

Time: The Final Frontier

fact, fiction & speculations about time travel

December 2, 2021

Robert Ehrlich

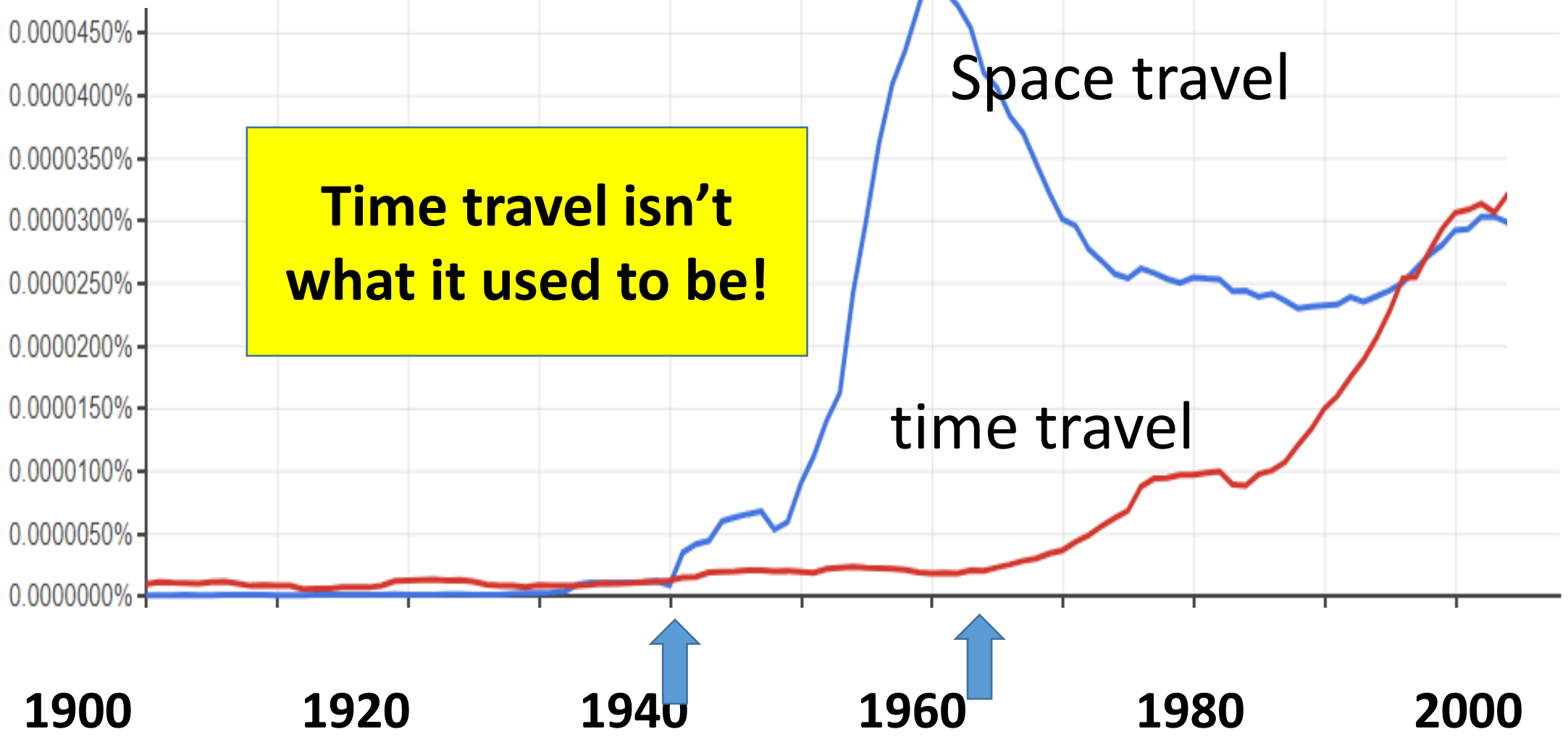
George Mason University

<http://Ehrlich.physics.gmu.edu>



What percentage of books use these phrases each year

0.00005%



Time travel isn't what it used to be!

Space travel

time travel

1900

1920

1940

1960

1980

2000

Google "ngram viewer"

0.0000600%

0.0000550%

You are time-traveling right now

... at the rate of one second each second!

But some seconds seem a lot longer than others



Usual meaning of time travel:

Changing the rate time passes

Jumping to some moment in the past or future

Two opposing views of time



Presentism:

Only the present is real



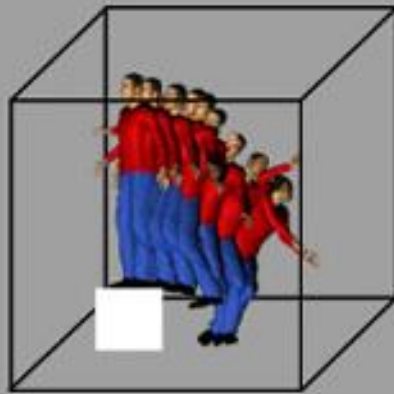
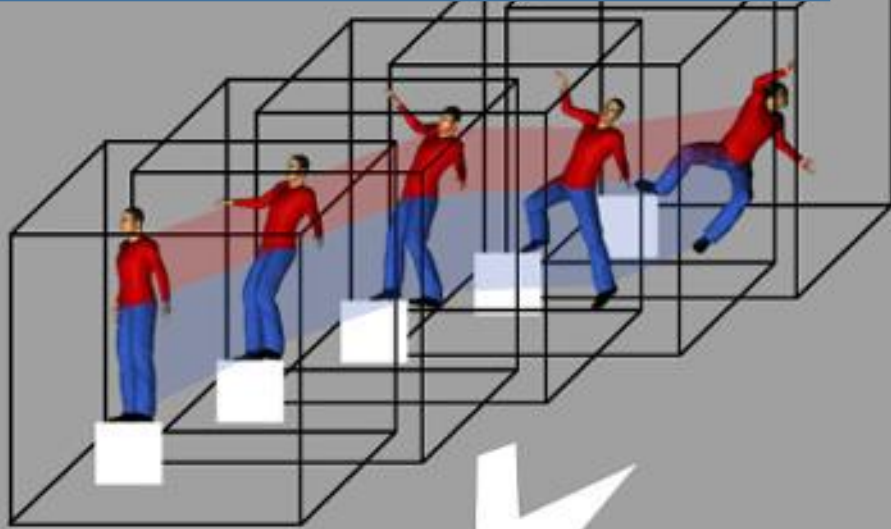
Time travel is impossible

