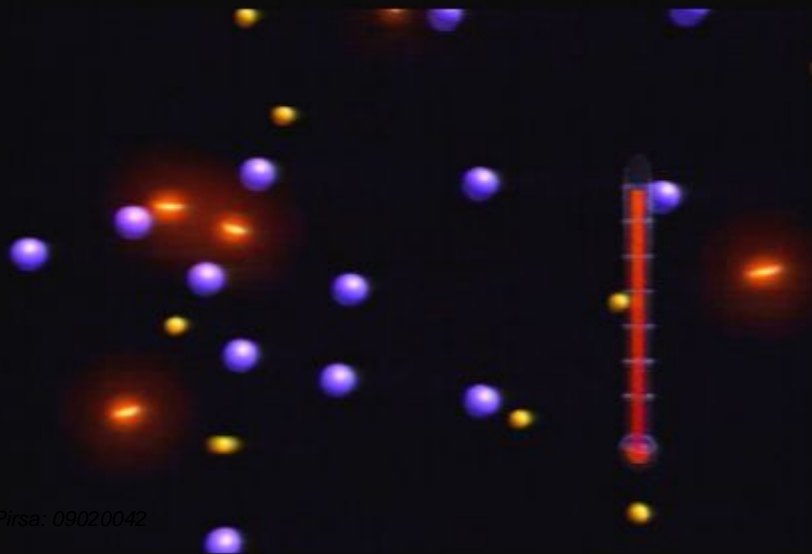
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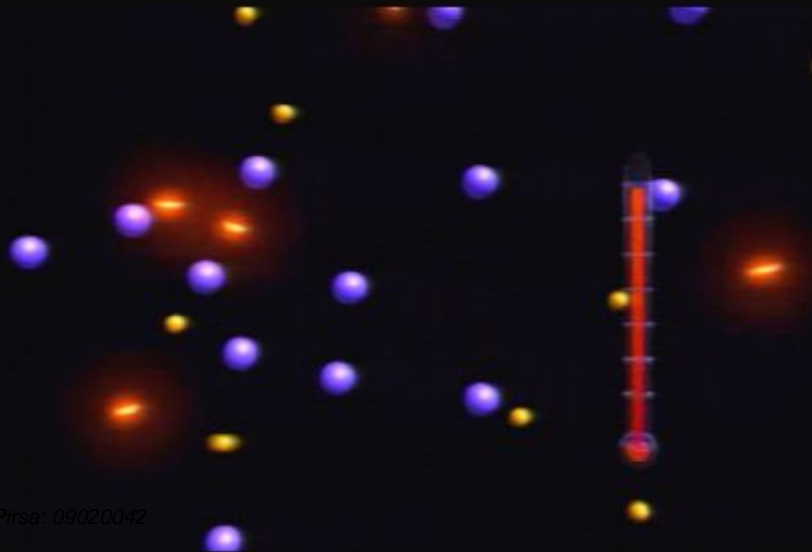
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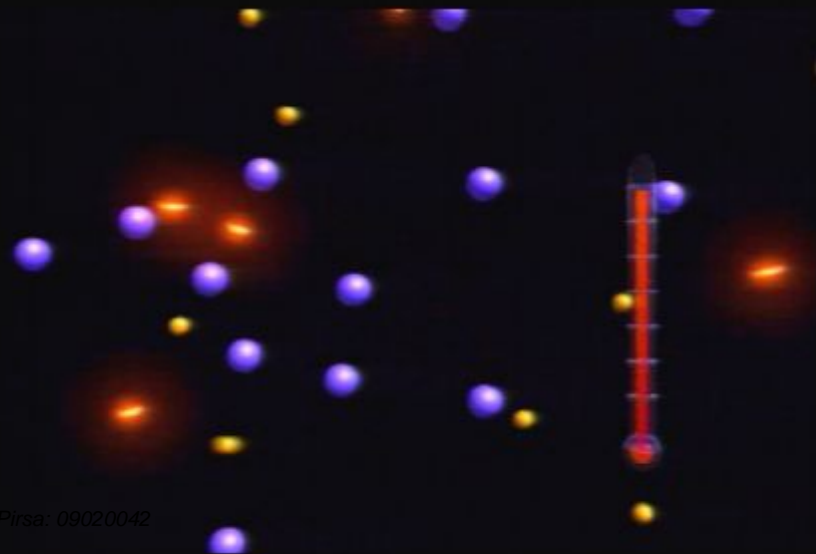
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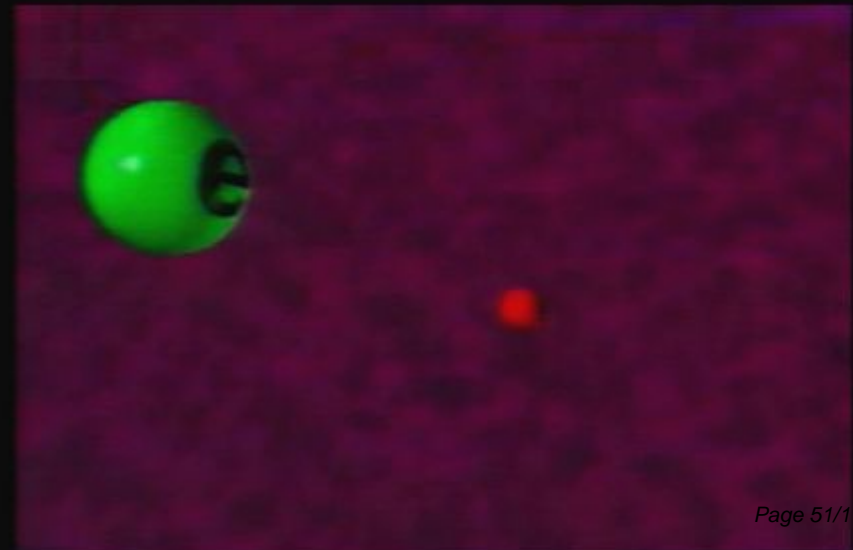
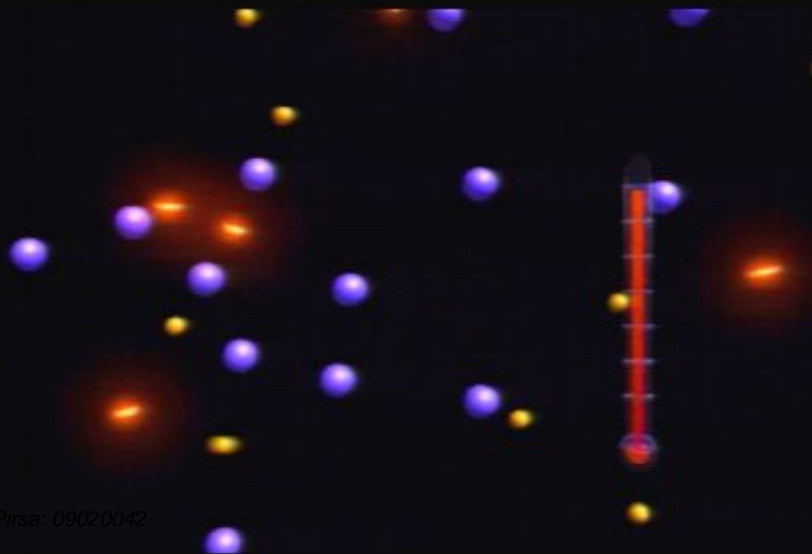
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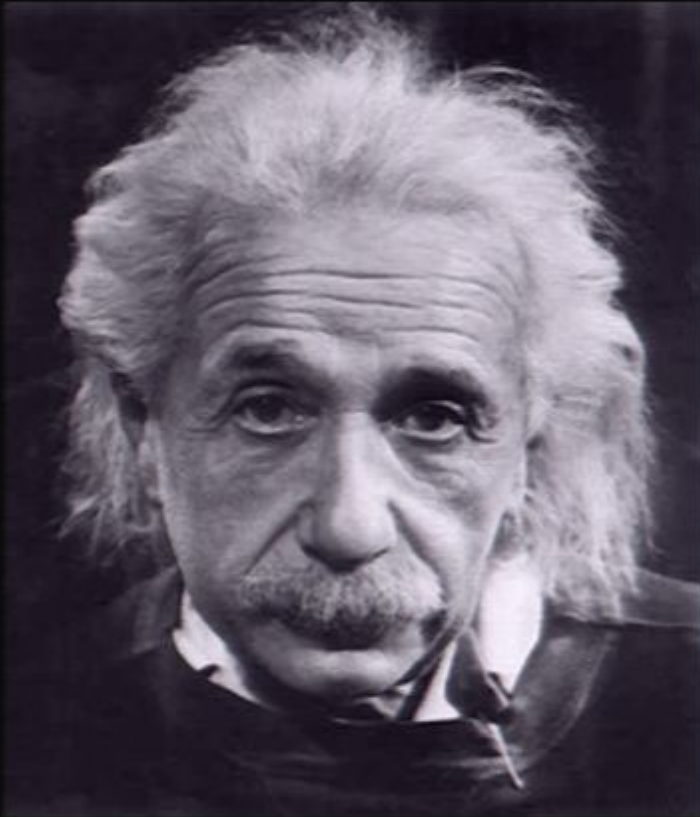
Energy & Mass
Interchangeable



