

Title: The Black Hole Wars

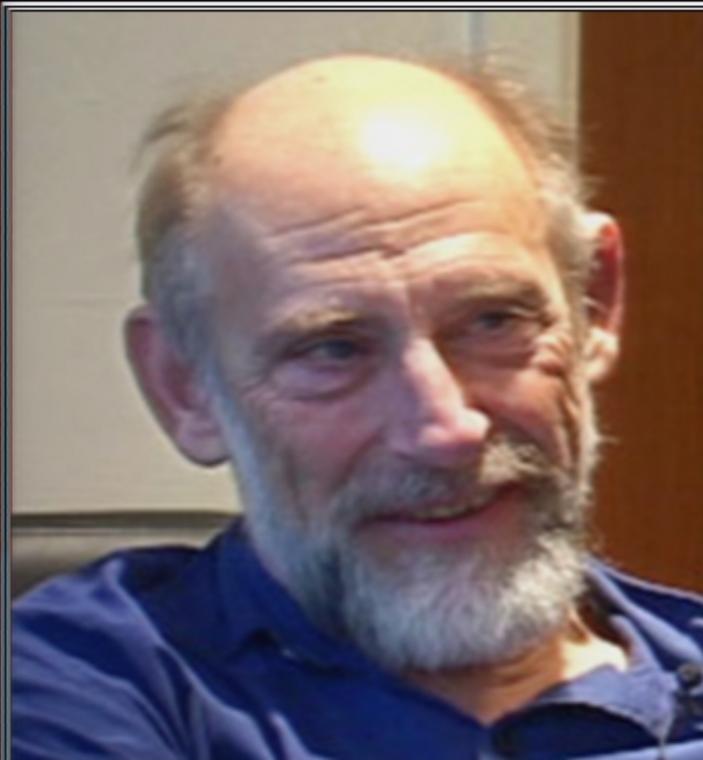
Date: Feb 02, 2005 06:30 PM

URL: <http://pirsa.org/05020004>

Abstract: The strange paradoxes and puzzles of the quantum behaviour of black holes and the things that fall into them led to a spirited battle of ideas between Stephen Hawking, Leonard Susskind and other scientists. Resolving the debate may change our entire understanding of space, time, matter and information – is the entire world, for example, a quantum hologram? <kw> black hole, Leonard Susskind, space-time, Einstein, Hawking, complementarity, uncertainty principle, holographic principle, string theory, </kw>