The block universe: All times on equal footing



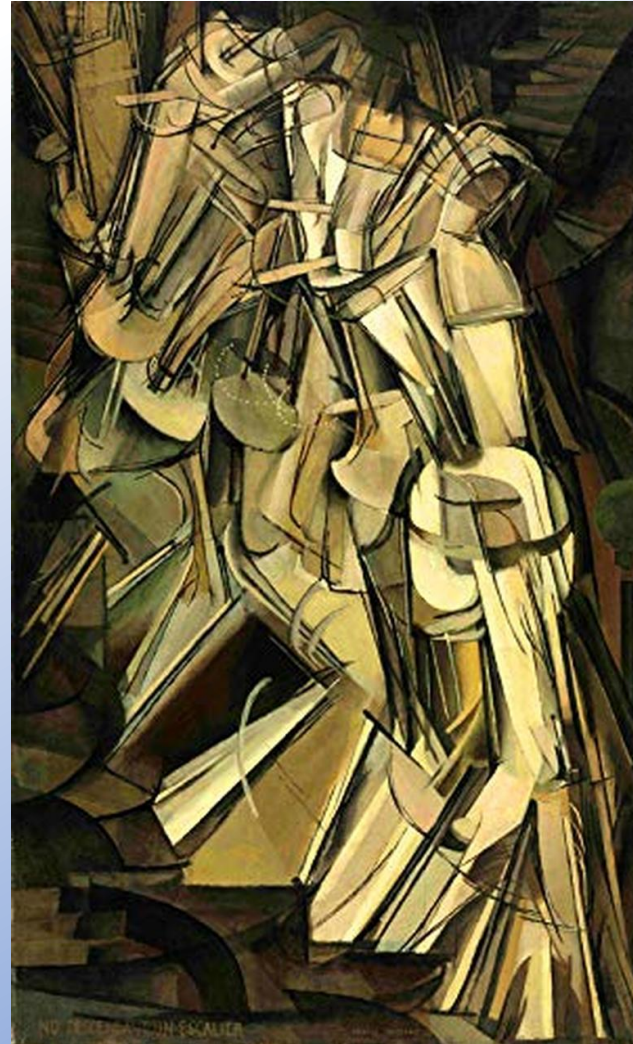
Time travel is possible

3D space + 1D time



4D spacetime

The block universe:



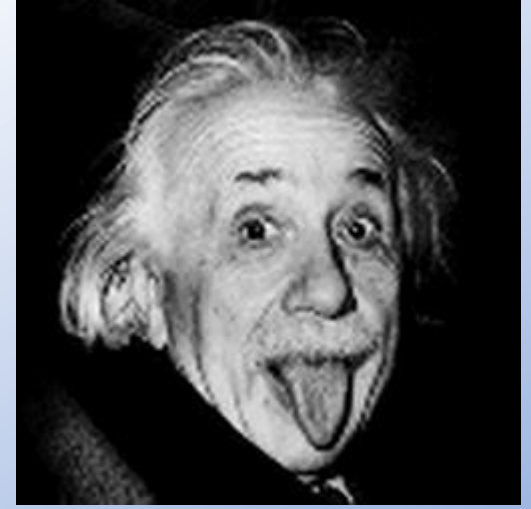
Nude Descending a staircase by Marcel Duchamp (1912)

All times on an equal footing

Passing time an illusion

Very compatible with relativity

"The distinction between past present and future is a stubbornly persistent illusion."



Einstein's 2 Theories of relativity

Special relativity (1905)

Unified space & time: 4-dimensional "spacetime." Math very easy

General relativity (1915)

Gravity is not a force but a warping of spacetime. Math very tough

How do we know relativity is correct? Isn't it just a theory?

What amazing things does relativity say about time?

No common “now” everywhere in universe

Simultaneity can be relative

Order of events in time can change

“Moving” clocks run slow

Gravity affects rate of passage of time

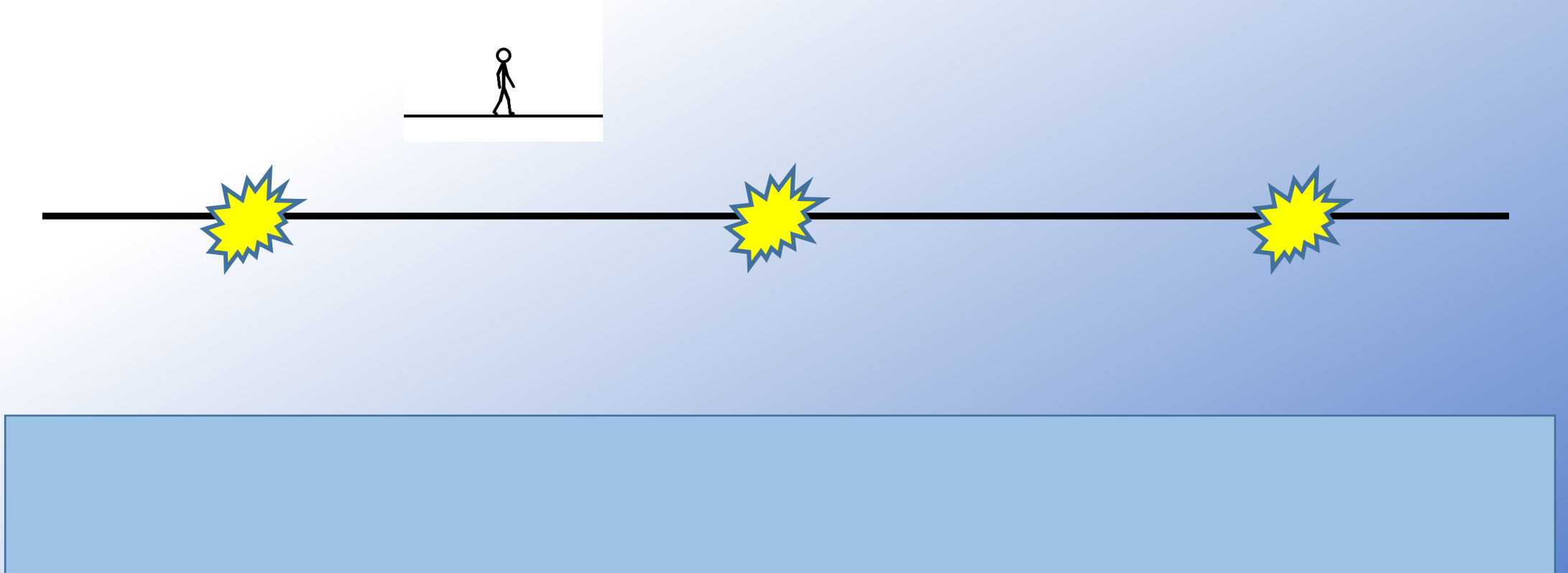
Time travel is possible

What kind of time travel is possible according to physicists?