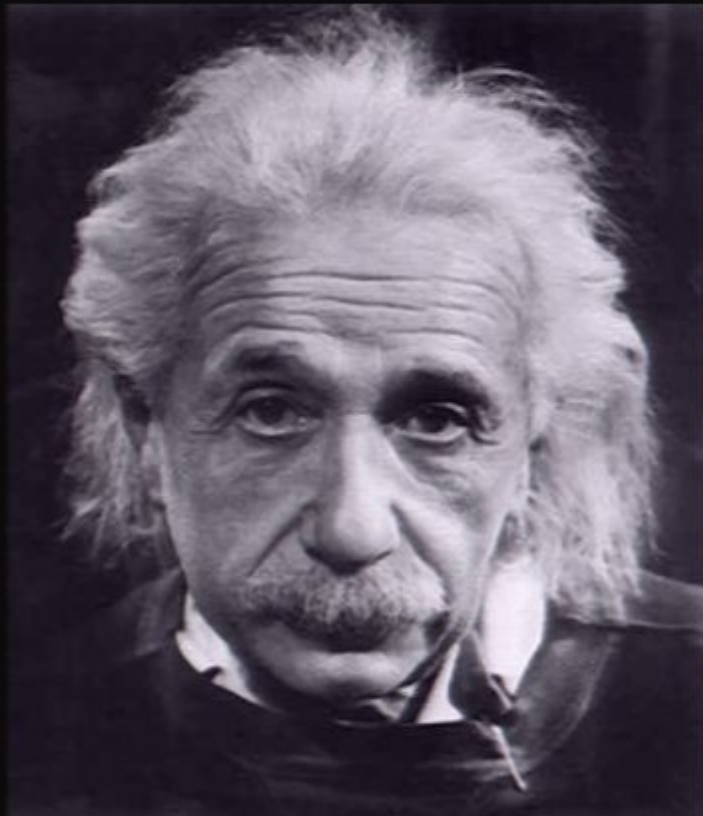
Also need to know:

Also need to know: Information is Physical

Also need to know: Information is Physical



Also need to know: Information is Physical



$$r = s \frac{R+R'}{R} - \frac{R'\alpha}{s}$$

$$r_0 = s_0 - \frac{1}{s_0} \dots (1)$$

$$s_0^2 = s \frac{R+R'}{R R' \alpha}$$

Einsteins.
$$r = \dots - \frac{R\alpha}{s} = \dots - \frac{R\alpha}{s_0} \sqrt{\frac{R+R'}{R R' \alpha}}$$

$$= \dots - \frac{1}{s_0} \sqrt{\frac{R}{R'} (R+R') \alpha}$$

S^{4r} macht mit dem negativen Term selbst auch für stark abgelenkte Strahl.