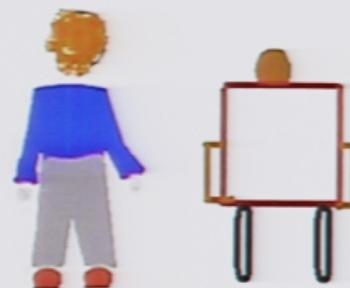
Leonard Susskind

Stanford University



The Black Hole Wars

February 2, 2005



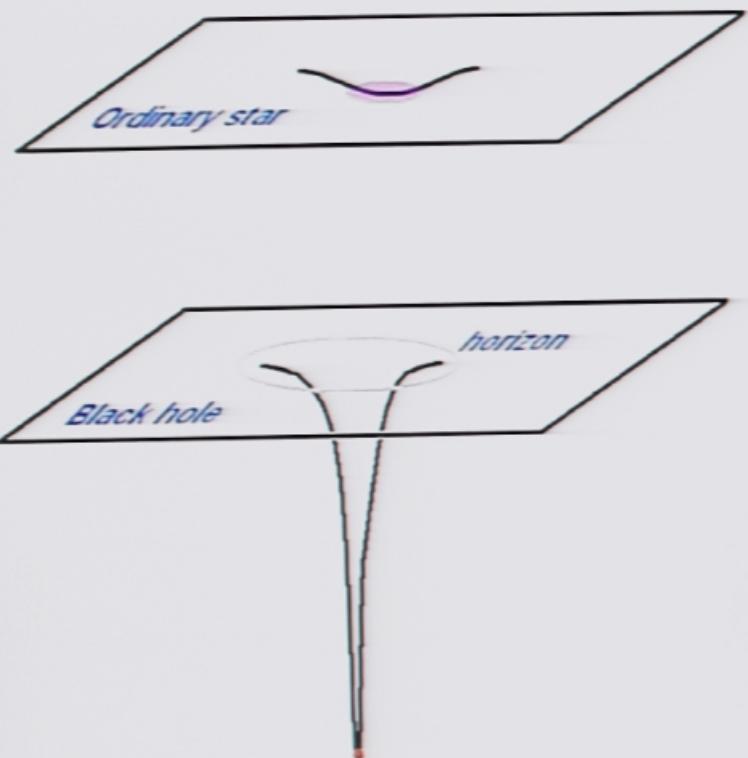
The Dark Star of Laplace

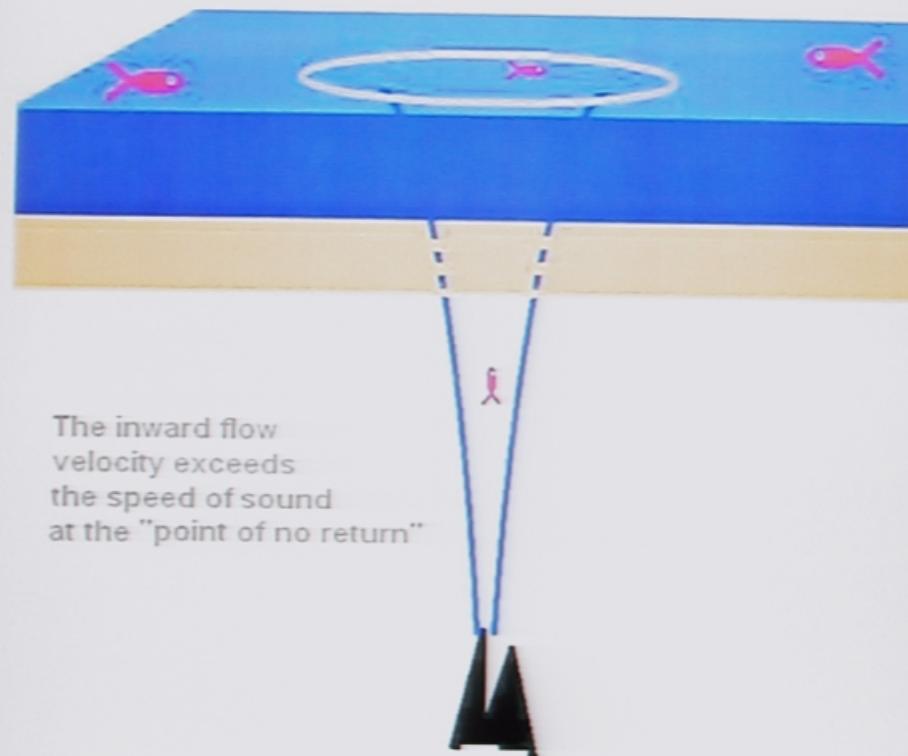


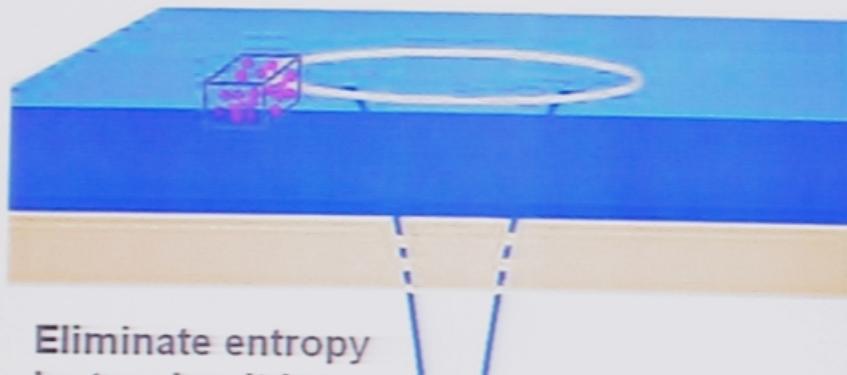
$$(\text{Escape velocity})^2 = \frac{2 M G}{R}$$

$$R_{\text{DS}} = \frac{2 M G}{c^2}$$

Gravity is a warping of space-time







Eliminate entropy
by tossing it into
black hole

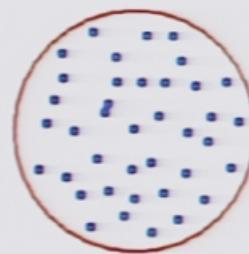
The gas will add
energy to the black
