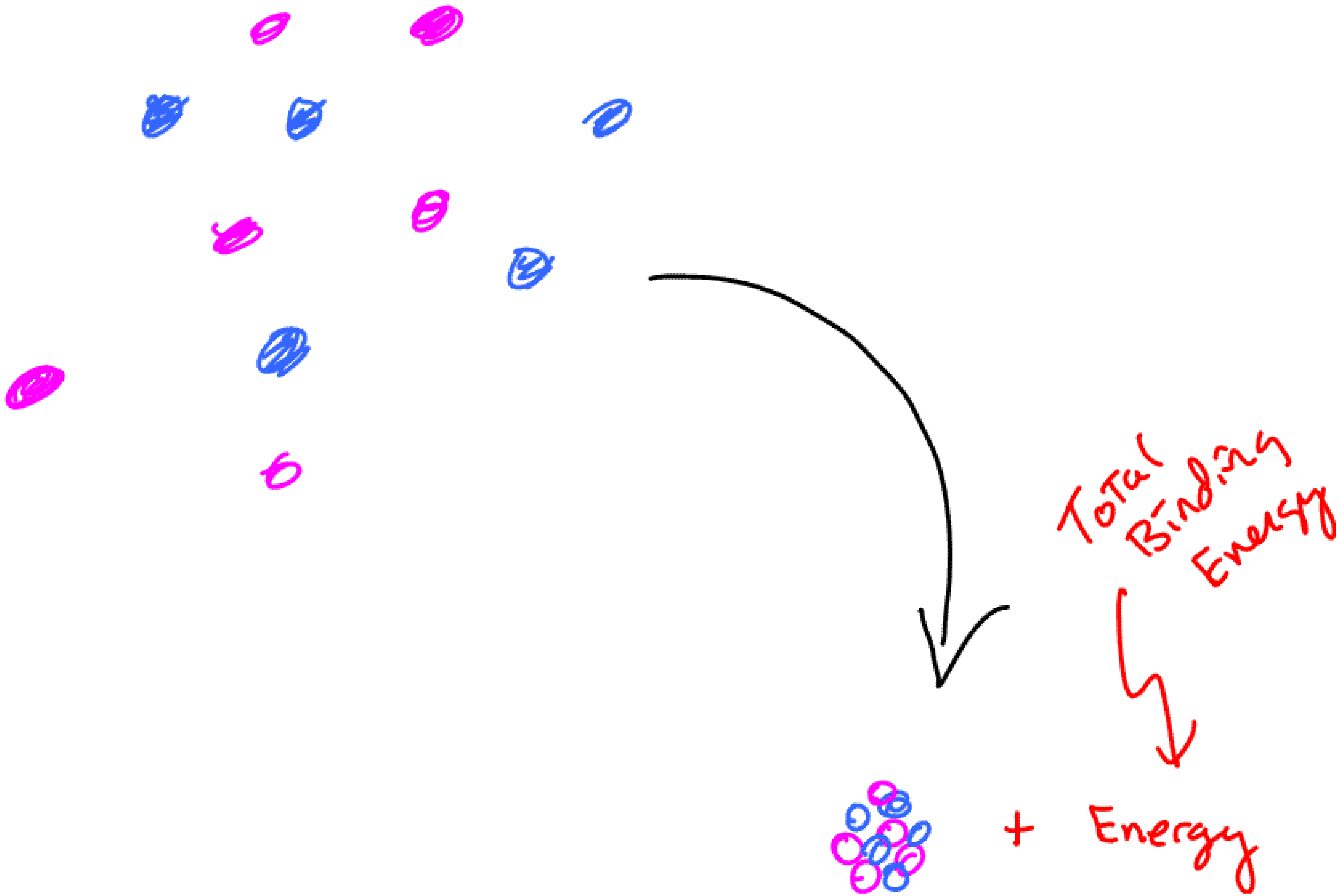
Physics 114 – April 27, 2010

- Exam regrades done ... can pick up here or in box

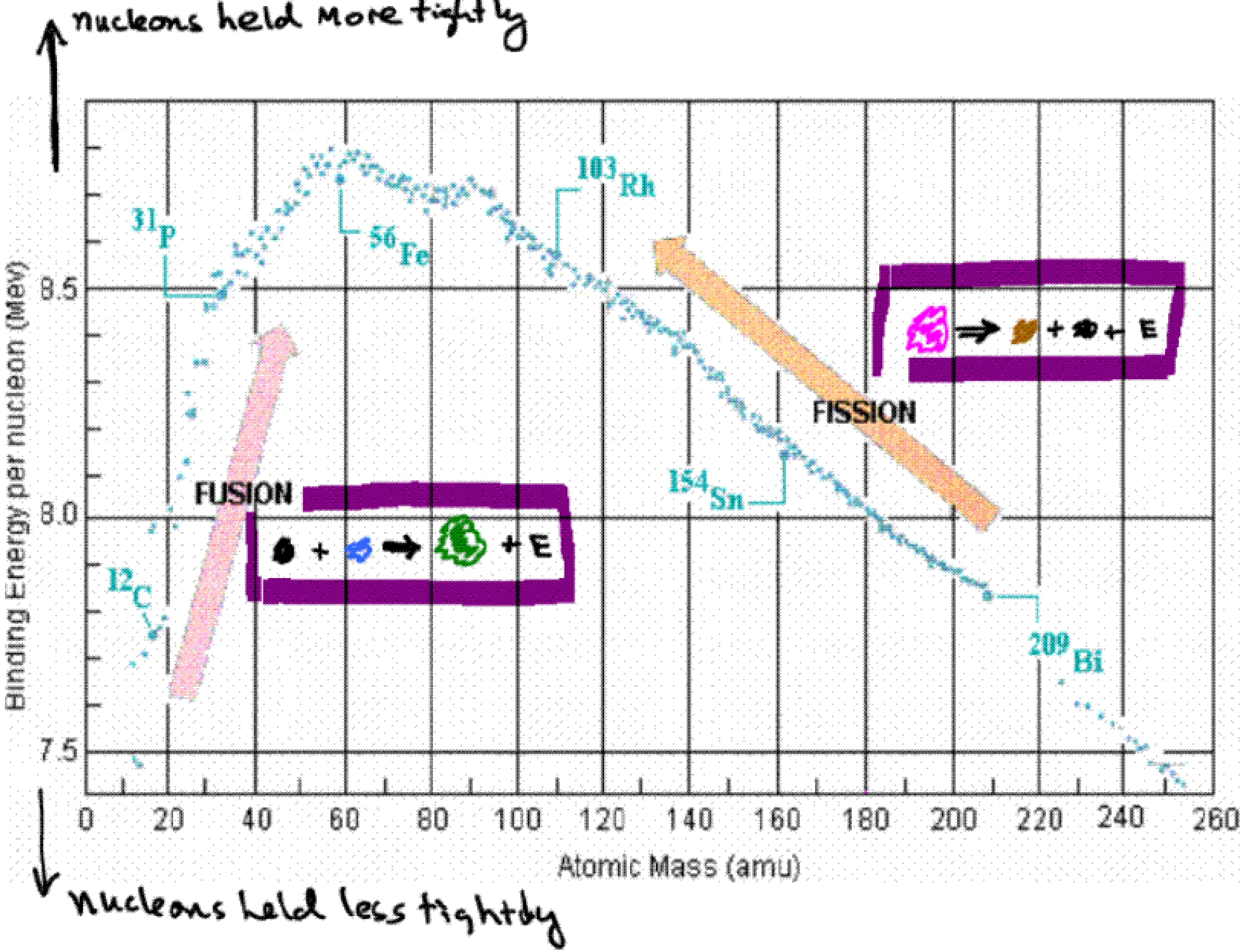
  All very reasonable requests Thanks!

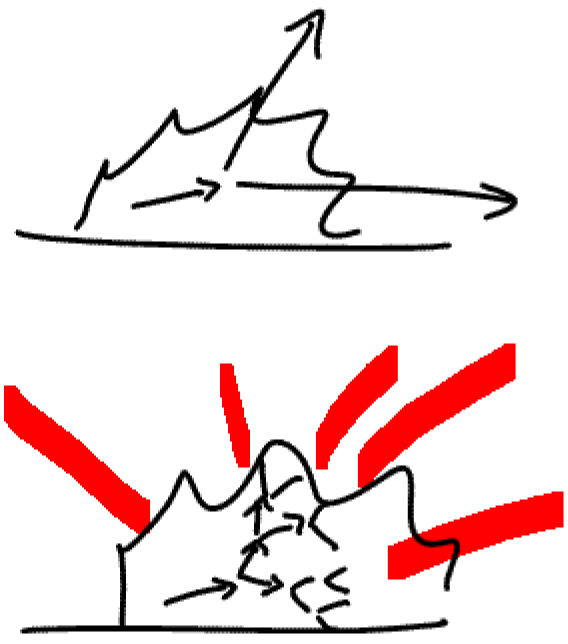
  Shirley, Rueda, Feldman, Cho, Foote, Beamish, Brown, Ostrager, Sung, Lee, Gelb

- Q+A session
- Final exam ~40% new material
  Topics listing sent out via email


Total Binding Energy
+ Energy

Inherent Nuclear stability as function of nuclear size

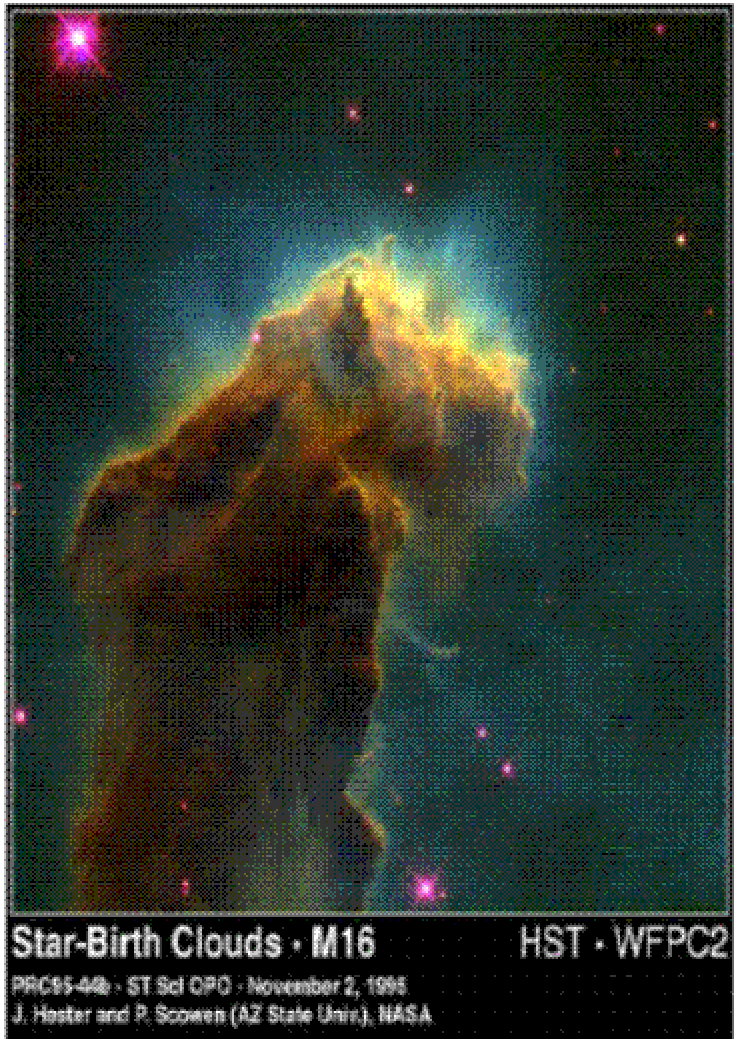




Stars - from dust to dust

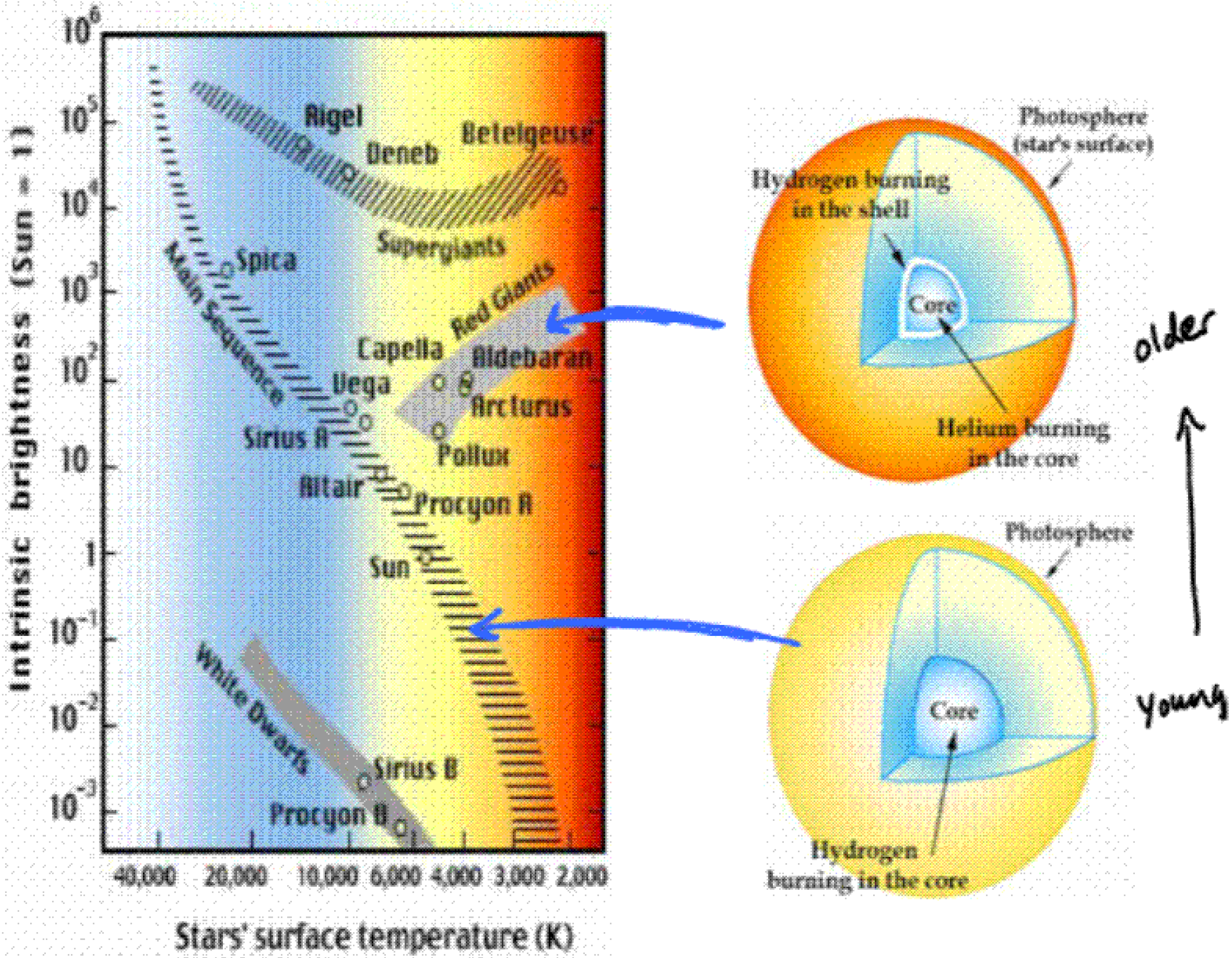
Stars form from condensation of gas/dust due to gravitation

mostly hydrogen gas

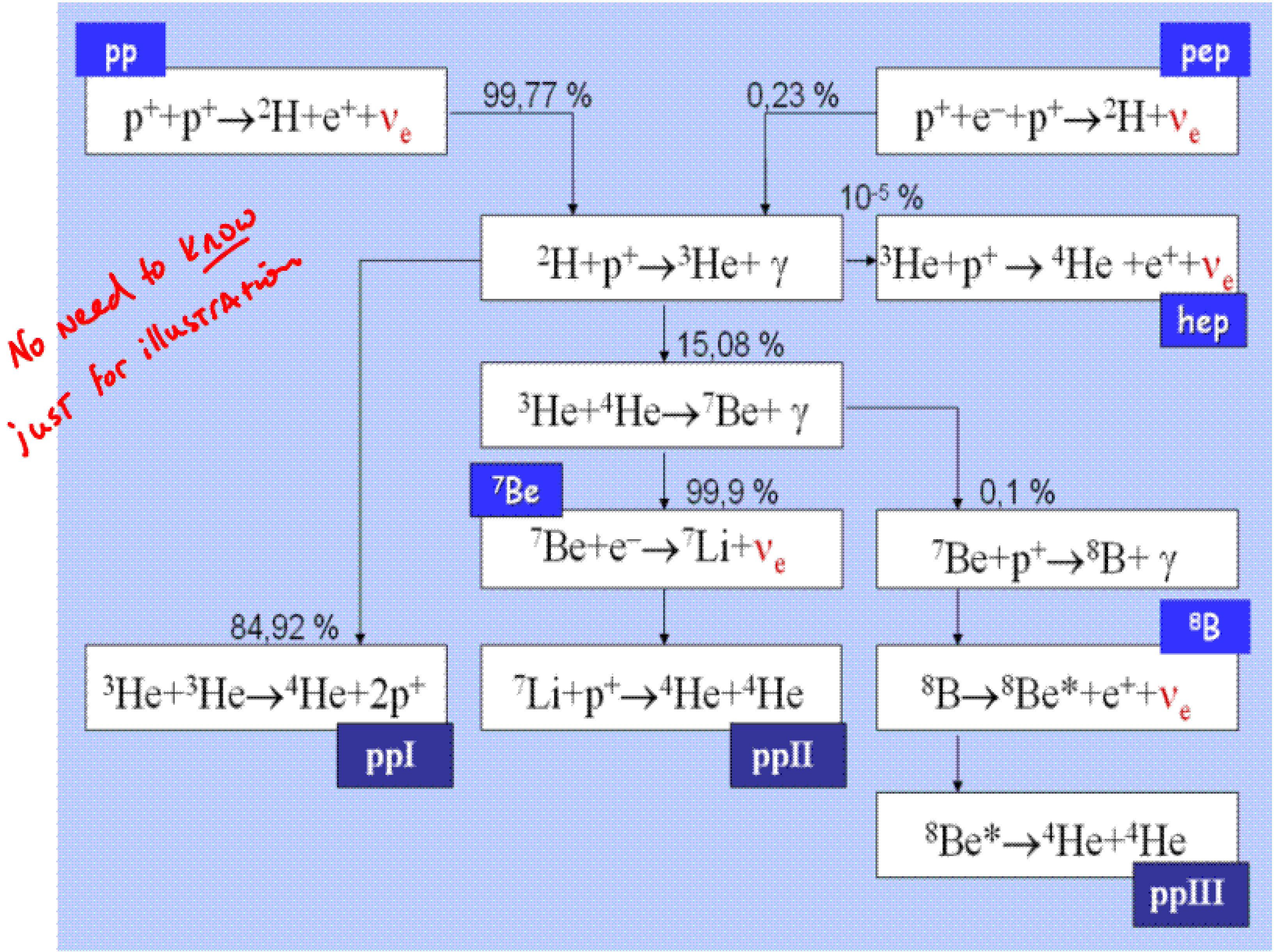


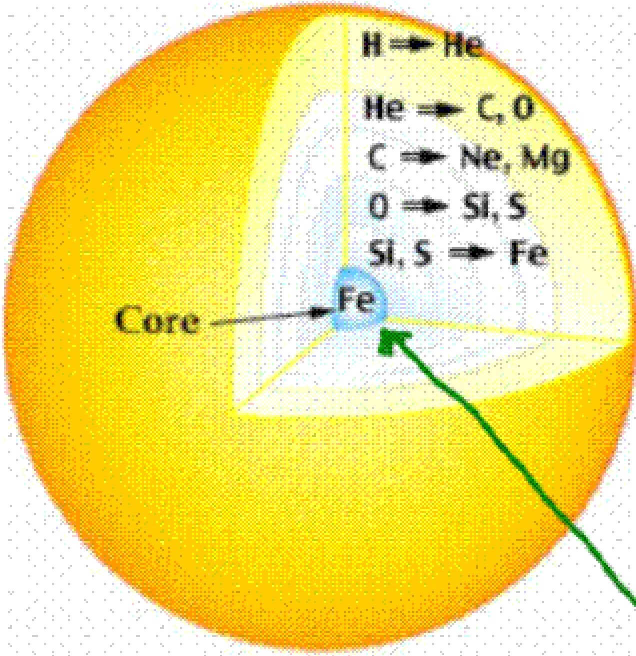
The Pleiades

Young stars residual dust surrounding them


Intrinsic brightness (Sun = 1)
Stars' surface temperature (K)
40,000
20,000
10,000
6,000
4,000
3,000
2,000
Rigel
Deneb
Betelgeuse
Supergiants
Spica
Main Sequence
Red Giants
Capella
Aldebaran
Vega
Arcturus
Sirius A
Pollux
Altair
Procyon A
Sun
White Dwarfs
Sirius B
Procyon B
Photosphere (star's surface)
Hydrogen burning in the shell
Core
Helium burning in the core
older
Photosphere
Core
Hydrogen burning in the core
young