Also need to know: Information is Physical



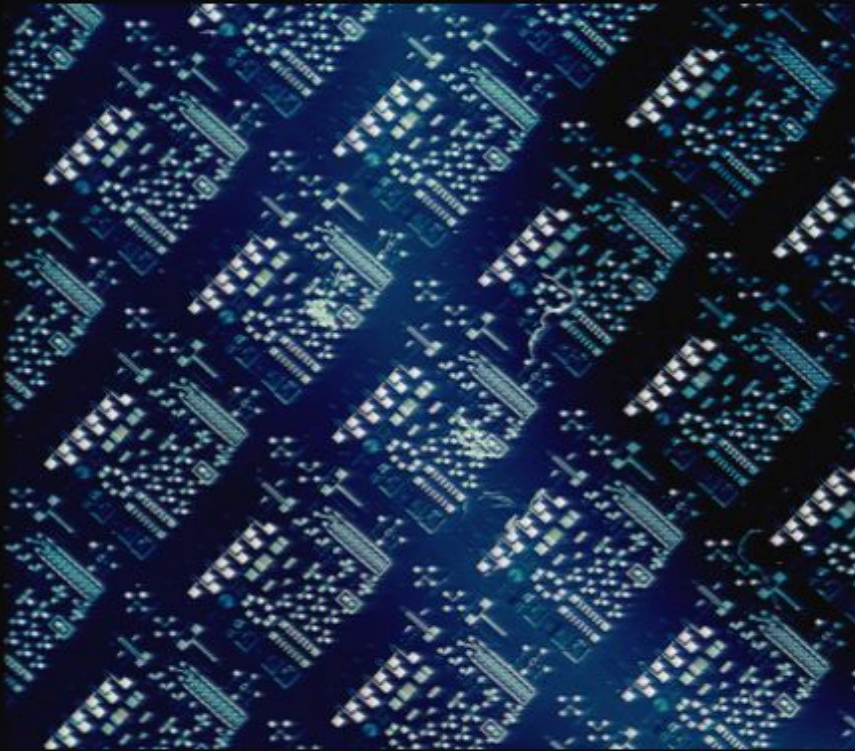
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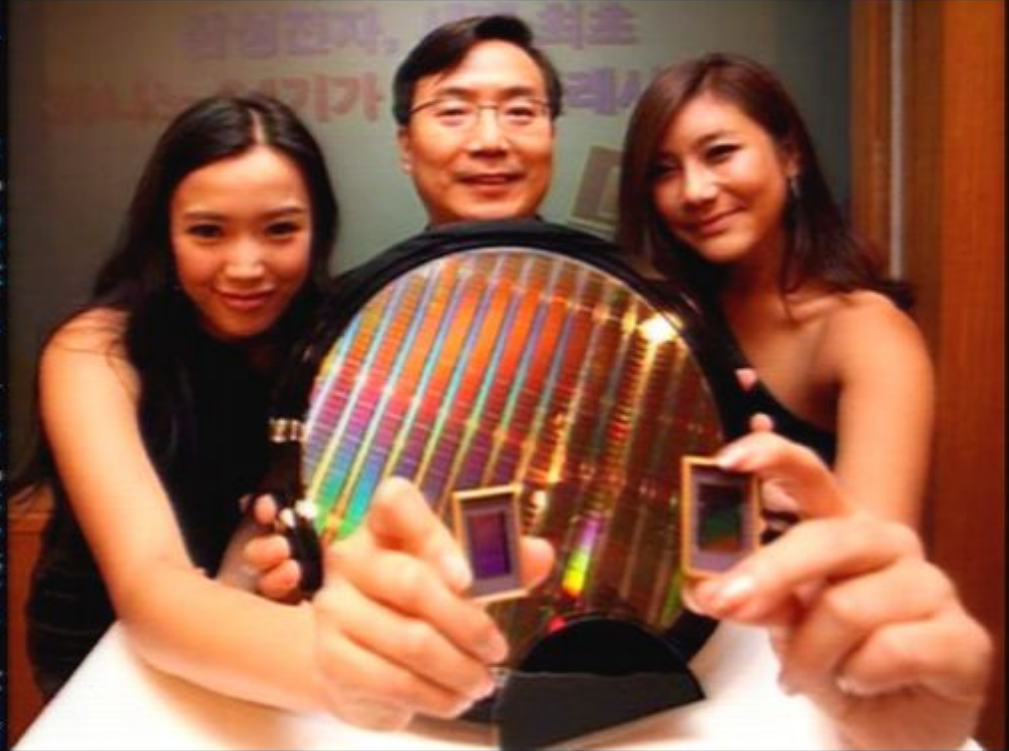
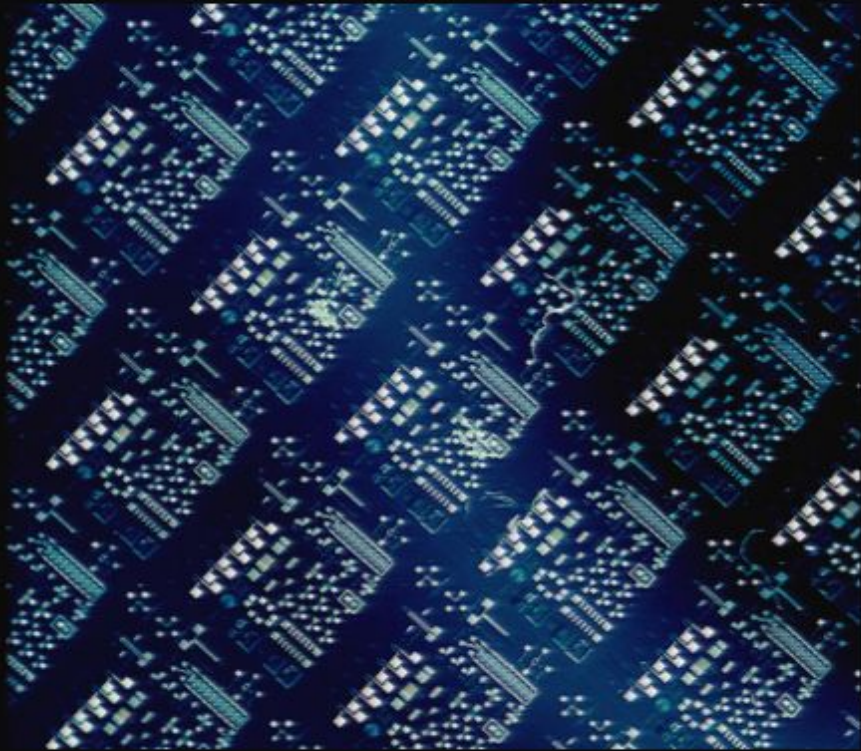
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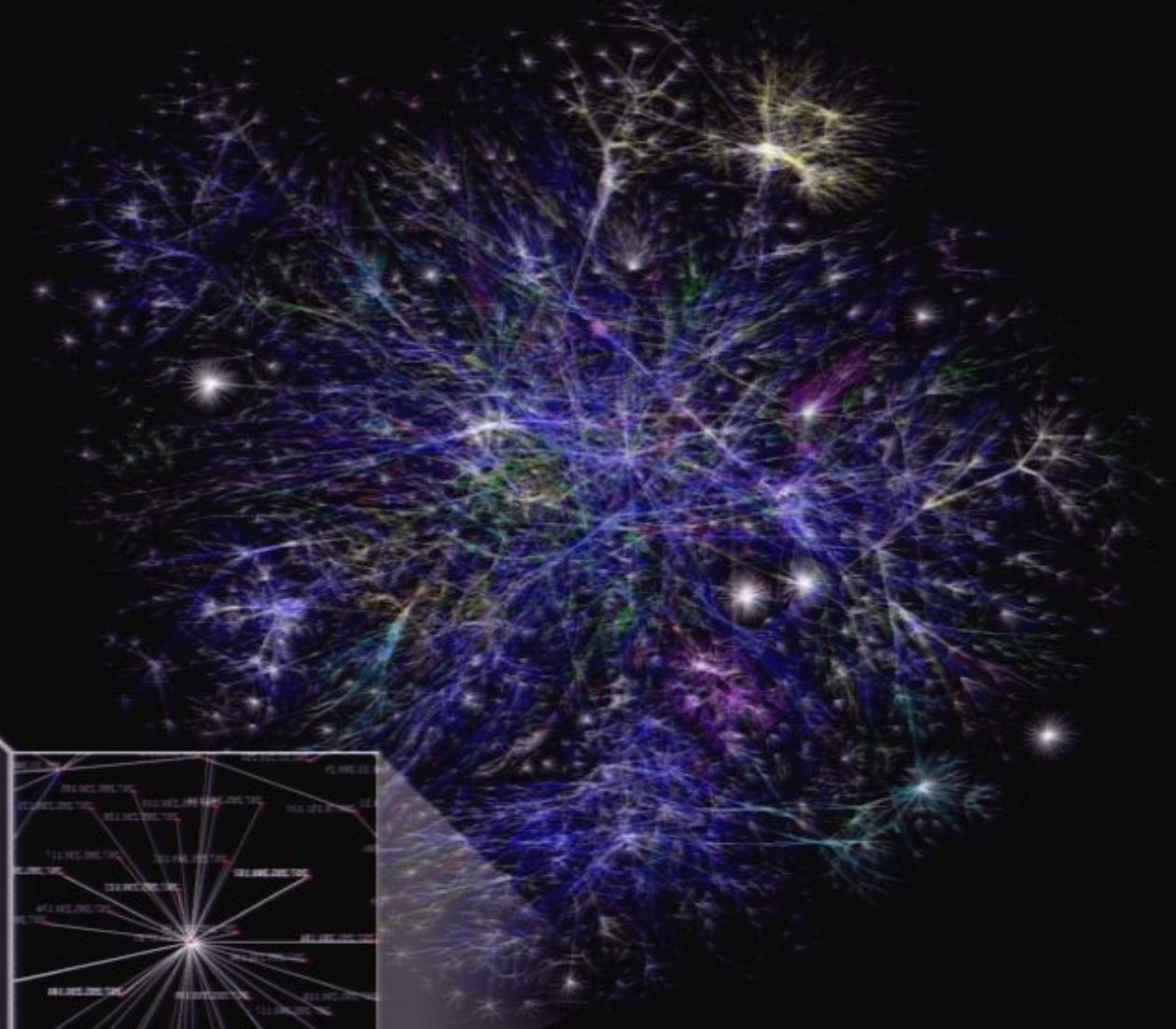
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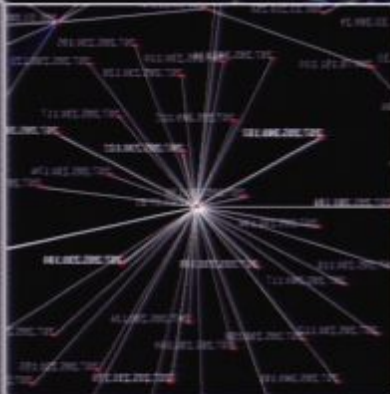
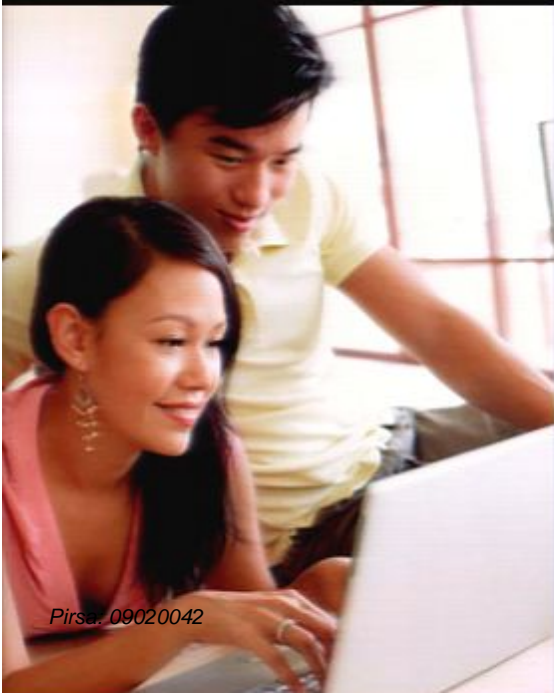
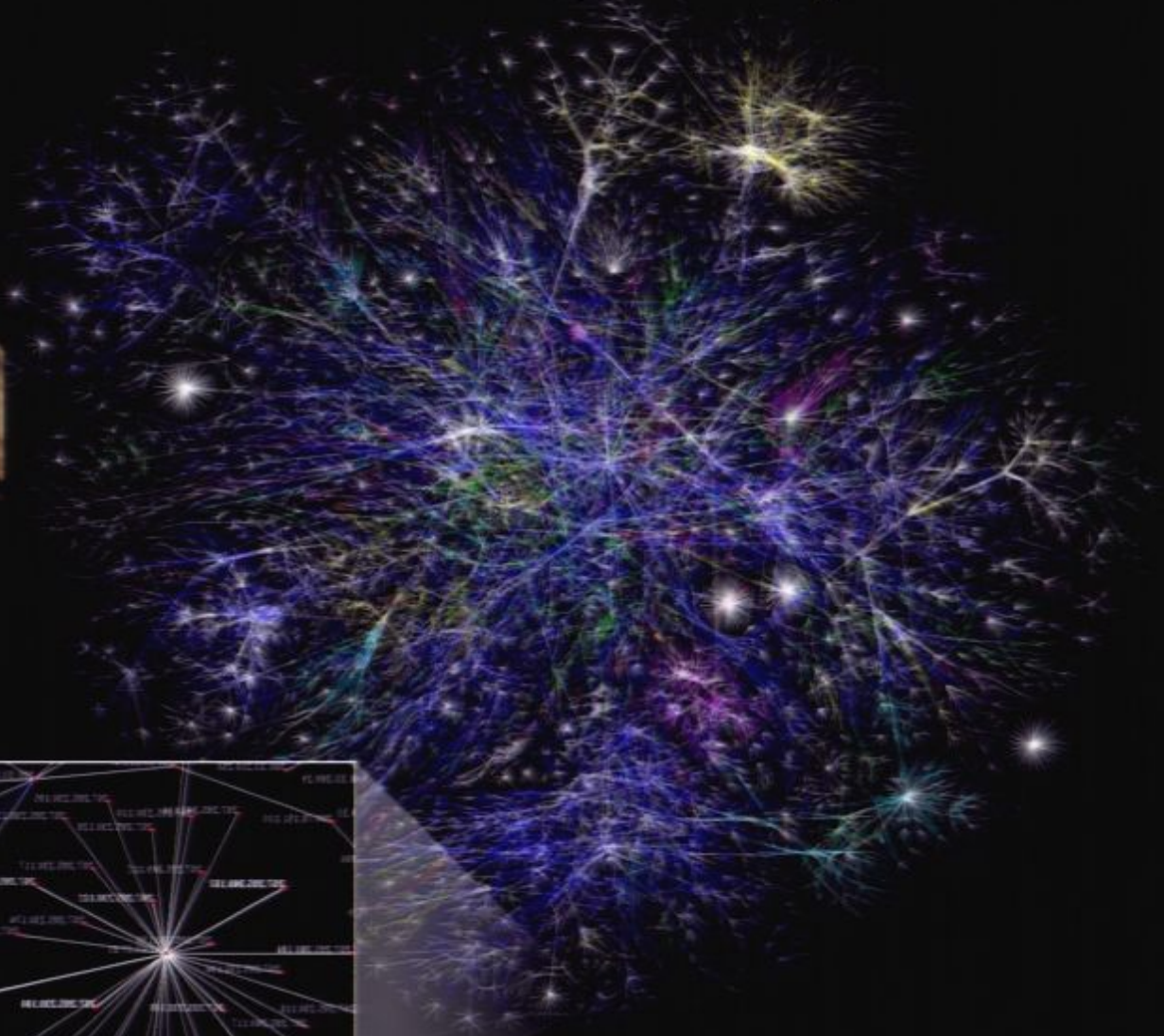
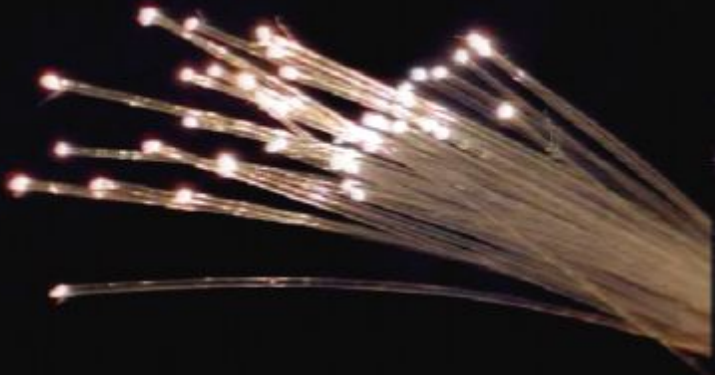
Also need to know: Information is Physical