	One-way	Two-way
To Past	maybe	maybe
To Future	Yes	maybe

Order of events in time can depend on the observer

A moving observer



**No reversals in time order if
time Separation > light travel time between events**

**Switch
OK?**

Event1

Event 2



Your birth

Your 50th birthday



**Sun emits giant flare
at 12:00PM**

**U.S. electrical grid
goes down at 12:05PM**



**A “warp drive” space ship
Takes off from Earth**

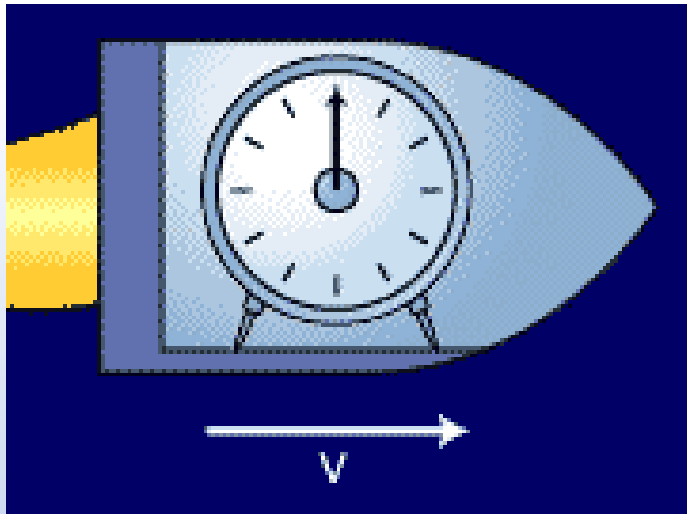
**The warp drive ship
lands on the moon**

Think how crazy that is!

***warp speed = faster-than-light**

Time slows down due to motion of clock

Clock on Earth



Clock on spaceship

Time dilation: "Moving" "clocks" run slow (why the quotes?)

This is how both clocks look to someone on Earth

How would they both look to someone on the moving spaceship?

Hint: The Earth clock then becomes the "moving" one.

Why does time dilation occur?

Can use a bouncing photon clock to understand it



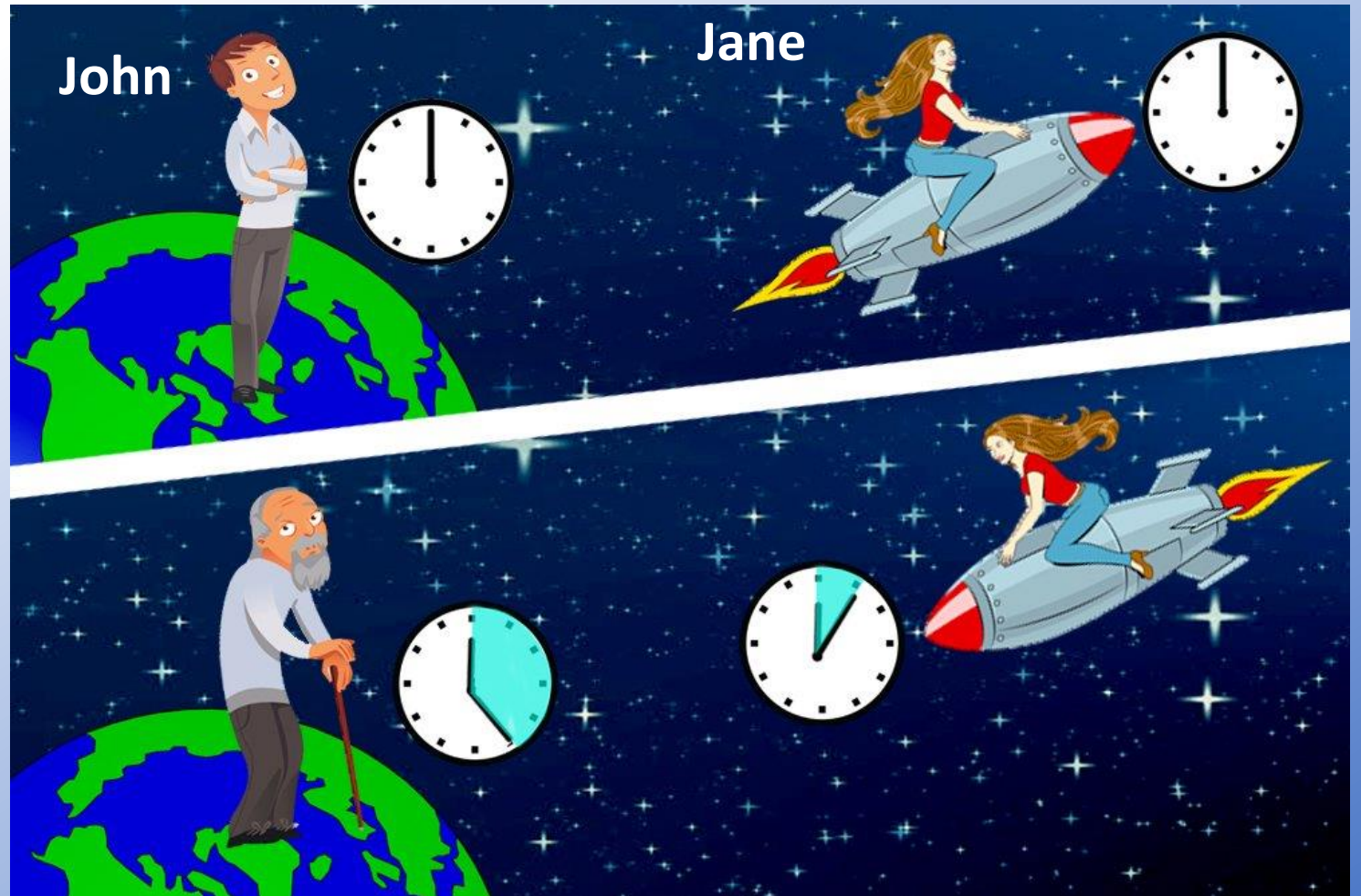
The "easy" kind of time travel: One-way to the future

Who has aged less when
Jane returns?

Why is this a paradox?

Has effect been observed?

To get a big effect need
speed close to light



Example: One-way trip to 3021 AD

Average ship speed: 99.99995% the speed of light

Destination: a star 500 light years away (1000 ly round trip)

On Earth 1000 years would pass before you return. For you, trip lasts 1 yr.

All physicists would agree with this, but quite a few technical problems!

But, is this truly time travel, or is it just suspended animation?