hole and increase its
size.

Black holes must have
entropy related to their
radius-- J. Bekenstein



1972

Entropy is Hidden Information. It is measured in BITS. It represents information hidden in microscopic degrees of freedom.



Entropy is the Logarithm of the number of quantum states that can't be distinguished.

Black holes have a heat content

Jakob Bekenstein
Stephen Hawking
William Unruh



$$\text{Energy} = M c^2$$

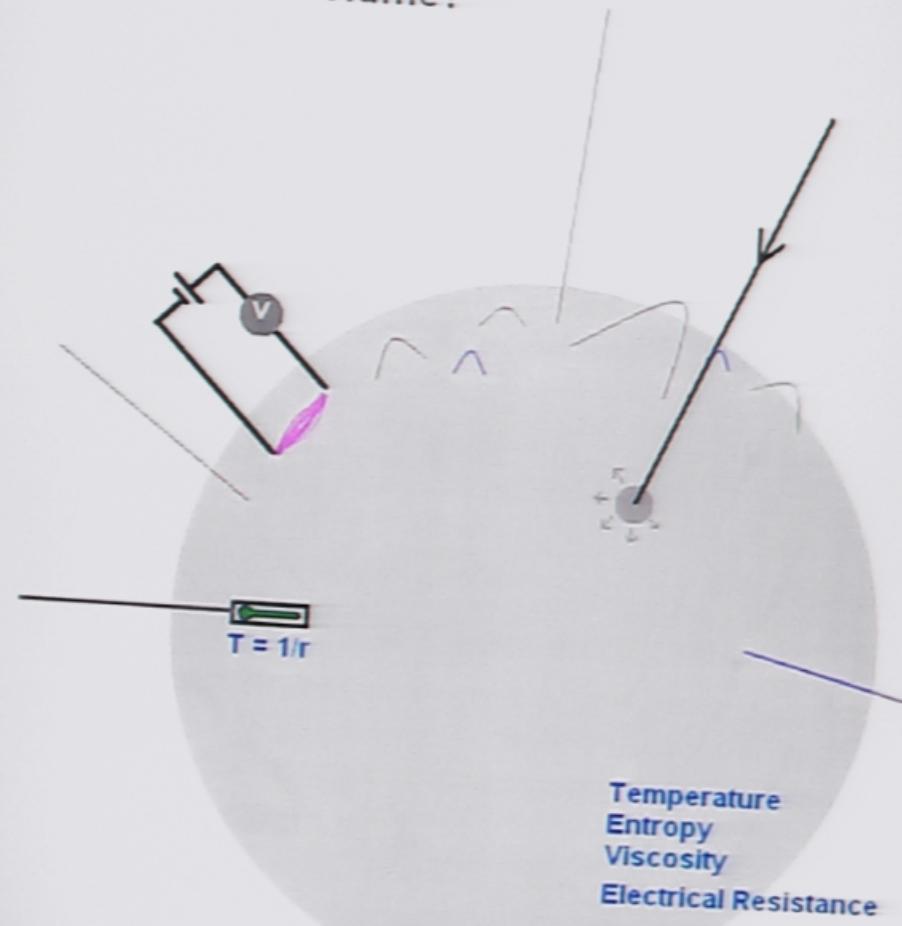
$$S = \frac{\text{Area } c^3}{4 \hbar G}$$

