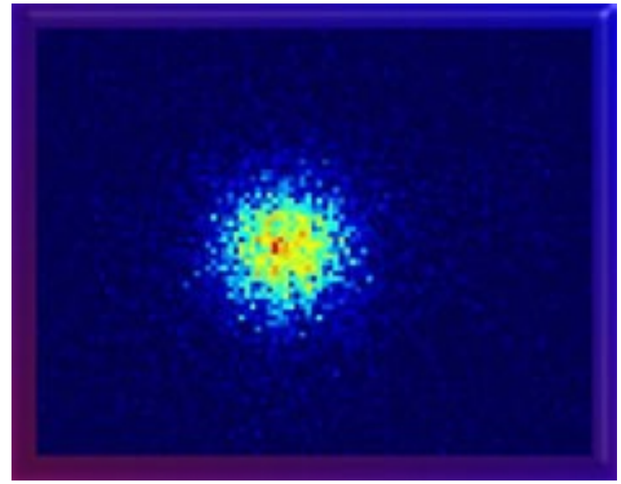
Soft Gamma-Ray Repeaters

E_{iso} ~ a few10^{44} erg in gamma-rays

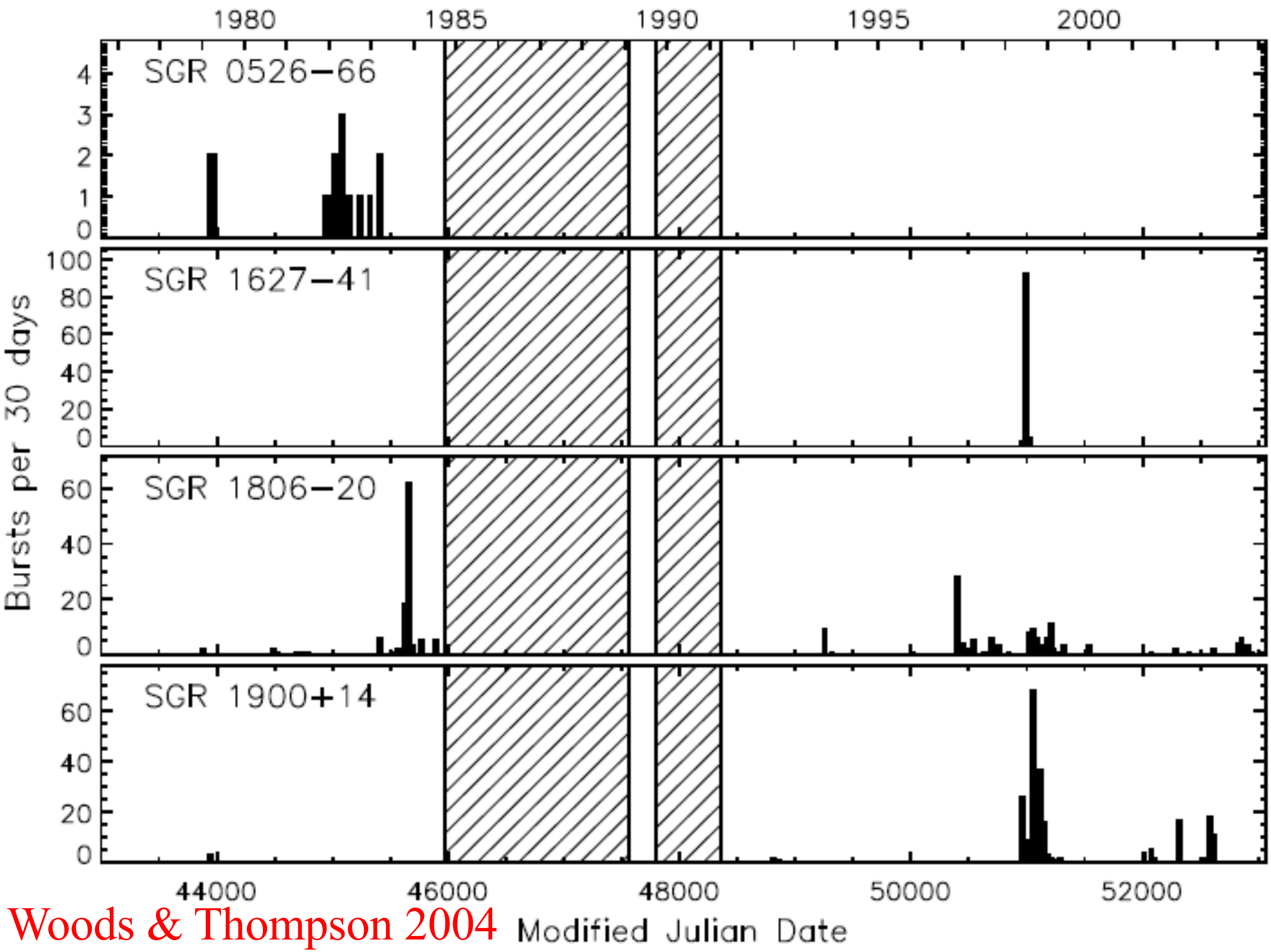
Where does this energy come from?