Primary Fusion Processes in the Sun

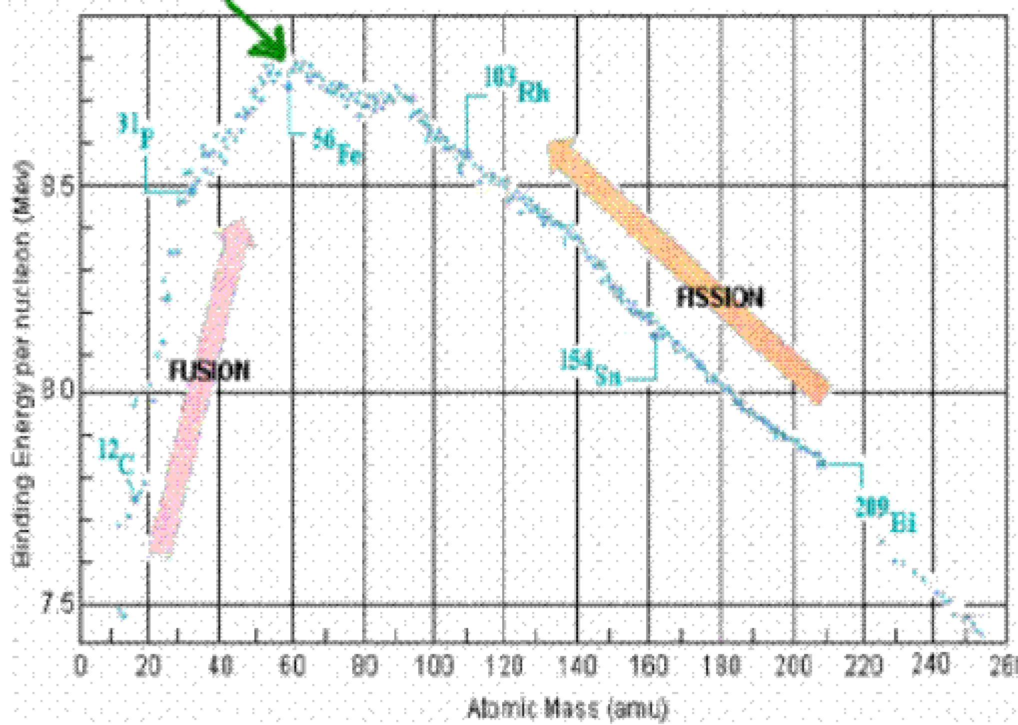


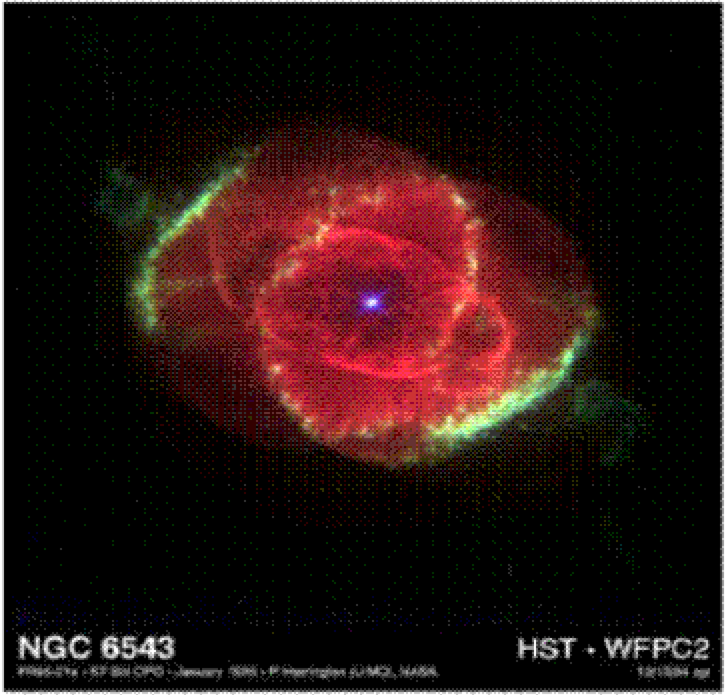


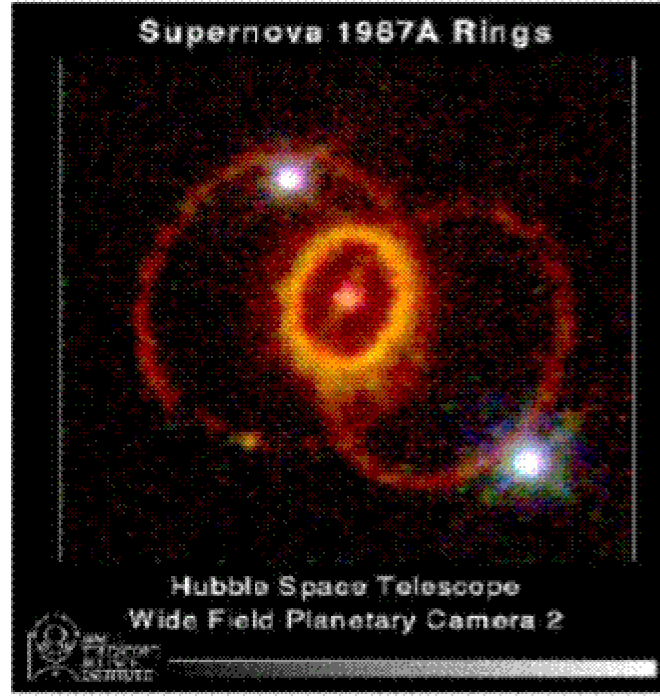
late life massive star

Fusion process into nuclei larger than ^{56}Fe takes energy rather than releasing energy

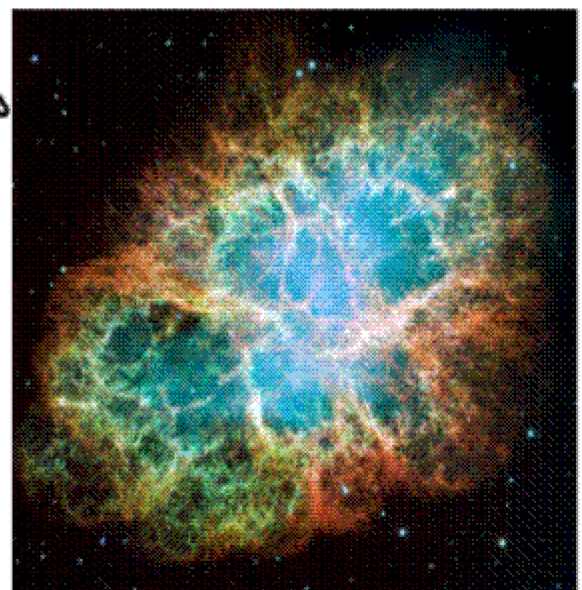
- Early universe almost entirely Hydrogen
- normal Stellar evolution
  ↳ fusion A up to ~57
- Supernovae processes
  ↳ fusion A > 57







STAR went Supernova in 1054 – observed during day by Chinese and Arab Astronomers

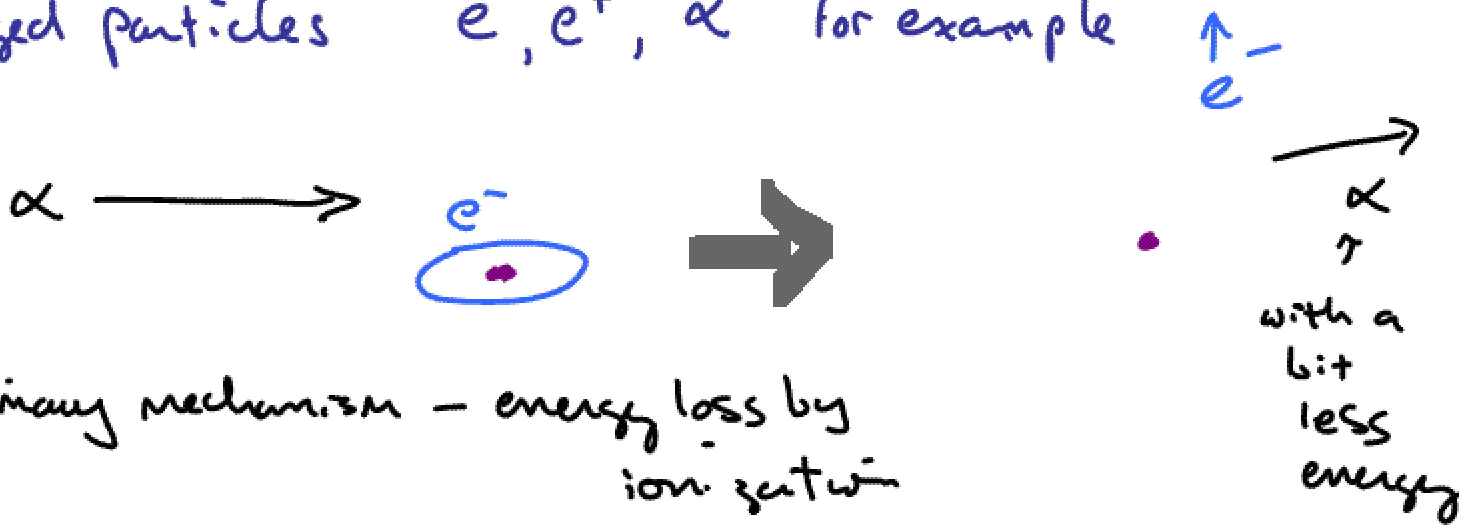


Crab Nebula

Star went Super Nova in 1054

Interaction of radiation with matter

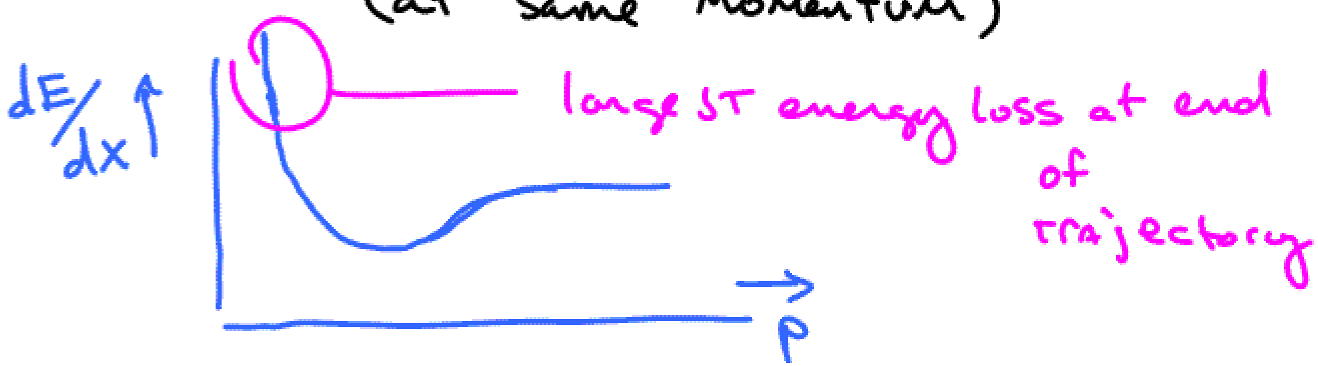
Charged particles e^-, e^+, α for example



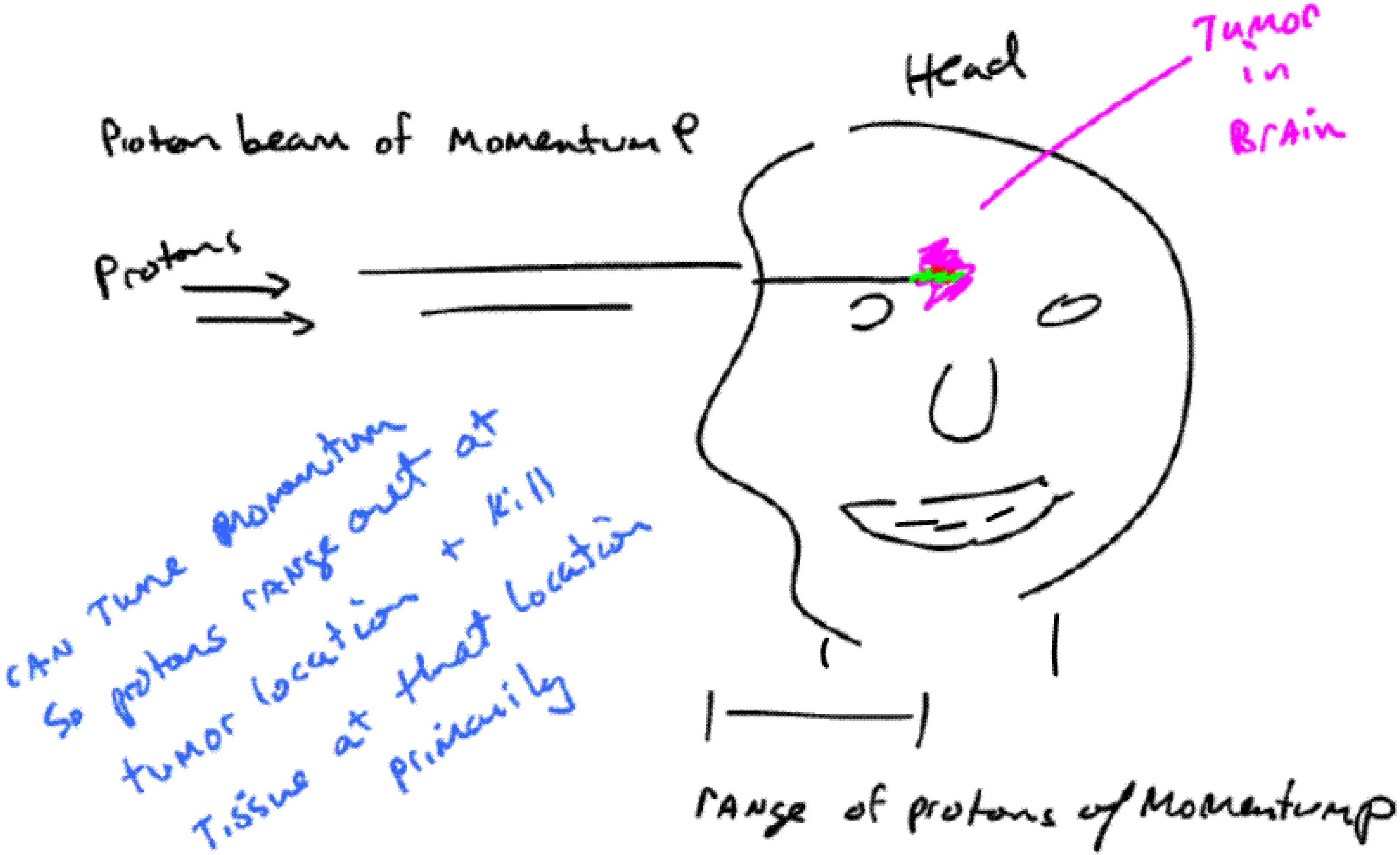
Primary mechanism – energy loss by ionization

Higher for large m, large q

∴ Range of α is shorter than e^- for example (at same momentum)