$$\text{Temp} = \frac{\hbar c^3}{8k\pi MG}$$

Hawking
black holes evaporate

Do black holes have a hidden micro-structure?

Why is the entropy proportional to the Area and not the Volume?



A Serious Conflict of Principles

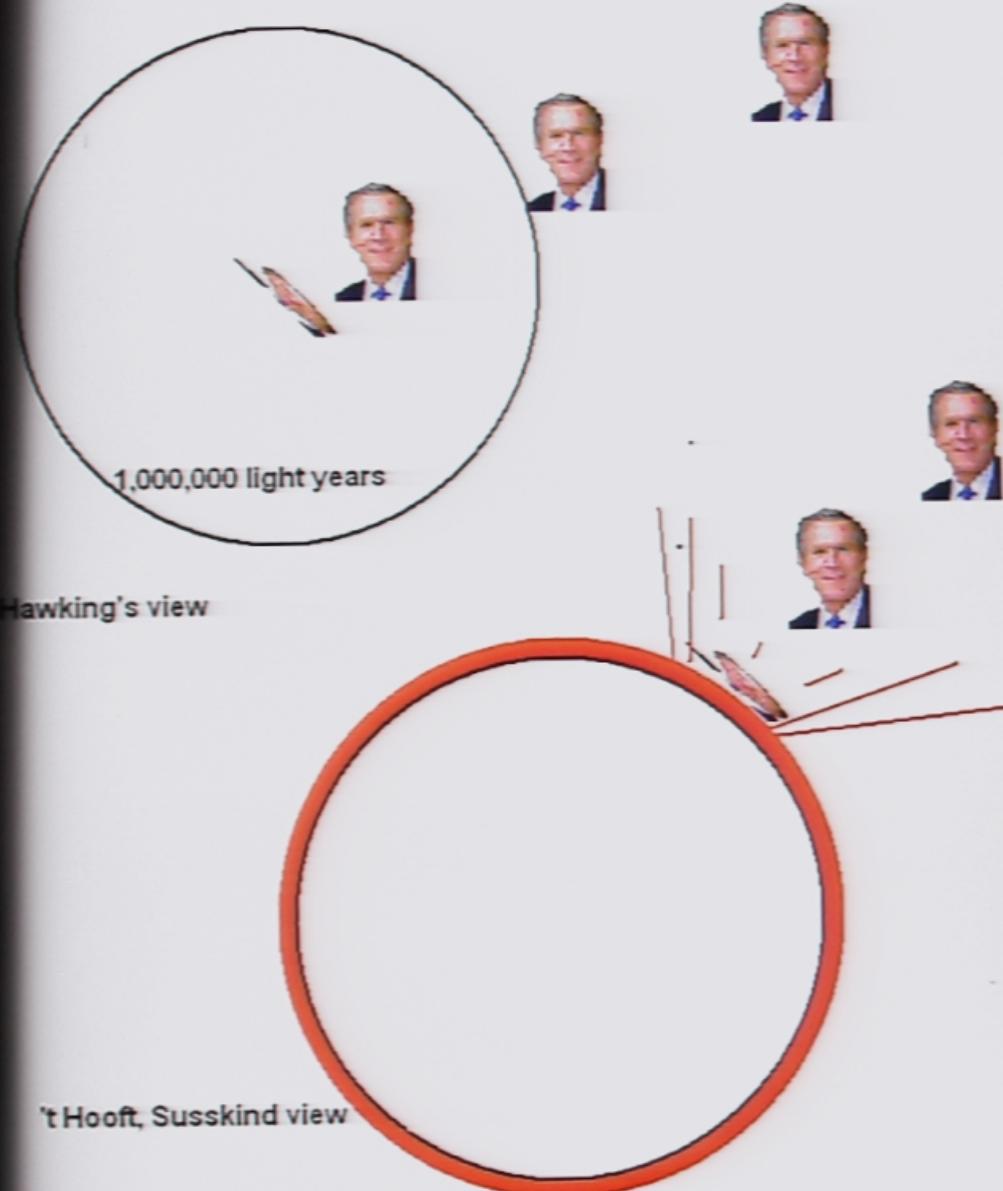


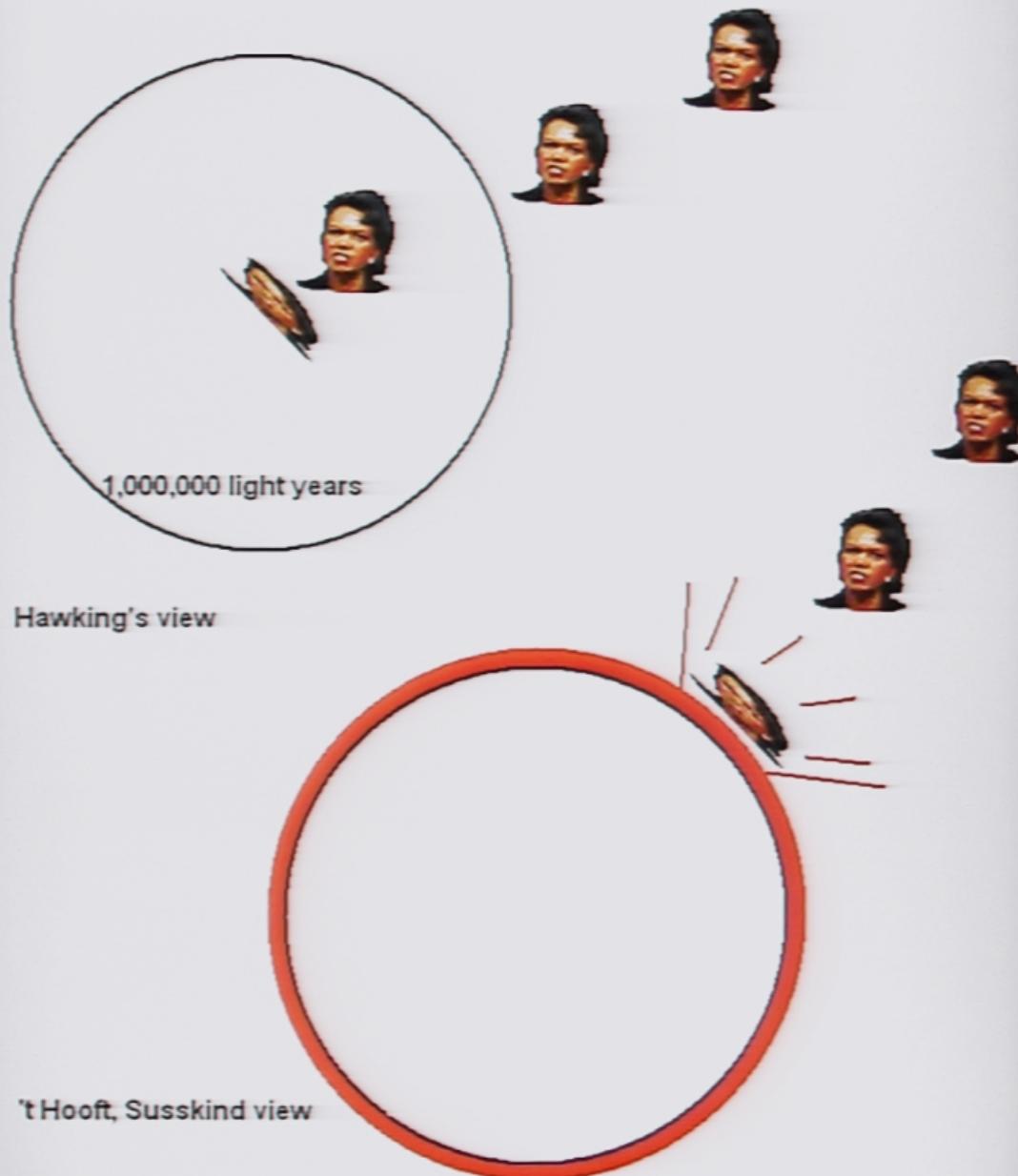
Equivalence
Principle

vs

Quantum
Information
Conservation

Hawking 1976





"When you have eliminated all that is impossible, whatever remains must be the truth, no matter how improbable."



Both stories are true
depending on who is telling
them!