X-ray image

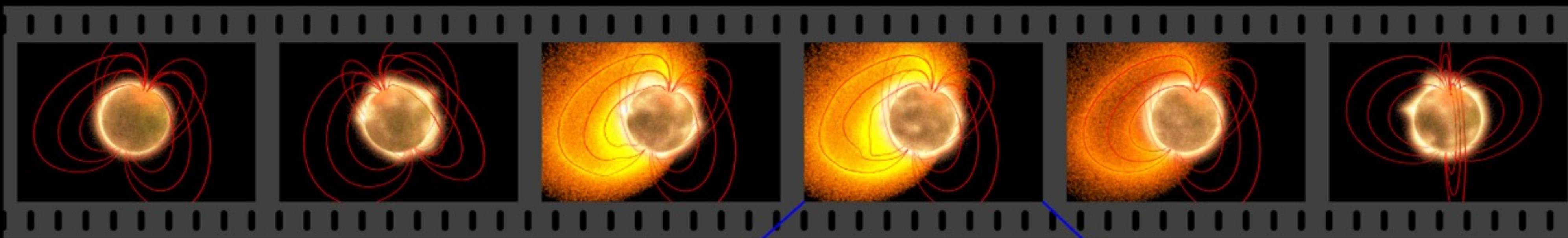
- Accretion? No sign of a disk
- Rotation? Not enough energy available
- Magnetic fields? Yes

Time history of the 4 confirmed SGRs:

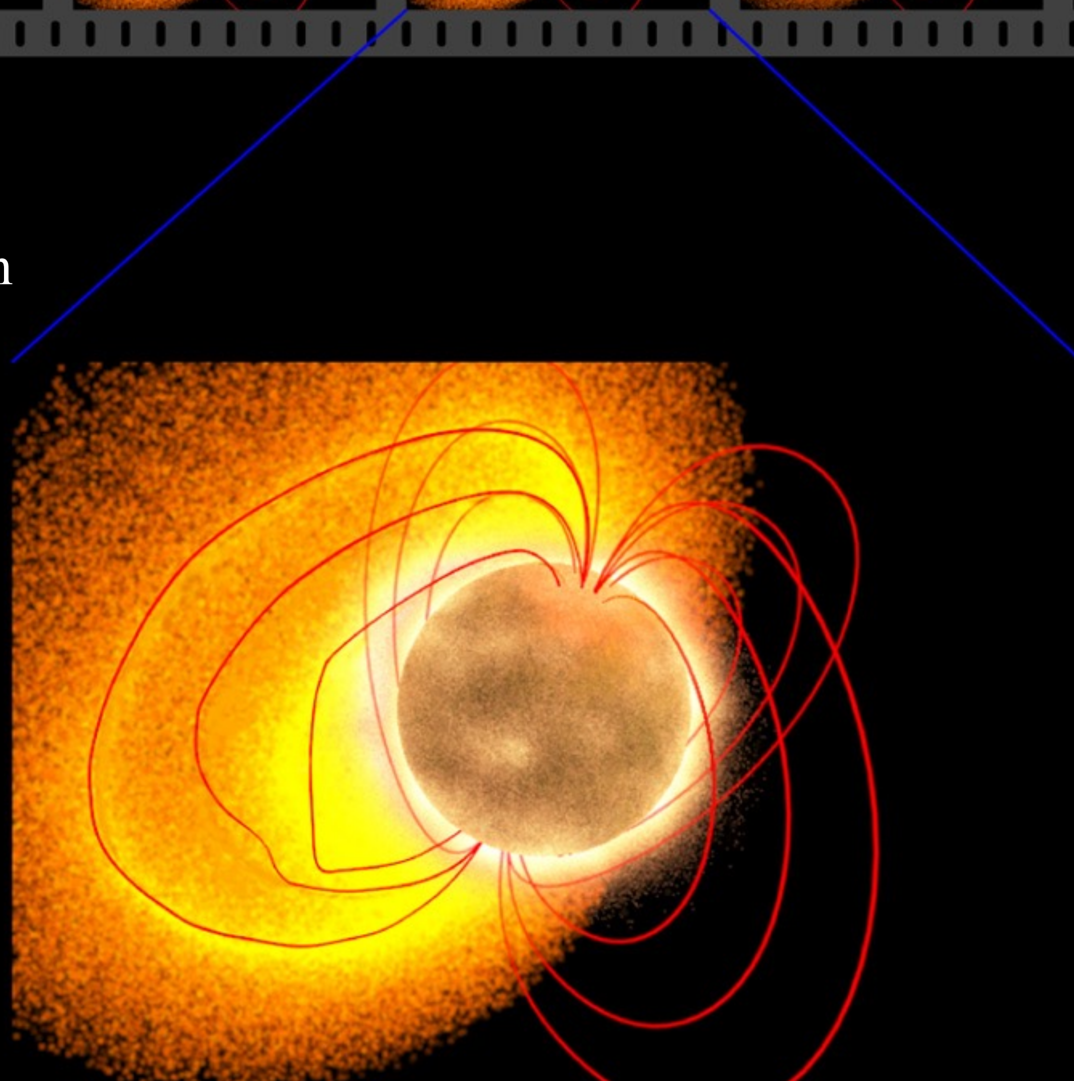


Woods & Thompson 2004

Magnetar burst sequence

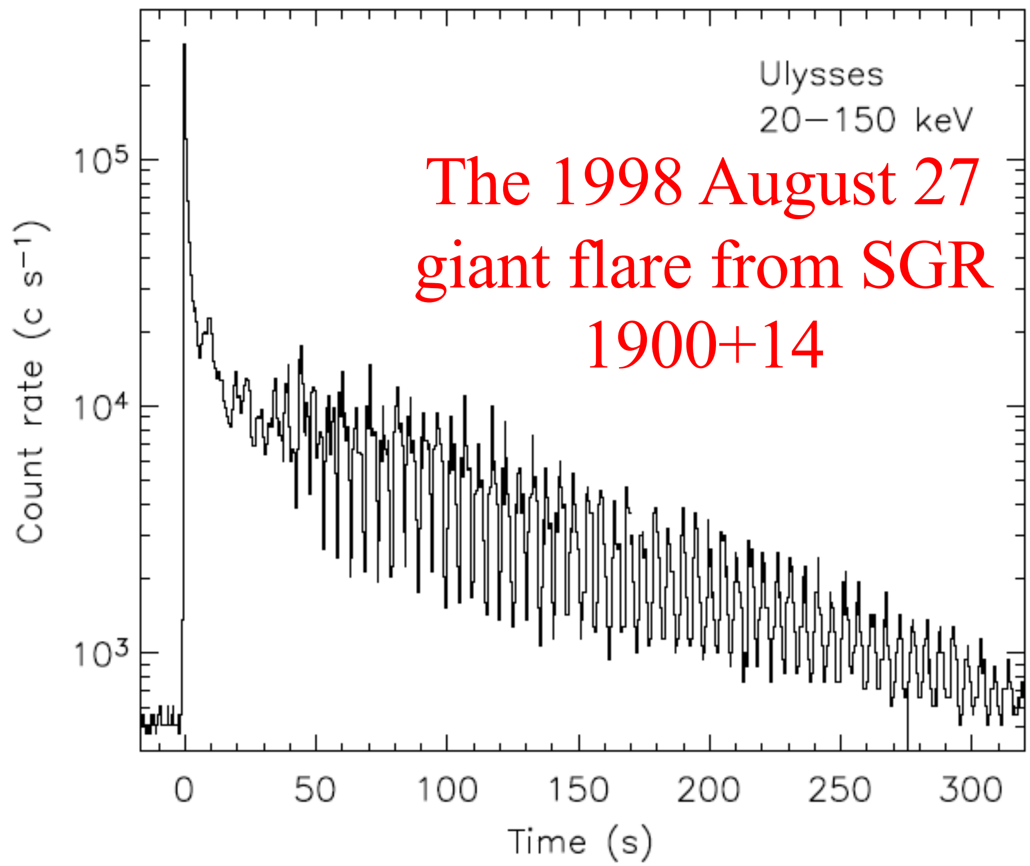


Adapted from
Duncan and Thompson
1992



Giant Flares from SGRs

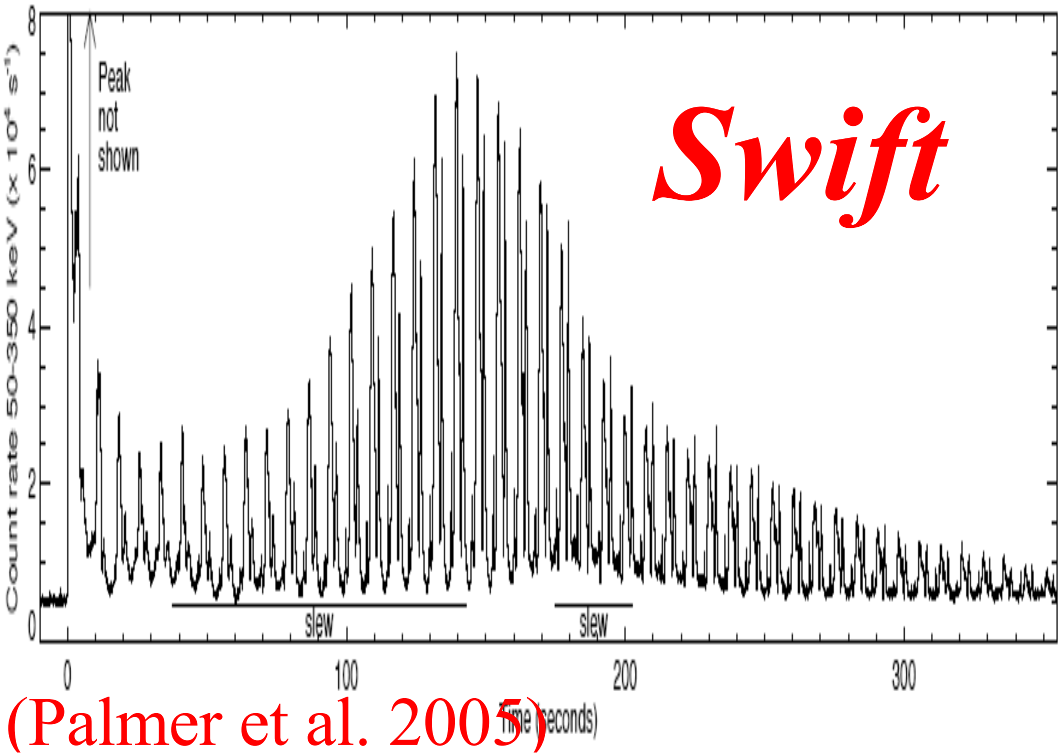
- Initial spike: **Δt** ~ 0.3 s , E_{iso} ~ a few10^{44} erg
  - hard spectrum
  - ~ ms rise time
- Pulsating tail
  - Lasts a few min.
  - Modulated at the NS rotation period
  - Softer spectrum