CAN use this



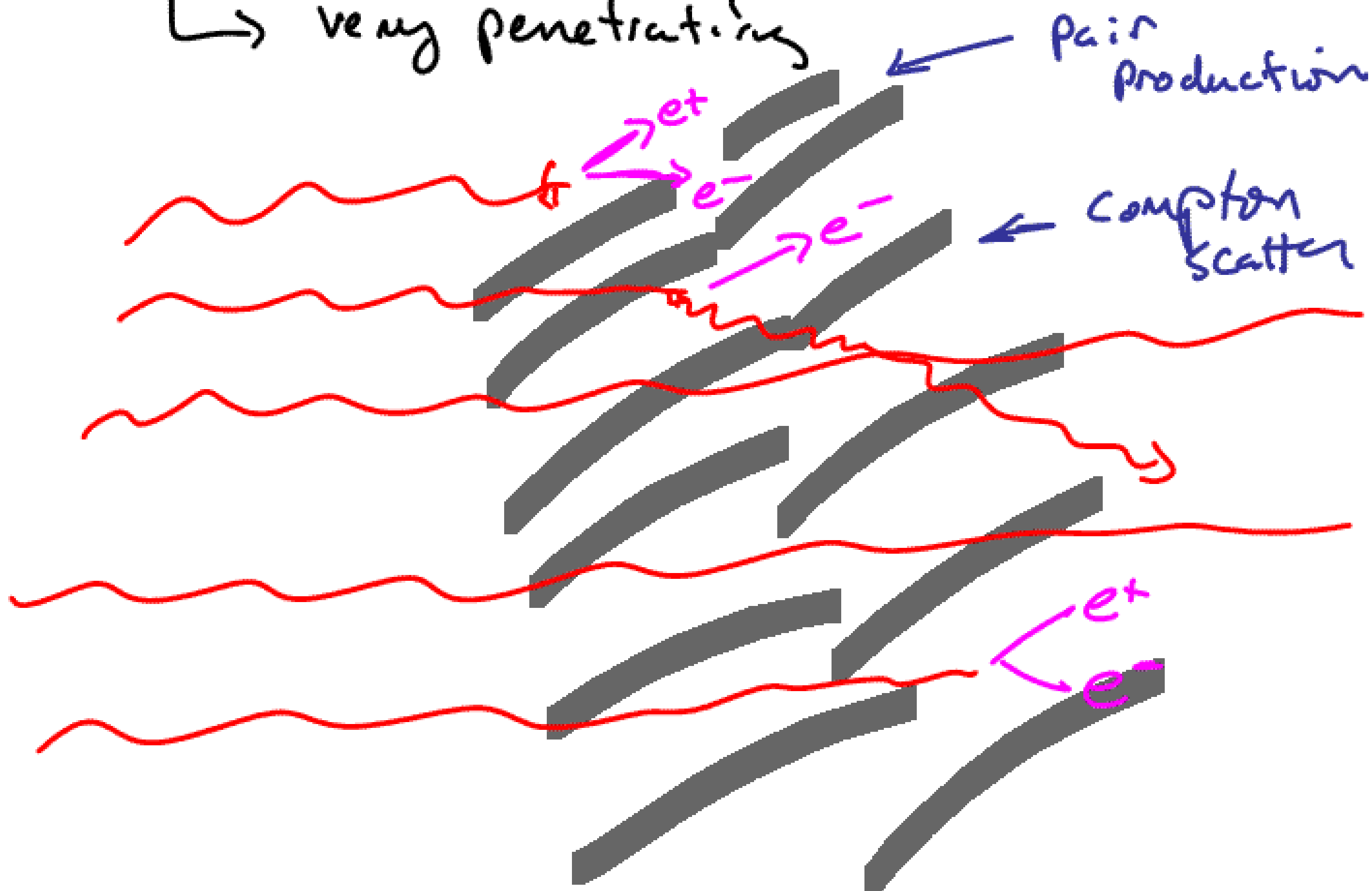
ionization energy loss greatest when proton almost stops . . . Energy deposition and Tissue destruction greatest at end of path

Natural α stopped by paper

β " " plexiglass or glass

γ - rays

↳ very penetrating



Radiation Danger Depends on

- Activity of Material
- location of Material relative to you + vital organs
- Exposure time
- Type of Radiation

outside body	inside body
Danger (relative)	
$\gamma > \beta > \alpha$	$\alpha > \beta > \gamma$

moral to this story: Don't ingest your α sources

Special Theory of Relativity

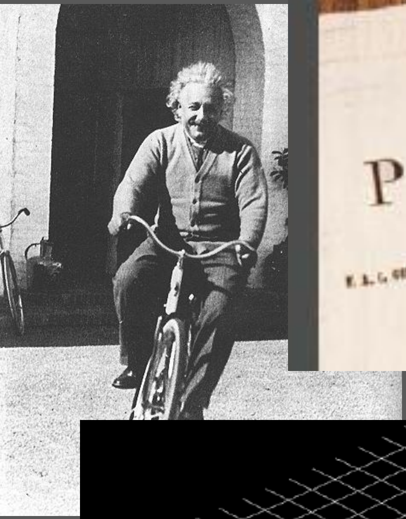
↳ PPT Slides

Know postulates of special relativity

How to do { length contraction, time dilation } problems

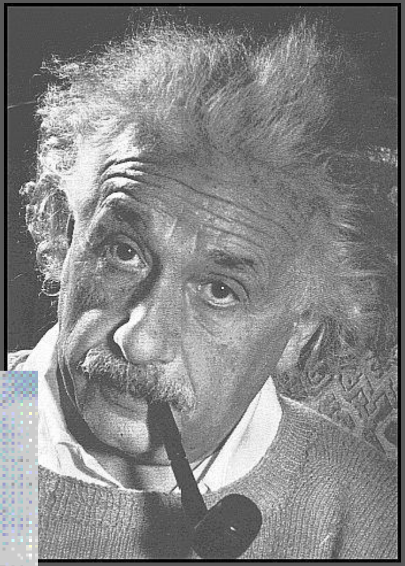
NO Lorentz transformations, Energy-Mass equivalence, general relativity

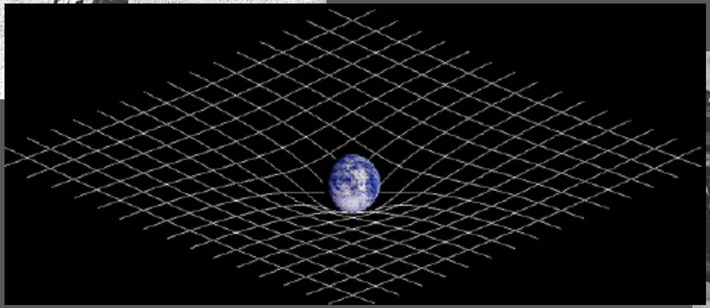
Relativity: the warping of space, time, and minds

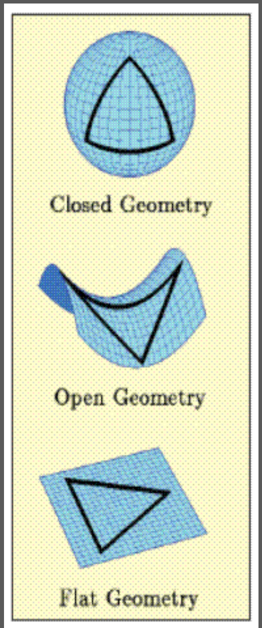


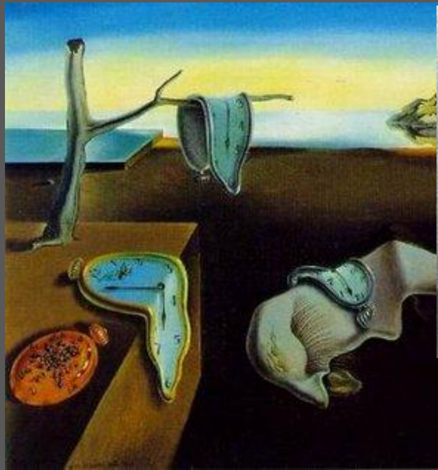
3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegen-[illegible]wärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf [illegible]bewegte Körper zu Asymmetrien führt, welche den Phänomenen [illegible]nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Mag-[illegible]neten und einem Leiter. Das beobachtbare Phänomen hängt [illegible] nur ab von der Relativbewegung von Leiter und Magnet, [illegible]während nach der üblichen Auffassung die beiden Fälle, daß [illegible] eine oder der andere dieser Körper der bewegte sei, streng [illegible]einander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten [illegible]elektrisches Feld von gewissem Energiewerte, welches an [illegible] Orten, wo sich Teile des Leiters befinden, einen Strom [illegible]. Ruht aber der Magnet und bewegt sich der Leiter, [illegible]

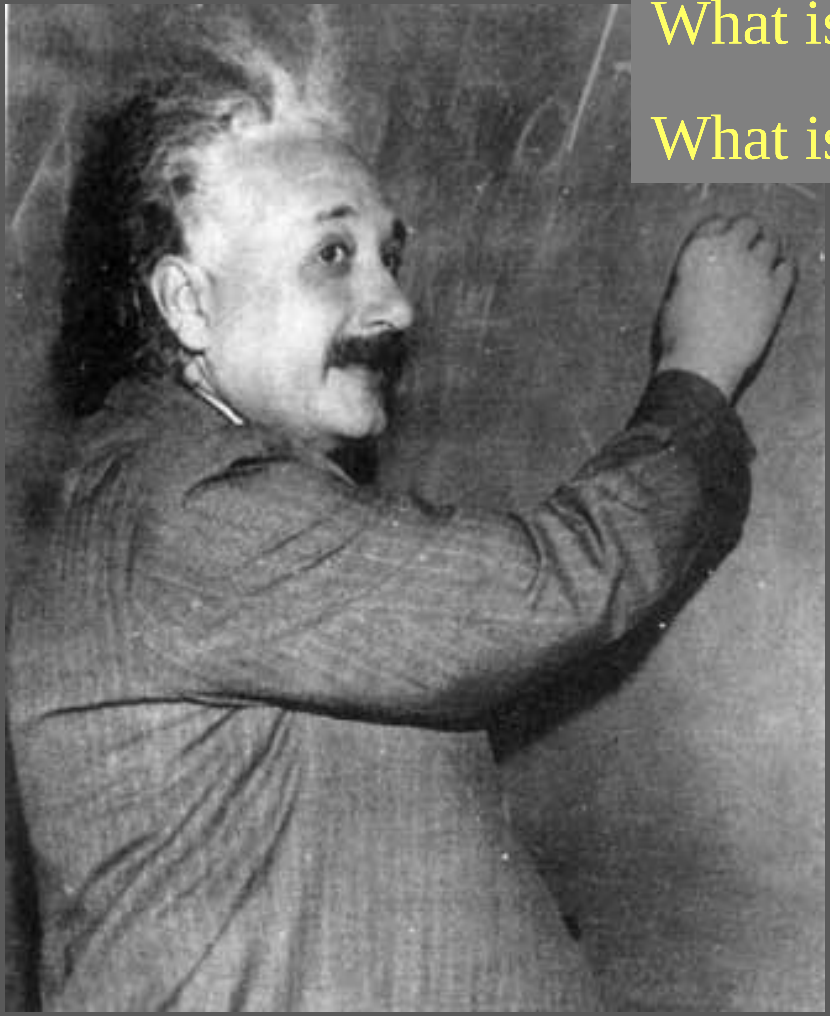








Steve Manly
Department of Physics and Astronomy
University of Rochester



What is time??

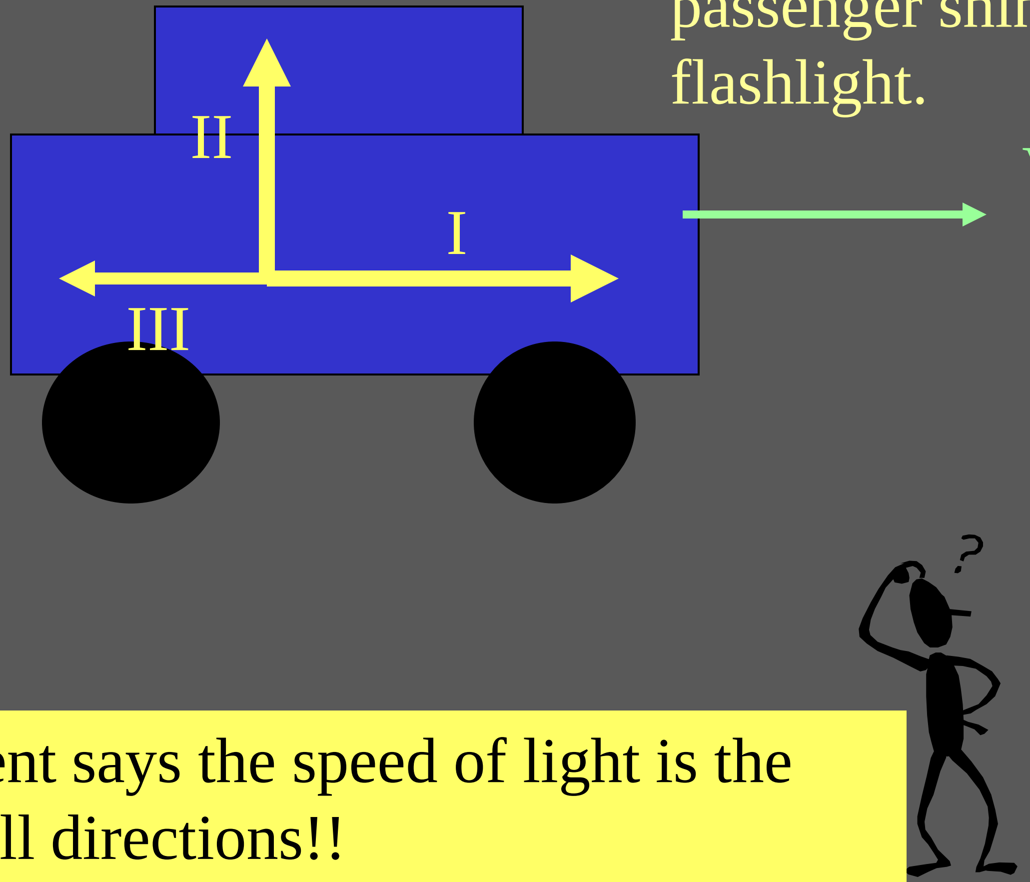
What is space??

Speed with respect to you is 4 mi/hr

Speed with respect to you is 2 + 4 = 6 mi/hr

The speed of light is greater for beam I, beam II or beam III?

Car moves while passenger shines a flashlight.



Experiment says the speed of light is the same in all directions!!

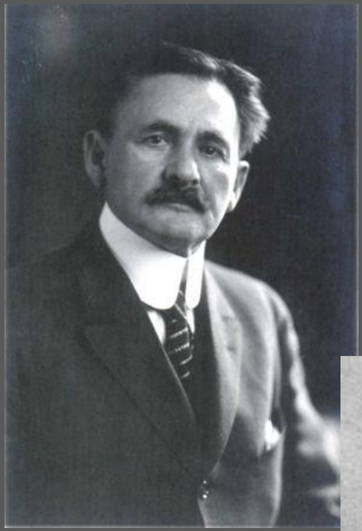
waves

Photo credit: Andrew Davidhazy

Michelson-Morley experiment

1881 – A.A. Michelson in Berlin

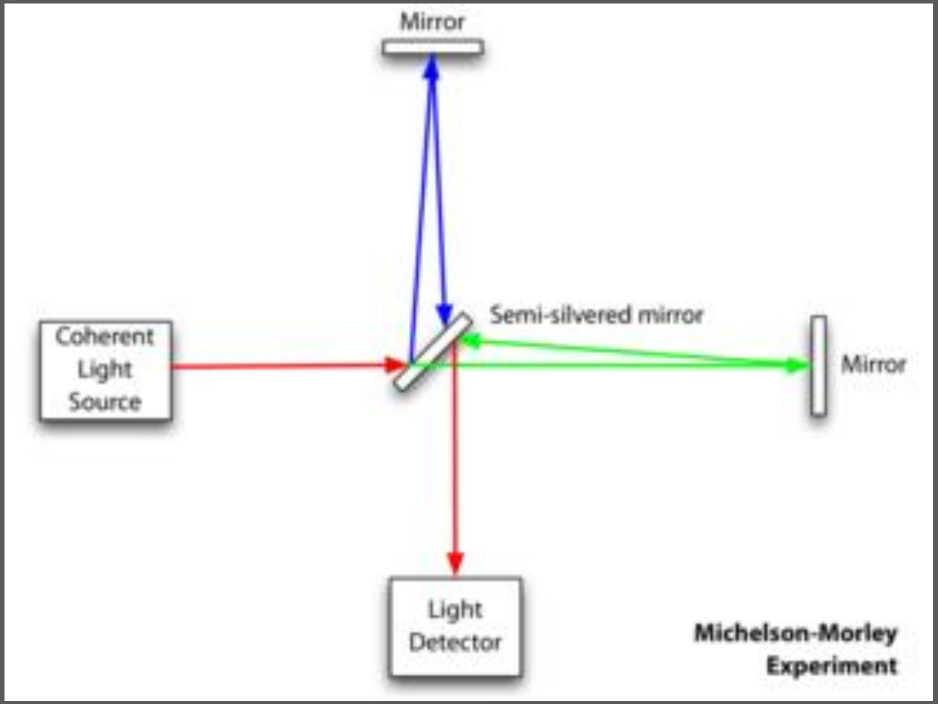
1887 - A.A. Michelson and E.W. Morley in US (Case Western)



1907 Nobel Prize in physics

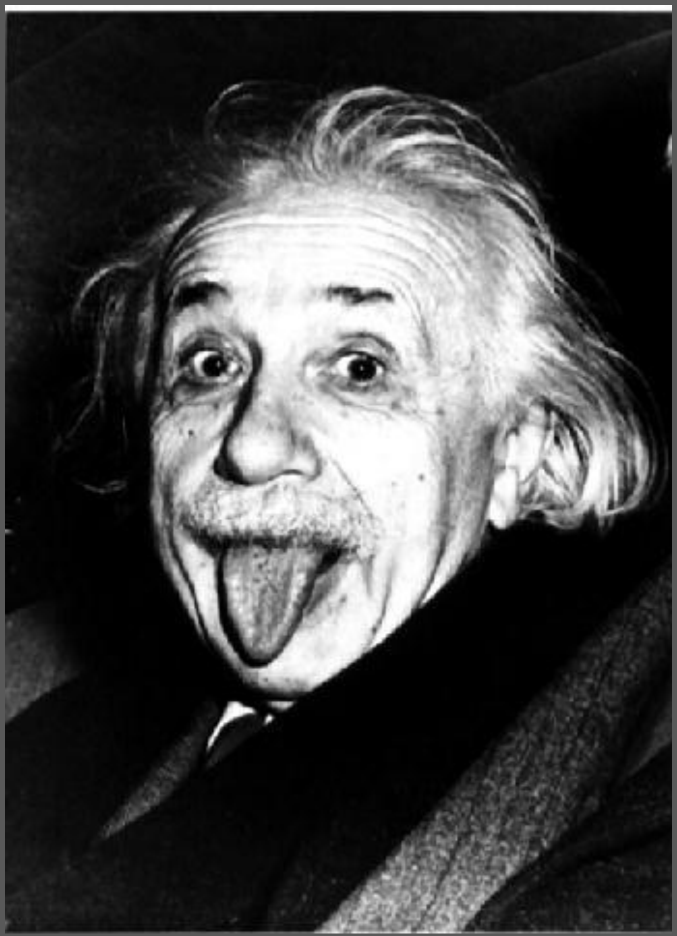
Michelson

Morley



Weird, huh? What does it mean for the real world?

