

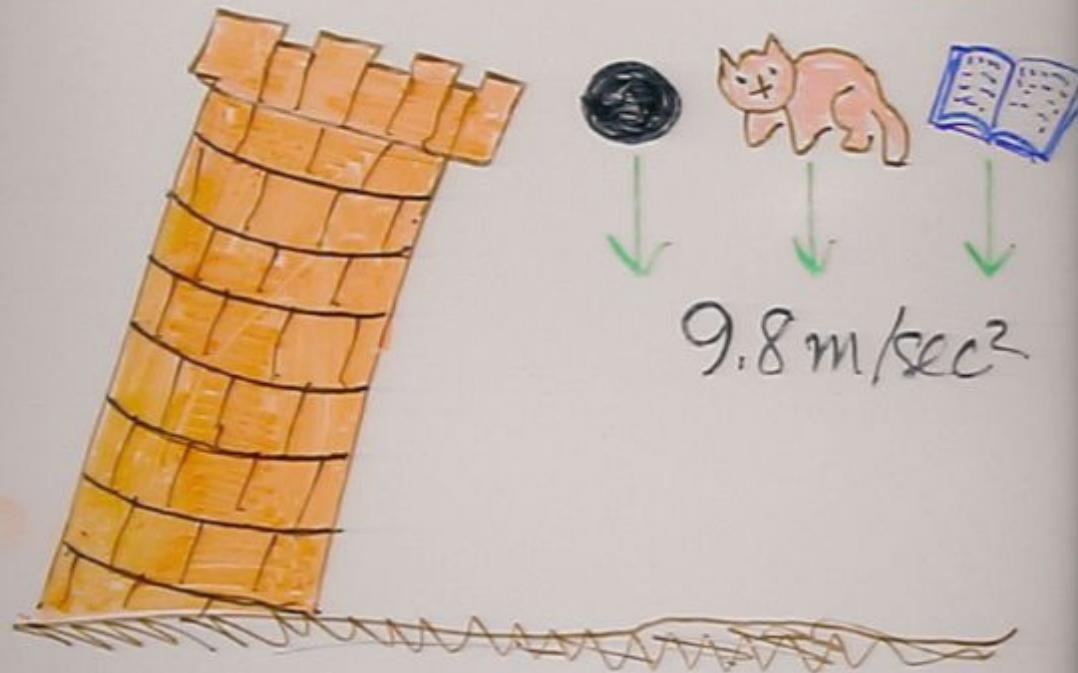
Title: James Hartle - Einstein's Vision and the Quantum Universe.

Date: Oct 02, 2004 03:00 PM

URL: <http://pirsa.org/04100004>

Abstract: Einstein's Vision and the Quantum Universe. <kw>James Hartle, Einstein, quantum theory, universe, gravity, Newton, general relativity, special relativity, quantum physics, uncertainty principle, superposition, Hawking, wave function, Schrodinger</kw>

A UNIVERSAL LAW OF PHYSICS.



ACCELERATIONS KNOWN EQUAL
TO A FEW PARTS IN
1,000,000,000,000

Lunar Laser Ranging



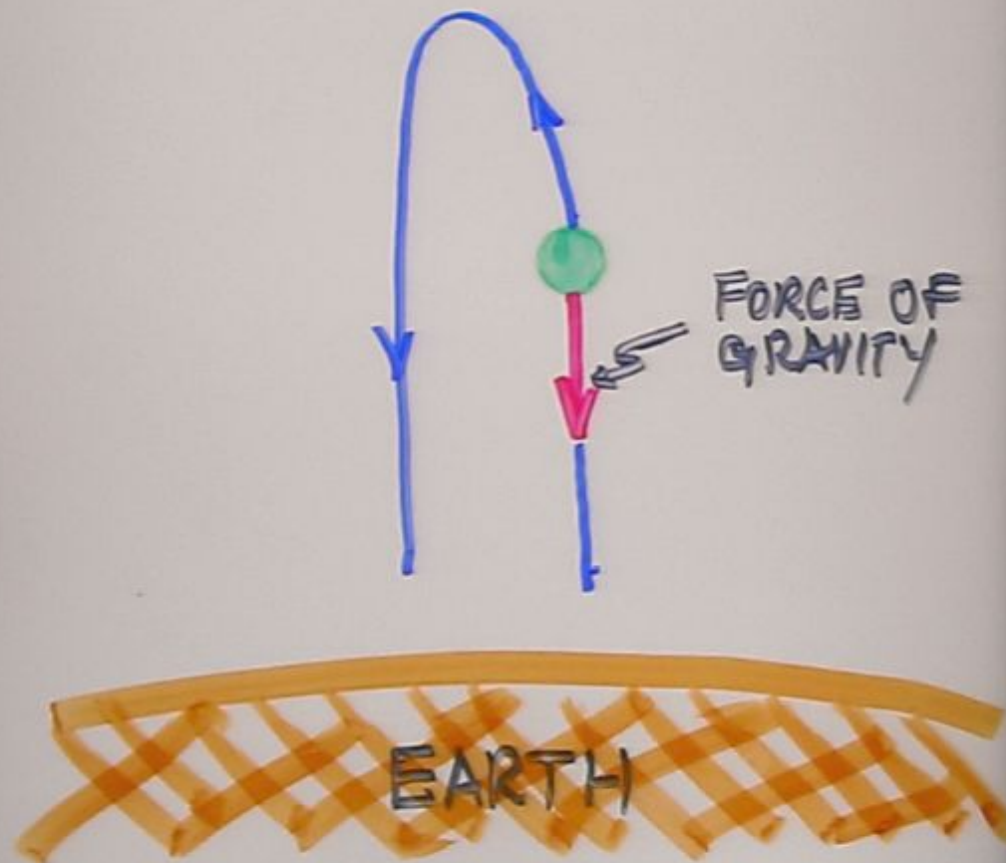
1	Transponder 1
2	Transponder 2
3	Transponder 3
4	Transponder 4
5	Transponder 5





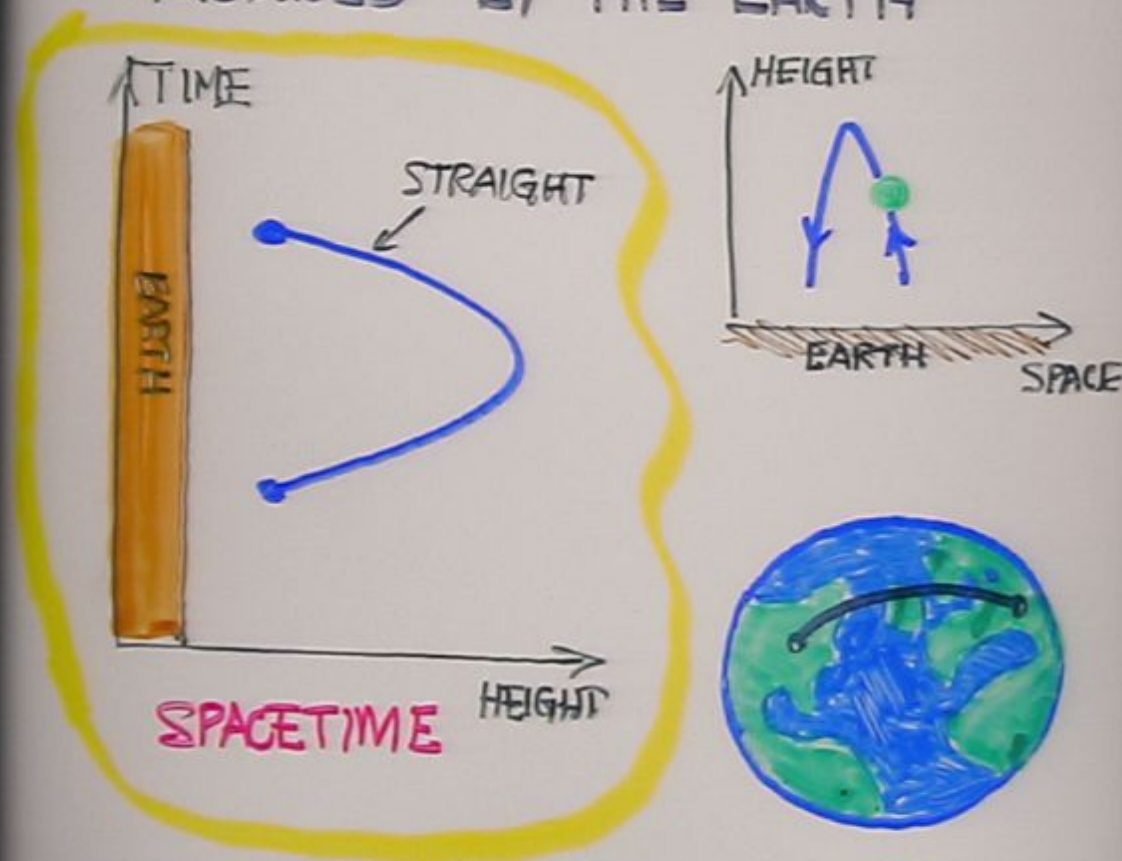
NEWTON'S FIRST LAW

BODIES MOVE IN STRAIGHT LINES
AT CONSTANT SPEED UNLESS
A FORCE ACTS ON THEM.