A real-life example of the twin paradox

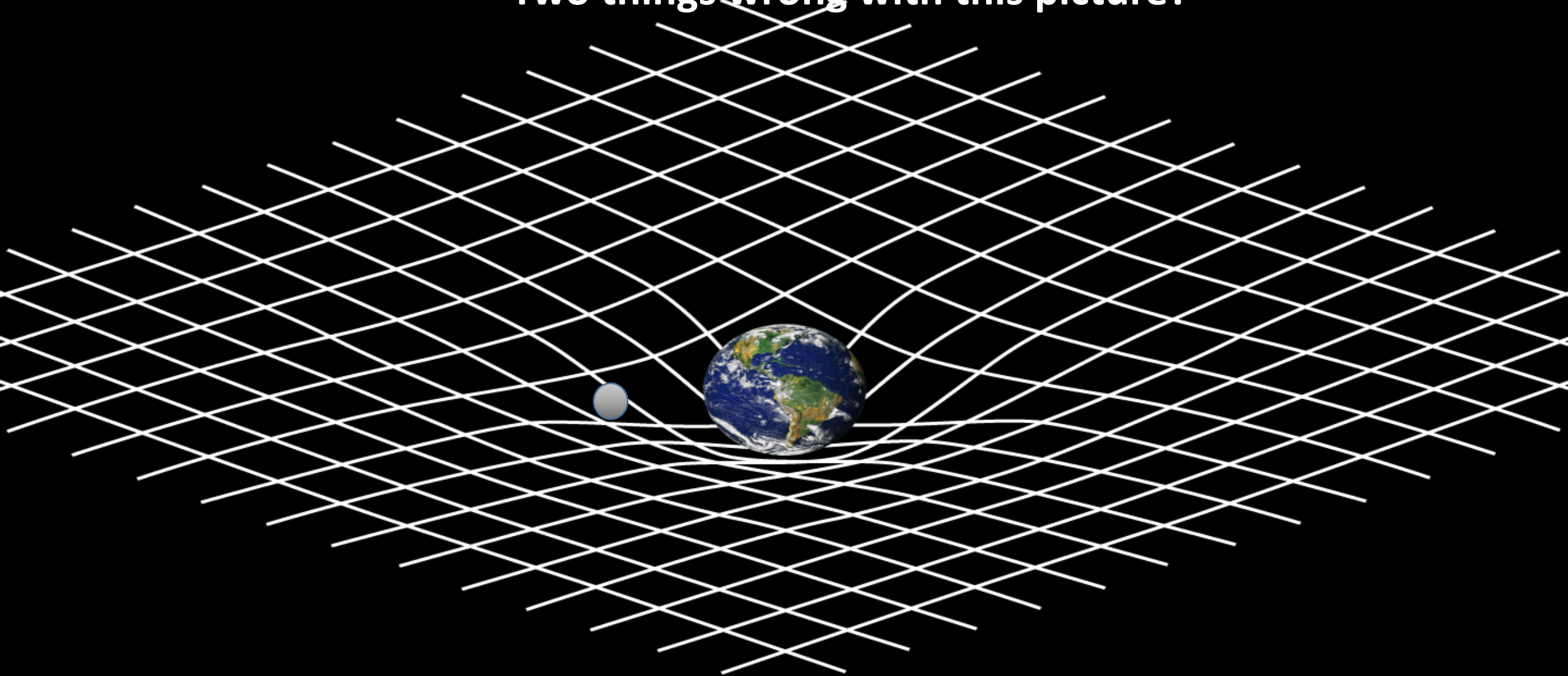


Scott & Mark Kelly. At birth, Mark was six min older. Now he is six min and 13 milliseconds older.

This tiny effect has been measured (with clocks not twins!)

In relativity gravity is just the warping of spacetime

Two things wrong with this picture?



Stronger gravity also slows passage of time



In a year clock at the base runs 1.5 millionths of a second slower than one at its top

GPS wouldn't work if we did not take it into account.

Extreme case: Just outside a black hole

Time passes much slower aboard planet orbiting black hole than it does back on Earth. It effectively stops right at the “event horizon.”

How could this effect enable us to travel to the distant future?



The "hard" kind of time travel: 2-way to the past or future

Two ways it might happen:

1. Faster than light speed travel (FTL)
2. A distortion of spacetime due to gravity that creates a loop in time.*

*Loop in time = Closed timelike curve

Equations of relativity suggest faster-than-light (FTL) implies backward in time

There was a young lady named Bright
Whose speed was far faster than light;
She set out one day
In a relative way
And returned on the previous night.