Enter our man Einstein!



Instead of trying to “save the current paradigm”, Einstein bowed before the experiment.

What if it is true??

Two postulates:

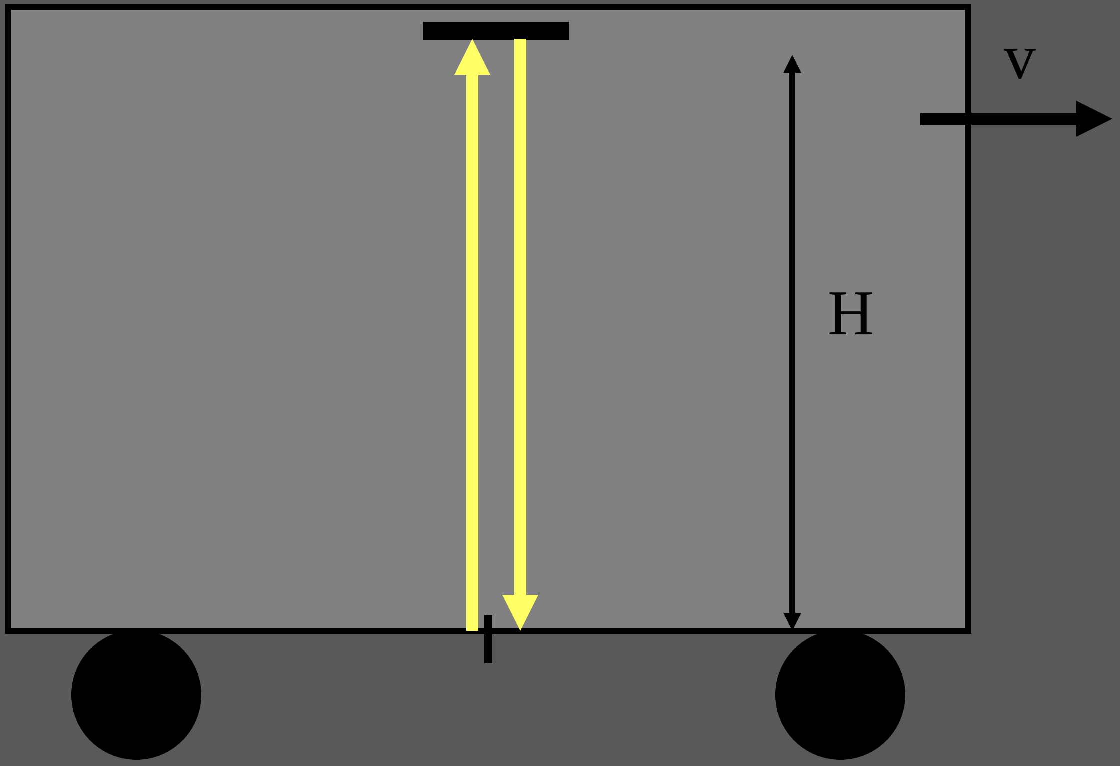
1) Michelson-Morley is correct. Speed of light is the same in all inertial reference frames

2) Physics is the same in all inertial reference frames

Point of view of observer

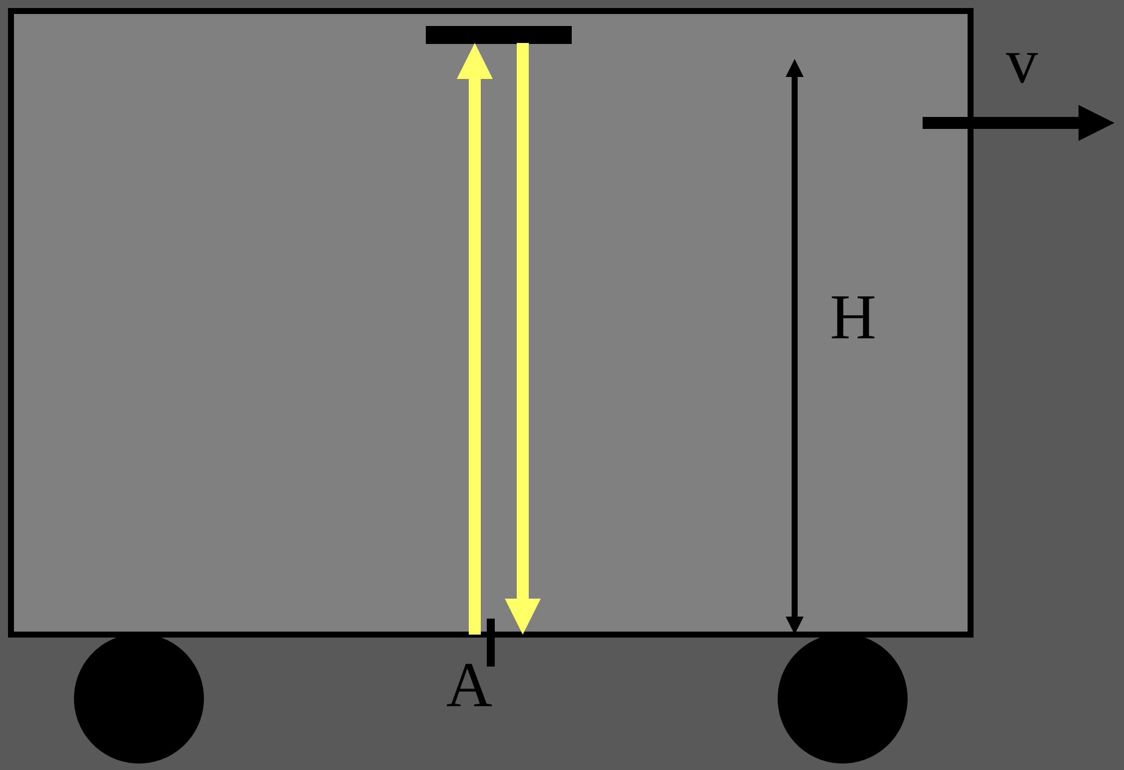
Moving at constant speed

Einstein thought experiment:
Consider a beam of light that is emitted from the floor of a train that bounces off a mirror on the ceiling and returns to the point on the floor where it was emitted.

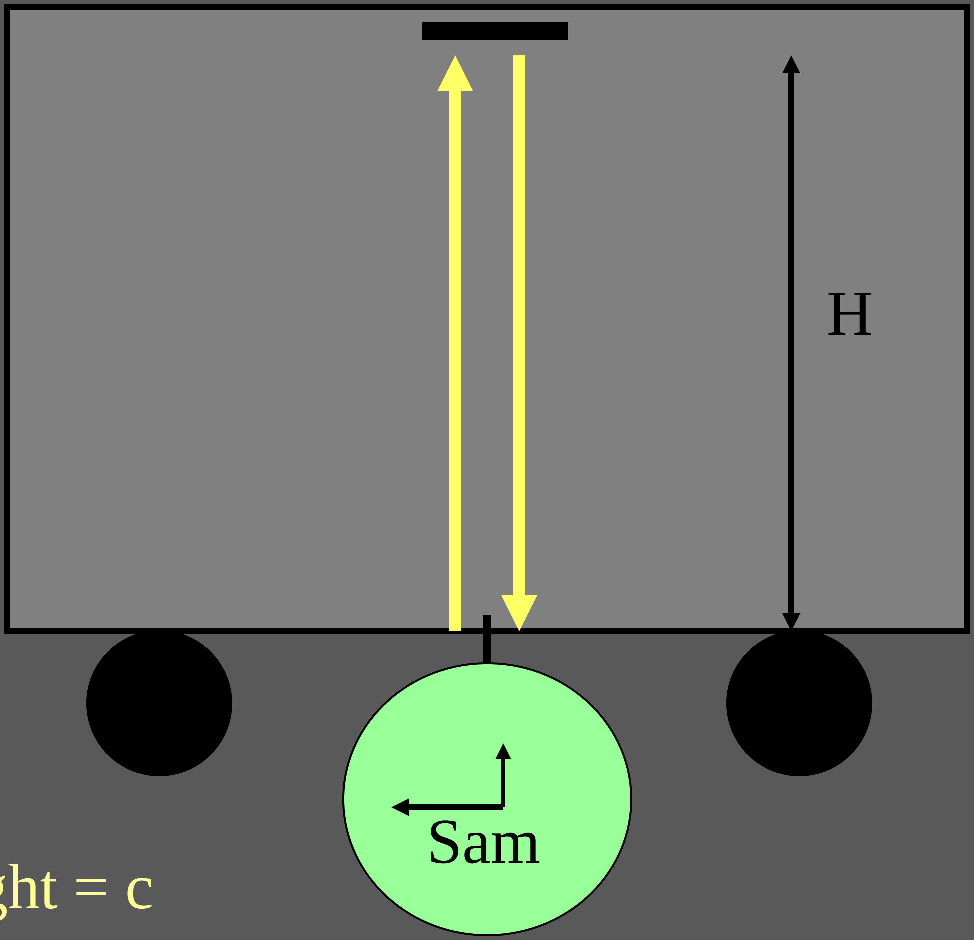


Fact: Light is emitted and detected at point A.

This fact must be true no matter who makes the measurement!!!!



Sam is on the train



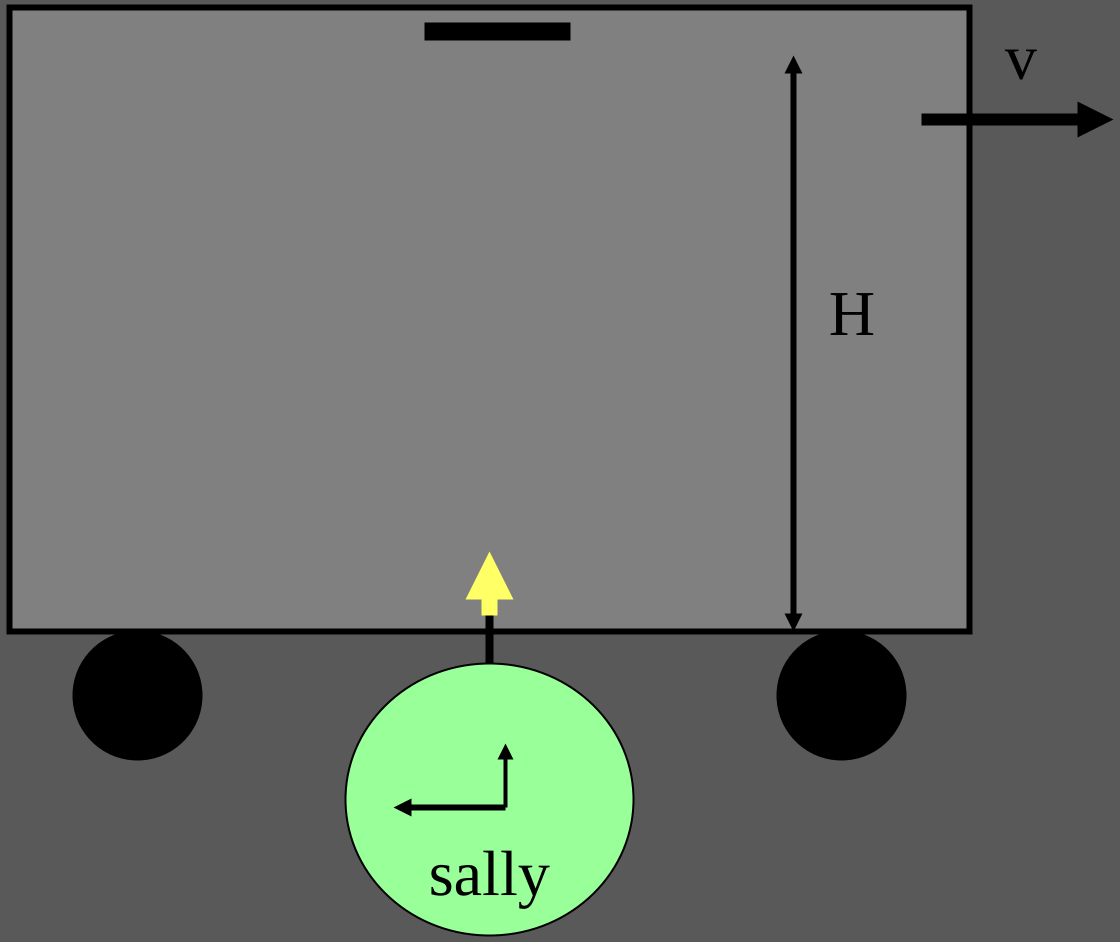
Velocity of light = c

c = distance/time

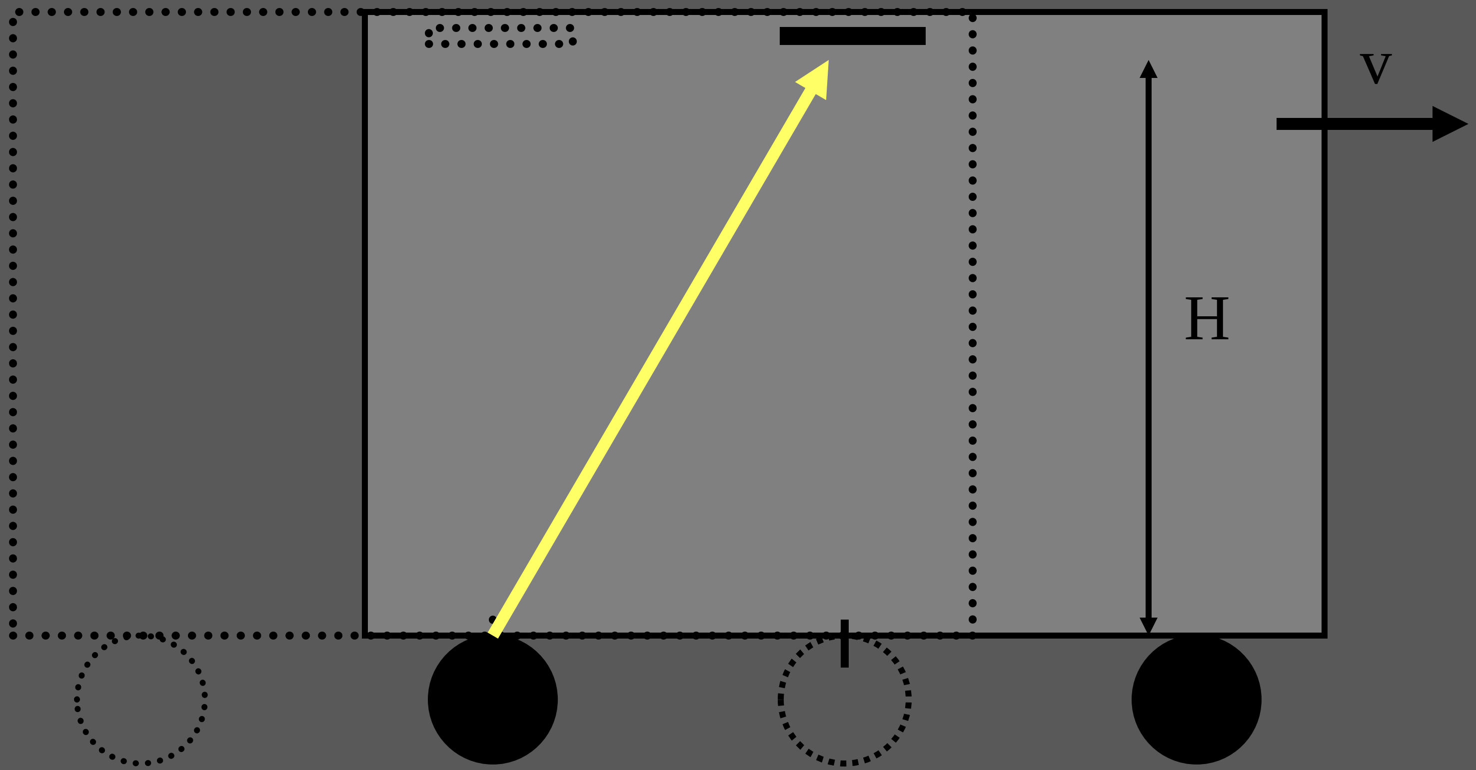
$c = 2H/T_{sam}$

$T_{sam} = 2H/c$

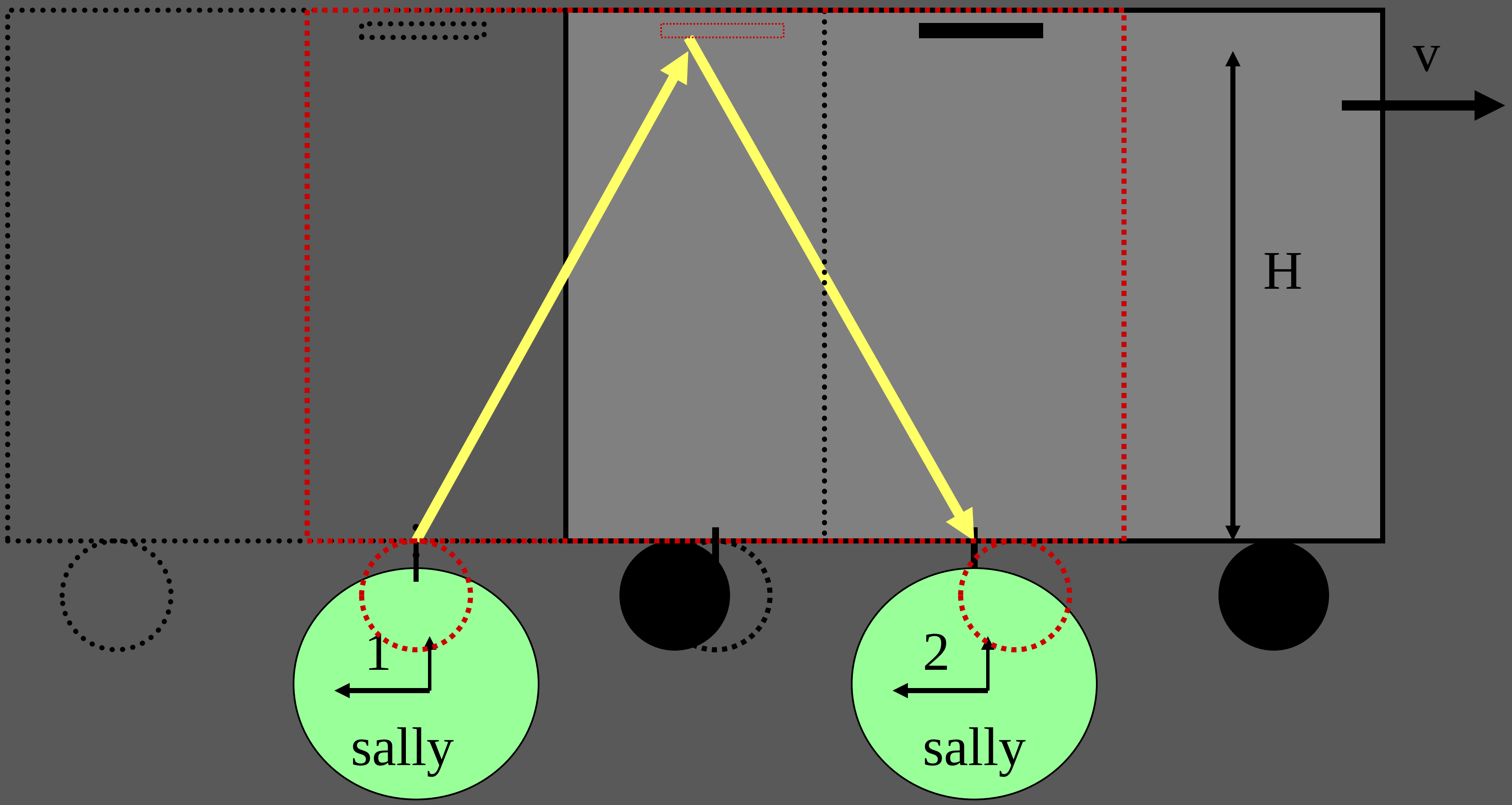
Sally watches the train pass and makes the same measurement.