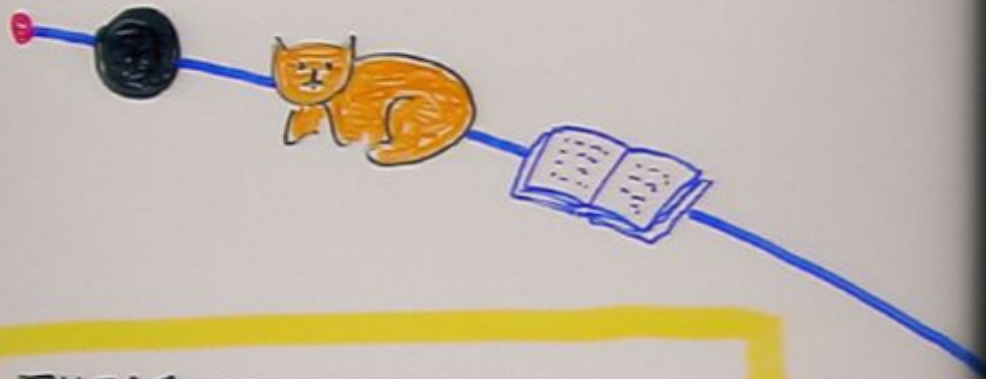


EINSTEIN'S GENERAL RELATIVITY

- NO GRAVITATIONAL FORCE
- BALL MOVES ON A STRAIGHT PATH IN THE CURVED SPACETIME PRODUCED BY THE EARTH



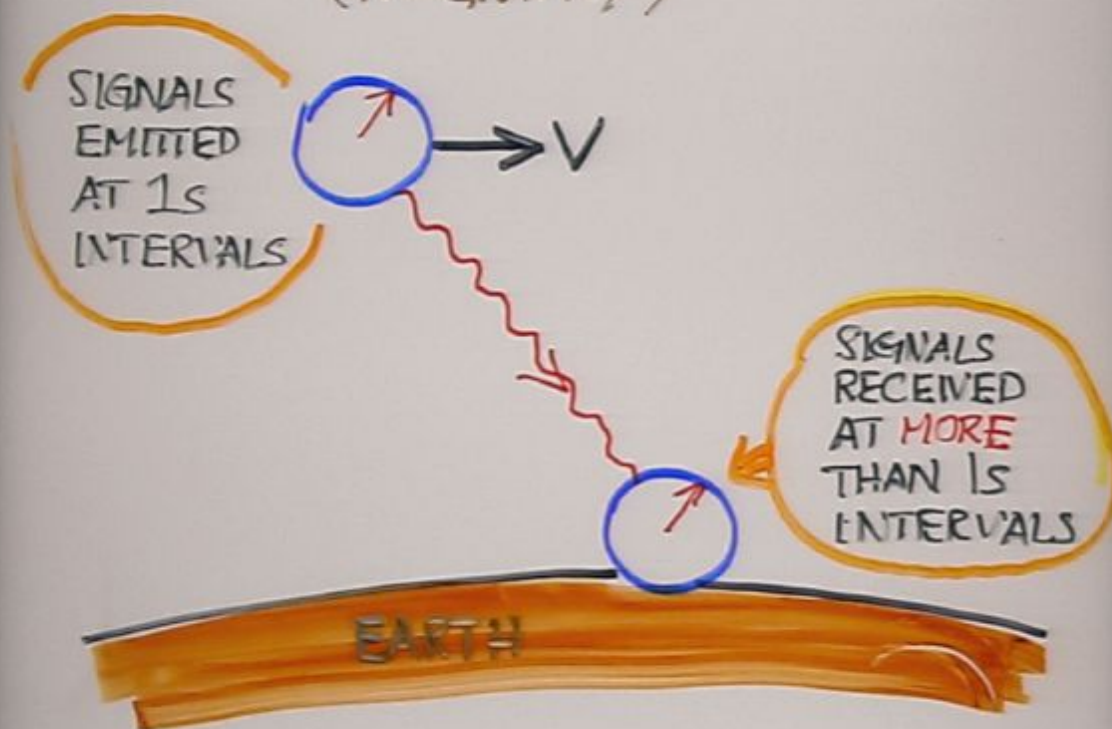
UNIVERSAL FREE FALL EXPLAINED



THERE IS ONLY ONE
STRAIGHT CURVE
BETWEEN TWO POINTS
IN SPACETIME
WHICH ALL BODIES FOLLOW
WHEN NO FORCE ACTS.

MOVING CLOCKS RUN SLOW

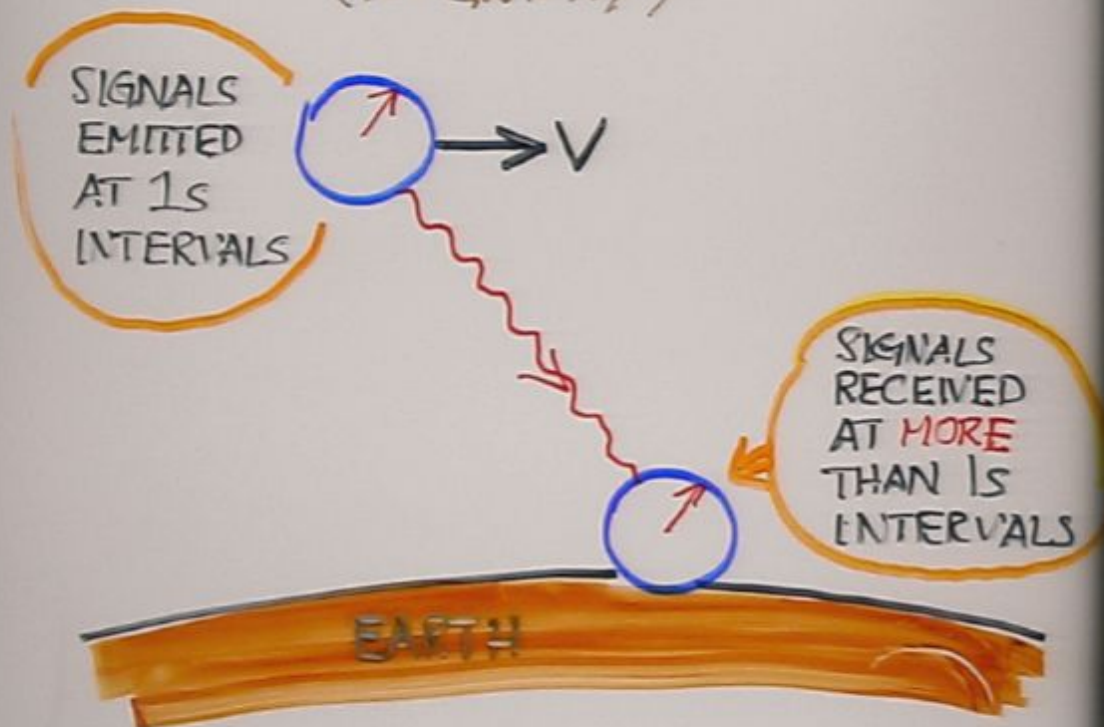
EINSTEIN'S 1916 SPECIAL RELATIVITY
(NO GRAVITY)



5 ten thousandths of a second
in a lifetime on airplanes

MOVING CLOCKS RUN SLOW

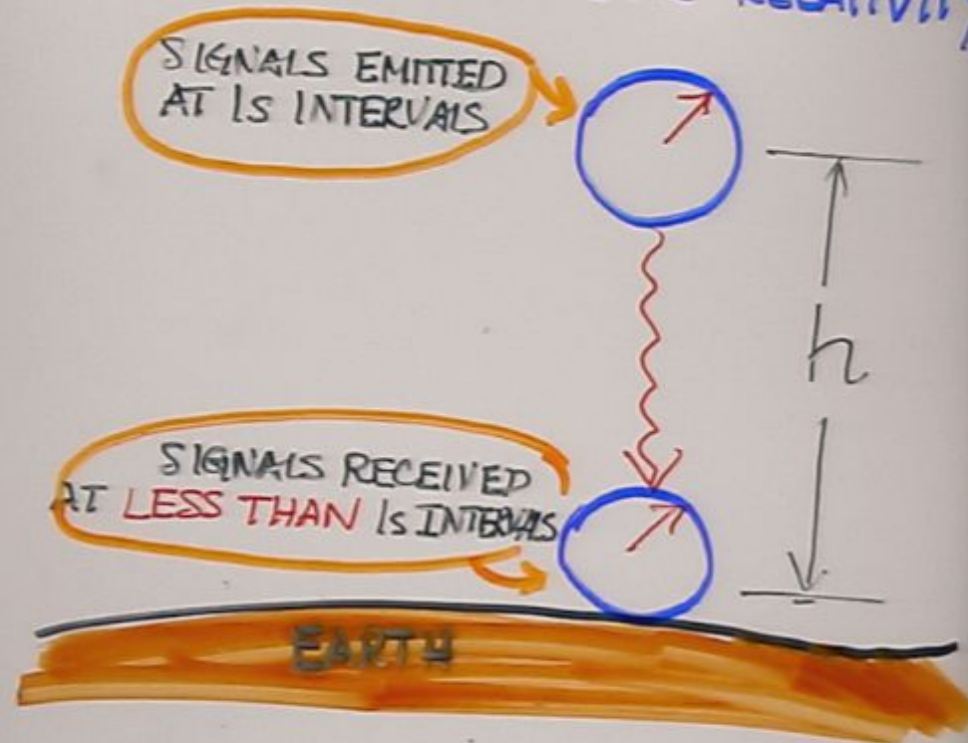
EINSTEIN'S 1916 SPECIAL RELATIVITY
(NO GRAVITY)



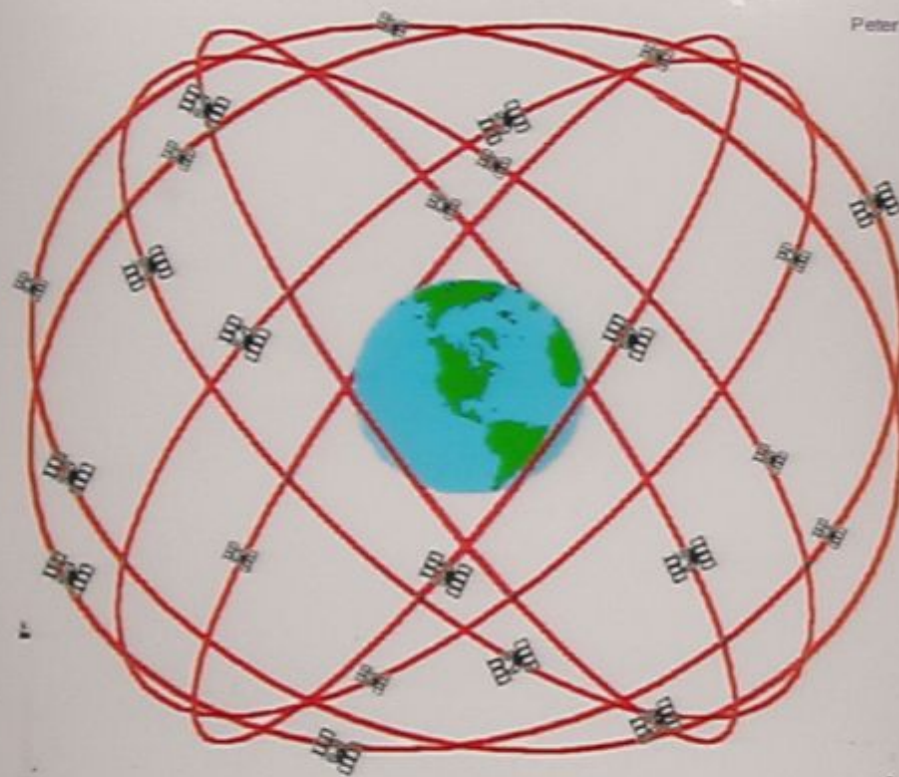
5 ten thousandths of a second
in a lifetime on airplanes