Black Hole Complementarity
1993

Complementarity



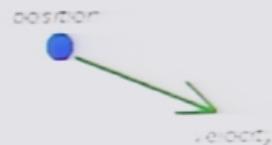
Light is waves

~~and~~ OR

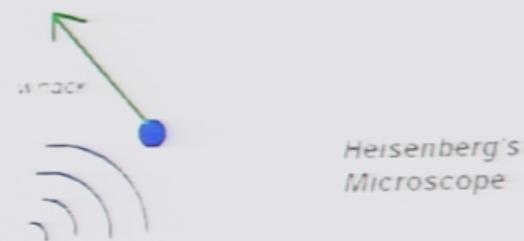
Light is particles



$$E = h\nu$$



An object has a position ~~and~~ OR a velocity



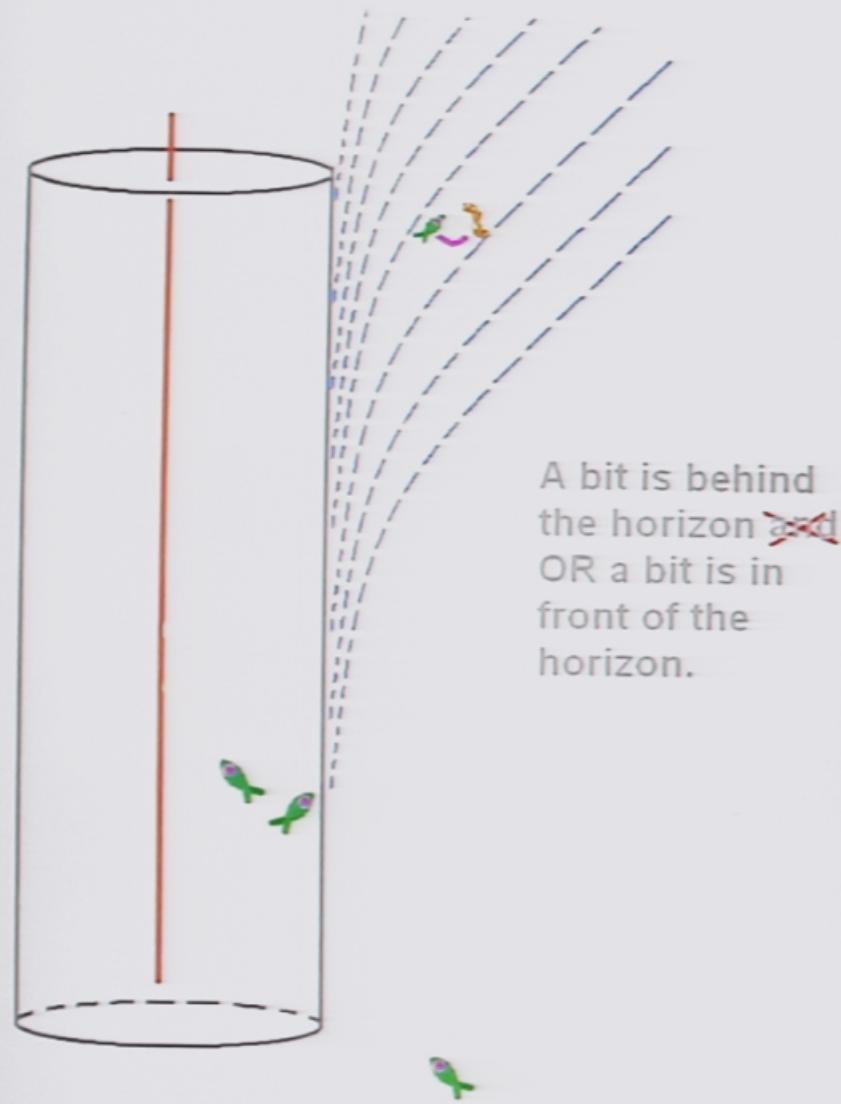
Uncertainty Principle

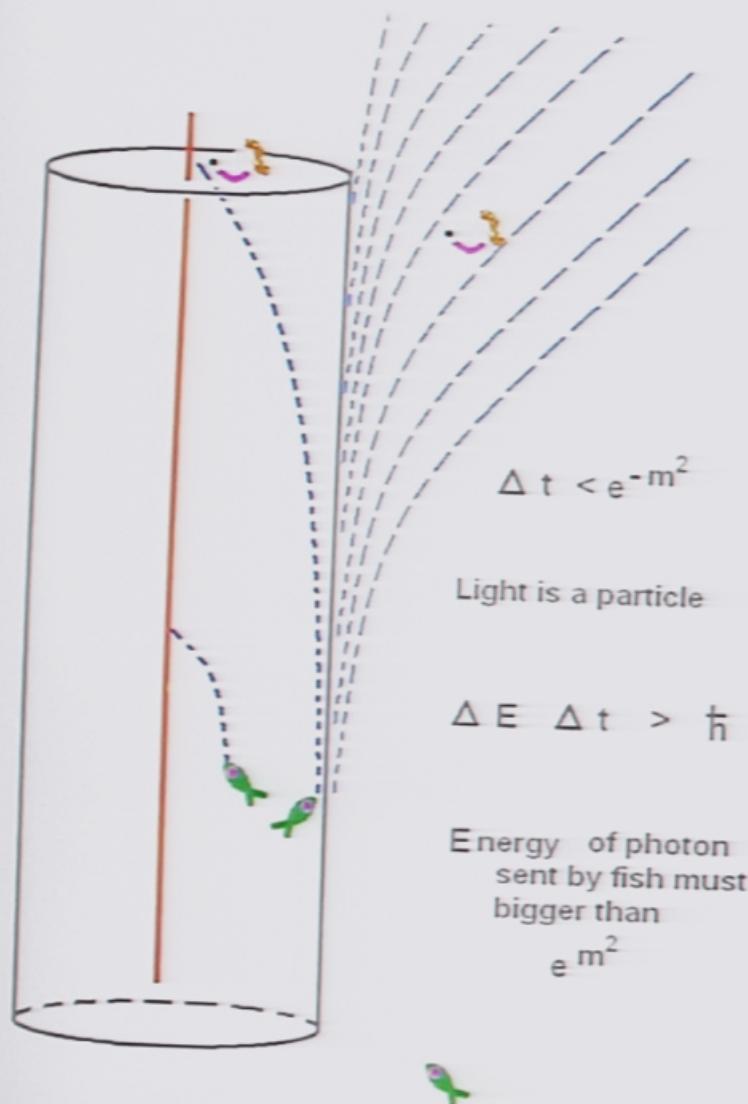