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Also need to know: Information is Physical



Summary So Far:



Summary So Far:



Quantum:
Photons have energy

Summary So Far:



Quantum:
Photons have energy



Relativity:
Energy is equivalent to mass

Summary So Far:



Quantum:
Photons have energy



Relativity:
Energy is equivalent to mass

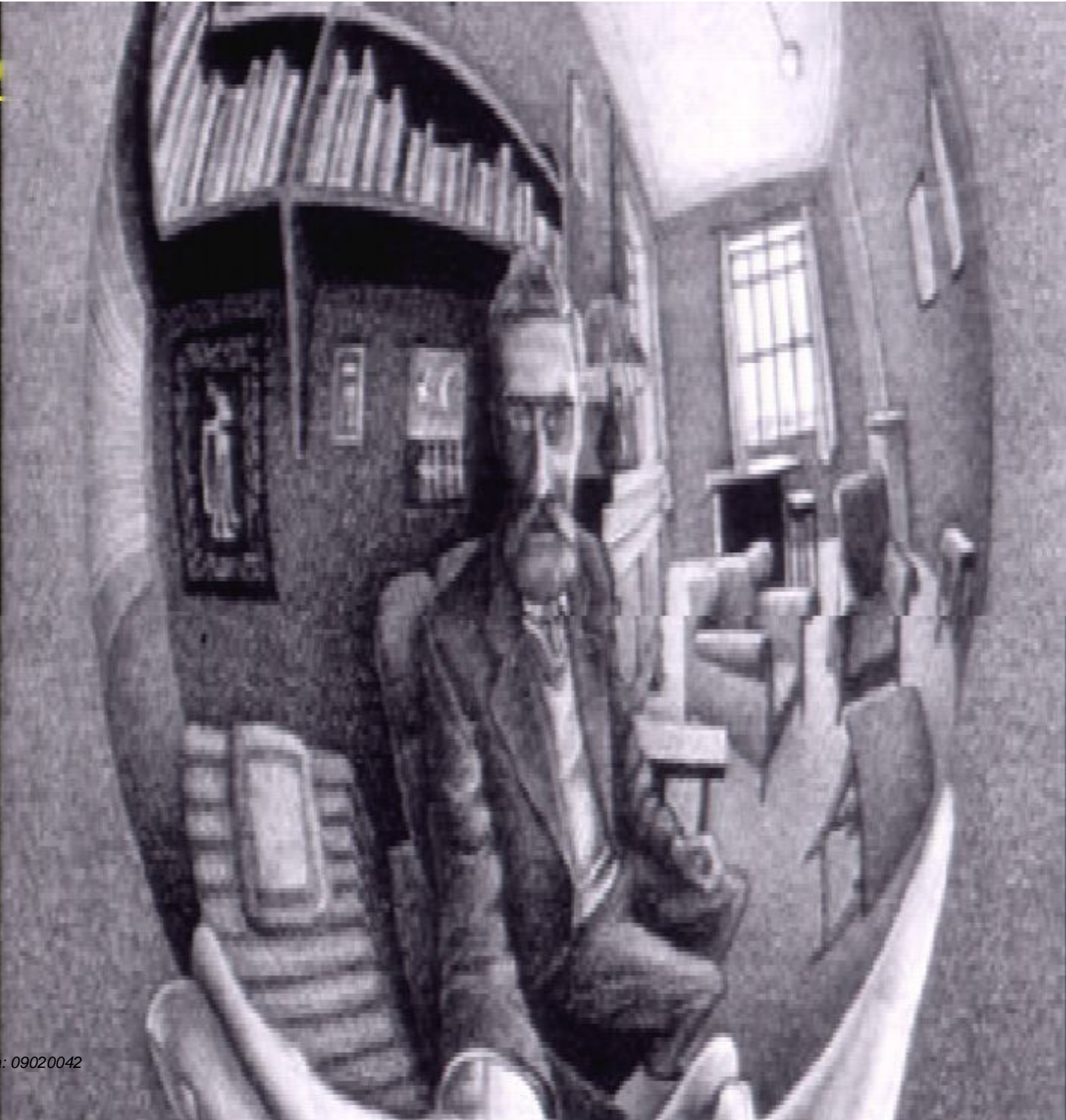


Information needs to be
embodied in a physical form

Step 2: What are Q & R trying to tell us?

St

I us?



Step 2: What are Q & R trying to tell us?



Step 2: What are Q & R trying to tell us?



Question:
How much
information
can we cram
into this
sphere?

Maximum Information?



Maximum Information?

Info = 101101001001...



Maximum Information?



Info = 101101001001...
Embody info in photons

Maximum Information?



Info = 101101001001...

Embody info in photons

1 photon = 1 bit of info

Maximum Information?



Info = 101101001001...

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1 photon = 1 bit of info

But each photon (bit of info) costs energy ($E = hf$)

Maximum Information?



Info = 101101001001...

Embody info in photons

1 photon = 1 bit of info

But each photon (bit of info) costs energy ($E = hf$)

More info...more energy

Maximum Information?



Info = 101101001001...

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More info...more energy

But energy and mass are interchangeable ($E = Mc^2$)

Maximum Information?



Info = 101101001001...

Embody info in photons

1 photon = 1 bit of info

But each photon (bit of info) costs energy ($E = hf$)

More info...more energy

But energy and mass are interchangeable ($E = Mc^2$)

More info...more mass

Maximum Information?

Is there a maximum mass?



Maximum Information?

Is there a maximum mass?

Yes: the black hole limit!



Maximum Information?



Is there a maximum mass?

Yes: the black hole limit!



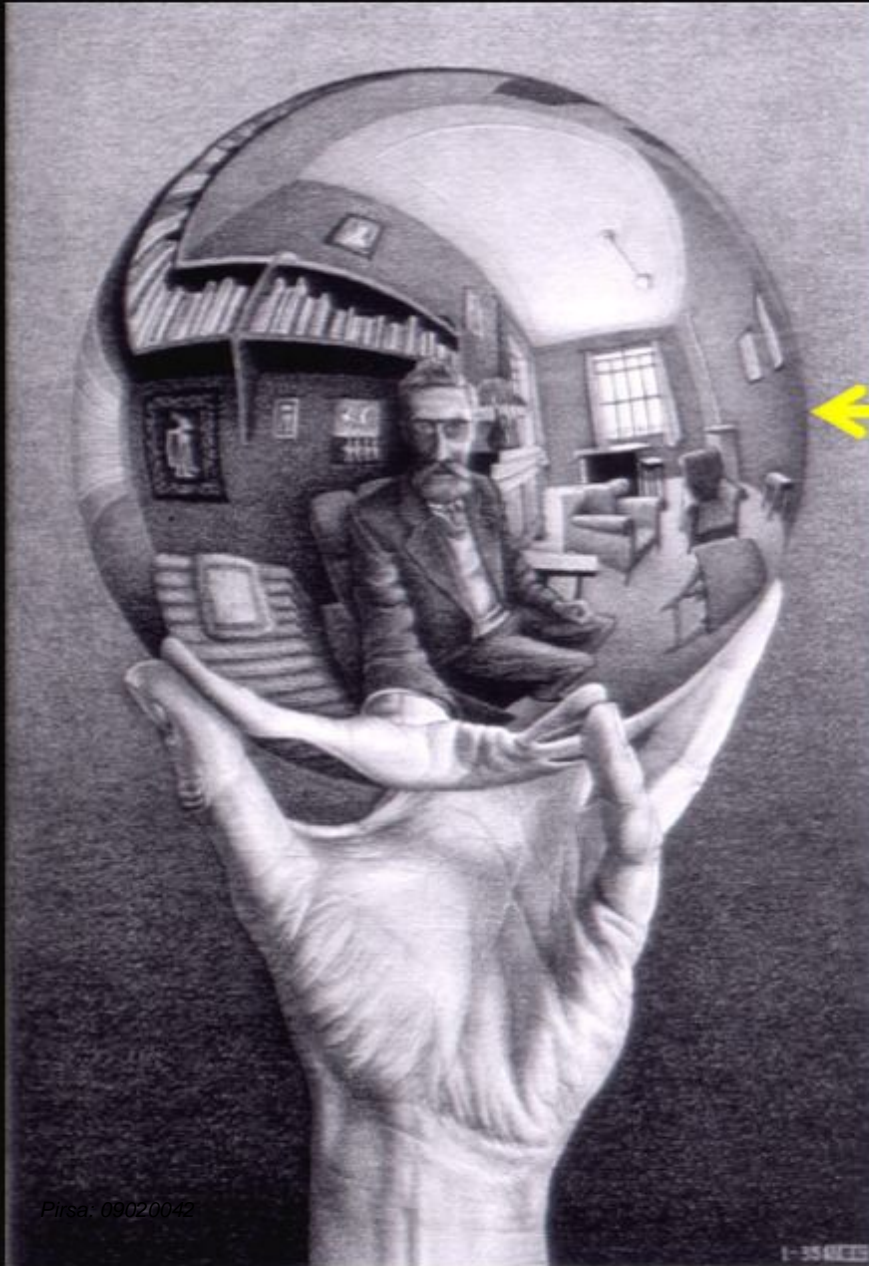
$$M = c^2 R / 2G \text{ (black hole)}$$

Maximum Information?