CLOCKS HIGH UP IN A
GRAVITATIONAL FIELD RUN **FAST**

EINSTEIN'S 1915 **GENERAL RELATIVITY**



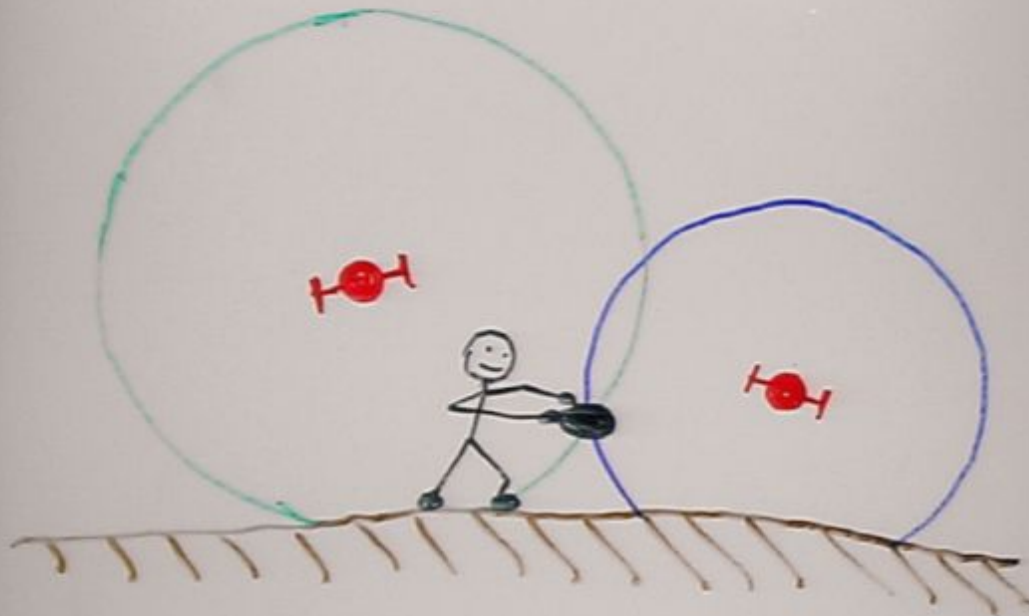
a few microseconds less
in a lifetime at 5 stories



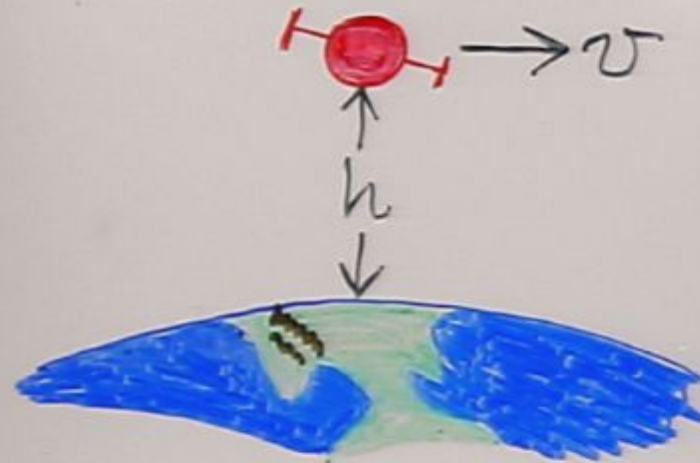
Peter H. Dana 9/22

GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

GPS



RELATIVISTIC EFFECTS IN GPS



- SPECIAL RELATIVITY

MOVING CLOCKS RUN SLOW

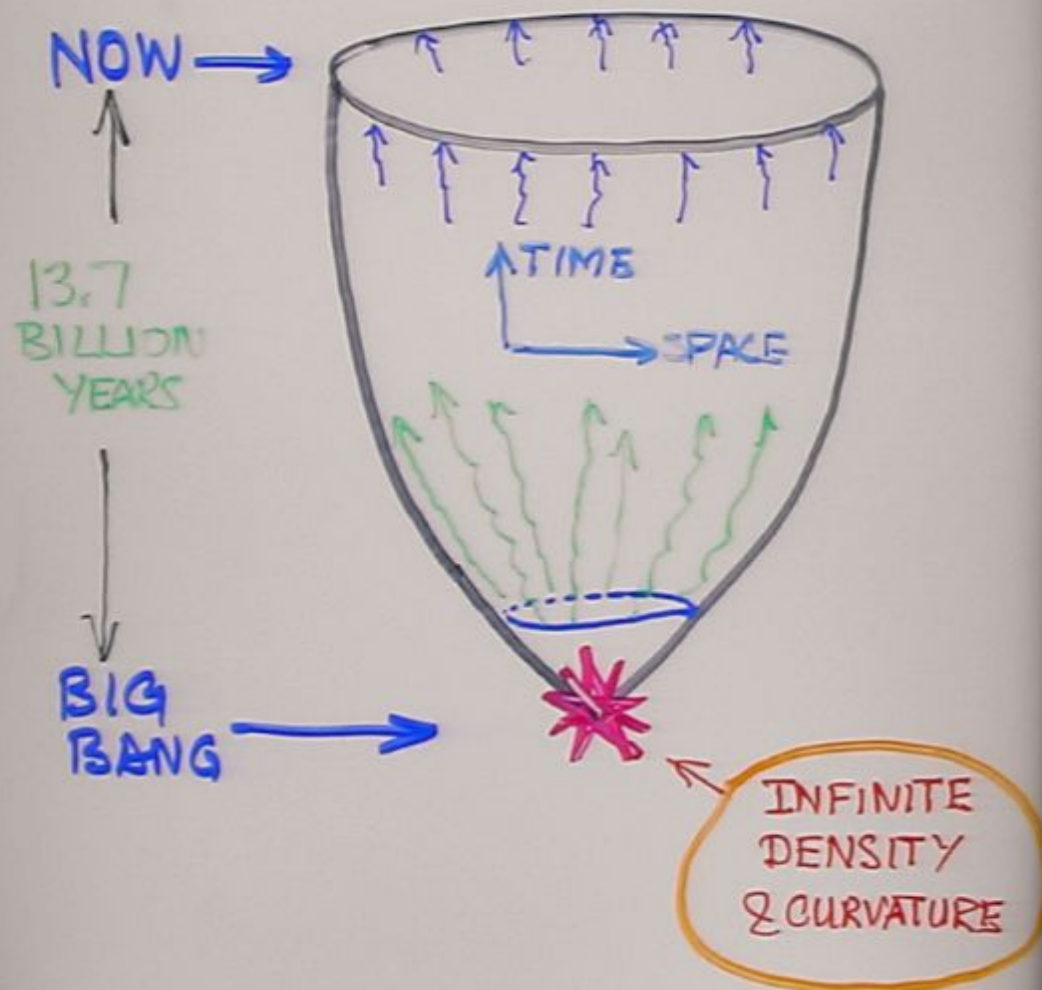
$$\sqrt{1 - v^2/c^2} \rightarrow 1 - .8 \times 10^{-10}$$

- GENERAL RELATIVITY

CLOCKS HIGHER IN A GRAVITATIONAL POTENTIAL RUN FAST.

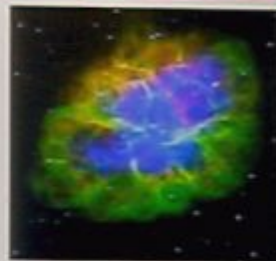
$$1 + \frac{gh}{c^2} \rightarrow 1 + 5.2 \times 10^{-10}$$

GENERAL RELATIVITY PREDICTS
THE UNIVERSE IS EXPANDING
FROM A HOT BIG BANG



GENERAL RELATIVITY & ASTROPHYSICS

- PULSARS



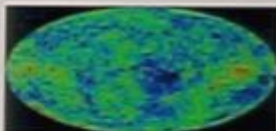
- BLACK HOLES POWERING QUASARS



- GALACTIC X-RAY SOURCES



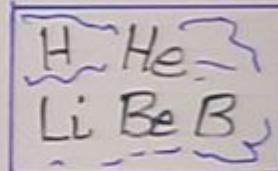
- COSMIC BACKGROUND RADIATION



- GRAVITATIONAL WAVES



- SYNTHESIS OF ELEMENTS AT THE BIG BANG.



EINSTEIN'S VISION

- ABSTRACT THE FUNDAMENTAL LAWS FROM SIMPLE CIRCUMSTANCES & PRINCIPLES.
- NATURE FAVORS THEORIES WITH EQUATIONS THAT ARE BEAUTIFUL & SIMPLE WHEN WRITTEN IN A MATHEMATICS ITSELF ABSTRACTED FROM THE NATURAL WORLD
- BE COURAGEOUS & EXPLORE CRAZY IDEAS IN THE SEARCH FOR BEAUTY, SIMPLICITY, & UNIFICATION IN REALMS FAR FROM IMMEDIATE EXPERIMENT.