A. H. Reginald Buller limerick (1937)

How to visit the past with a FTL spaceship

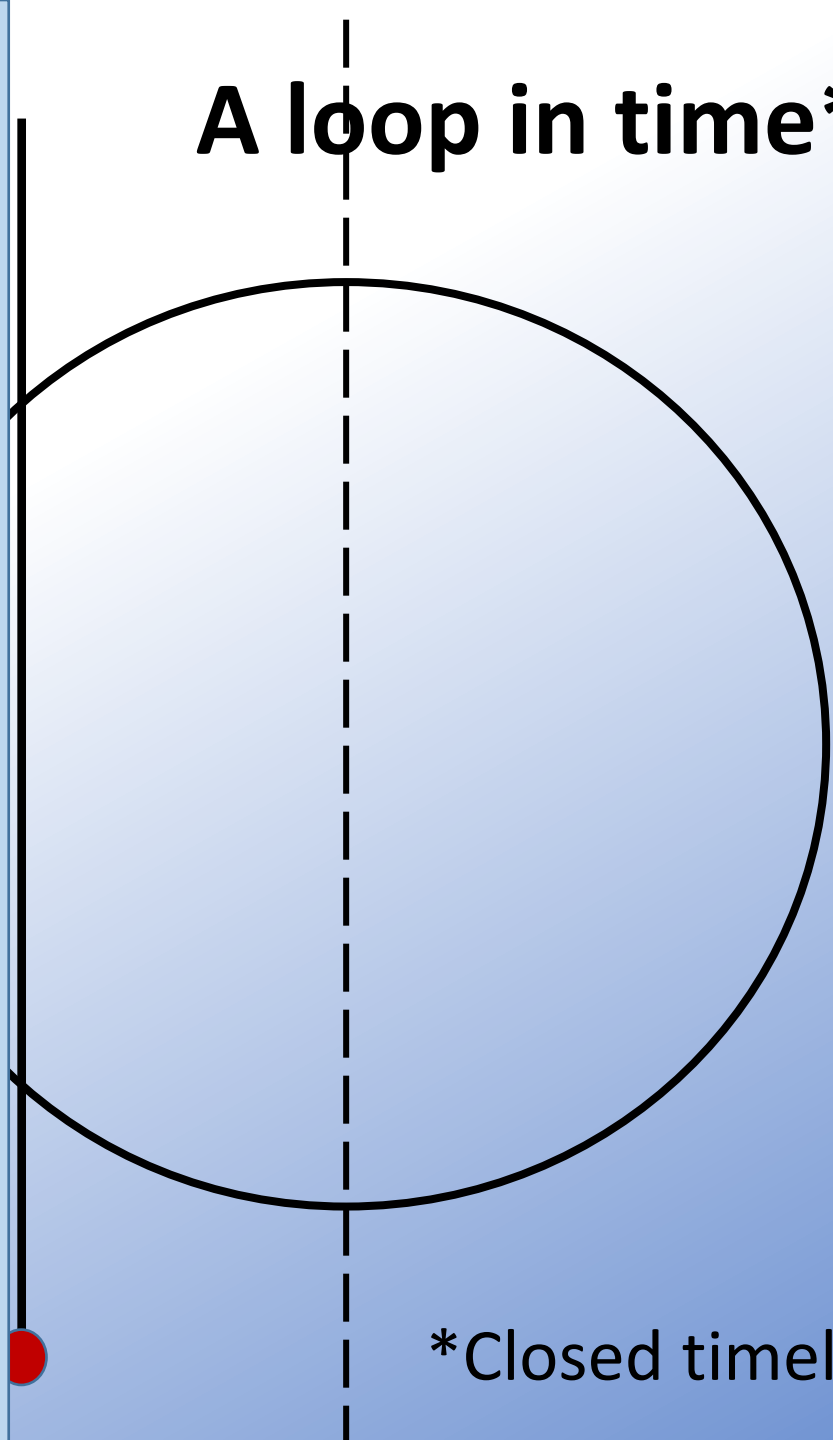


Take a ride on a FTL space ship to a star 20 light years away

Your return to Earth could be up to 20 years before you left

A loop in time*

2041
2021
2001
1981
1961



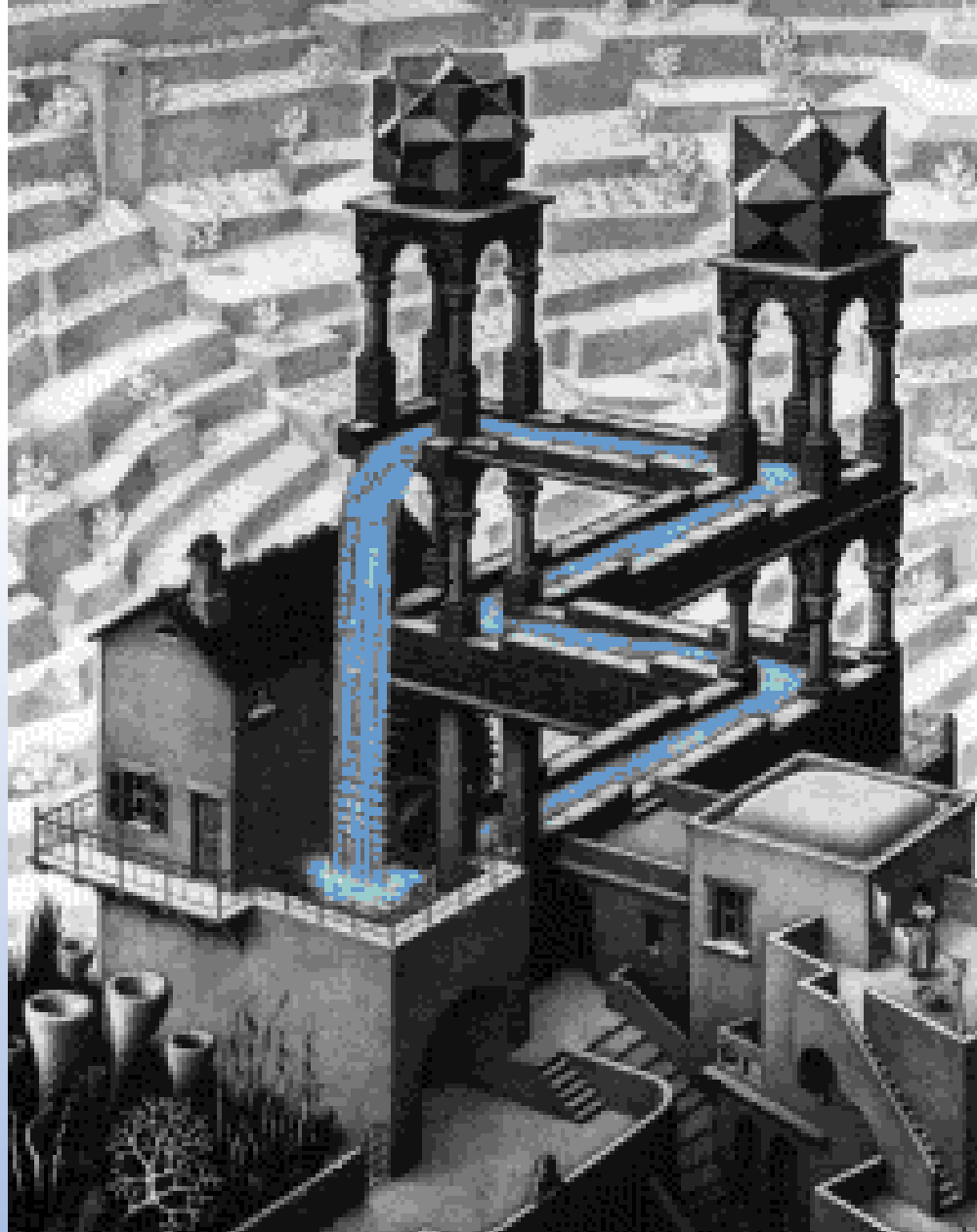
“Shortcut” back to earlier time?

In this example You might meet your past self in 1981

*Closed timelike Curve

Time is like a flowing river

M.C. Escher's
"Waterfall"