A black hole will form
when number of bits of
info = $\text{Area} / 4\mathcal{A}$

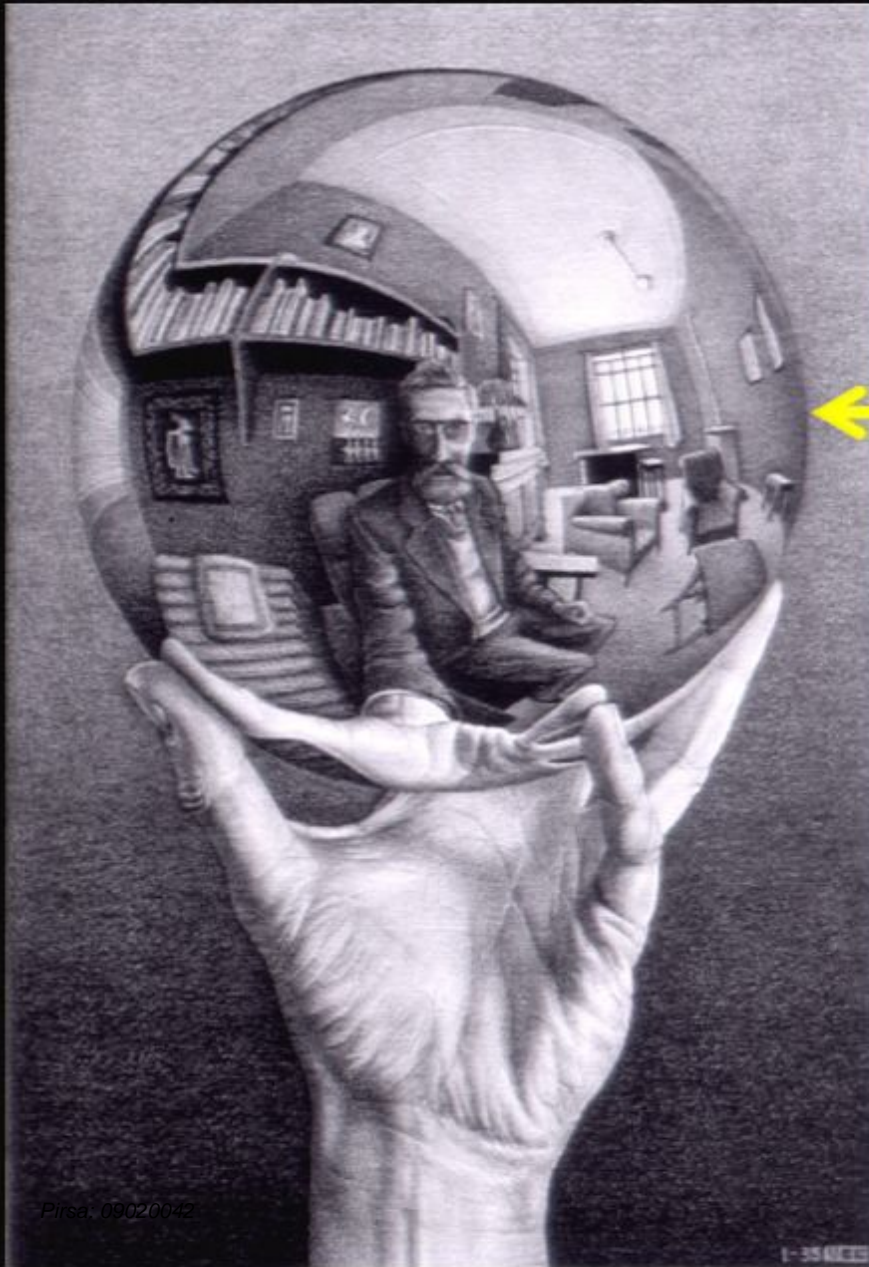
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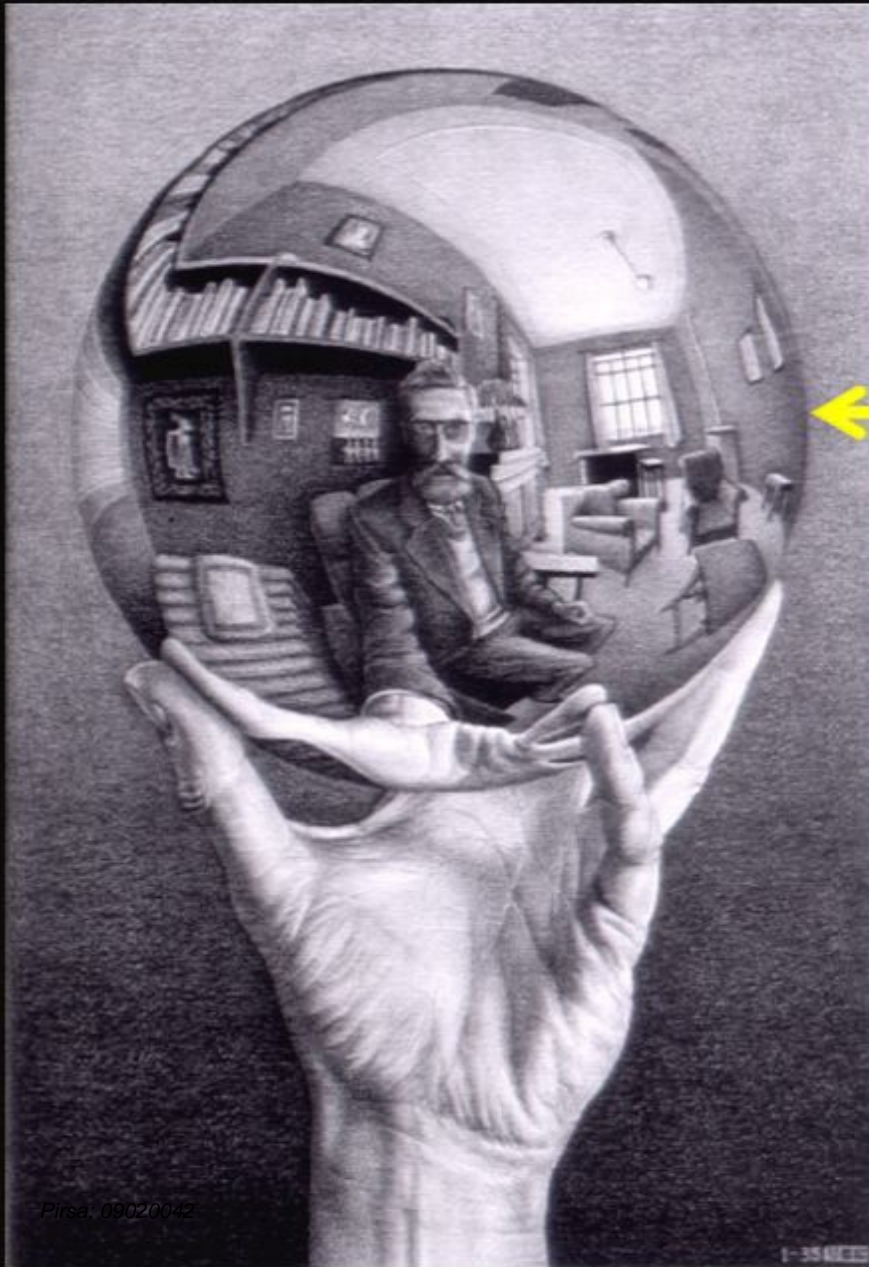
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A black hole will form
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$\mathcal{A} = 10^{-66} \text{ m}^2$ (Planck area)

Maximum Information?