$$\Delta x \Delta p > h$$

An event has a time ~~and~~ OR an energy



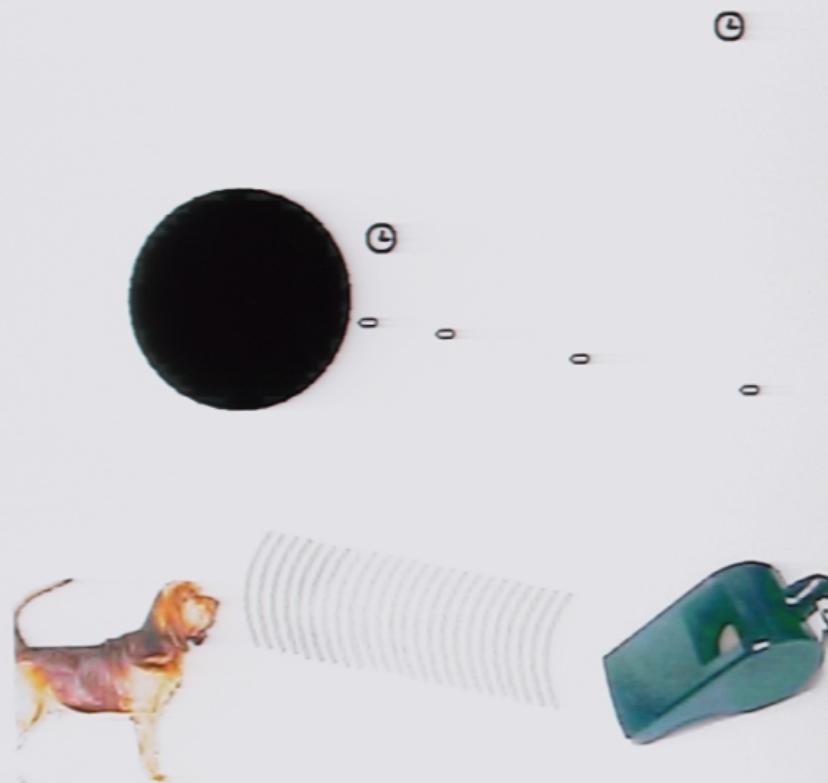
$$\Delta E \cdot \Delta t > h$$





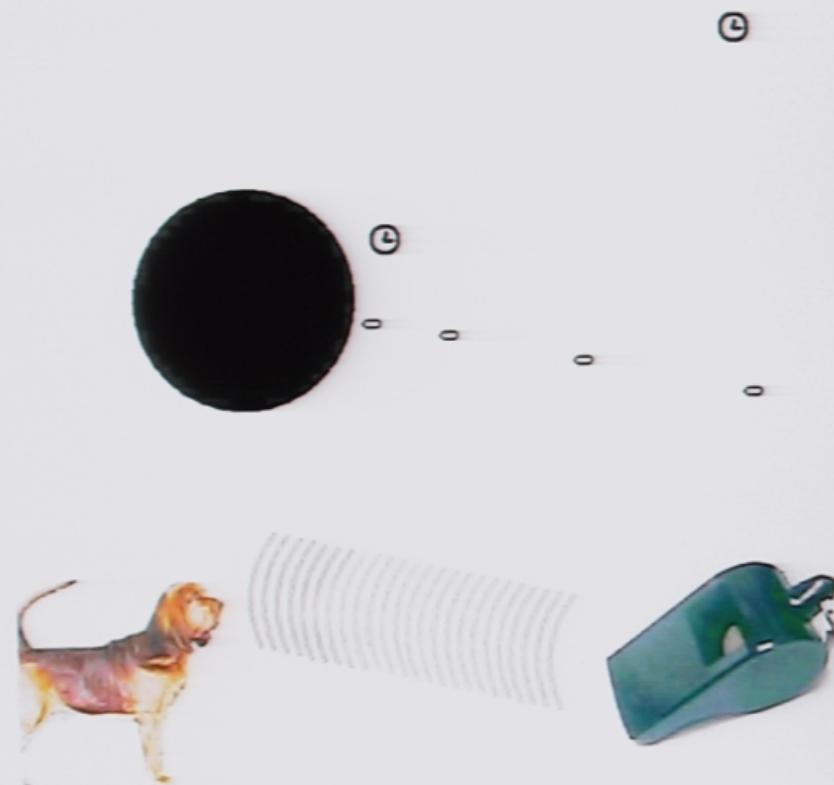
Strings and Black Holes

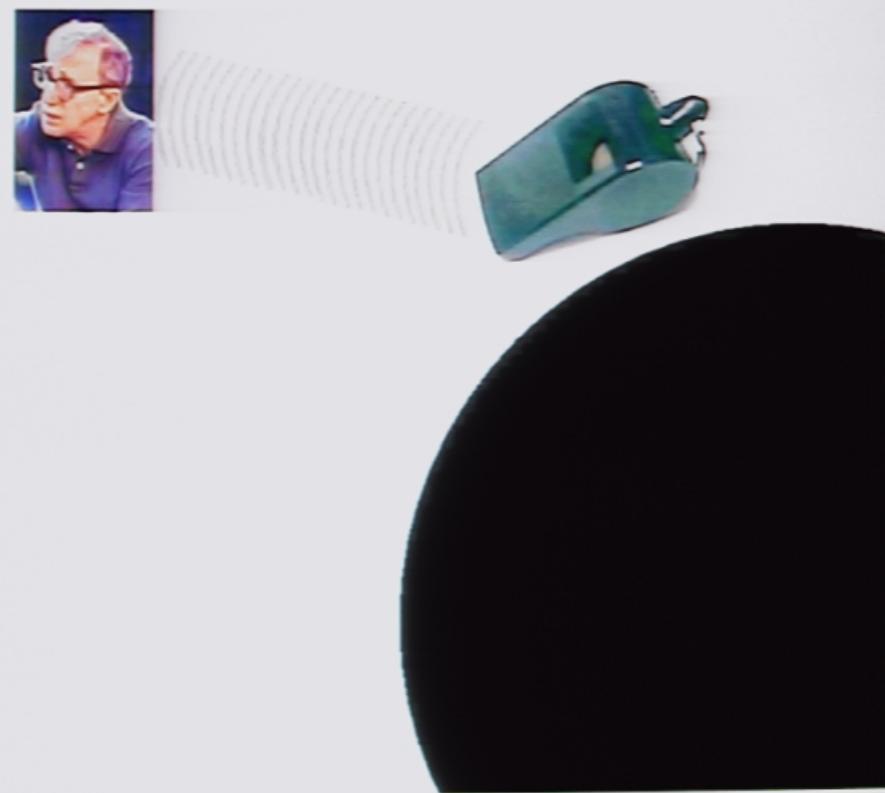
How could there be such a large ambiguity as to the location of a bit.