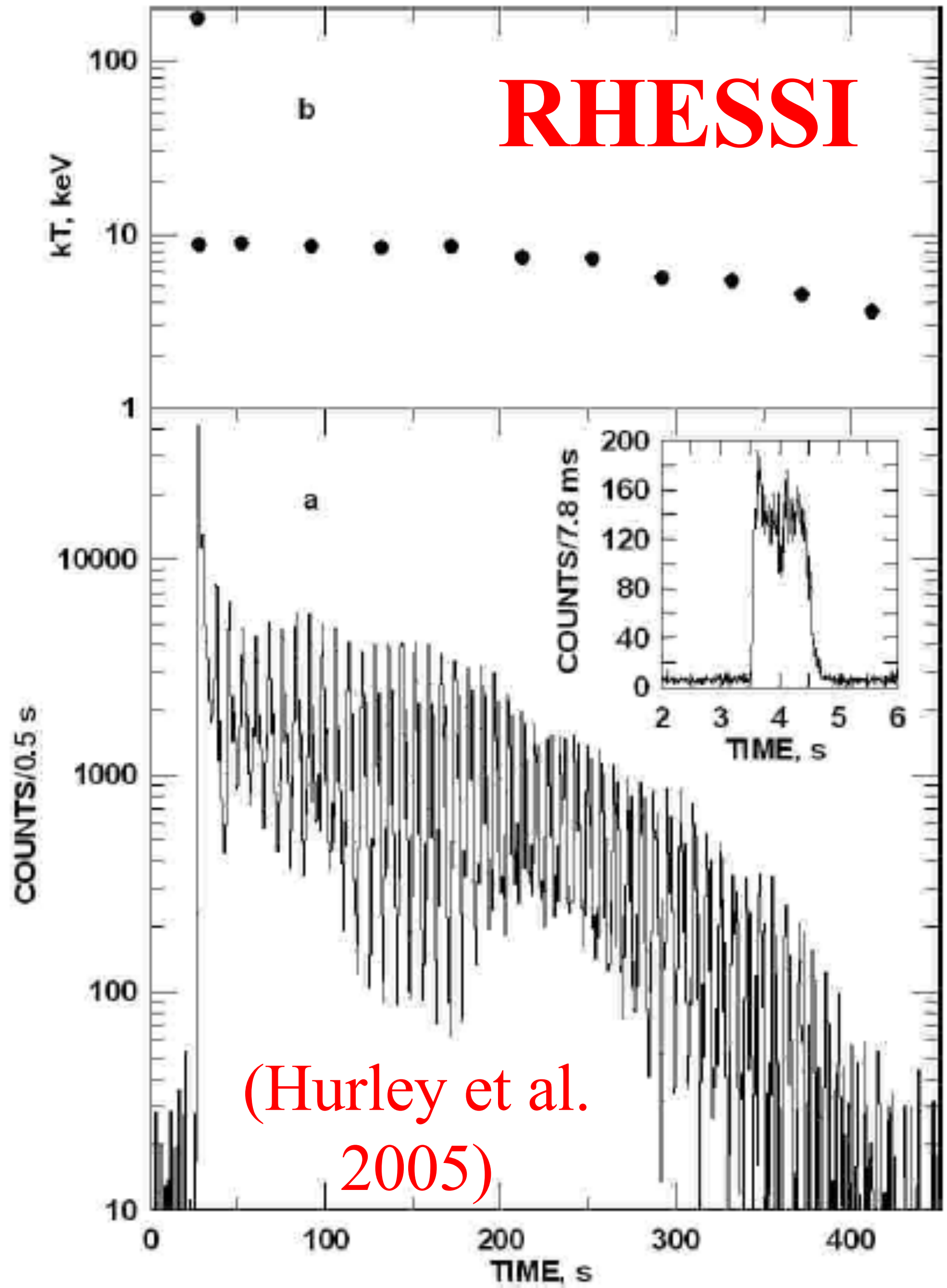
- Only 2 previous events ever recorded: in 1979 (SGR 0526-66 in LMC) & 1998 (SGR 1900-14)