QUANTUM THEORY

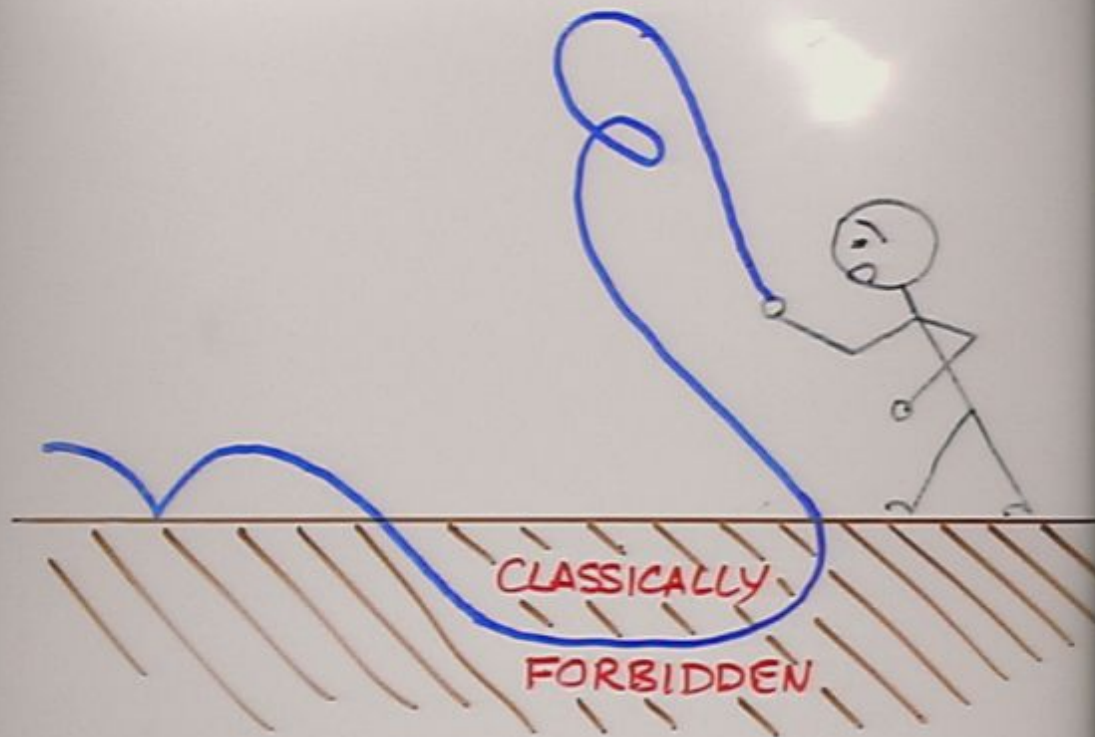
QUANTUM MECHANICS EXPLAINS:

- HOW STARS SHINE
- THE CHEMICAL BONDS THAT MAKE MATTER & LIFE
- WHY TRANSISTORS WORK
- WHY H-BOMBS WORK
- SUPERCONDUCTIVITY
- WHY ATOMS ARE STABLE
- WHY YOUR ATOMS DON'T FALL THROUGH YOUR CHAIRS ATOMS.



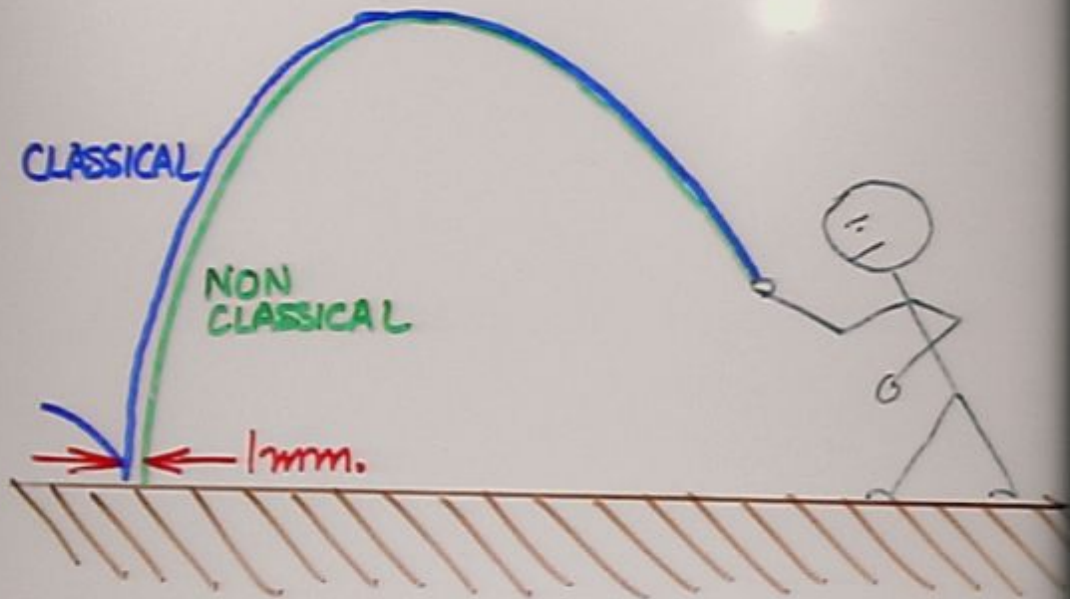
CLASSICAL LAWS ARE
DETERMINISTIC

—
QUANTUM LAWS ARE
PROBABILISTIC



NON - CLASSICAL PATH
(NOT PREDICTED BY NEWTON'S LAW.)



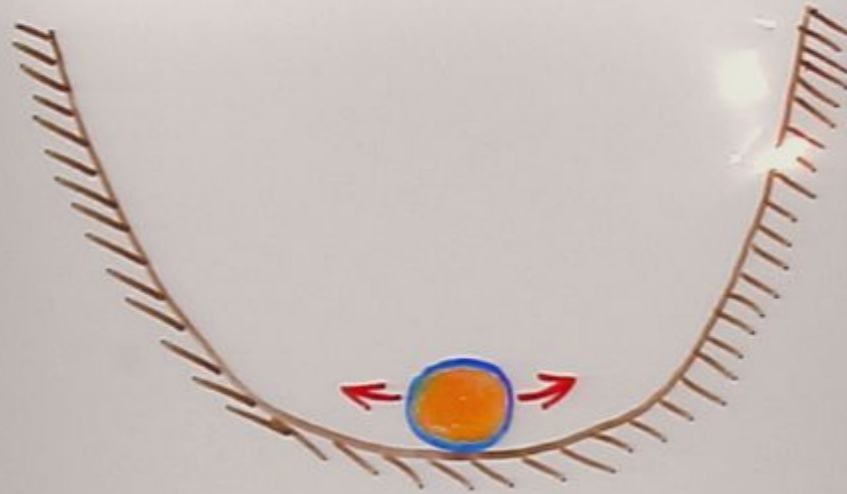


ONE CHANCE IN
1,000,000,000,000,000.....
100,000,000,000,000,000,000,000,000
ZEROS!

UNCERTAINTY PRINCIPLE OF QUANTUM MECHANICS

$$\left(\begin{array}{c} \text{UNCERTAINTY} \\ \text{IN POSITION} \end{array} \right) \cdot \left(\begin{array}{c} \text{UNCERTAINTY} \\ \text{IN VELOCITY} \end{array} \right) > \frac{h}{(\text{MASS})}$$

h = PLANCK'S CONSTANT



THE UNCERTAINTY PRINCIPLE
IMPLIES THAT IN ITS
LOWEST ENERGY STATE
THE PARTICLE'S POSITION
EXECUTES SMALL
QUANTUM FLUCTUATIONS
ABOUT THE BOTTOM OF THE BOWL

IN CLASSICAL PHYSICS
THE STATE
OF A SYSTEM MEANS THE
POSITION
AND
VELOCITY
OF EVERY PARTICLE
AT ONE INSTANT.