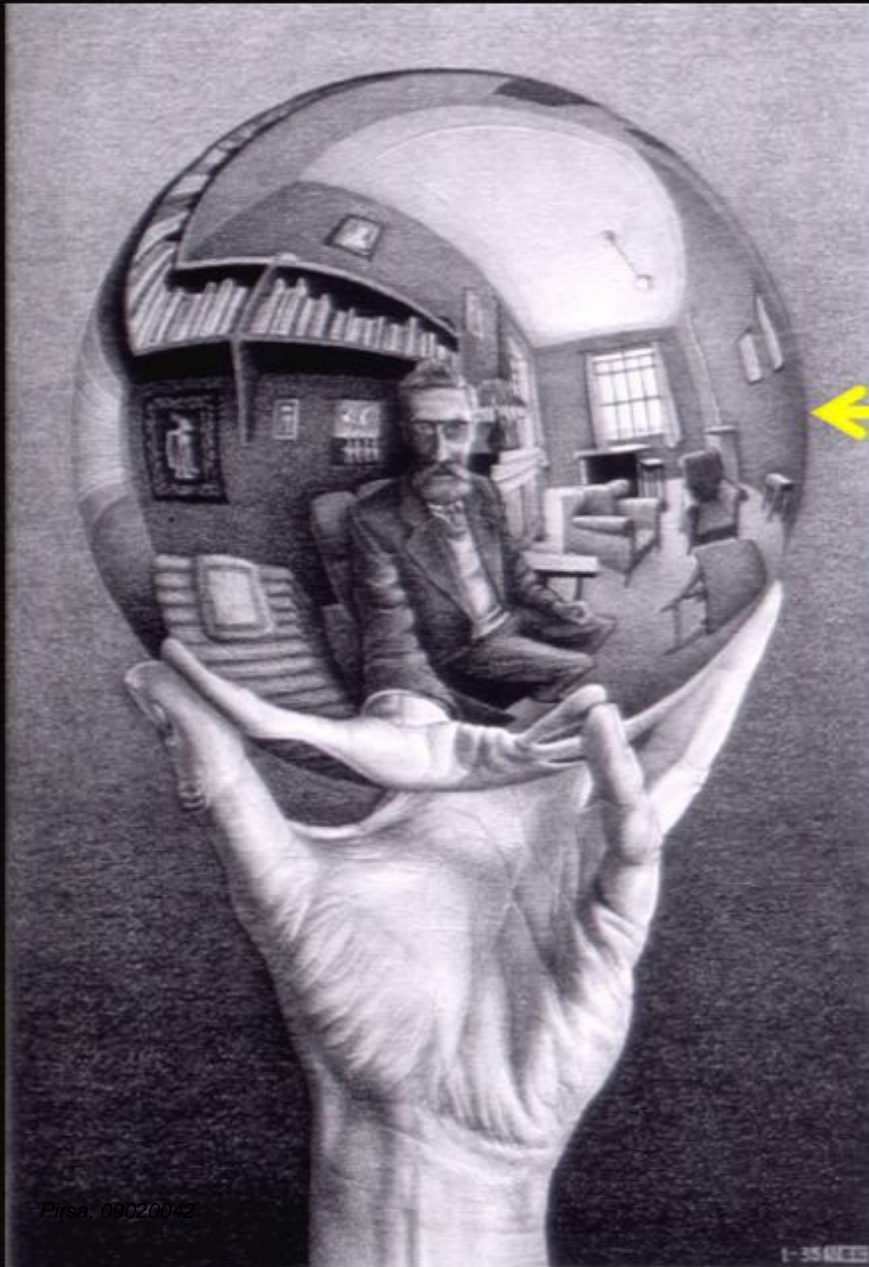


A black hole will form
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$\mathcal{A} = 10^{-66} \text{ m}^2$ (Planck area)

Bizarre: Max Info...

Maximum Information?



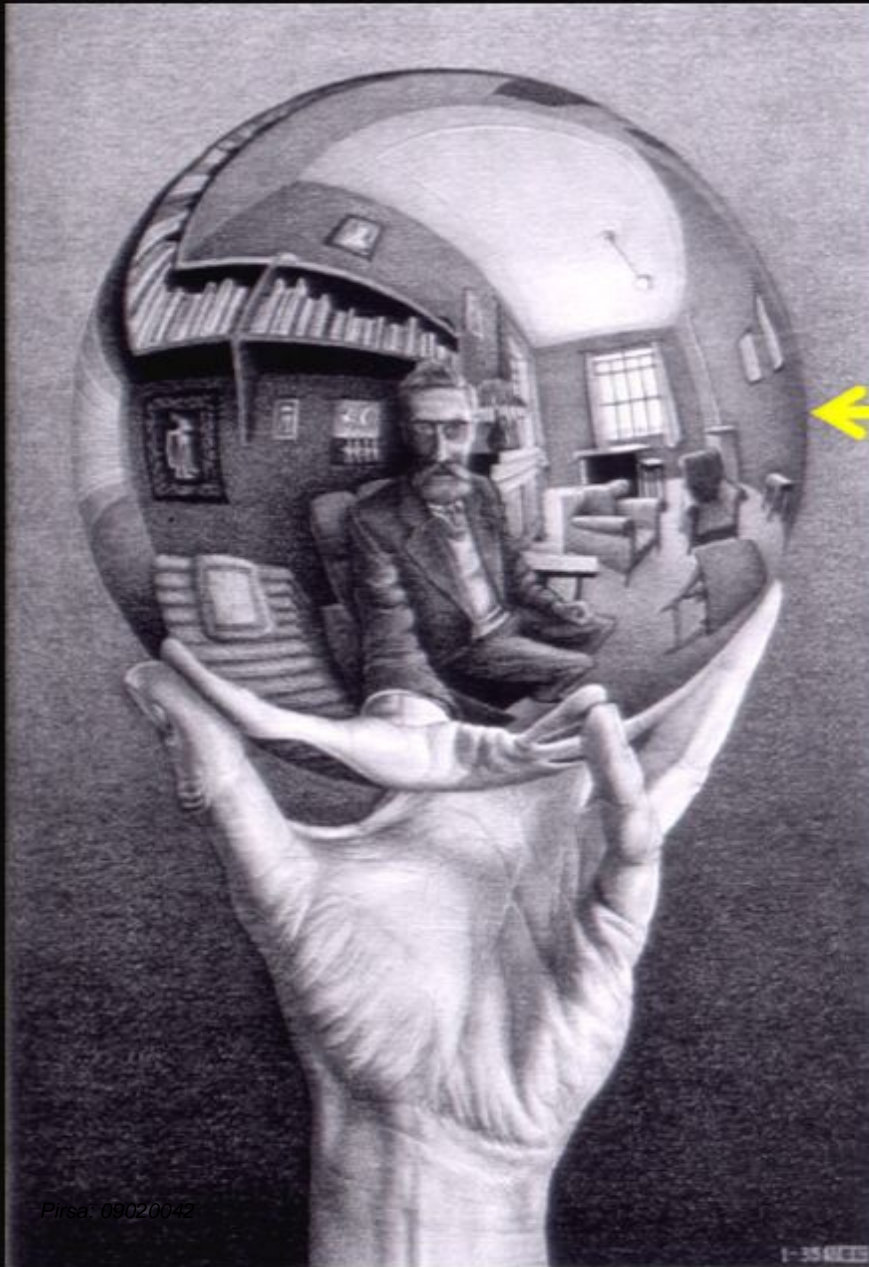
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Bizarre: Max Info...

1. Finite

Maximum Information?



A black hole will form
when number of bits of
info = Area / $4\mathcal{A}$

$\mathcal{A} = 10^{-66} \text{ m}^2$ (Planck area)

Bizarre: Max Info...

1. Finite
2. Depends on Area
not Volume

Our deepest hint at the nature of reality?

Our deepest hint at the nature of reality?



Our deepest hint at the nature of reality?

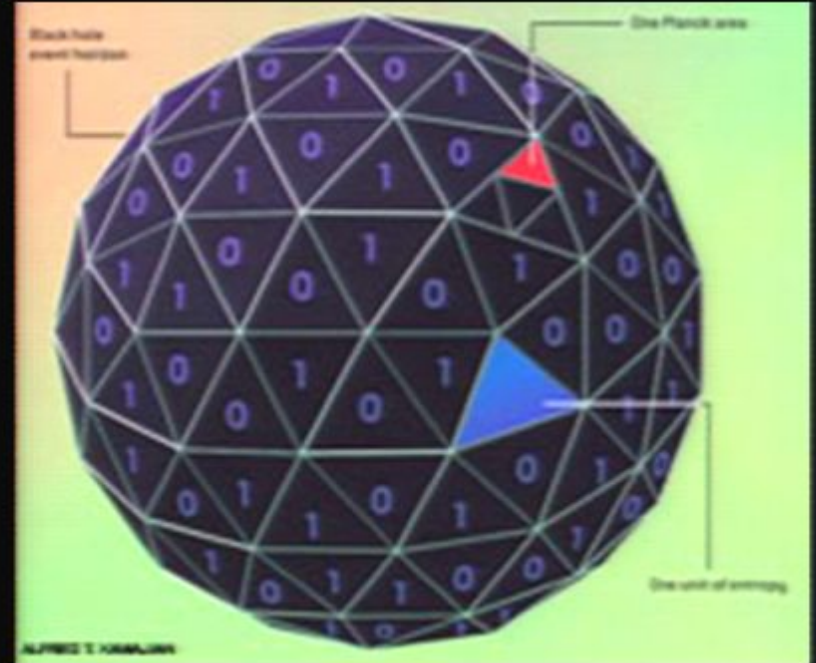


$$\begin{aligned} \text{Max Info} \\ = \\ \text{Area} / 4\mathcal{A} \end{aligned}$$

Our deepest hint at the nature of reality?