The 2004 Dec. 27 SGR1806-20 Giant Flare

- was ~5^{o} from the sun
- It's distance ≈ 15 kpc
- E_{iso} ~ 10^{46} erg

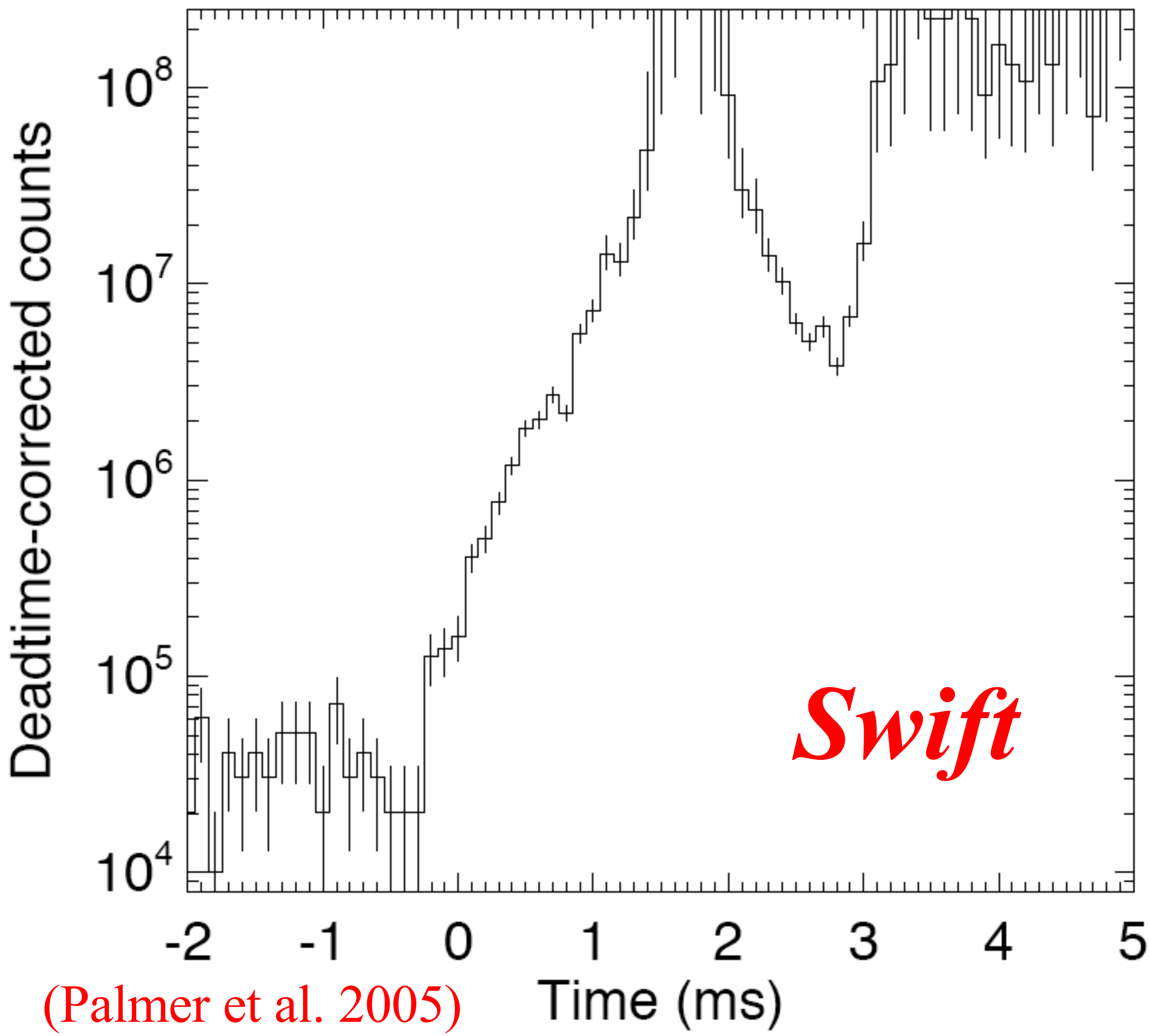


(Palmer et al. 2005)



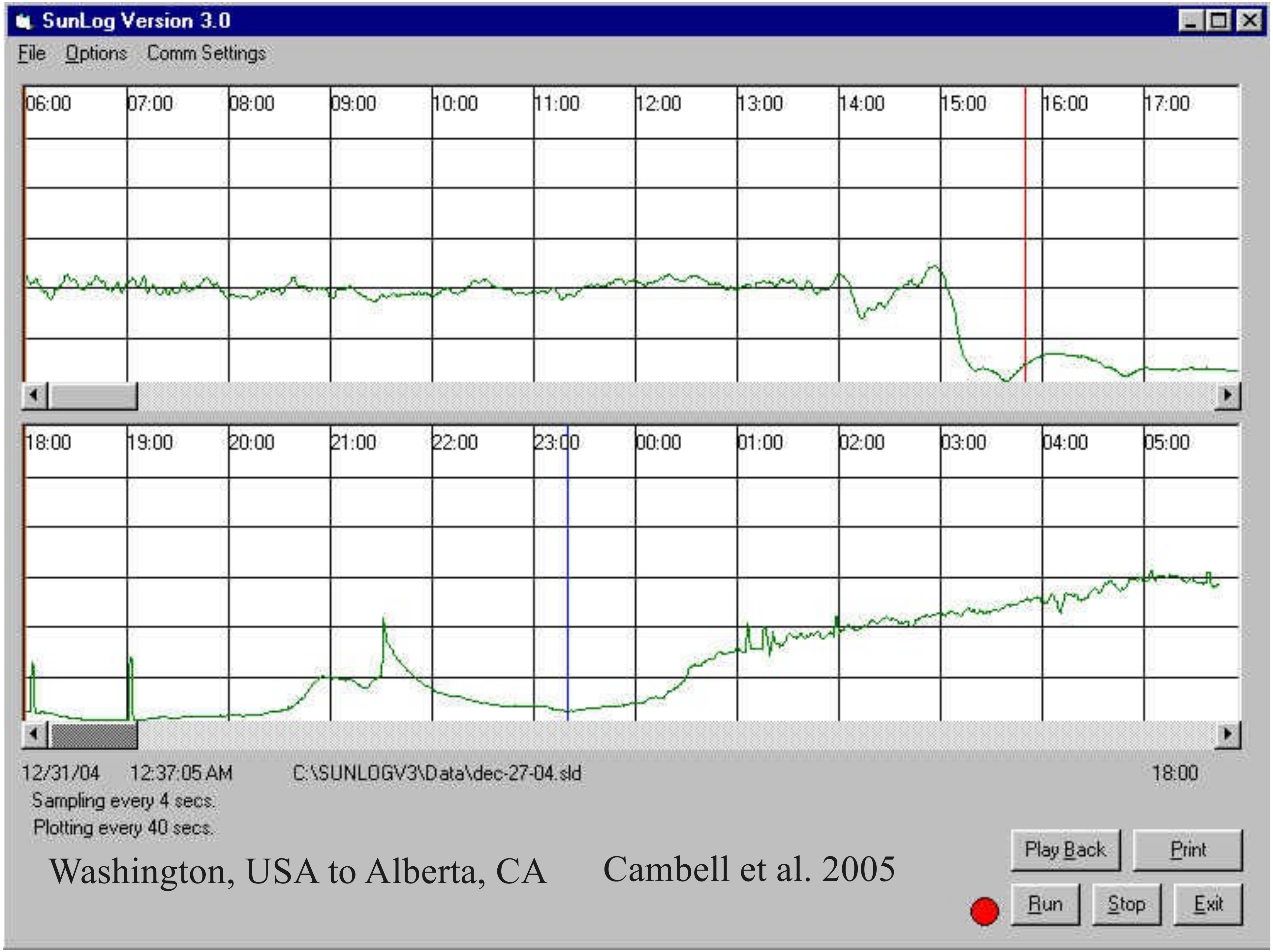
(Hurley et al. 2005)