NEWTON

IN QUANTUM MECHANICS

THE STATE

OF A SYSTEM

IS SUMMARIZED BY

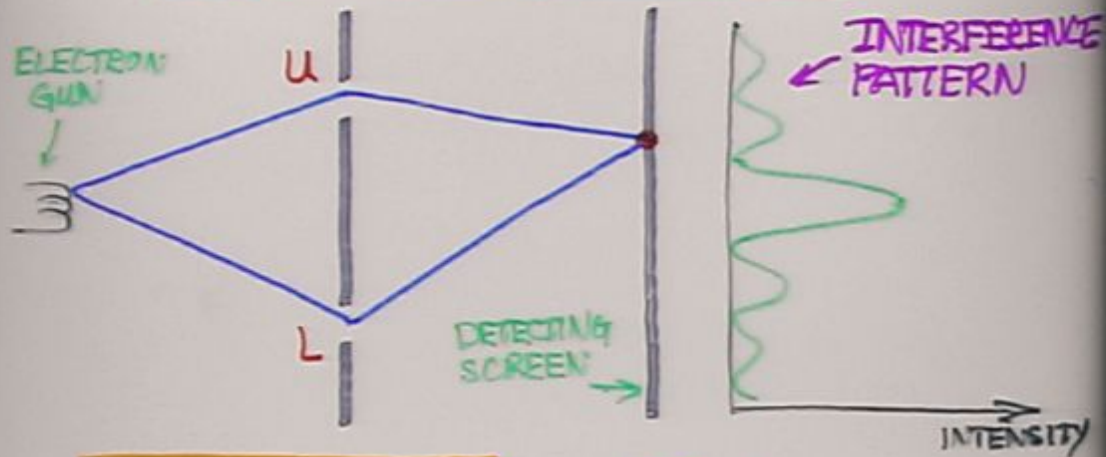
A WAVE FUNCTION



AT AN INSTANT

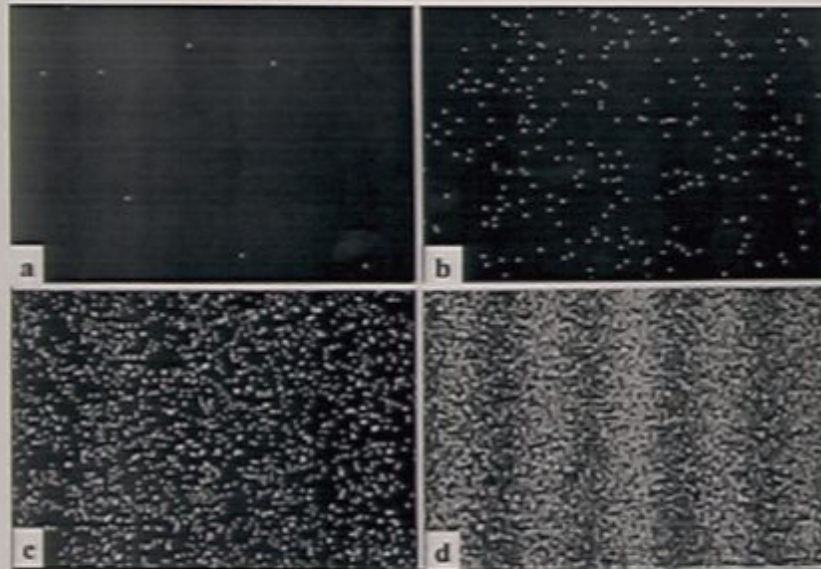
SCHRÖDINGER

DOUBLE-SLIT EXPERIMENT



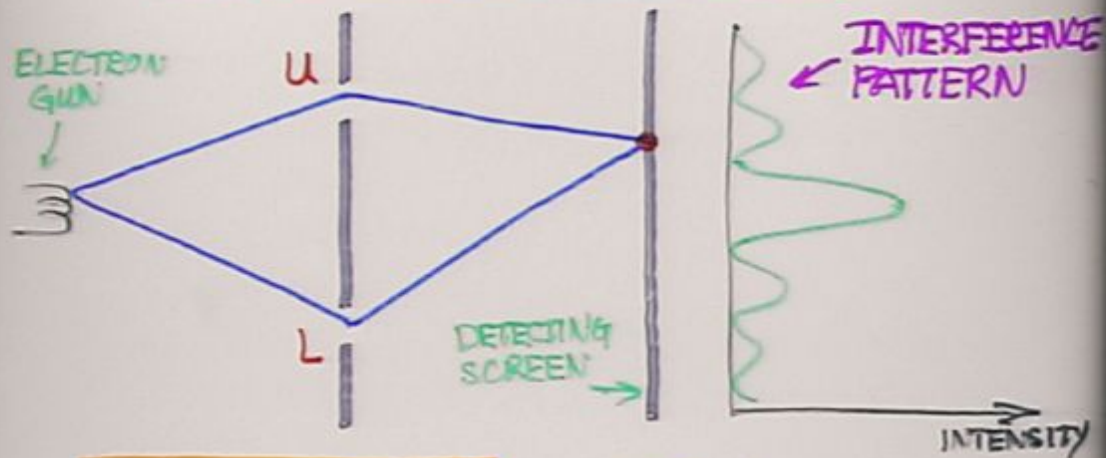
$$\psi = \psi_U + \psi_L$$

← A SUPERPOSITION



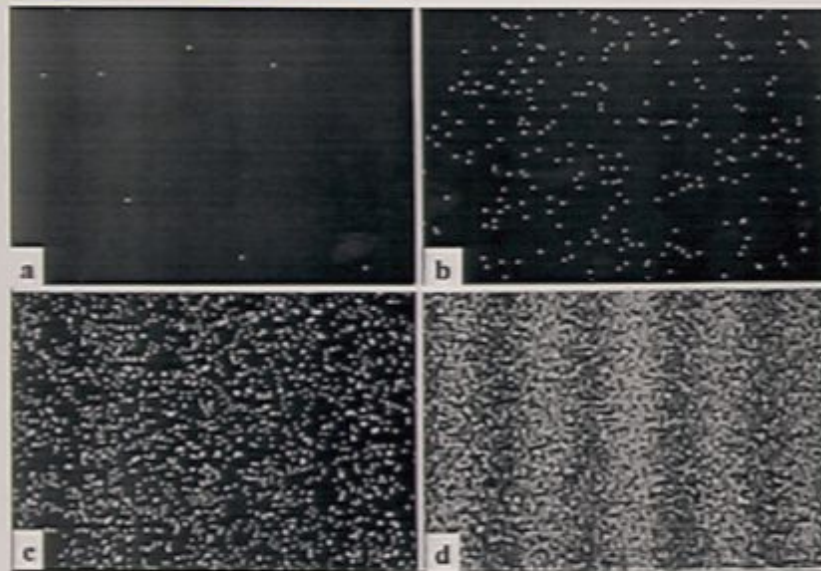
TONOMURA, ET. AL.

DOUBLE-SLIT EXPERIMENT



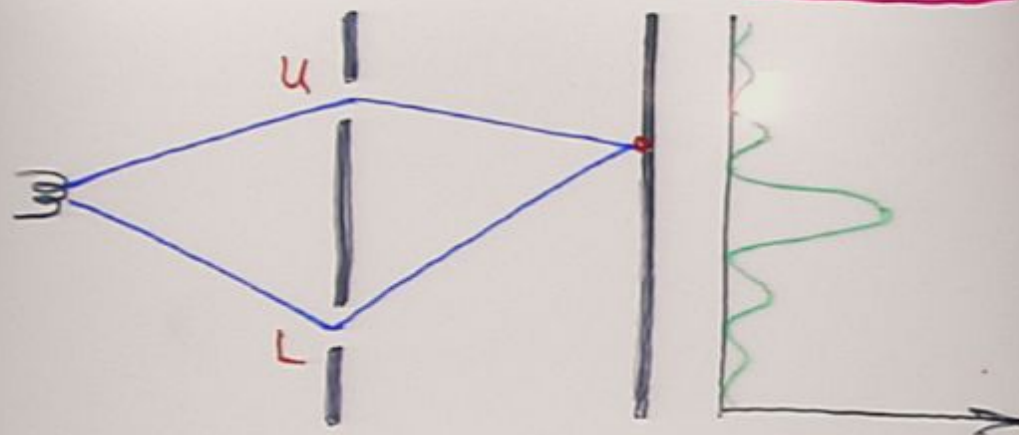
$$\psi = \psi_U + \psi_L$$

← A SUPERPOSITION



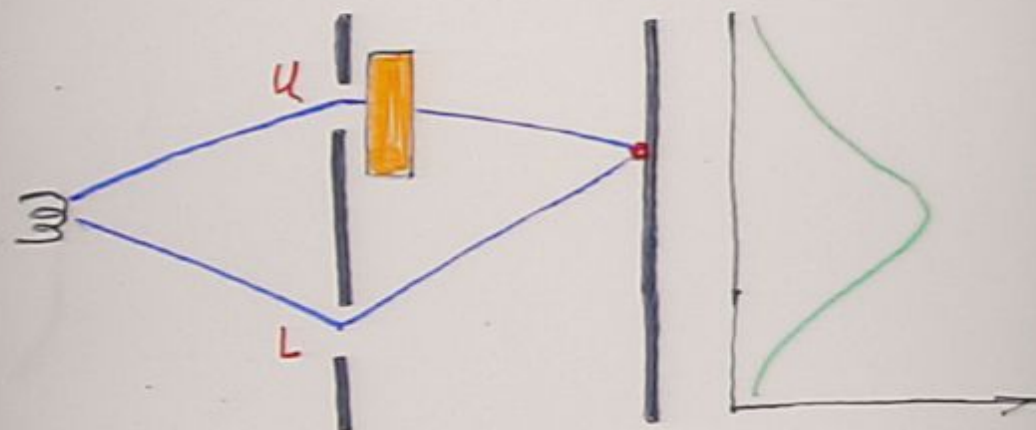
TONOMURA, ET. AL.

TWO COMPLEMENTARY VIEWS



SUPERPOSITION OR NOT

WAVE

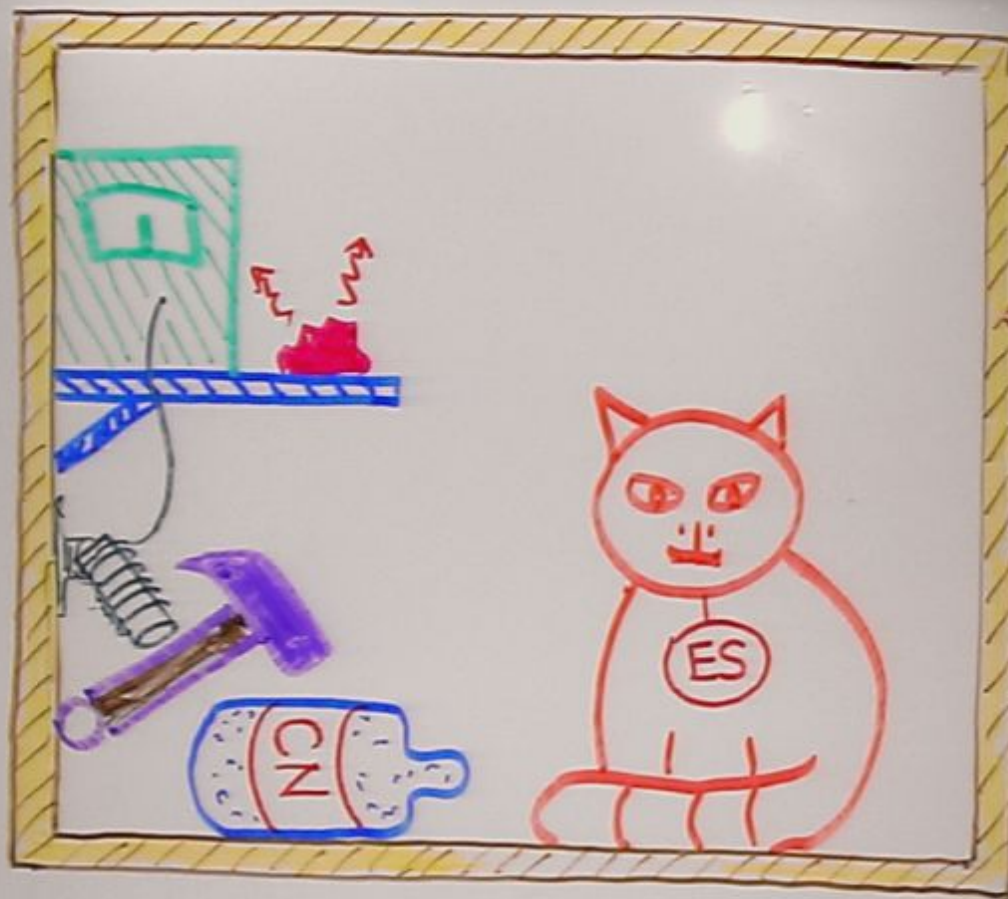


UPPER OR LOWER SLIT

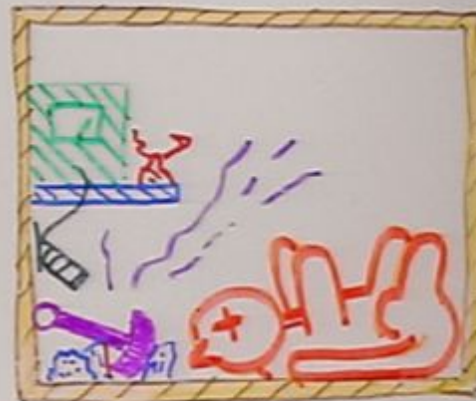
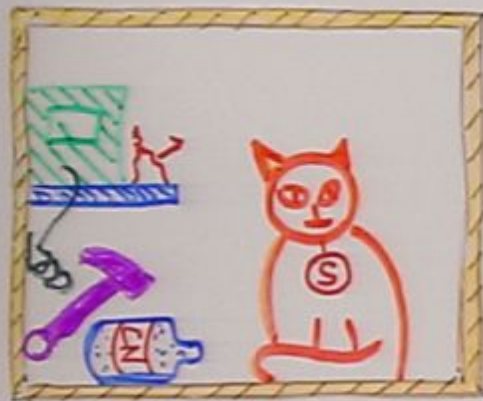
PARTICLE

IT DEPENDS ON WHICH YOU CHECK!