Light is emitted

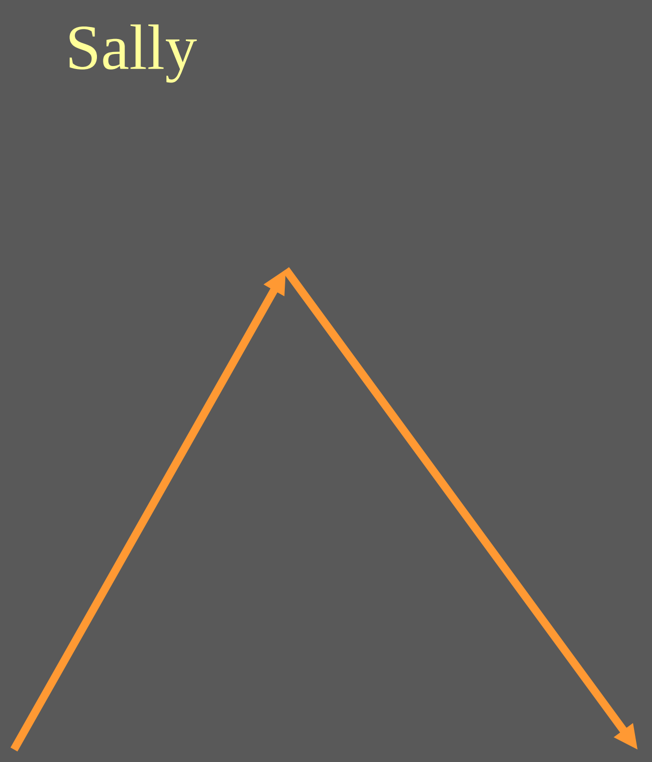

v
H

Sally is standing still, so it takes two clocks.



Light is emitted

Light returns

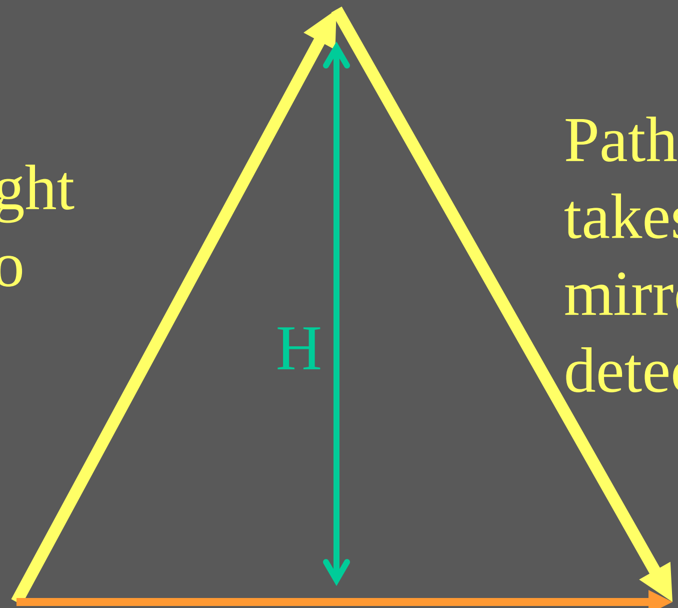


Sally sees the light traveling further. If light travels at a constant speed, the same “event” must seem to take longer to Sally than Sam!

Time is relative … not absolute!!

From Sally’s point of view

Path light takes to mirror



Path light takes from mirror to detector

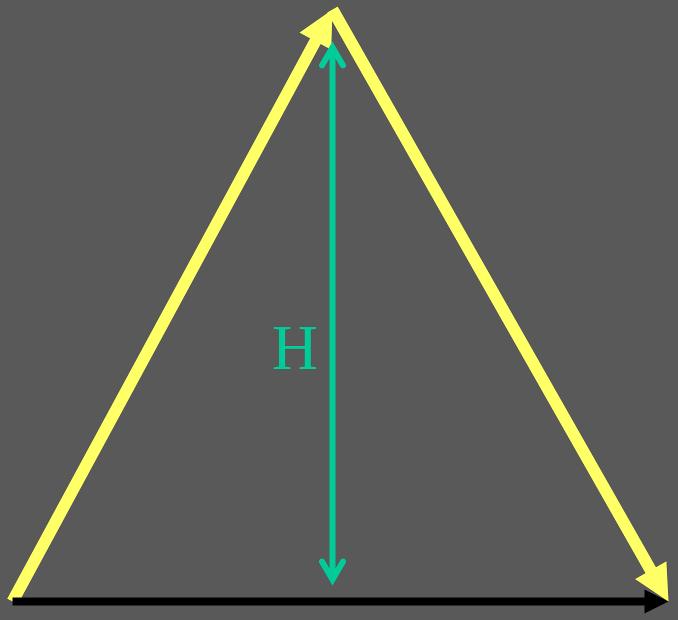
Distance train travels while light is traveling

$= VT_{sally}$

$$D = \sqrt{H^2 + (\frac{1}{2} vT_{sally})^2}$$

Makes use of Pythagorian theorem

From Sally's point of view



$$c = \text{distance/time} = 2D/T_{sally}$$

$$T_{sally} = 2D/c$$

Sam (on train)

Sally (on ground)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

$$c = \frac{2}{T_{sally}} \sqrt{H^2 + (\frac{1}{2} vT_{sally})^2}$$

$$\frac{2H}{T_{sam}} = \frac{2}{T_{sally}} \sqrt{H^2 + \left(\frac{1}{2} vT_{sally}\right)^2}$$

$$\left(\frac{2H}{T_{sam}}\right)^2 = \left(\frac{2H}{T_{sally}}\right)^2 + \left(\frac{2}{T_{sally}}\right)^2 \left(\frac{1}{2} vT_{sally}\right)^2$$

$$\left(\frac{2H}{T_{sam}}\right)^2 = \left(\frac{2H}{T_{sally}}\right)^2 + \mathrm{v}^2$$

$$\left(\frac{1}{T_{sam}}\right)^2 = \left(\frac{1}{T_{sally}}\right)^2 + \frac{\mathrm{v}^2}{(2H)^2}$$

Recall 2H/T_{sam} = c or 2H=cT_{sam}

$$\left(\frac{1}{T_{sam}}\right)^2 = \left(\frac{1}{T_{sally}}\right)^2 + \frac{\mathrm{v}^2}{(cT_{sam})^2}$$

$$c^2 = \frac{c^2 T_{sam}^2}{T_{sally}^2} + \mathrm{v}^2 \quad \longrightarrow \quad T_{sally} = \left[\frac{1}{\sqrt{1-\left(\frac{\mathrm{v}}{c}\right)^2}}\right] T_{sam}$$

Sam (on train)

Sally (on ground)

$2H/T_{sam} = c$

$c = 2D/T_{sally}$

$$c = \frac{2}{T_{sally}}\sqrt{H^2 + (\frac{1}{2}\mathrm{v}T_{sally})^2}$$

A bit of algebra.

$$T_{sally} = \left[\frac{1}{\sqrt{1-\left(\frac{\mathrm{v}}{c}\right)^2}}\right]T_{sam}$$

This number is >1.

It becomes larger as

v approaches c.

Think about it!

Sam and Sally measure the time interval for the same event.

The ONLY difference between Sam and Sally is that one is moving with respect to the other.

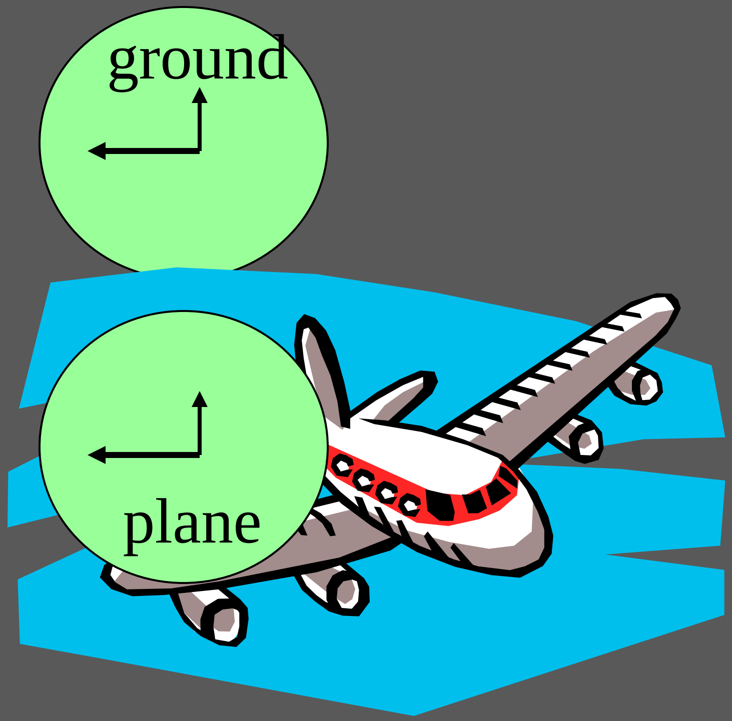
Yet, $T_{sally} > T_{sam}$

The same event takes a different amount of time depending on your "reference frame"!!

Time is not absolute! It is relative!

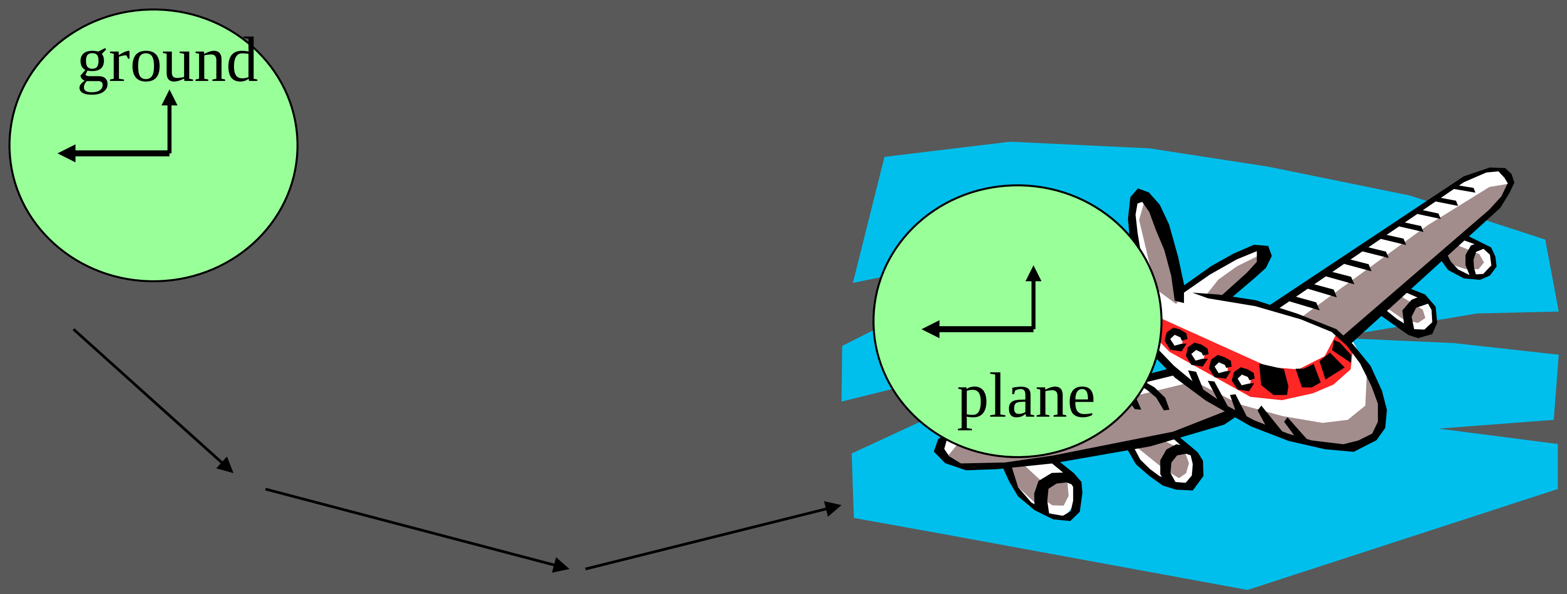
Can this be true??

Experiment says YES!

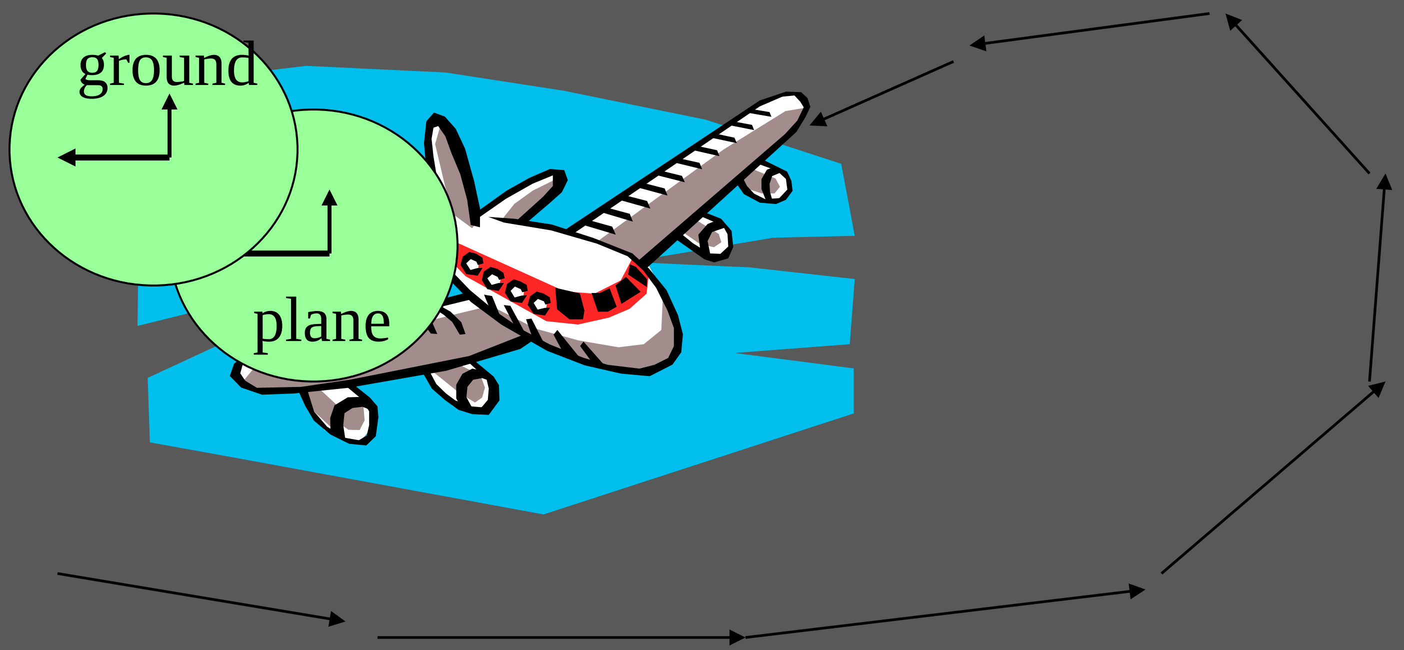


Can this be true??

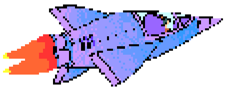
Experiment says YES!