Rise time: < 1 ms



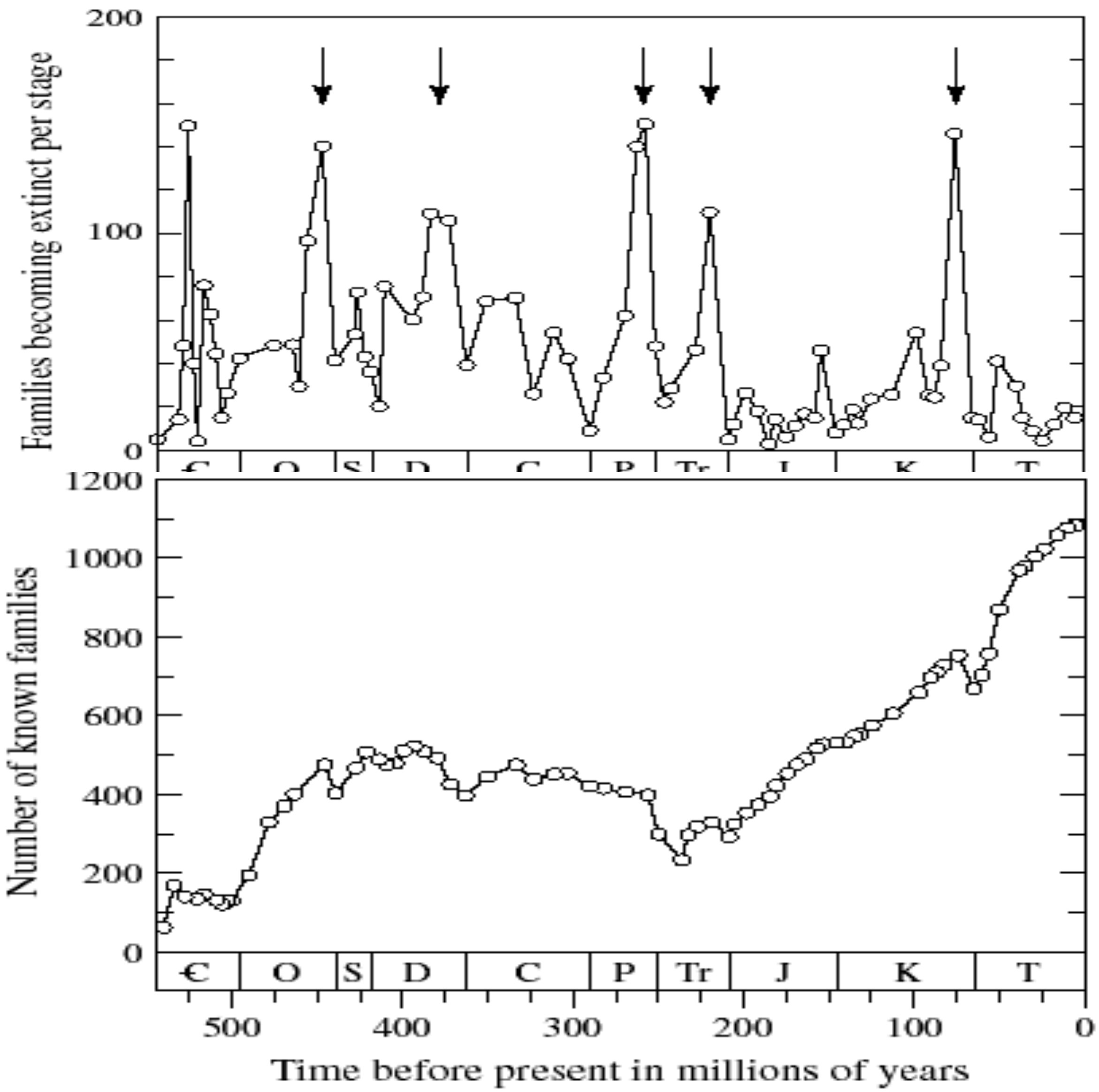
(Palmer et al. 2005)

Sudden Ionospheric Disturbance (SID)