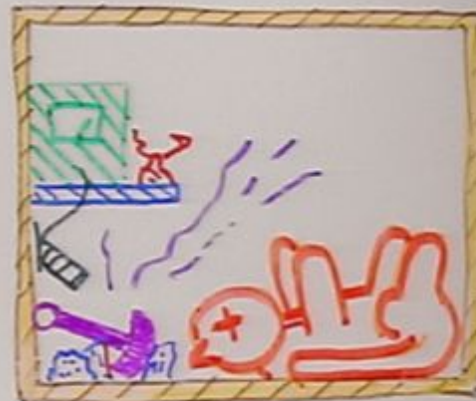
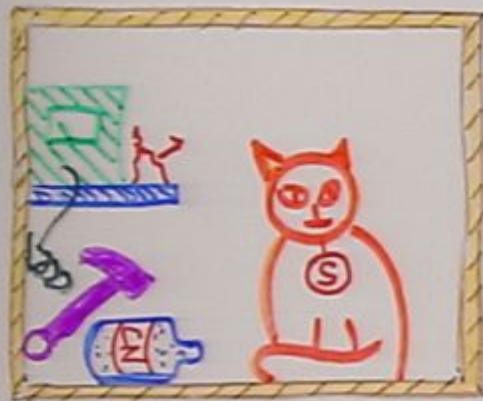




$$\Psi = \phi \left(\begin{array}{l} \text{NO DECAY} \\ \text{NO CLICK} \\ \text{ALIVE} \end{array} \right)$$



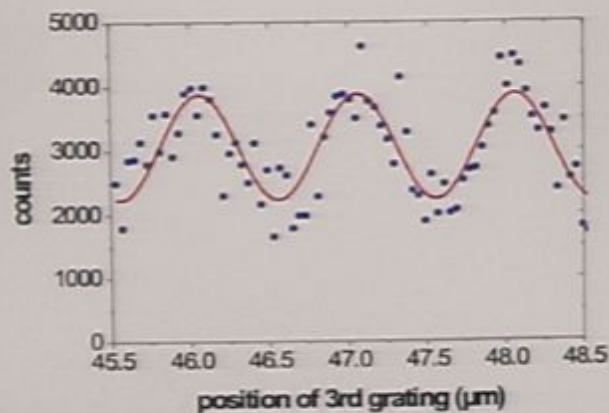
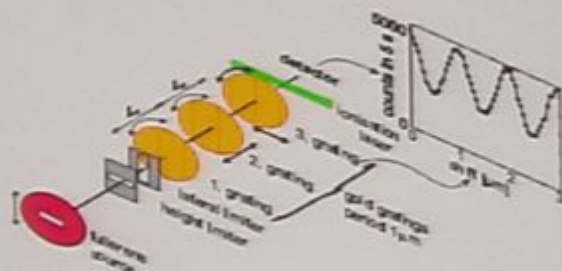
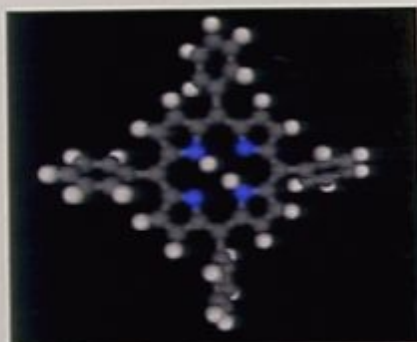
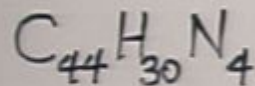
$$\Psi = \frac{1}{\sqrt{2}} \left[\phi_A \begin{pmatrix} \text{no decay} \\ \text{no click} \\ \text{alive} \end{pmatrix} + \phi_D \begin{pmatrix} \text{decay} \\ \text{click} \\ \text{dead} \end{pmatrix} \right]$$



$$\Psi = \frac{1}{\sqrt{2}} \left[\phi_A \begin{pmatrix} \text{no decay} \\ \text{no click} \\ \text{alive} \end{pmatrix} + \phi_D \begin{pmatrix} \text{decay} \\ \text{click} \\ \text{dead} \end{pmatrix} \right]$$

INTERFERENCE OF BIOMOLECULES

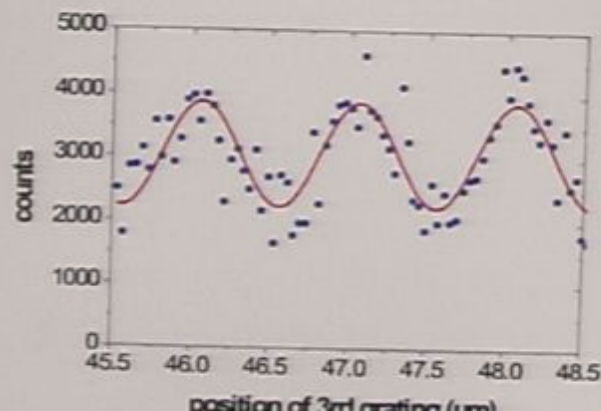
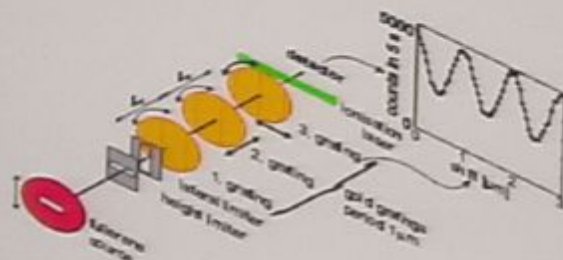
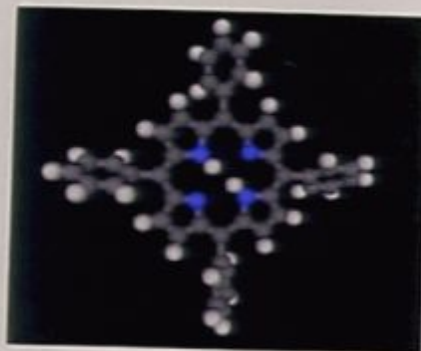
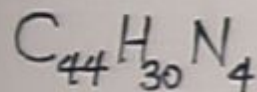
TETRAPHENYL
-PORPHYRIN



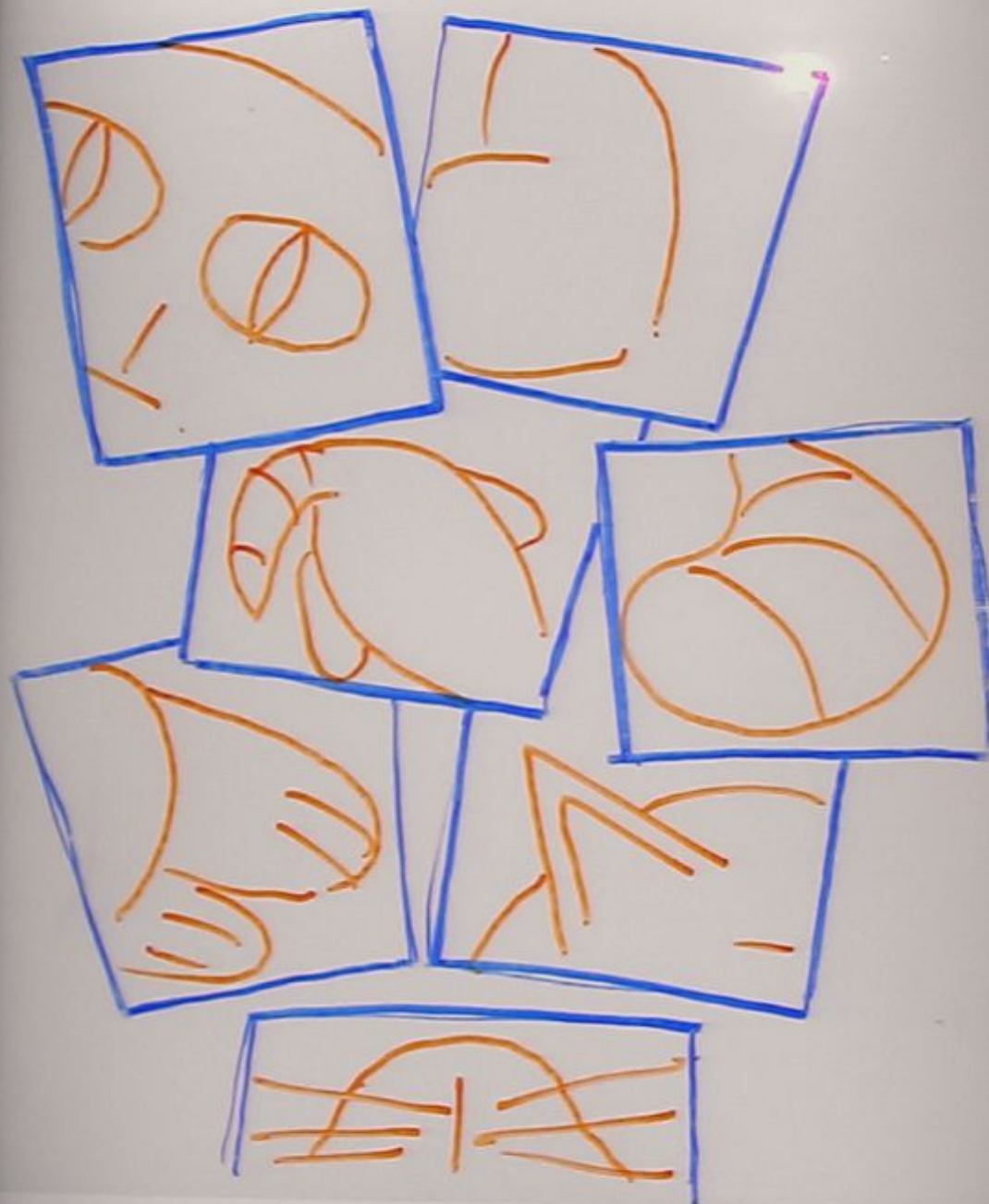
L. Hackermüller, et. al. PRL (2003).