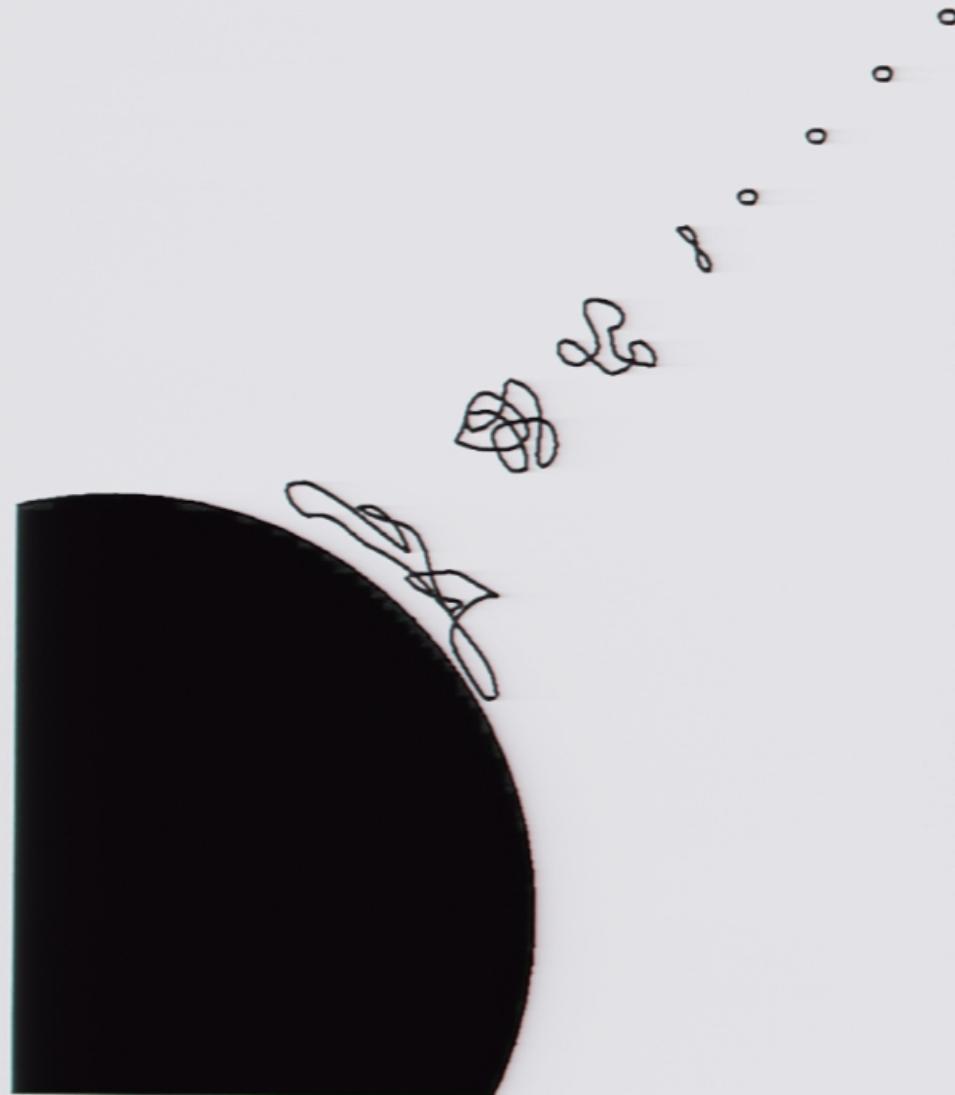


Strings and Black Holes

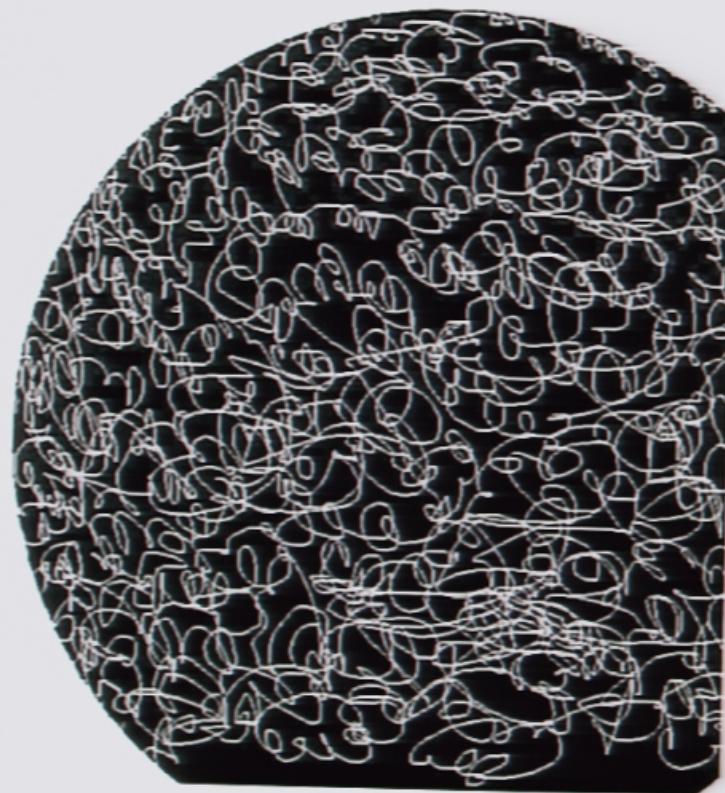
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2 2