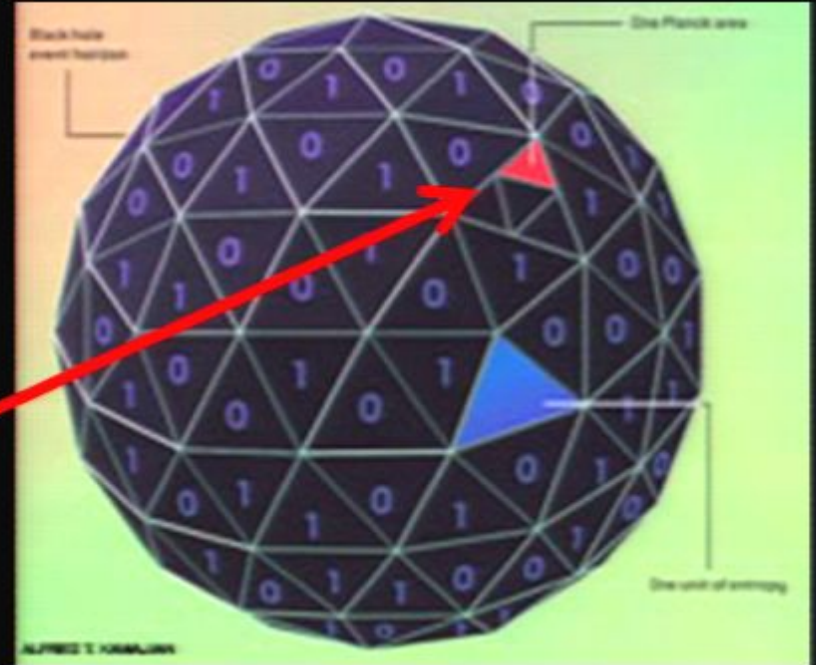
$$\text{Max Info} = \text{Area} / 4\mathcal{A}$$



Our deepest hint at the nature of reality?



$$\text{Max Info} = \text{Area} / 4\mathcal{A}$$

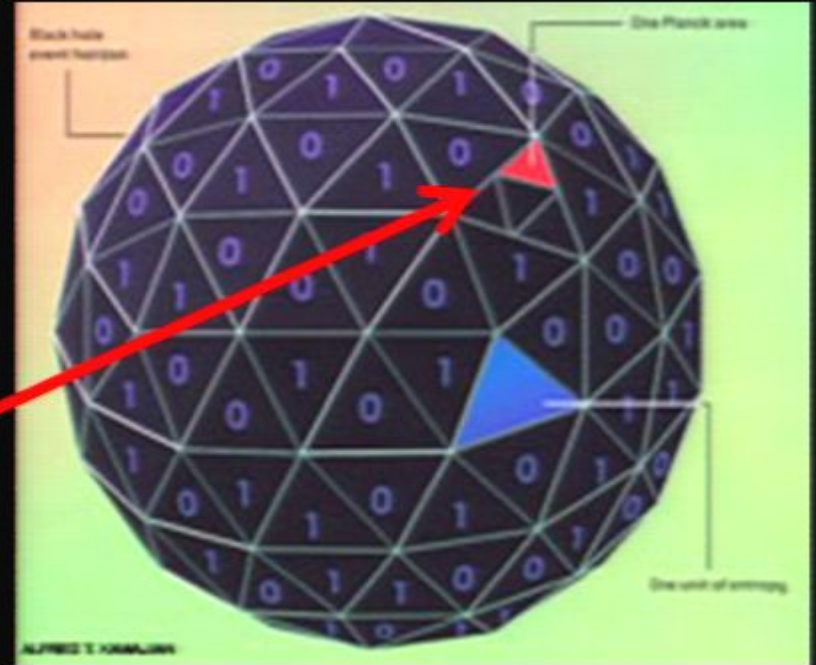


I think

Our deepest hint at the nature of reality?



$$\text{Max Info} = \text{Area} / 4\mathcal{A}$$



Think about it: This is *much less* info than expected. It's the same amount of info as for a reality "living" on just the surface surrounding the volume!

The World as a Hologram?

The World as a Hologram?

2-D hologram...



The World as a Hologram?

2-D hologram...



...contains 3-D info

The World as a Hologram?

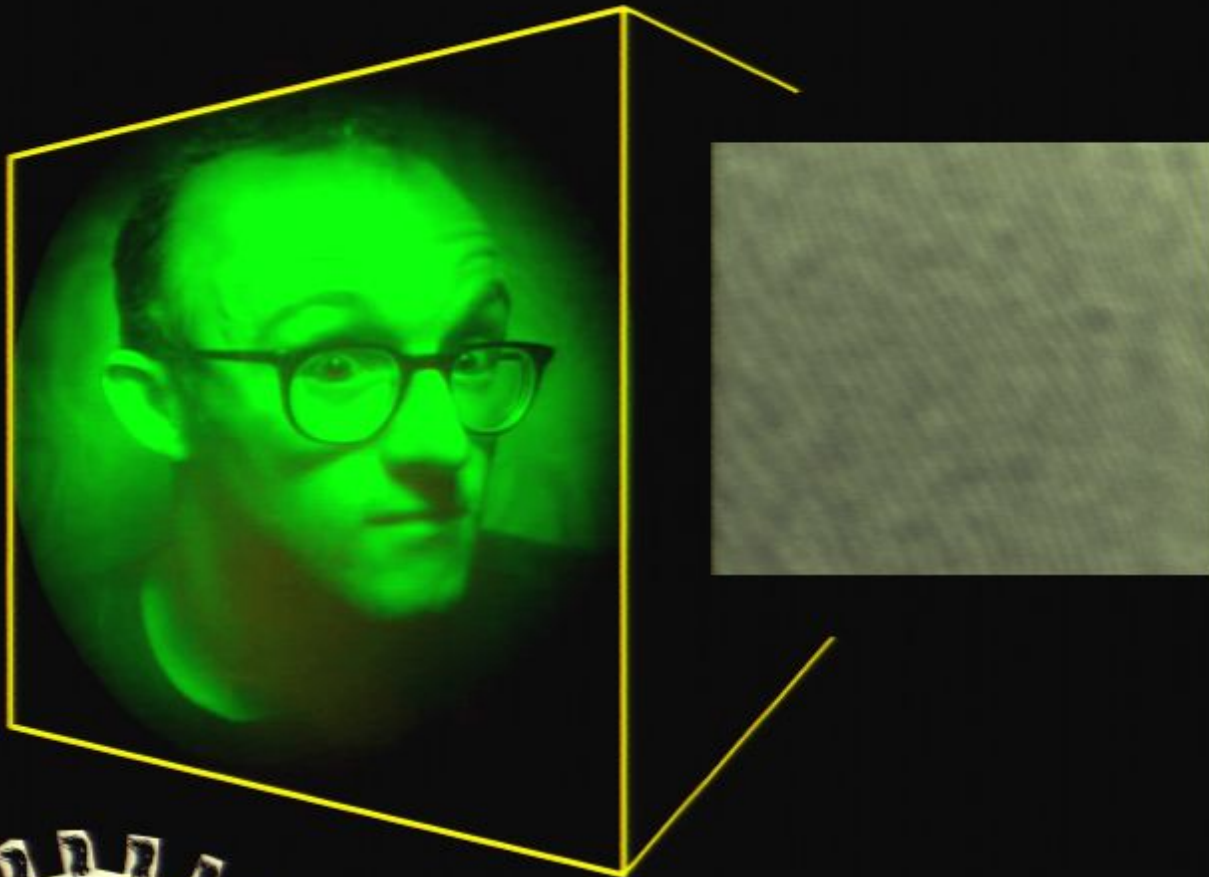
2-D hologram...



...contains 3-D info

The World as a Hologram?

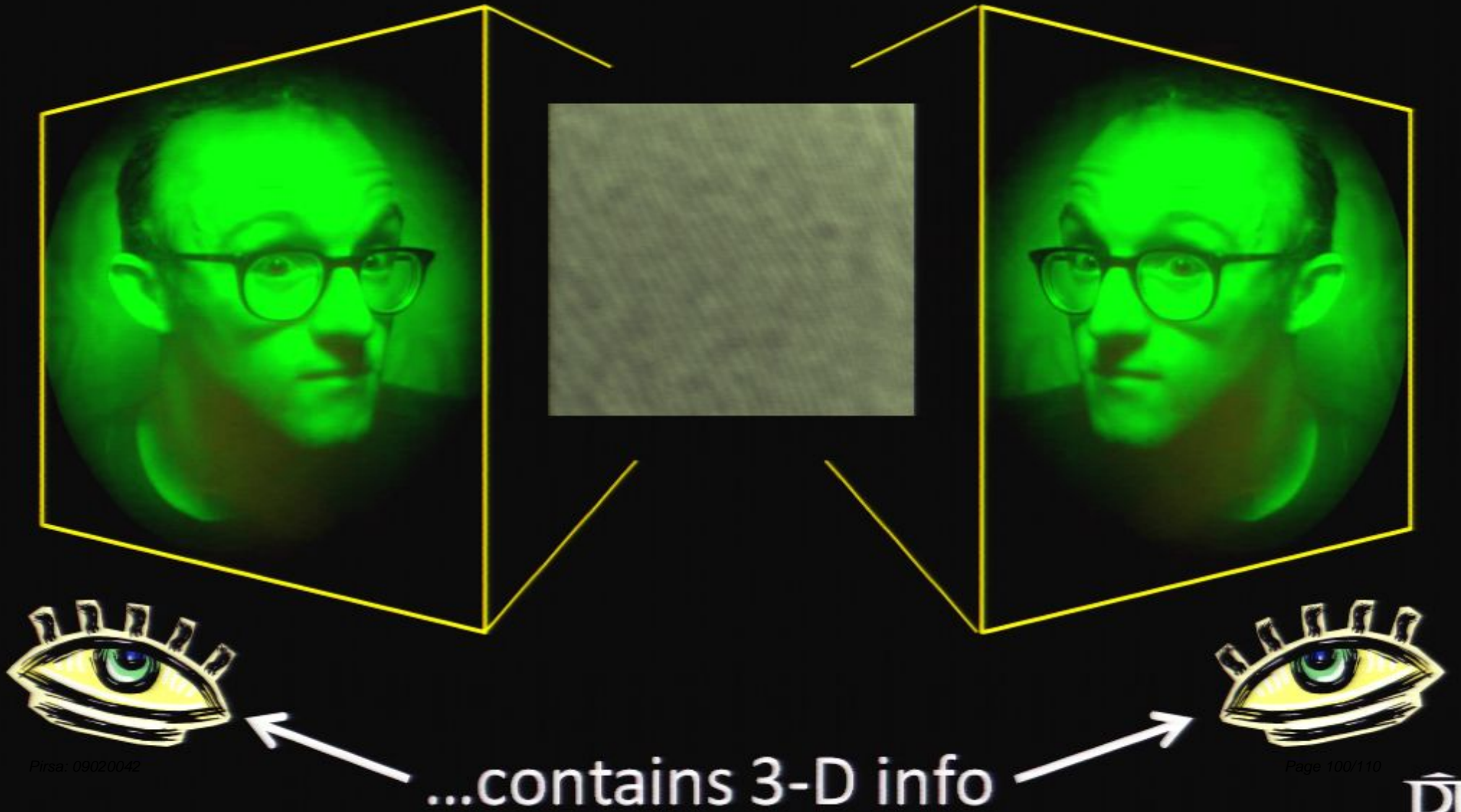
2-D hologram...