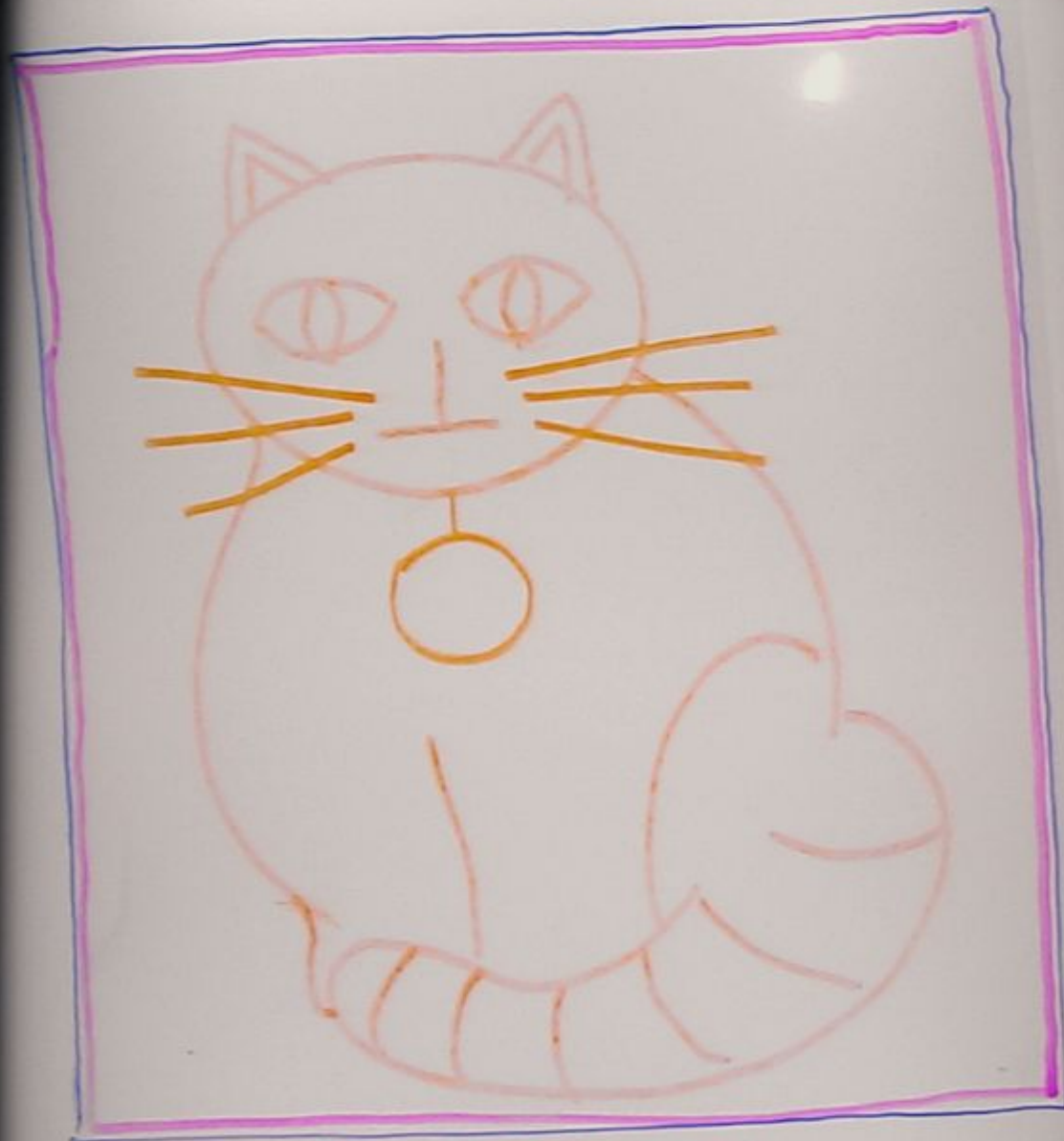
INTERFERENCE OF BIOMOLECULES

TETRAPHENYL
-PORPHYRIN

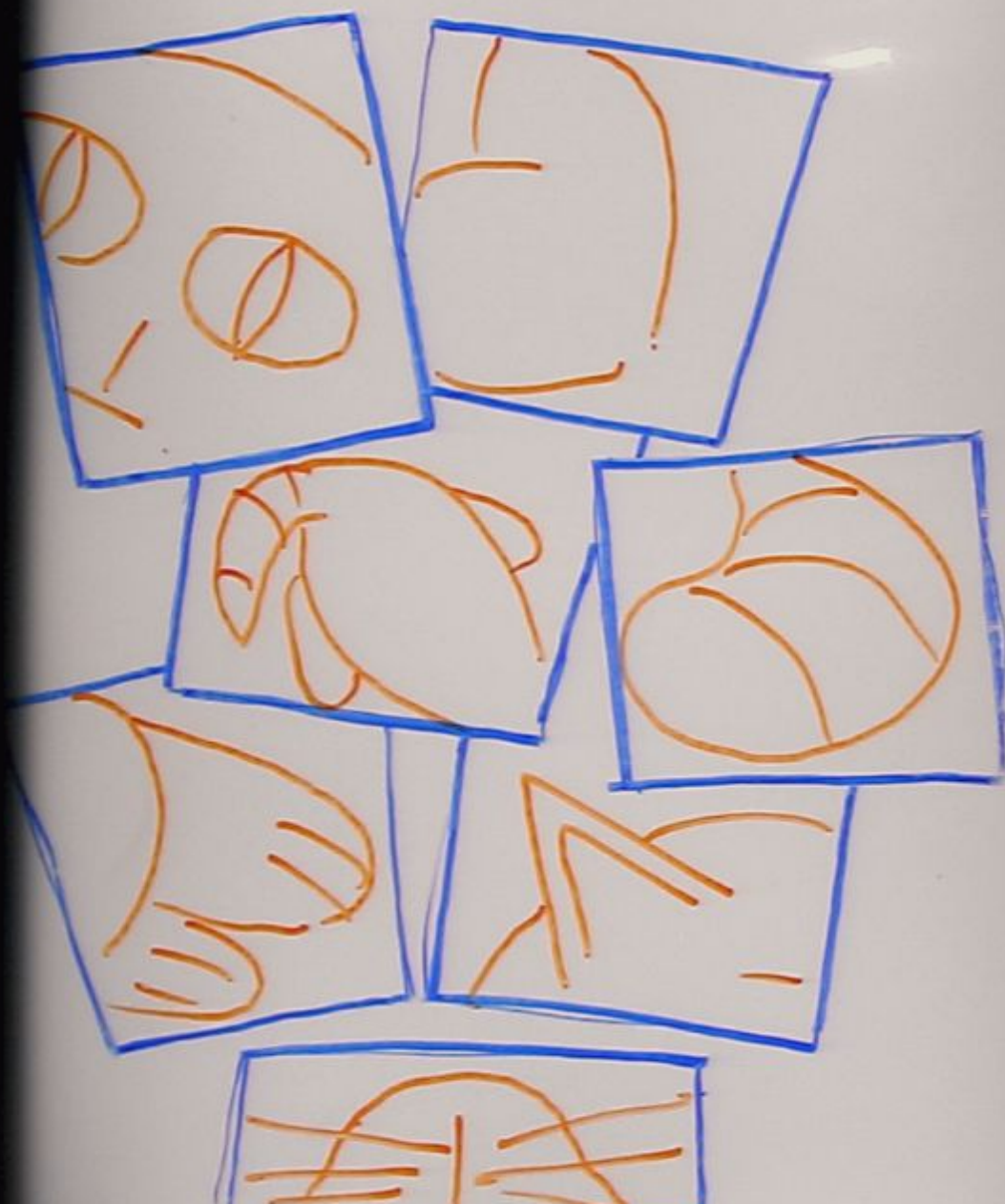


L. Hackermüller, et. al. PRL (2003),





CLASSICALLY



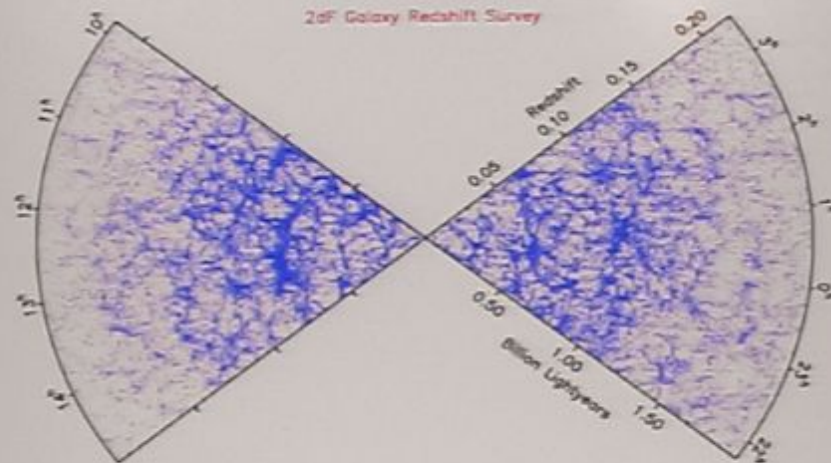


IN QUANTUM COSMOLOGY
THE INITIAL CONDITION
OF THE UNIVERSE
IS SPECIFIED BY
A WAVE FUNCTION
OF THE UNIVERSE.