Washington, USA to Alberta, CA   Cambell et al. 2005

The Fossil Record is Marked by Mass Extinction Events

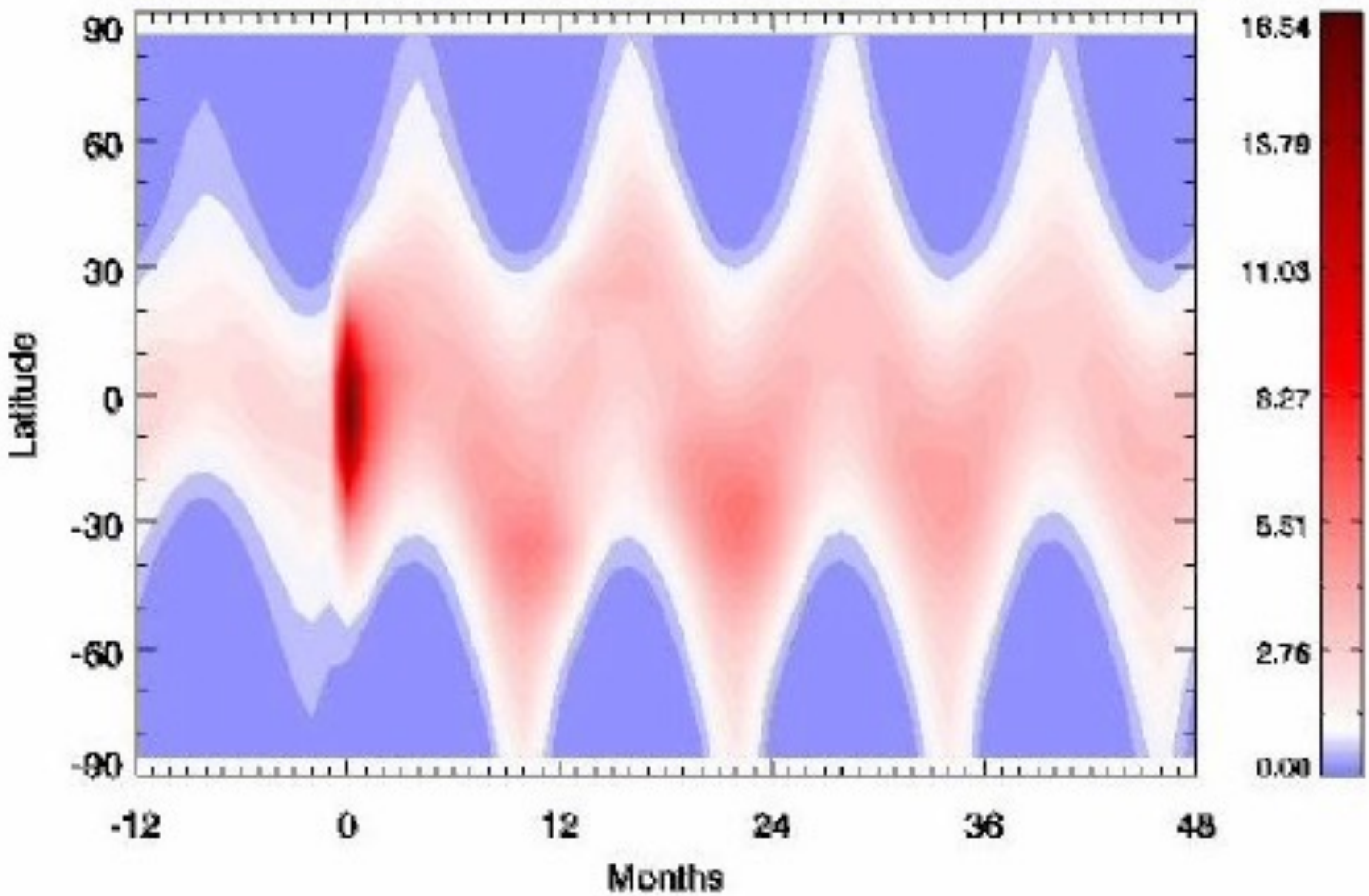


Extinction	Genus loss
End Ordovician	60%
End Devonian	57%
End Permian	82%
End Triassic	53%
End Cretaceous	47%

From Solé & Newman 2002

Effects of a nearby GRB on Earth

Melott et al. 2004

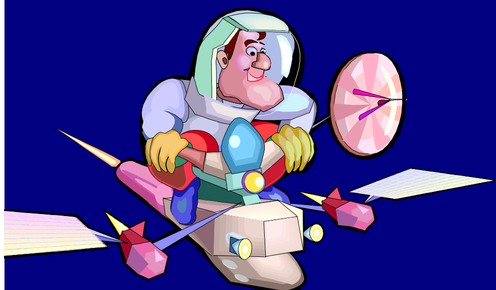


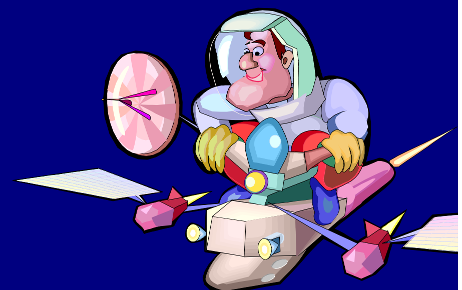
VLA/LWA1 Tour

- VLA Tour this Saturday Sept. 28
- Depart UNM at 7:30am from RH parking lot; 10am VLA+LWA1 tour Noon: lunch at picnic tables; return UNM ~3pm
- Drivers: Greg(4), Olwyn(4), Giovanna(4), Franco(3), Elizabeth(4)

- Bring
  - Sturdy shoes, hat, sunscreen, water bottle, snacks
  - Camera, $$$ if you want to shop at the Visitor Center
  - Lunch and extra water will be provided

Classical Relativity

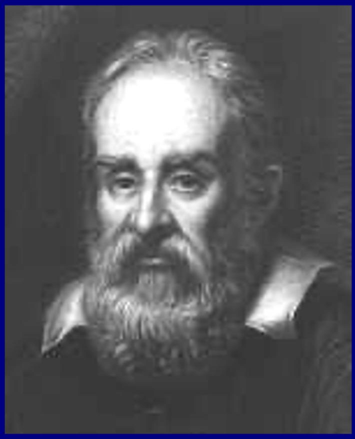




→ 1,000,000 m/s

← 1,000,000 m/s

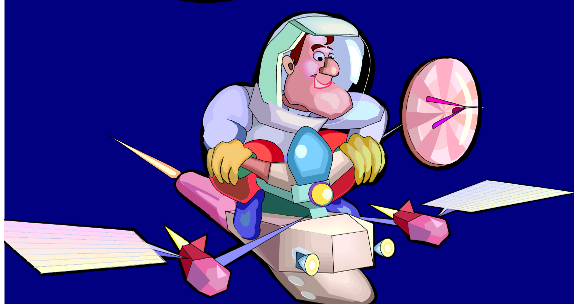
- How fast is Spaceship A approaching Spaceship B?
- Both Spaceships see the other approaching at 2,000,000 m/s.
- This is Classical Relativity.