Loop in water flow
without a pump is
impossible

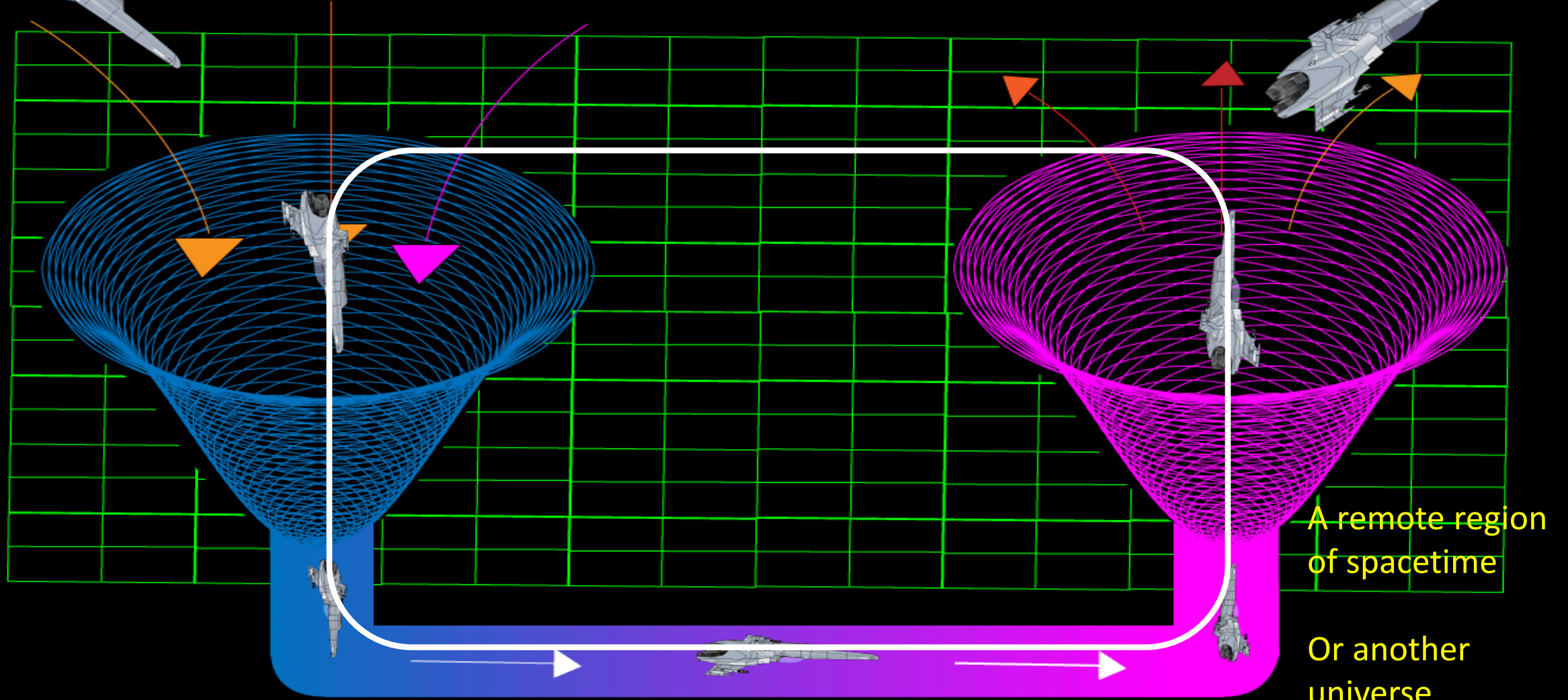
Loop in time may
be possible

What about
paradoxes?

How to create a time loop in relativity?