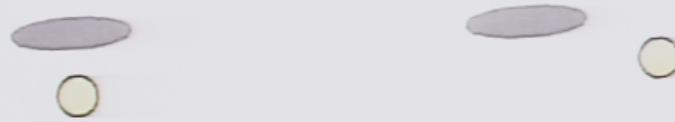


A new relativity principle:



Simultaneity is relative

But



Inside is
inside

Outside is
outside

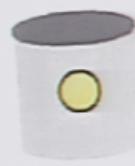
But in the new physics even this depends
on the state of motion of the observer!

A new relativity principle



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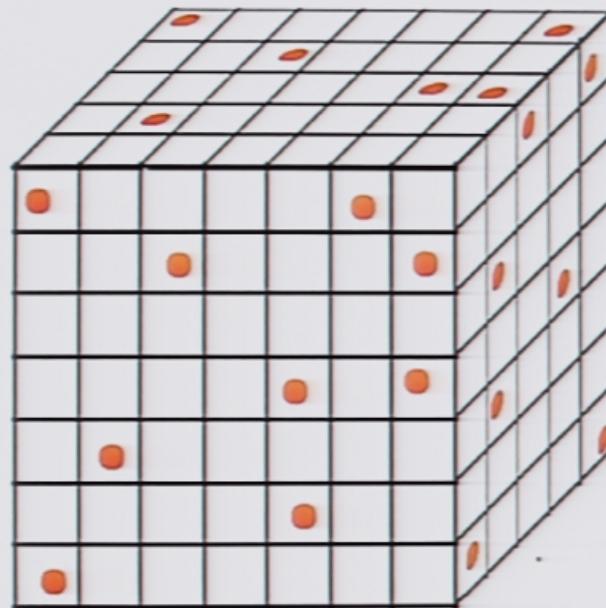


Outside is
outside

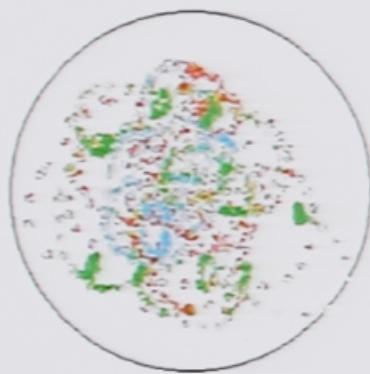
But in the new physics even this depends
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The Holographic Principle

Dividing space into voxels



The maximum number of bits you can hide is the number of planckian cells; the volume measured in planck units.



What is the maximum number of bits that can be contained in a given volume?



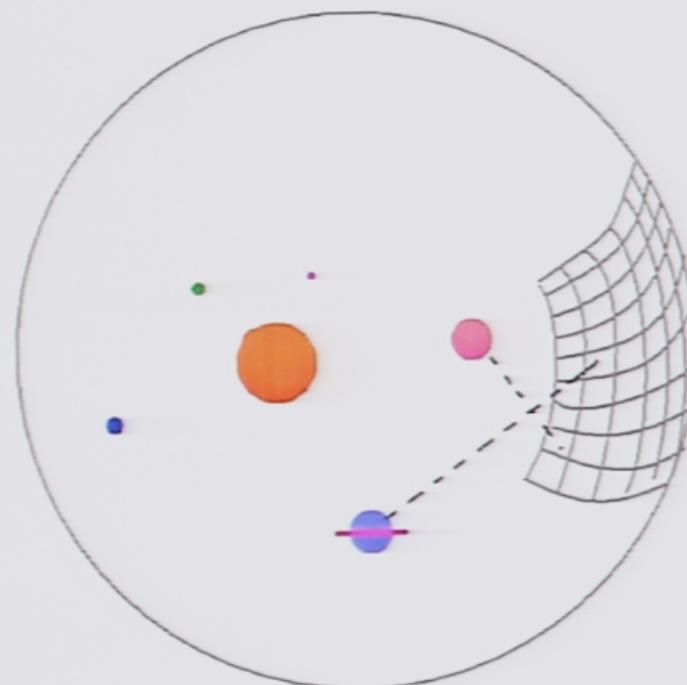
Trap them in a black hole.

The final entropy is

$$\frac{\text{Area } c^3}{4 \hbar G}$$

The Maximum number of bits that is needed to describe a region of space is proportional to its **AREA** (in Planck units)

The world is described by pixels, not voxels!



The world is a "quantum hologram"

<http://us.f422.mail.yahoo.com/m/ShowLetter/20aJPG?viewmsg=1&box=inbox&MsgId=-1/28/2005>



Maldacena's Holographic Example in
anti-deSitter space

Maldacena's Holographic Example in anti-deSitter space