Less time elapsed on the clocks carried on the airplane



V=0.98c



Lifetime=70 years on spaceship

Earth at rest

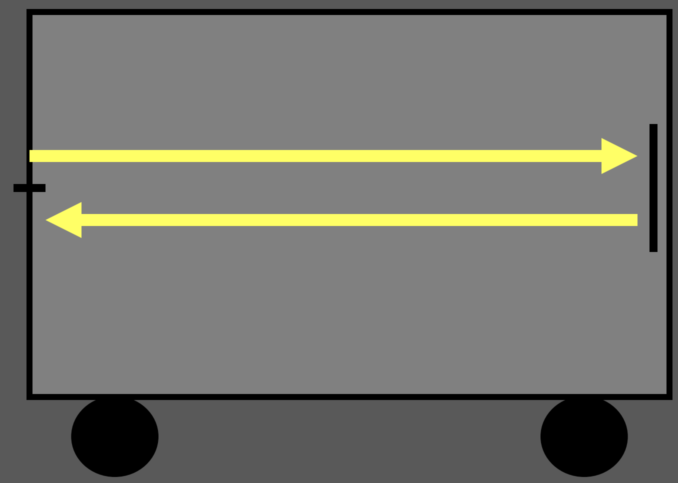
How long does person appear to live to astronomers on earth?

$$t_{earth} = \underbrace{\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}}_{\gamma > 1} \; \underbrace{t_{spaceship}}_{\text{"Proper Time"}}$$

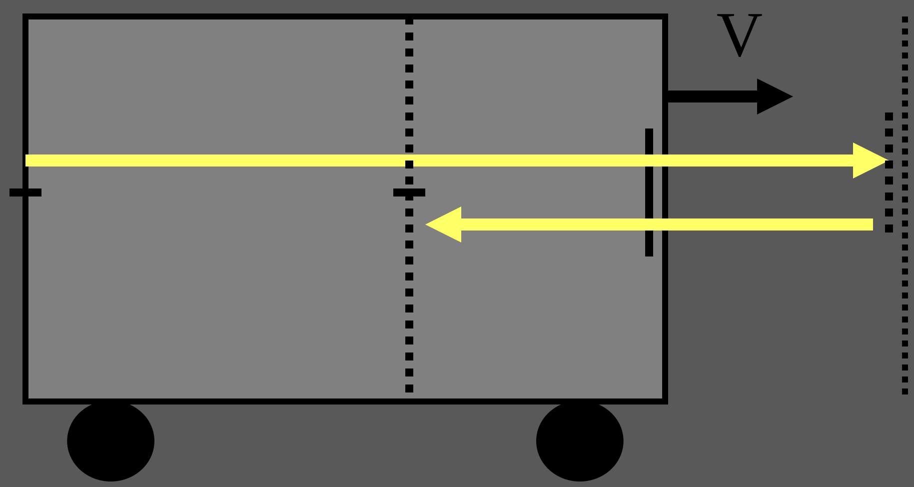
$$t_{earth} = \frac{1}{\sqrt{1-\left(\frac{.98c}{c}\right)^2}} (70 \text{ years})$$

$$t_{earth} = (5)(70 \text{ years})$$

$$t_{earth} = 350 \text{ years!}$$



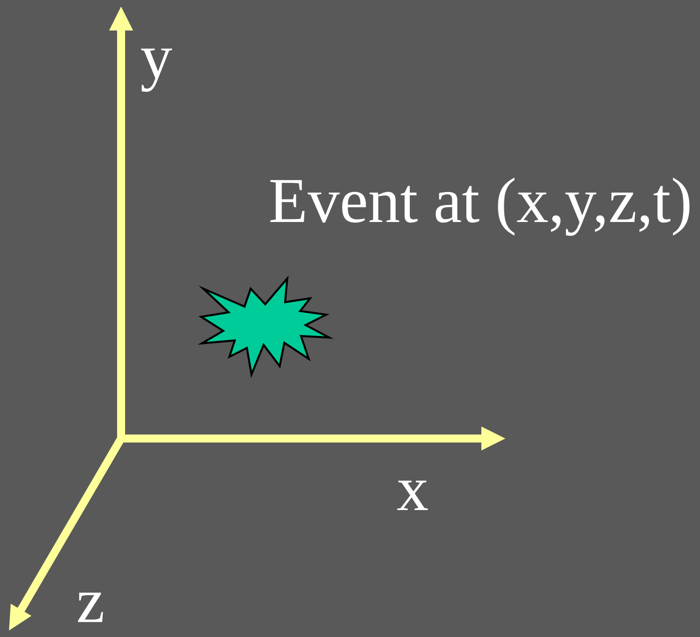
Measure the length of a boxcar where you are on the car.



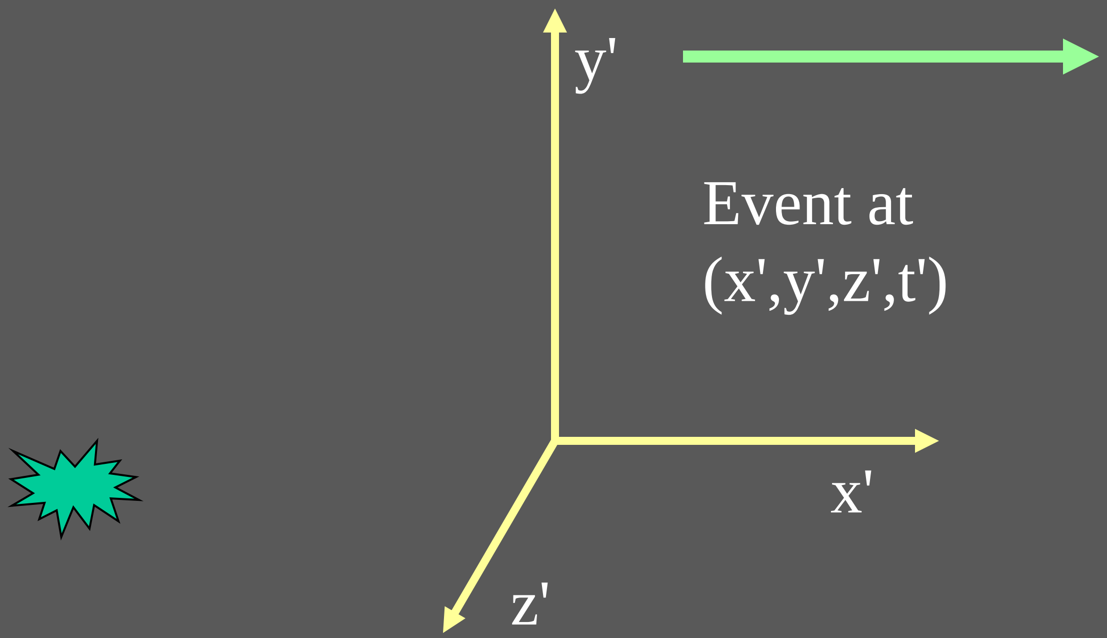
Measure the length of a boxcar moving by you.

Length is relative, too!

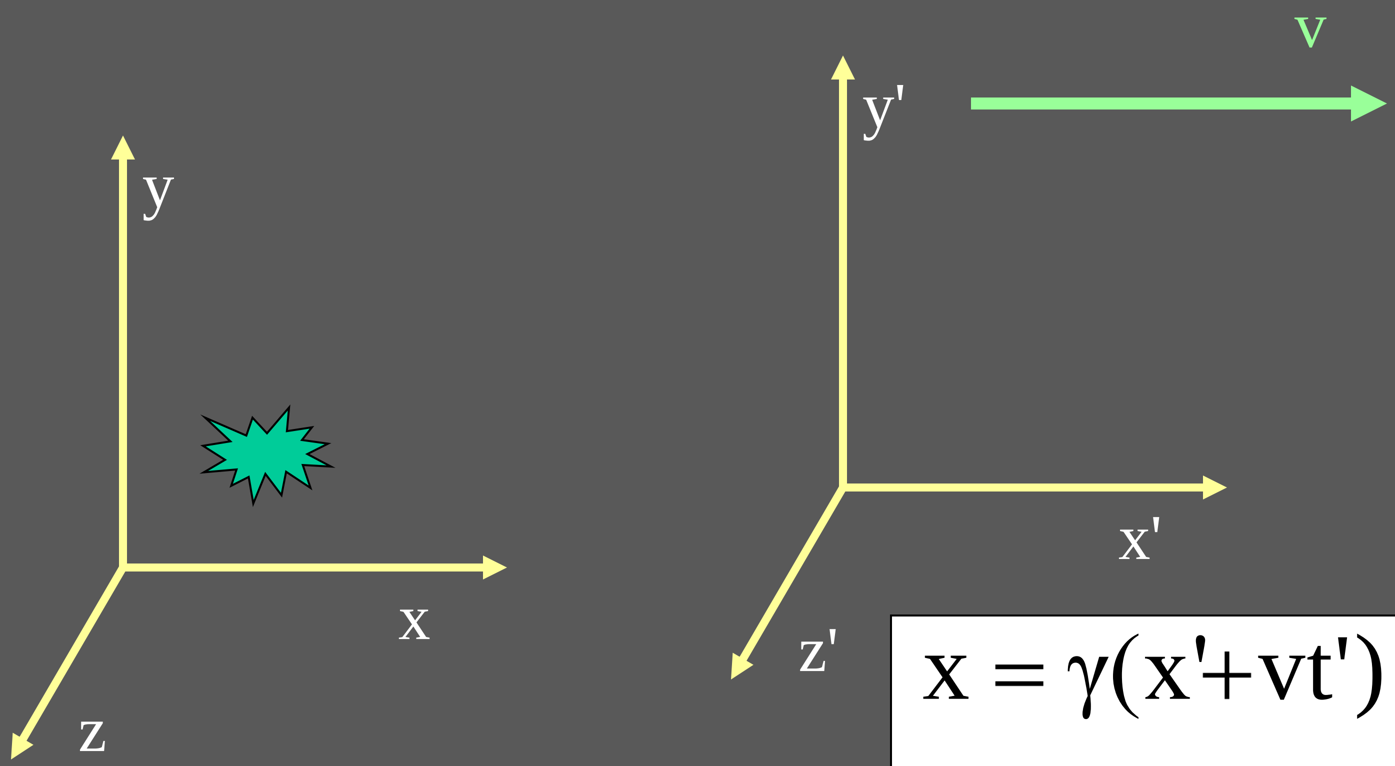
Lorentz transformations



Lorentz transformations



Lorentz transformations



How are (x,y,z,t) related to (x',y',z',t')?

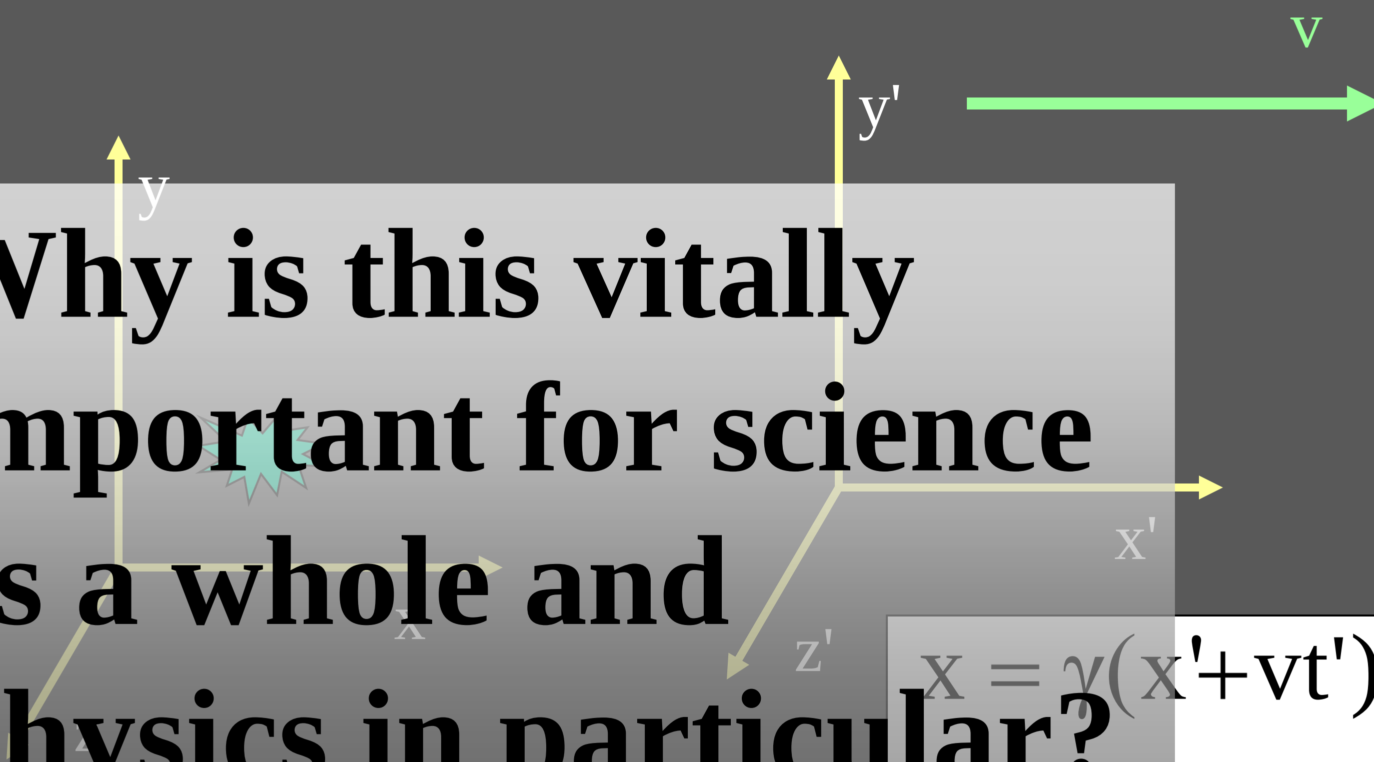
$$x = \gamma(x' + vt')$$

$$y = y'$$

$$z = z'$$

$$t = \gamma\left(t' + v\frac{x'}{c^2}\right)$$

Lorentz transformations



Why is this vitally important for science as a whole and physics in particular?

How are (x,y,z,t) related to (x',y',z',t')?

$$x = \gamma(x' + vt')$$

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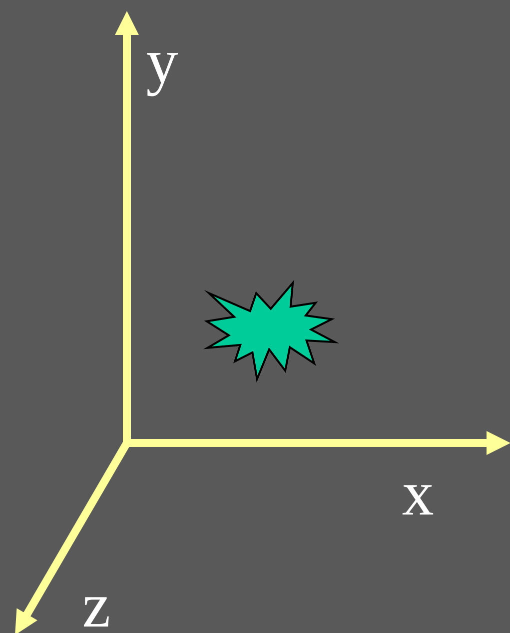
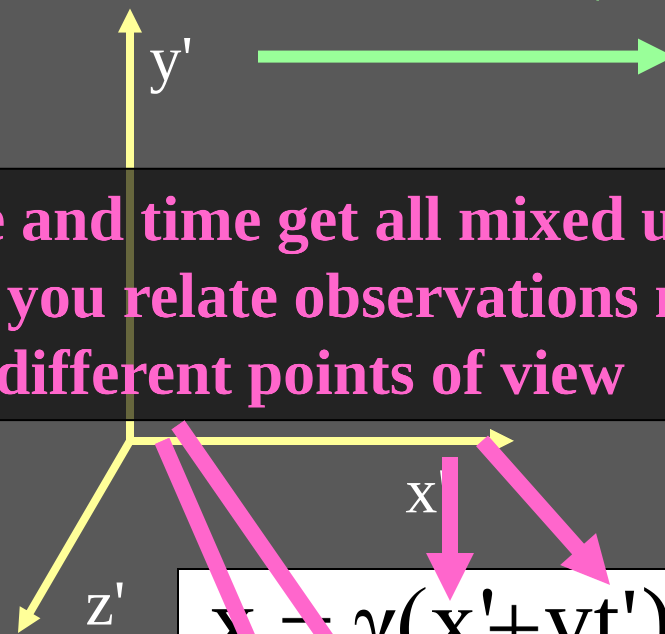
Lorentz transformations





Space and time get all mixed up when you relate observations made from different points of view

$$x = \gamma(x' + vt')$$

$$y = y'$$

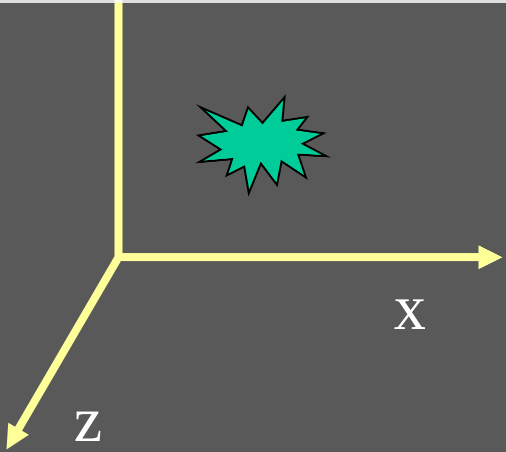
$$z = z'$$

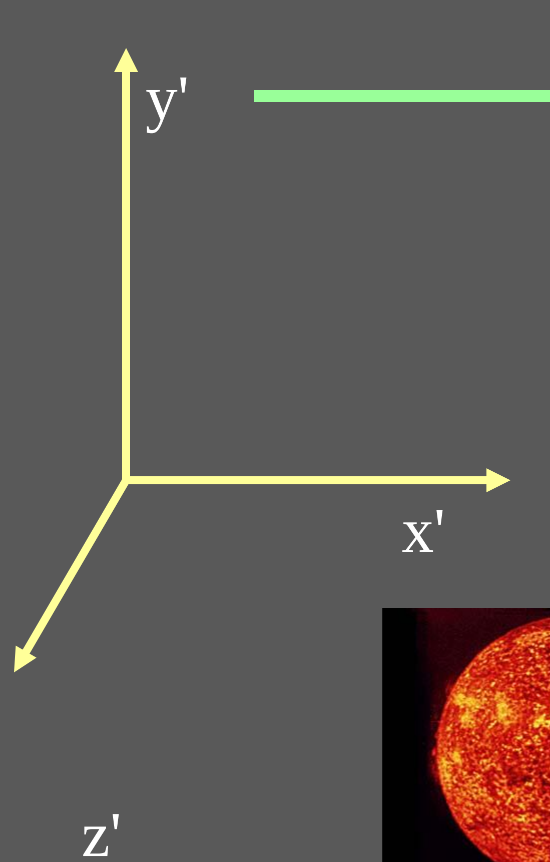
$$t = \gamma\left(t' + v\frac{x'}{c^2}\right)$$

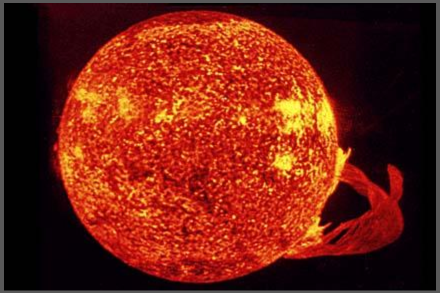
How are (x,y,z,t) related to (x',y',z',t')?