Black Hole

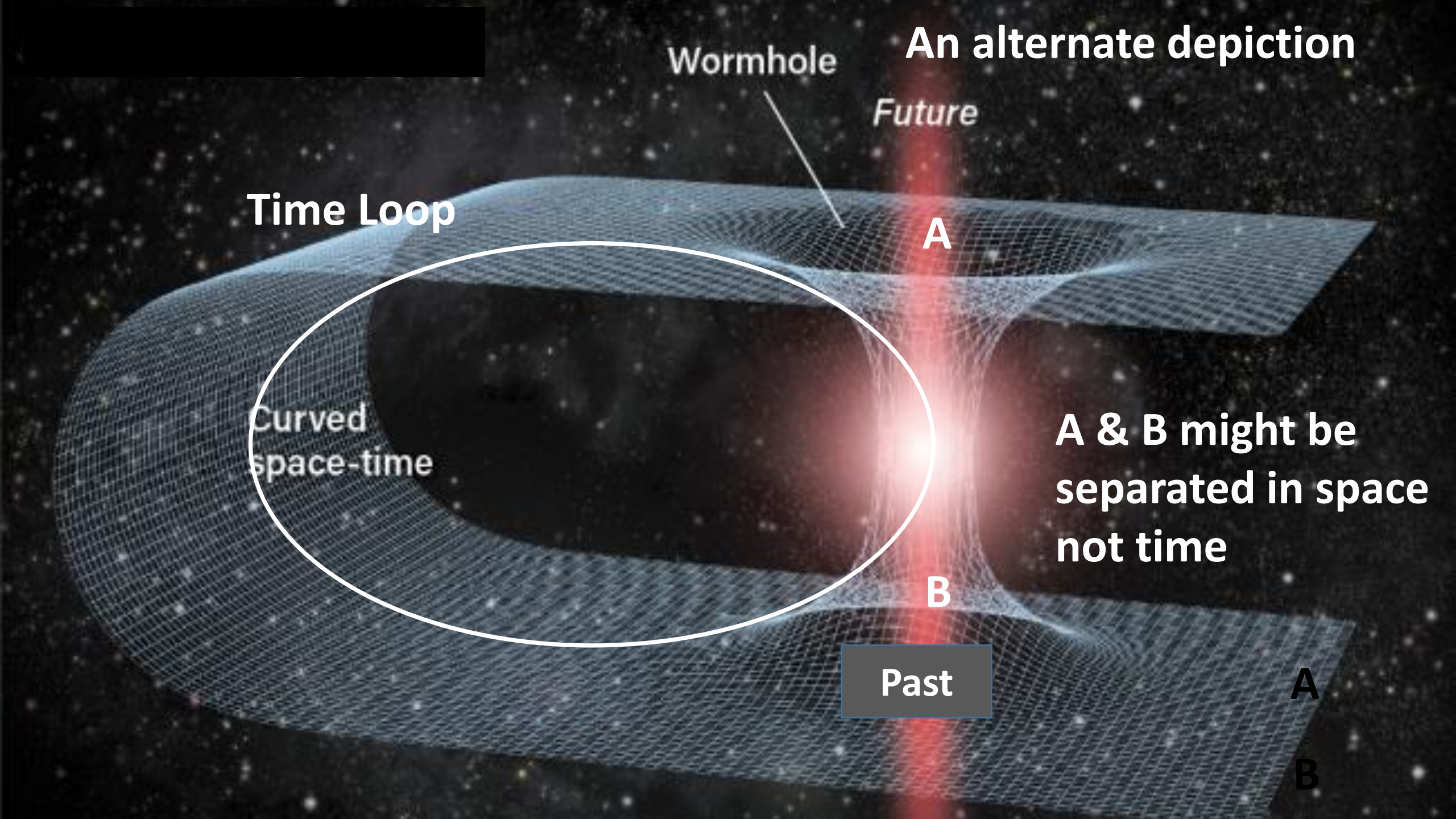
White Hole



Wormhole

A remote region
of spacetime

Or another
universe



An alternate depiction

Wormhole

Future

Time Loop

A

Curved
space-time

A & B might be
separated in space
not time

B

Past

A

B

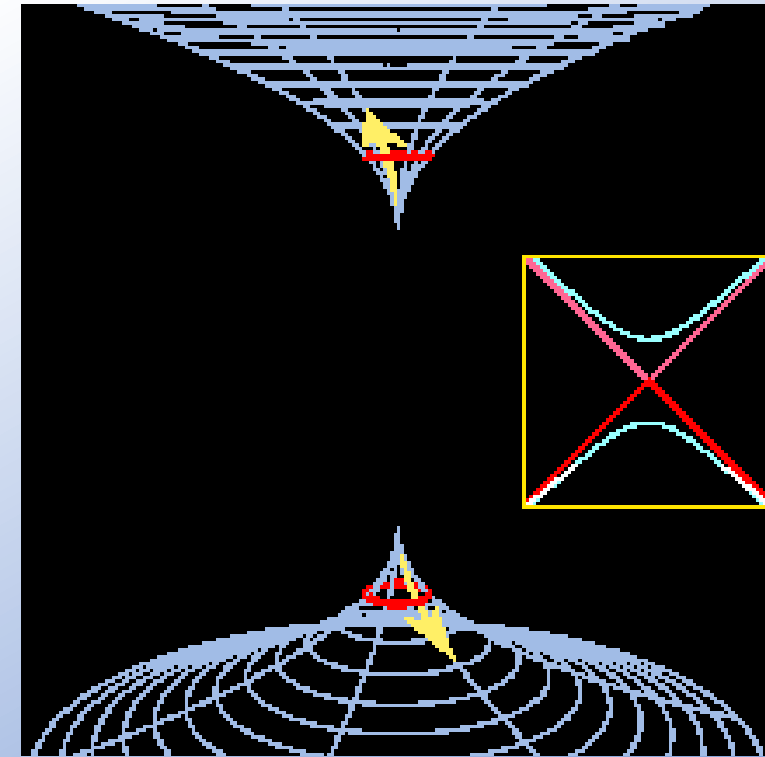
History of wormhole concept

Einstein-Rosen bridge* (1935): GR equations allows a structure joining two distant regions of spacetime (or another universe)

John Wheeler: Such bridges collapse as soon as they form & he renamed them wormholes (1962).

Stephen Hawking: "Chronology Protection Conjecture" -- no stable wormholes, but changed his mind (2018)

Wormholes would be time machines (if they exist)



*Originally discovered by Ludwig Flamm in 1916

Wormholes

Great for both space
travel and time travel

Big questions:

Existence?

Formation?

Stability?

Traversability?

Existence of "exotic" matter?

November 3, 2003



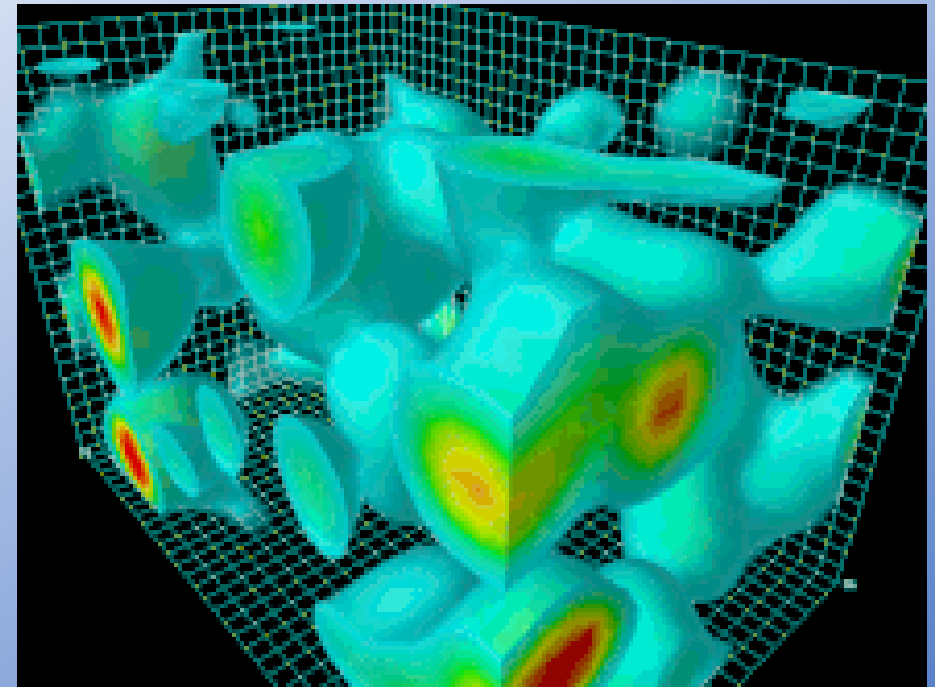
Very tiny wormholes *probably* exist*

On very small scales space and time continually fluctuate

On scale of 1.6×10^{-35} meters

3×10^{-26} times smaller than atom

Could one be enlarged and made stable? (Naturally or artificially)



Quantum foam

*But never observed

Where might we find a giant wormhole?



**Entrance to the
intergalactic
wormhole
Metro?**



First image of a black
hole in Messier 87
(6.5 billion times
mass of sun)

Black hole at the center of our galaxy & others might be wormholes.

How could we tell? Perhaps based on gravitational lensing effect



Having a wormhole
in your own home
might be a good way
to escape to another
universe.