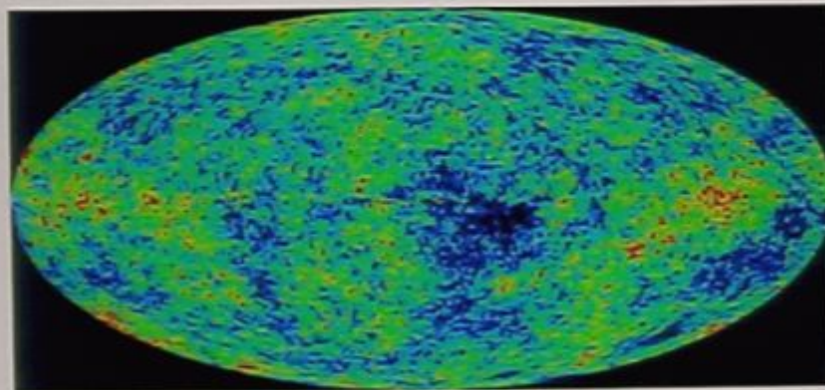


HAWKING,

OUR UNIVERSE IS SYMMETRIC ON LARGE SCALES



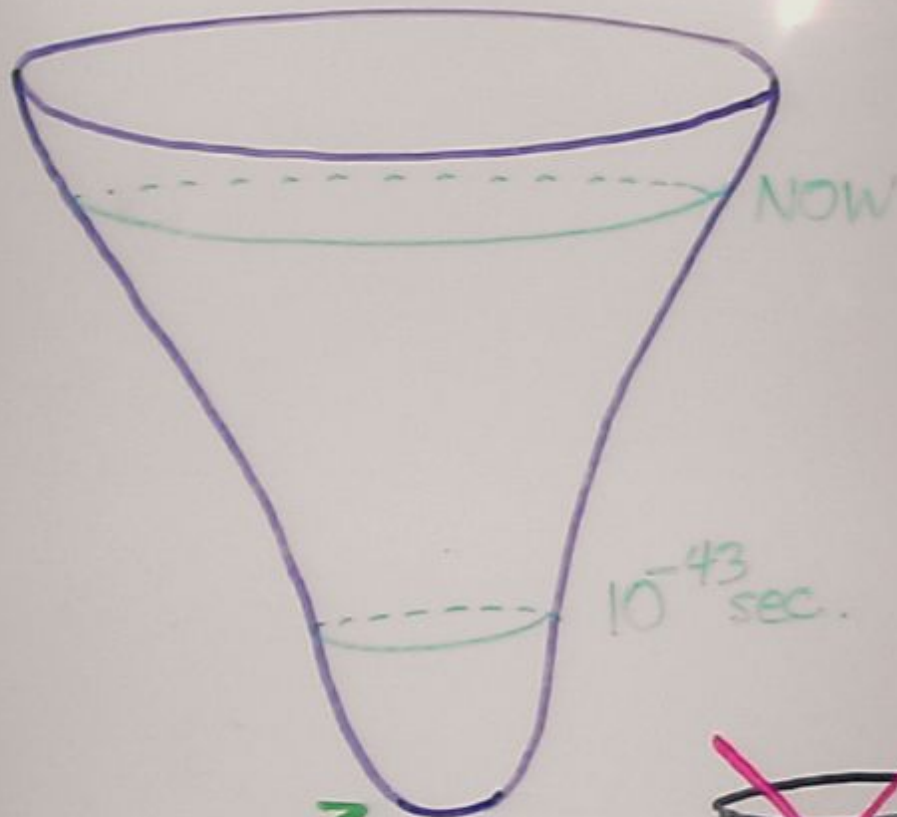
TODAY - 14 billion yrs ABB



WMAP SATELLITE

400,000 yrs ABB

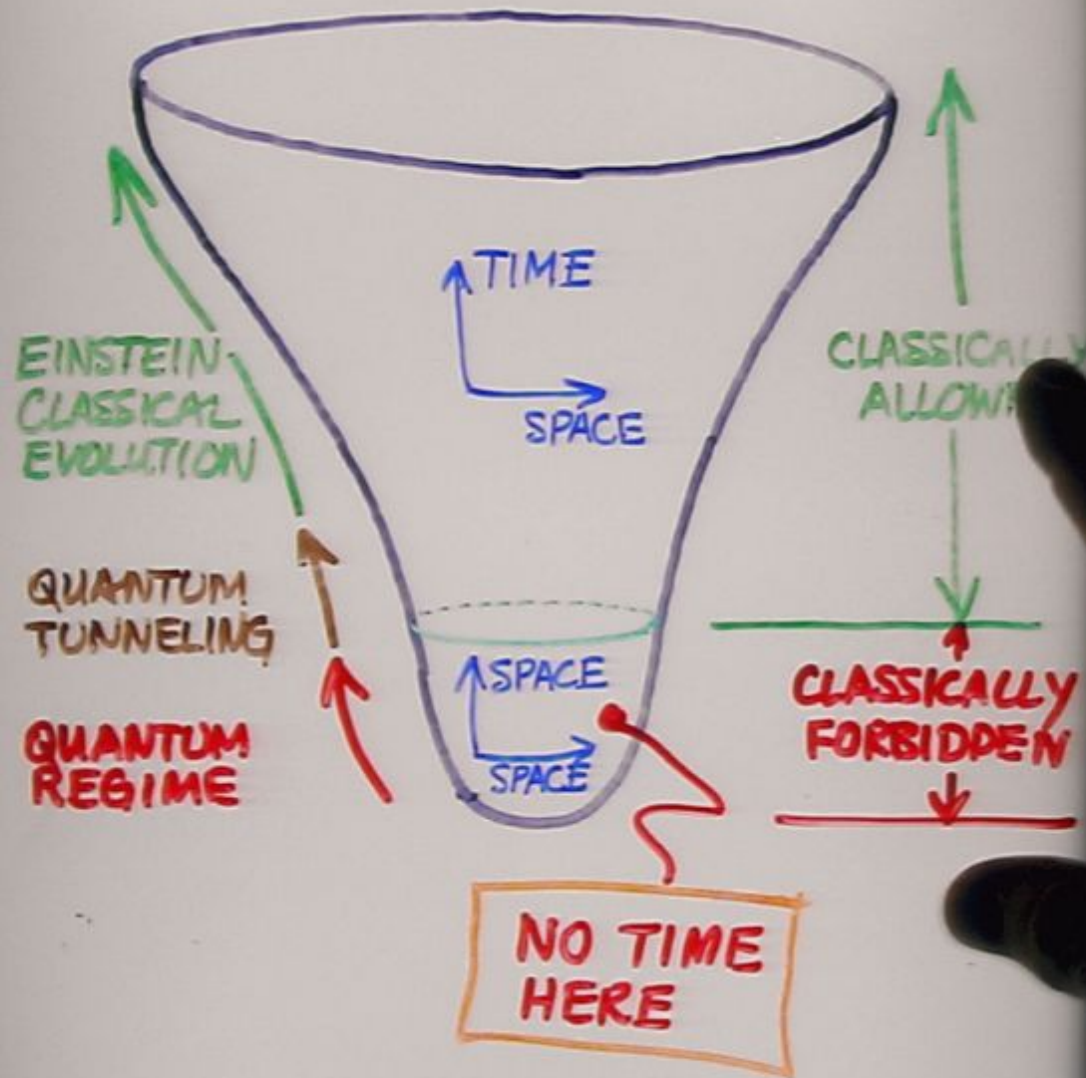
NO-BOUNDARY SPACETIMES



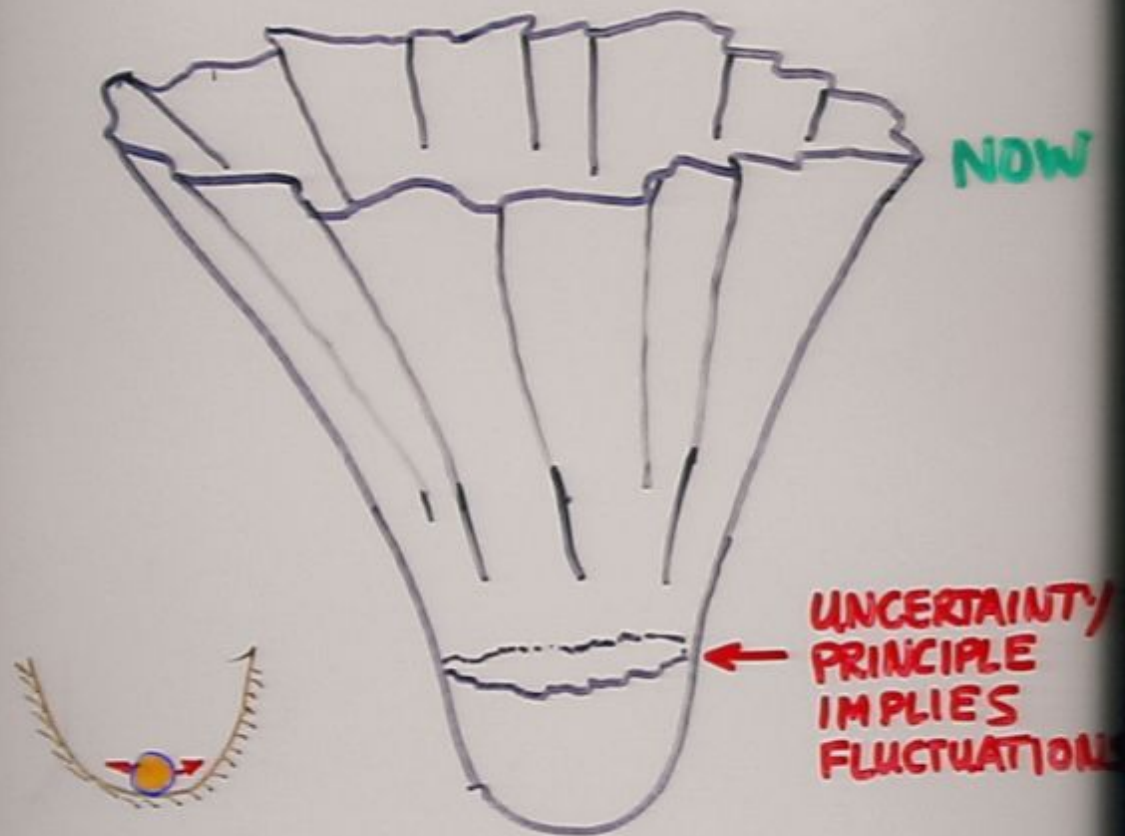
NO BOUNDARY
NO SINGULARITY



BREAKDOWN OF NOTION OF TIME



QUANTUM FLUCTUATIONS FROM EXACT HOMOGENEITY PREDICTED



THEY GROW INTO GALAXIES!

THE UNIVERSE IS IN
A SUPERPOSITION

$$\begin{aligned}\Psi &= \phi_1 \left(\text{img}_1 \right) \\ &+ \phi_2 \left(\text{img}_2 \right) \\ &+ \phi_3 \left(\text{img}_3 \right) \\ &+ \dots\end{aligned}$$

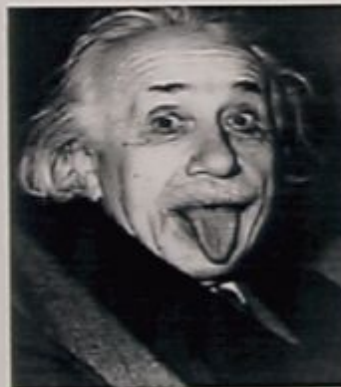
WE ARE ALL
SCHRÖDINGER CATS
IN HAWKING'S
WAVE FUNCTION OF THE UNIVERSE

$$\Psi = \phi_1 \left(\text{img}_1 \right) + \phi_2 \left(\text{img}_2 \right) + \phi_3 \left(\text{img}_3 \right) + \dots$$

$$\Psi = \sum_{\text{HISTORIES}} \phi \left(\begin{array}{l} \text{HISTORY} \\ \text{OF HOW THINGS} \\ \text{HAPPENED} \end{array} \right)$$

QUANTUM REALITY
CONSISTS OF MANY
MUTUALLY EXCLUSIVE
EQUALLY NECESSARY
COMPLEMENTARY
VIEWS

QUANTUM REALITY
CONSISTS OF MANY
MUTUALLY EXCLUSIVE
COMPLEMENTARY VIEWS
EQUALLY NECESSARY
FOR A COMPLETE
DESCRIPTION.





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