...contains 3-D info

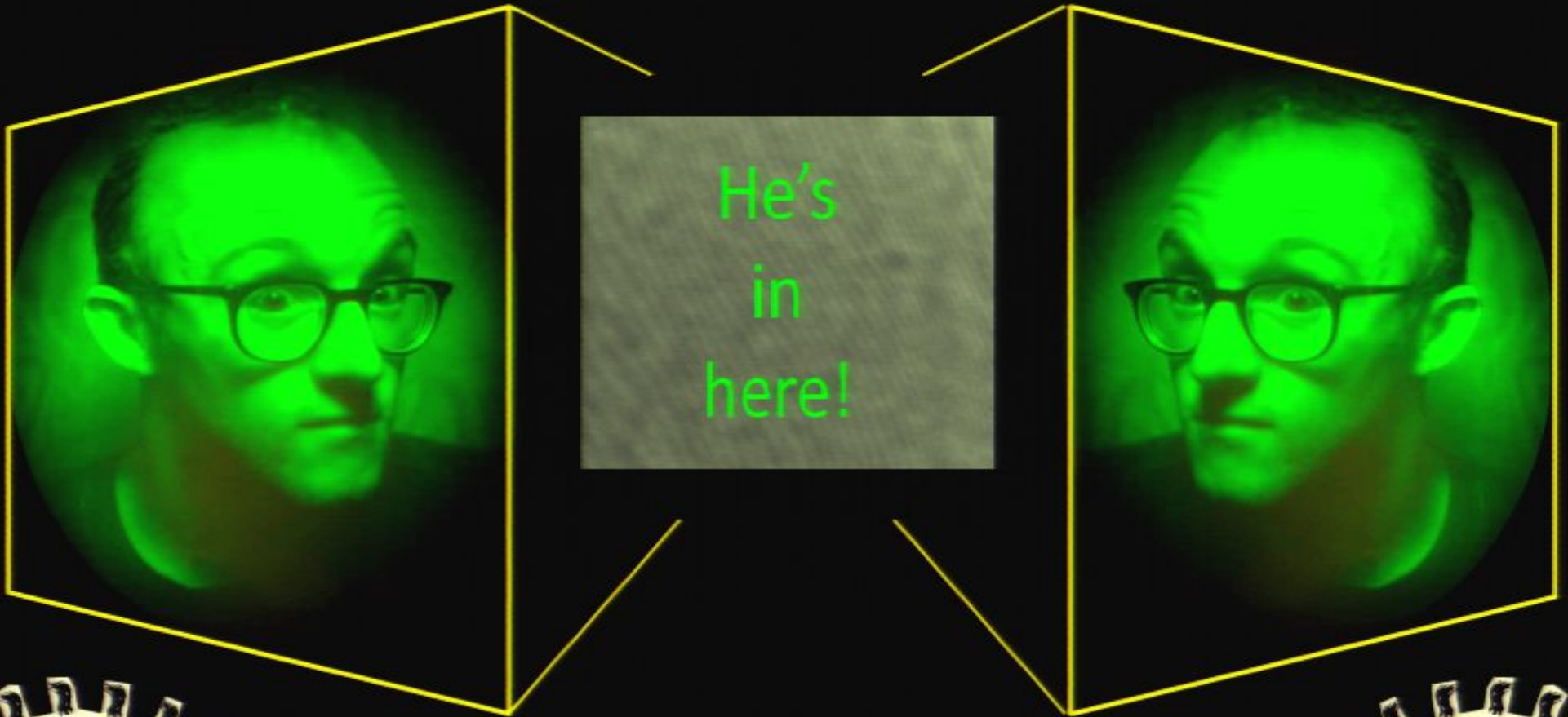
The World as a Hologram?

2-D hologram...



The World as a Hologram?

2-D hologram...



...contains 3-D info

The World as a Hologram?

2-D hologram...



The World as a Hologram?



The World as a Hologram?

2-D



The World as a Hologram?



The World as a Hologram?

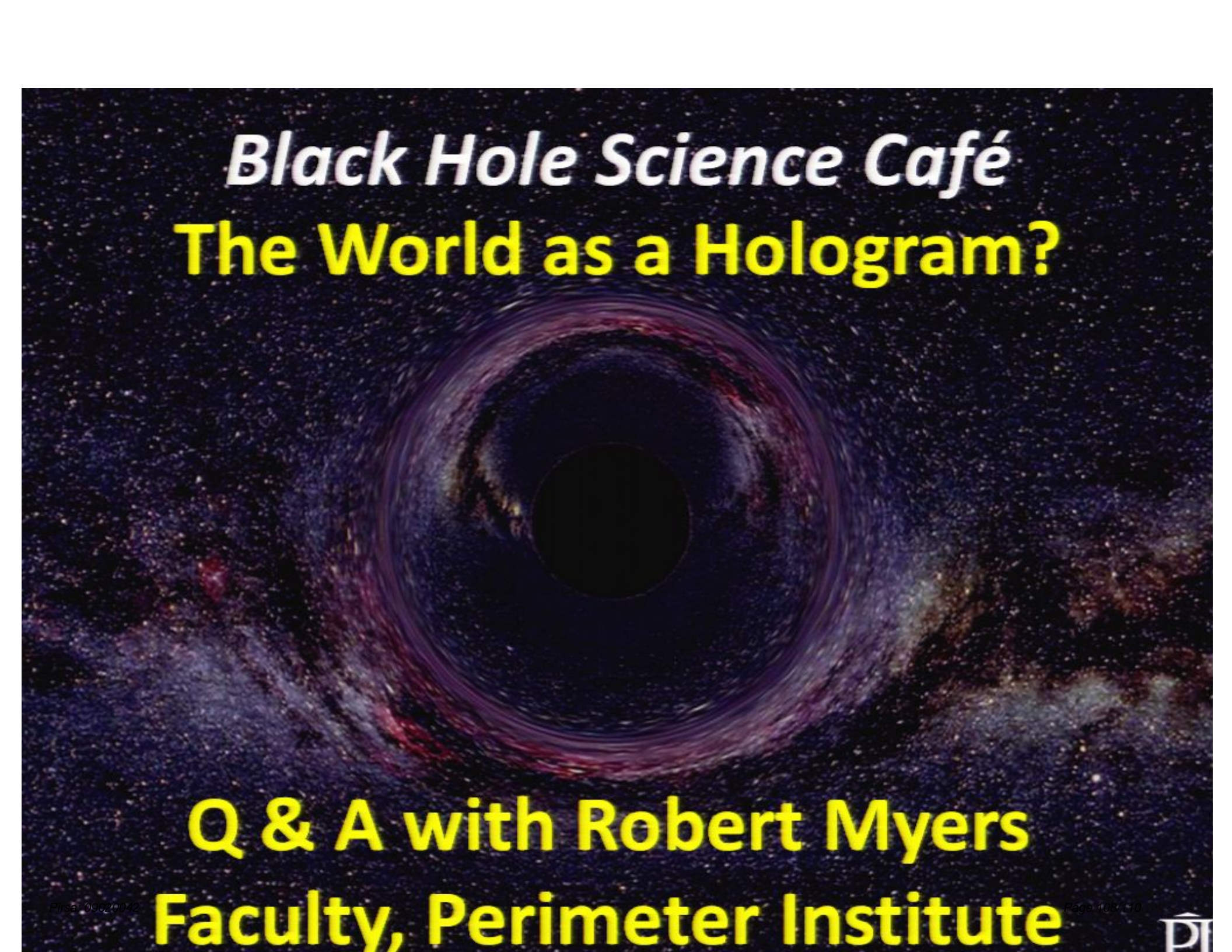


“Our everyday perceptions of the world as 3-D would then be either a profound illusion or merely one of two alternative ways of viewing reality.” – Jacob Bekenstein

The World as a Hologram?



What do you think?

A central black hole with a glowing accretion disk, surrounded by a field of stars. The text is overlaid on this image.

Black Hole Science Café
The World as a Hologram?

Q & A with Robert Myers
Faculty, Perimeter Institute

Please join us for the next
Black Hole Science Café



Please join us for the next
Black Hole Science Café



...meanwhile, visit the PI website:

public lectures...what we research...