Spacetime

All other things that can be observed must have "relativisitic transformations", too!







$$x = \gamma(x' + vt')$$

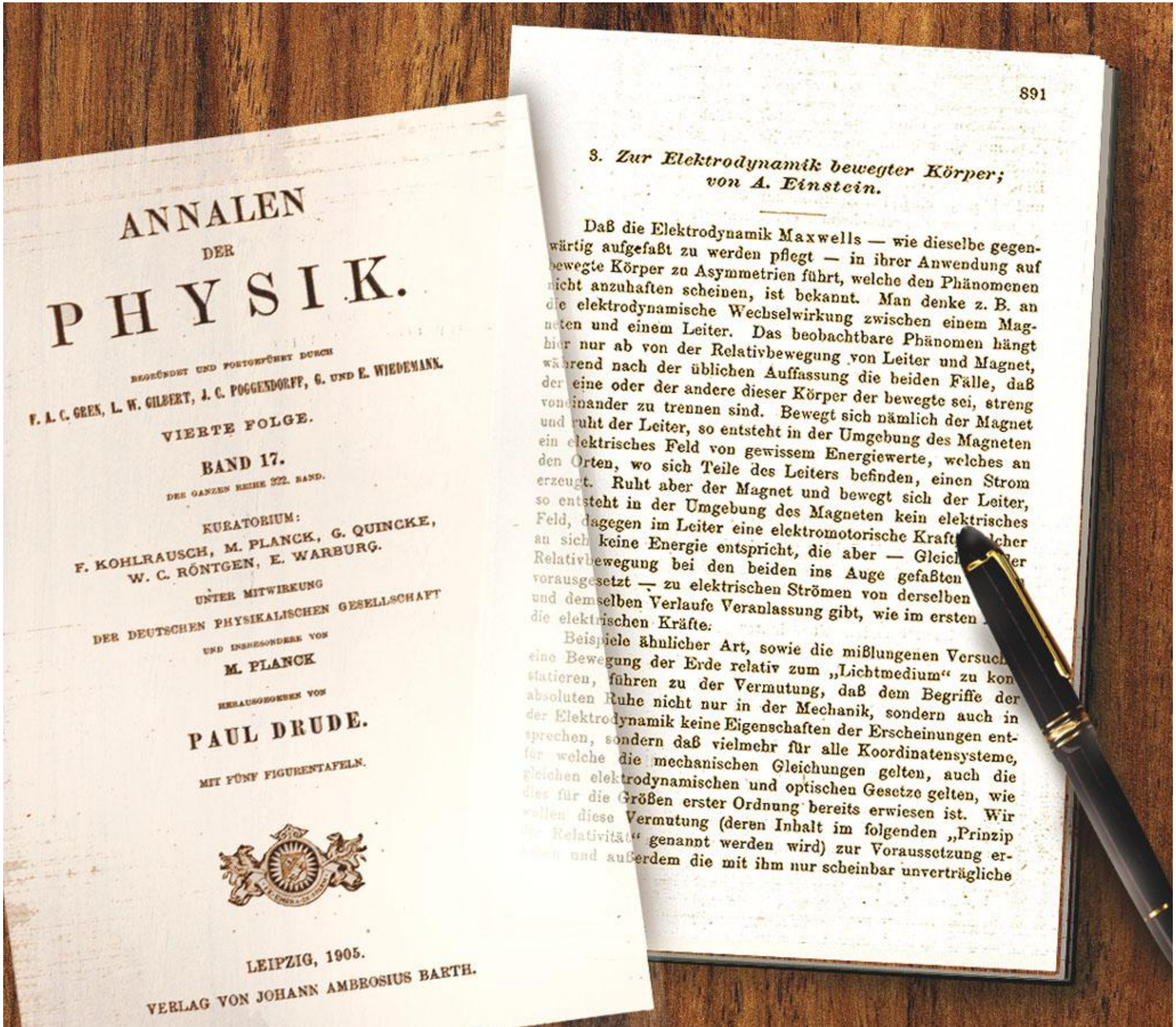
$$y = y'$$

$$z = z'$$

$$t = \gamma\left(t' + v\frac{x'}{c^2}\right)$$

$$p = mv$$

$$\mathbf{E=mc^2}$$



ANNALEN

DER

PHYSIK.

BEGRÜNDET UND FORTGEFÜHRT DURCH

F. A. C. GREN, L. W. GILBERT, J. C. POGGENDORFF, G. UND E. WIEDEMANN.

VIERTE FOLGE.

BAND 17.

DER GANZEN REIHE 322. BAND.

KURATORIUM:

F. KOHLRAUSCH, M. PLANCK, G. QUINCKE,
W. C. RÖNTGEN, E. WARBURG.

UNTER MITWIRKUNG

DER DEUTSCHEN PHYSIKALISCHEN GESELLSCHAFT

UND INSBESONDERE VON

M. PLANCK

HERAUSGEGEBEN VON

PAUL DRUDE.

MIT FÜNF FIGURENTAFELN.

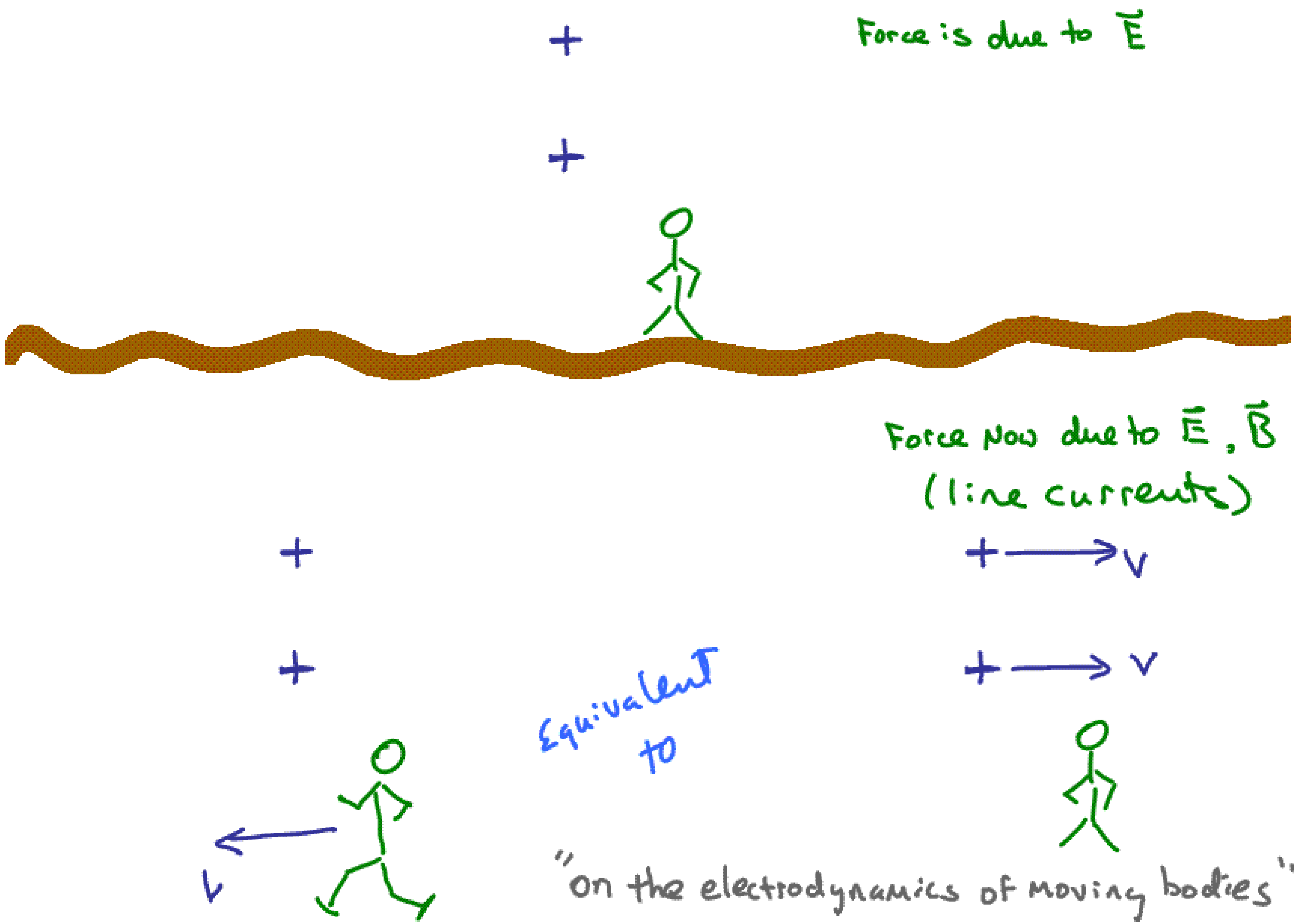
LEIPZIG, 1905.

VERLAG VON JOHANN AMBROSIUS BARTH.

3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

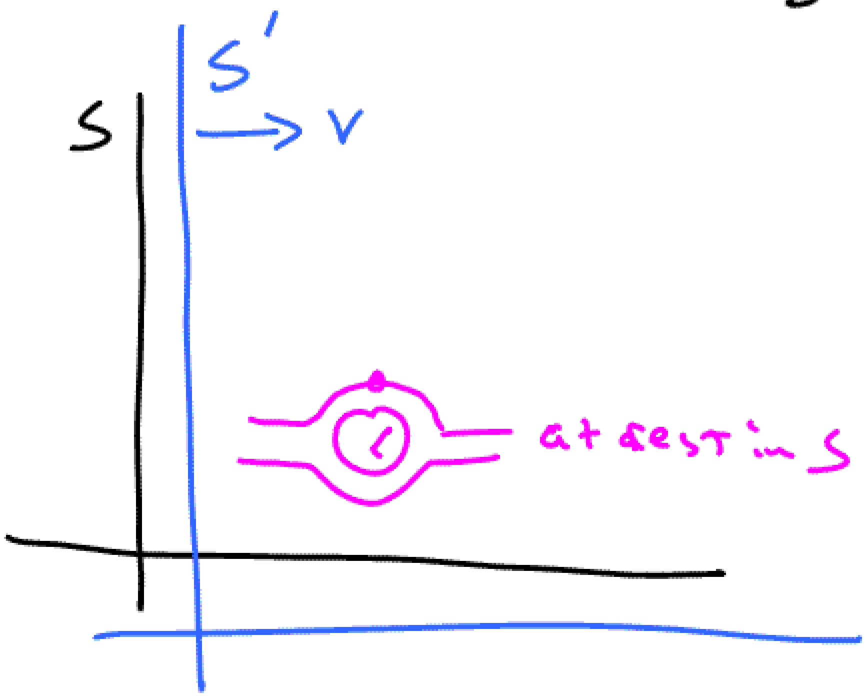
Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, ... lcher an sich keine Energie entspricht, die aber — Gleich... ler Relativbewegung bei den beiden ins Auge gefaßten ... vorausgesetzt — zu elektrischen Strömen von derselben ... und demselben Verlaufe Veranlassung gibt, wie im ersten ... die elektrischen Kräfte.

Beispiele ähnlicher Art, sowie die mißlungenen Versuch... eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung er... und außerdem die mit ihm nur scheinbar unverträgliche


Force is due to $\vec{E}$
Force now due to $\vec{E}$, $\vec{B}$
(line current)
v
v
Equivalent to
v
"On the electrodynamics of moving bodies"