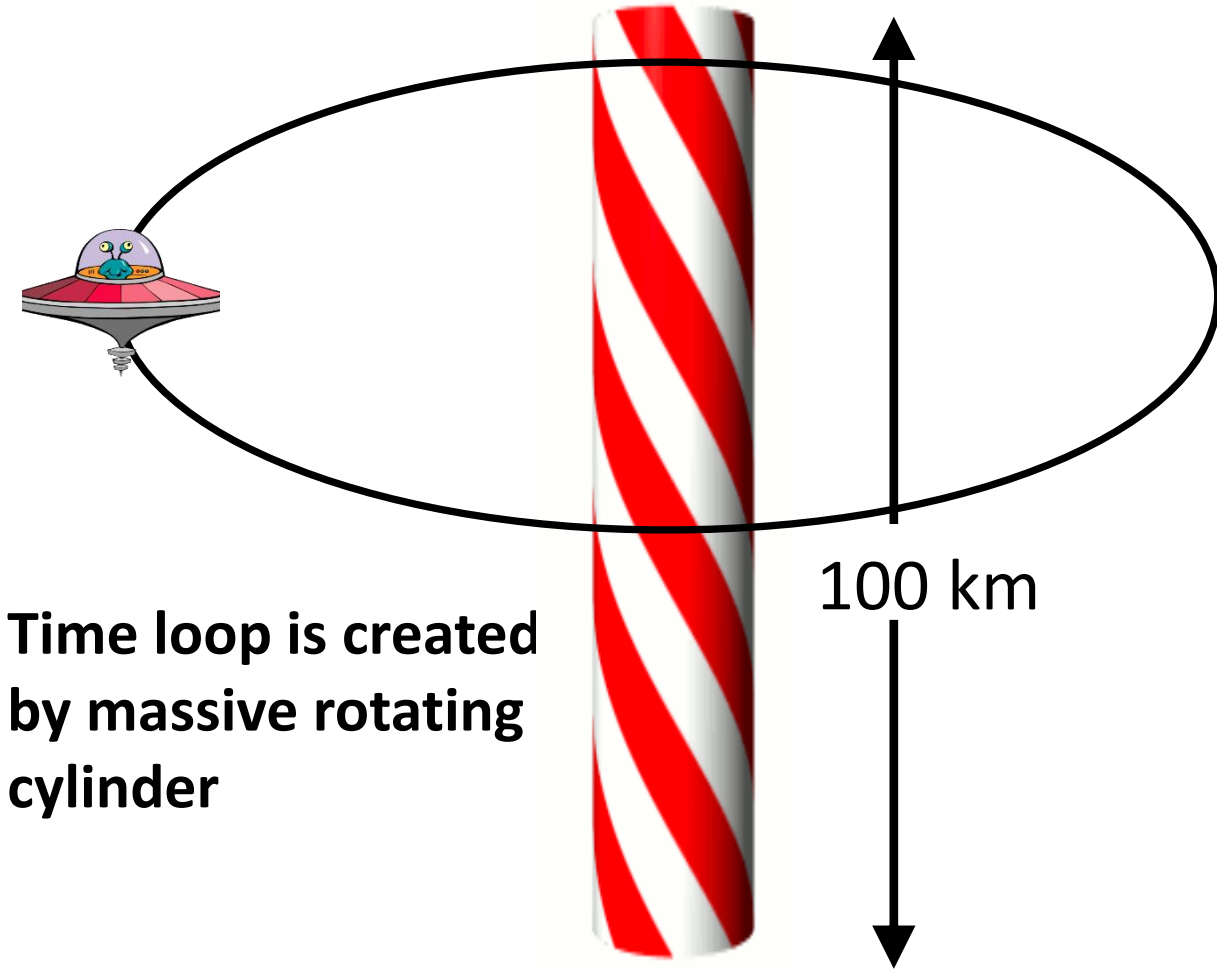
The Tipler Cylinder time machine

Circulate around a spinning cylinder in the direction of its spin & you go back in time.

No ordinary cylinder!

Mass at least 3 million times the mass of the Earth! Spinning a few billion rpm.

Could some hyper-advanced civilization build such a thing?



The Fermi Paradox: If time travel is possible, where are the time travelers?

Escaping the Fermi Paradox

- They are trained to blend in
- Very few allowed to travel back
- They go back only to certain eras
- They cannot be seen by us
- No going back before time machines
- Maybe we just haven't noticed them?

The grandfather paradox



Grandfather pair o' ducks

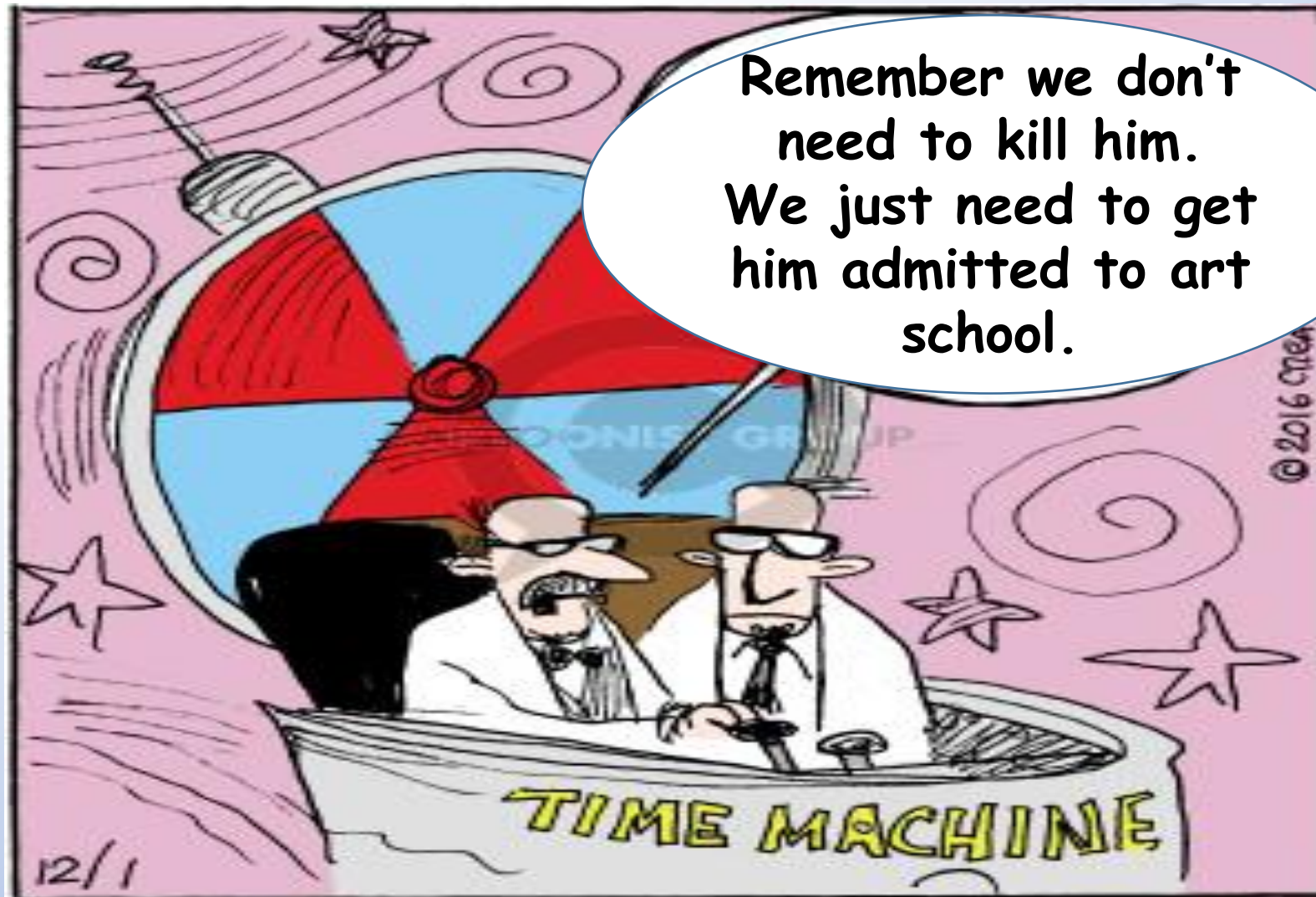


**I WENT BACK
IN TIME AND
KILLED ADOLF HITLER!**

**NEVER
HEARD OF HIM**

An invasion of time travelers?

They've come from the future to save us



“Proof” that time travelers exist



Summary of Talk

Einstein's theories of relativity raise the possibility of time travel

One-way travel to the future is possible for sure.

Time travel to the past or two-way travel to the future might be possible.

Time travel involves various paradoxes.

The best candidate for a time machine (a loop in time) is the wormhole.

Wormholes are consistent with general relativity equations

Tiny wormholes very likely exist, but do large, stable, traversable ones?

The Tipler cylinder and FTL speed travel are two other possibilities

Learn more about "tachyons" and time travel

The tachyon Nexis web site:
Ehrlich.physics.gmu.edu

The Tachyon Nexus

A tacky web site on tachyons & time travel

Faster-than-light neutrinos: are they imaginary or *imaginary*?



About me



My tachyon prediction



Book in progress