S is proper frame

event at rest



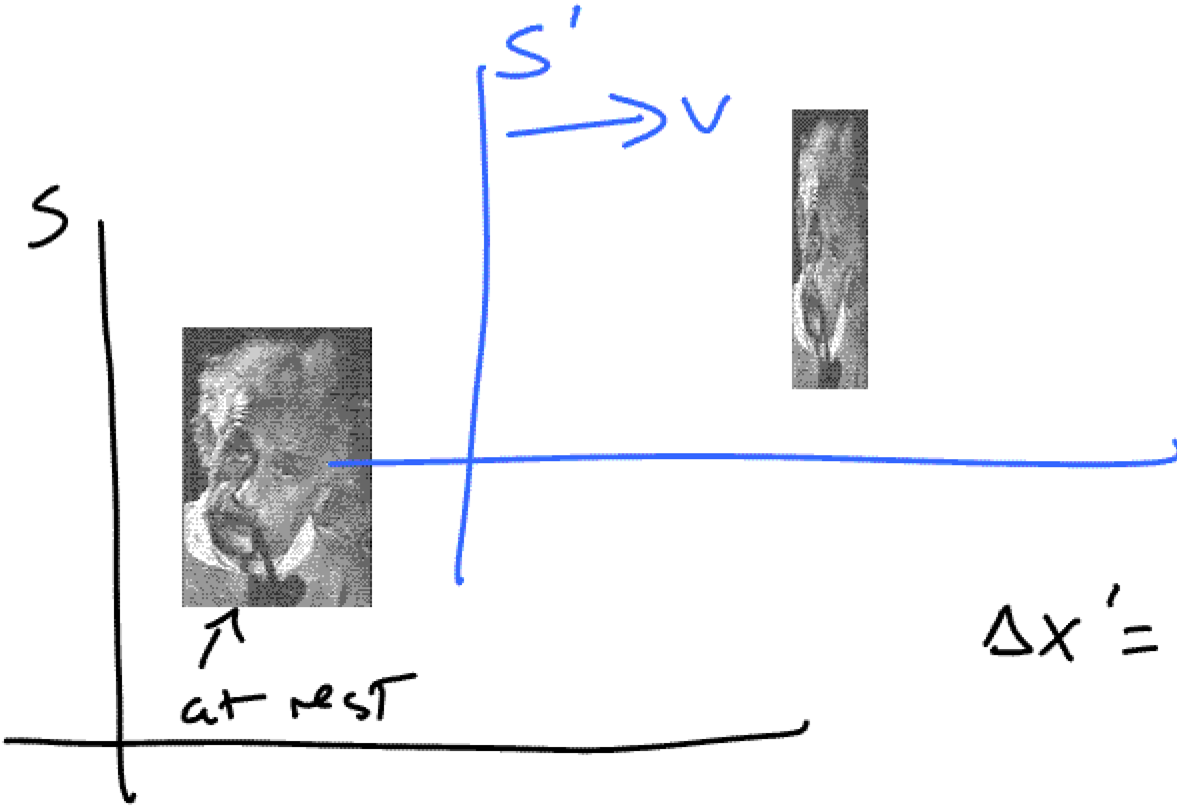
$$\Delta t' = \gamma \Delta t$$

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$> 1$$

measured time is shortest in proper frame

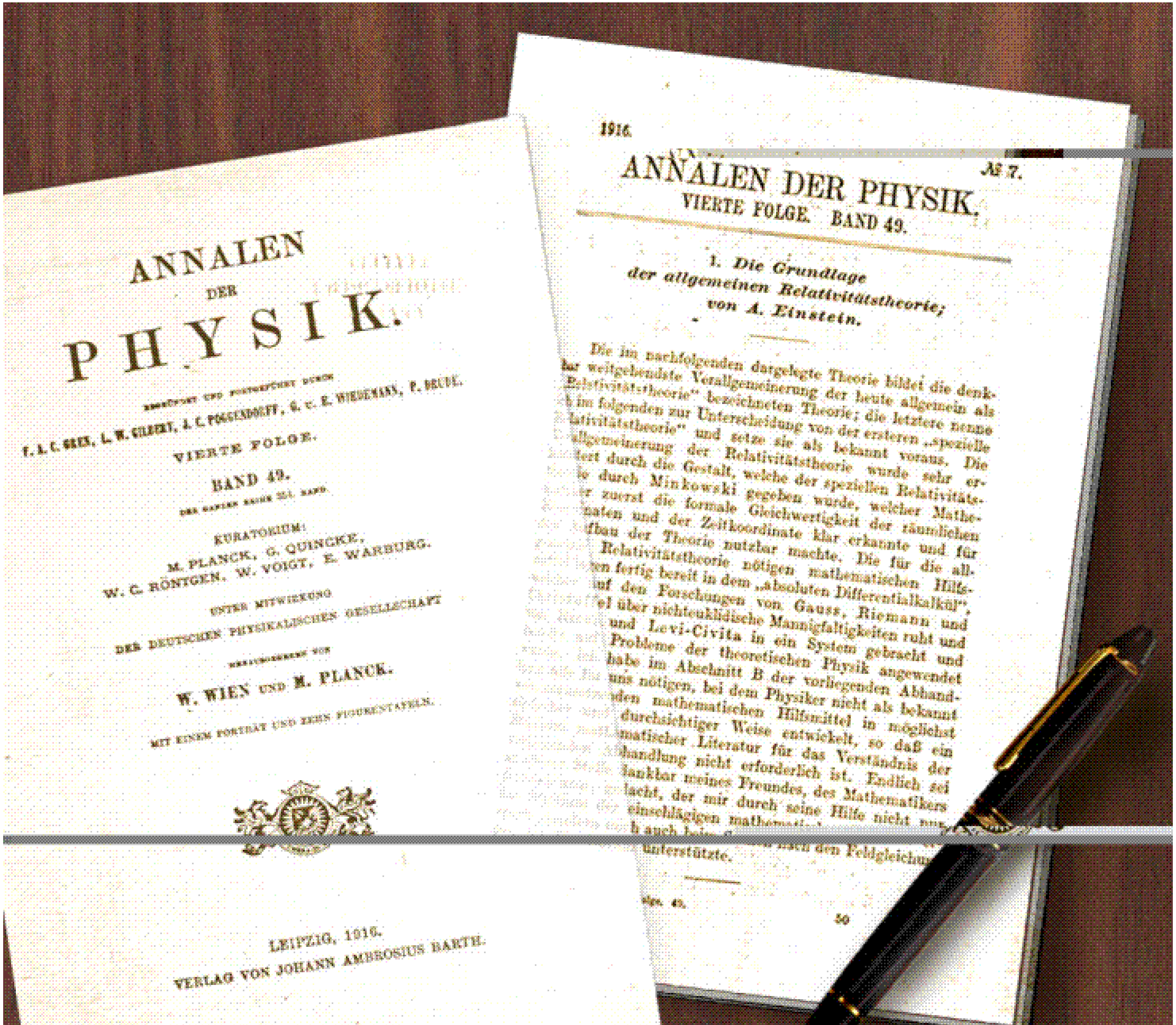
where event at rest



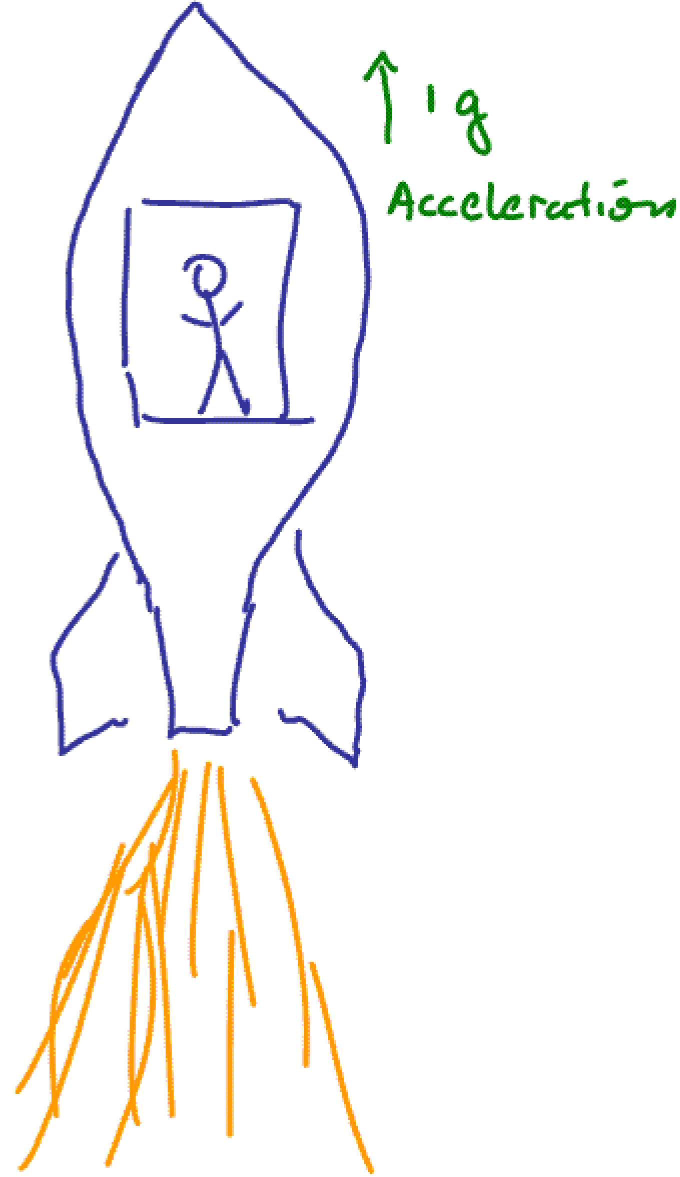
$$\Delta x' = \frac{\Delta x}{\gamma}$$

Length is greatest in proper frame of reference

The Theory of General Relativity – Einstein 1916



vs



accelerated reference frames

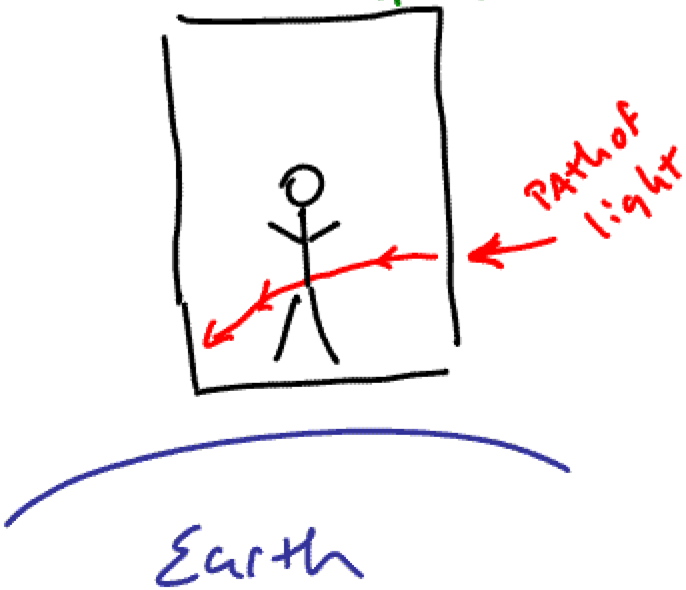
≡

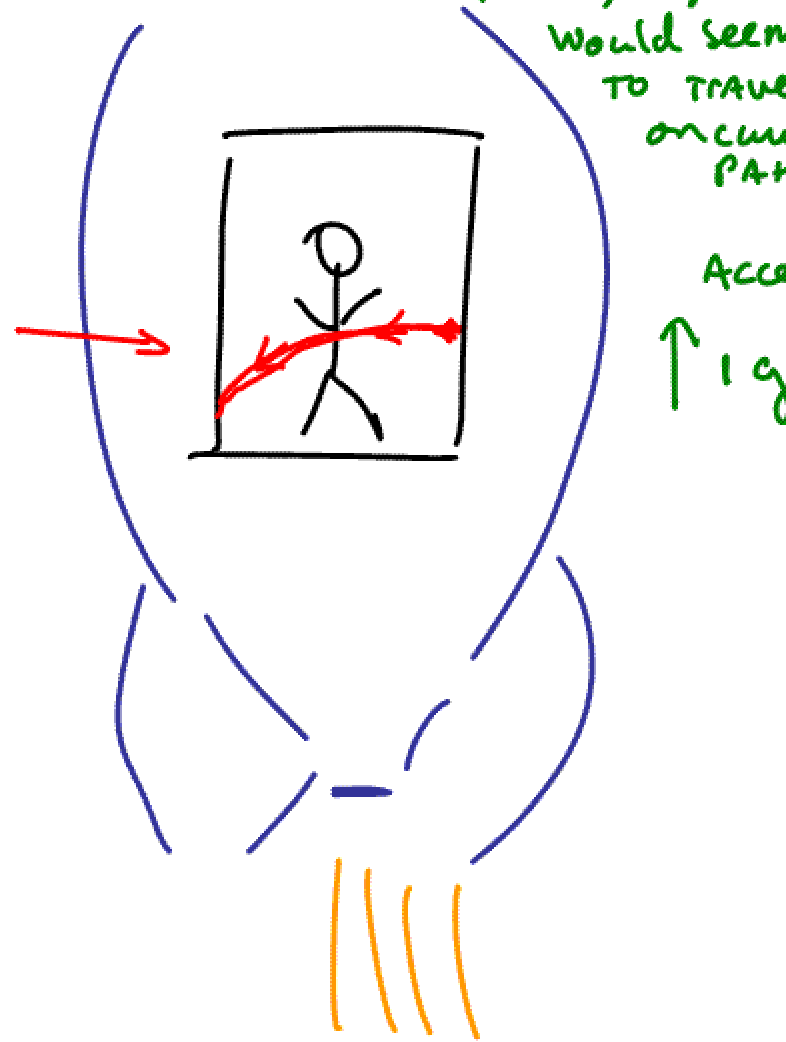
gravitational field

If you are in a closed box —
you can't tell if you are at rest on earth's surface or accelerating in a rocket at 1g.

Equivalence of gravity ⟸ In accelerated rocket ship case, light would seem to travel on curved path

Means grav. field must curve spacetime



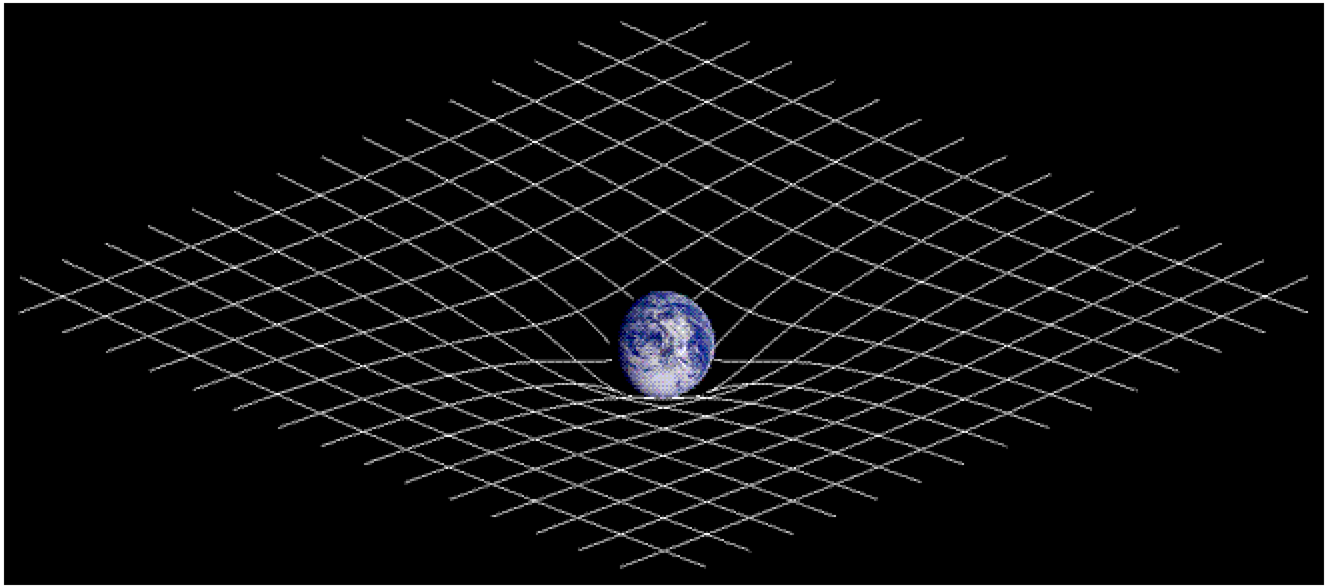


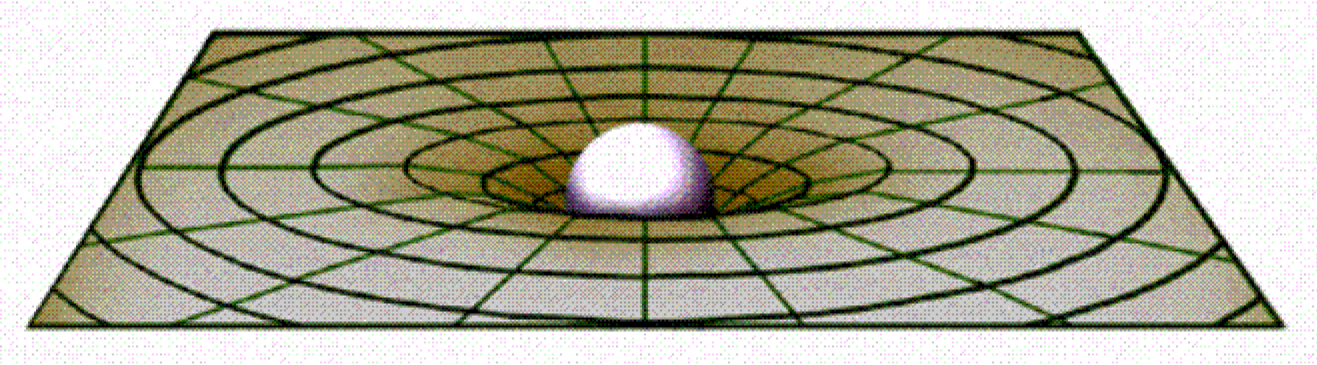
grav ≡ Accel. frame

light moves on a geodesic

↑ shortest dist. between two points

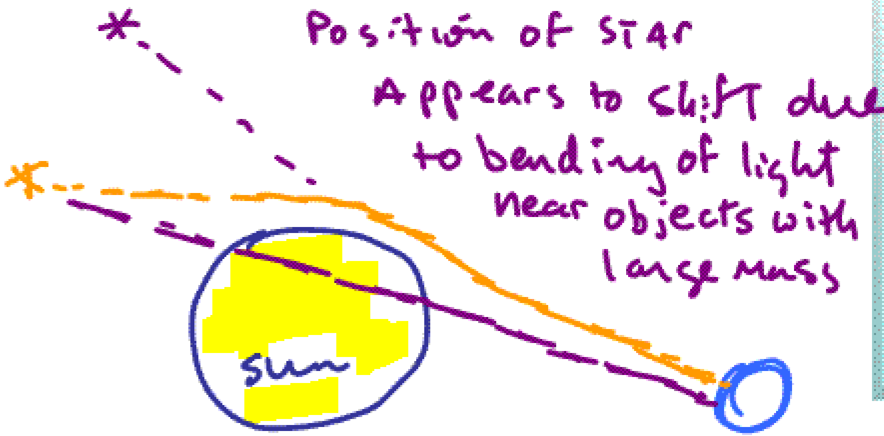
So, Einstein interprets gravitation as a <u>curvature of spacetime</u>

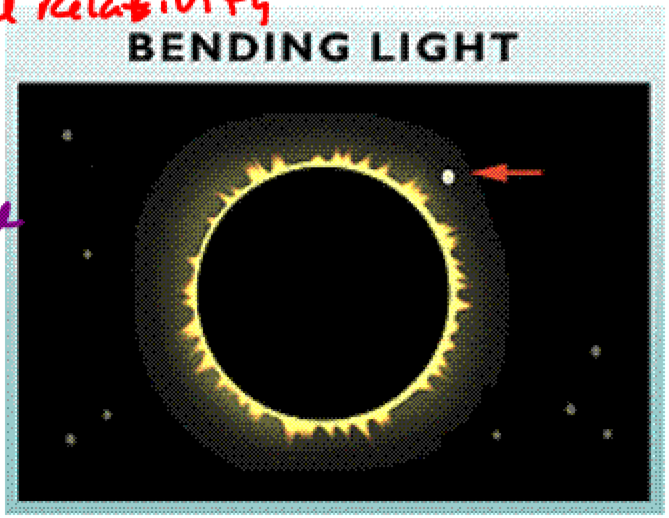




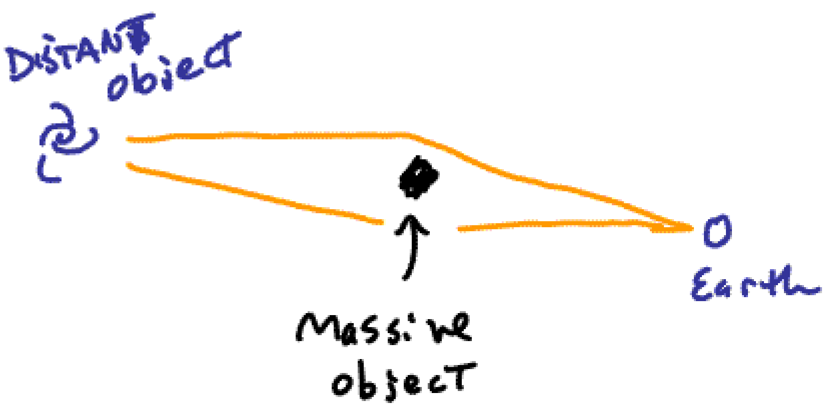
Imagine that mass causes curvature / depression in the fabric of spacetime ... is it true??

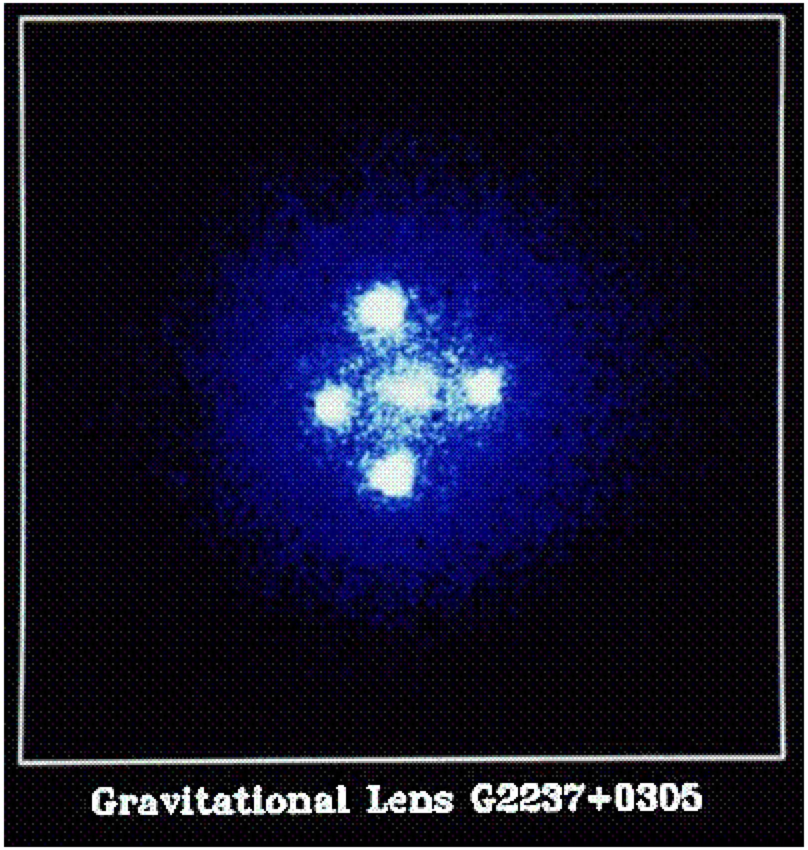
Experimental evidence supporting General Relativity





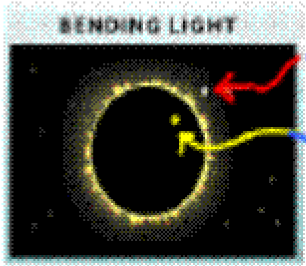
Gravitational Lensing





Gravitational Lens G2237+0305

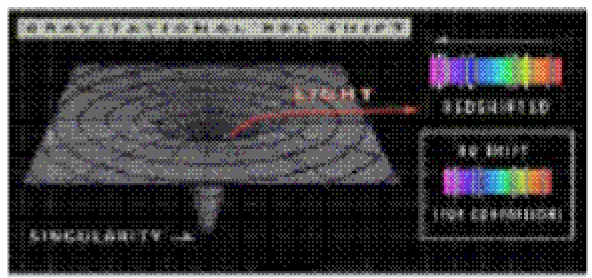
Apparent position



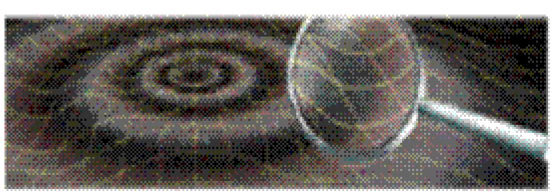
- Bending of light by gravitational field ✓

Actual Position

- Gravitational Redshift of light ✓



- Perihelion advance of Mercury ✓



- Gravitational Waves ?

Amplitude $\sim 10^{-16}$ m

LIGO