Animated cartoons by Adam Auton

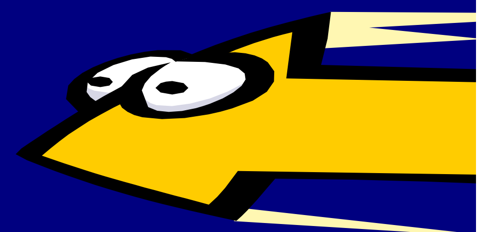
Einstein's Special Relativity

0 m/s



1,000,000 m/s

There was an old lady called Wright
who could travel much faster than light.
She departed one day
in a relative way
and returned on the previous night.



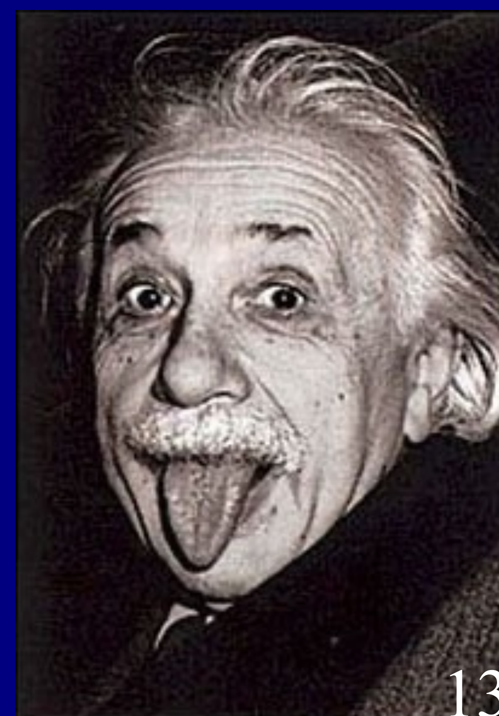
300,000,000 m/s

- Both spacemen measure the speed of the approaching ray of light.
- How fast do they measure the speed of light to be?

Special Relativity

- Stationary man measures 300,000,000 m/s
- Man traveling at 1,000,000 m/s
  - Moving at 300,000,000 m/s ? - A
  - Moving at 301,000,000 m/s ?– B

All observers measure the SAME speed for light.



Postulates of Special Relativity

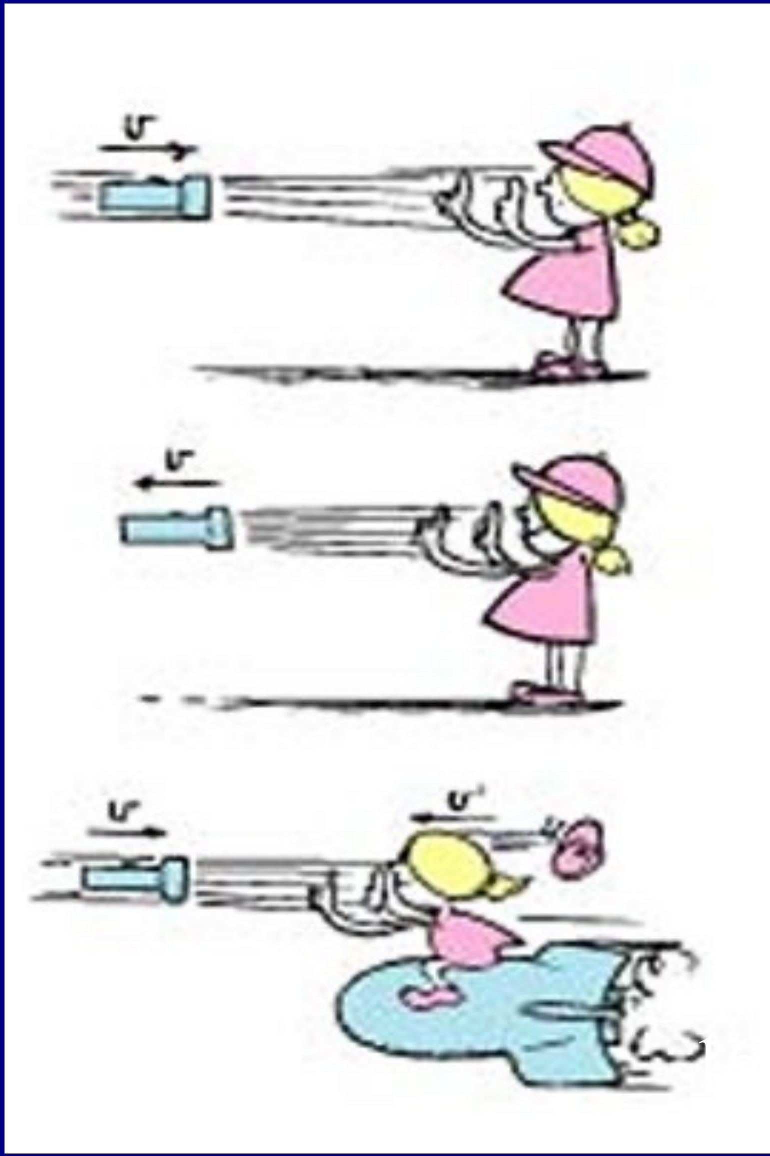
- 1st Postulate
  - The laws of nature are the same in all uniformly moving frames of reference.
    - Uniform motion – in a straight line at a constant speed
- Ex. Passenger on a perfectly smooth train
  - Sees a train on the next track moving by the window
    - Cannot tell which train is moving
  - If there are no windows on the train
    - No experiment can determine if you are moving with uniform velocity or are at rest in the station!
- Ex. Coffee pours the same on an airplane in flight or on the ground.

Combining “Everyday” Velocities

- Imagine that you are firing a gun. How do the speeds of the bullet compare if you are:
  - At rest with respect to the target?
  - Running towards the target?
  - Running away from the target?

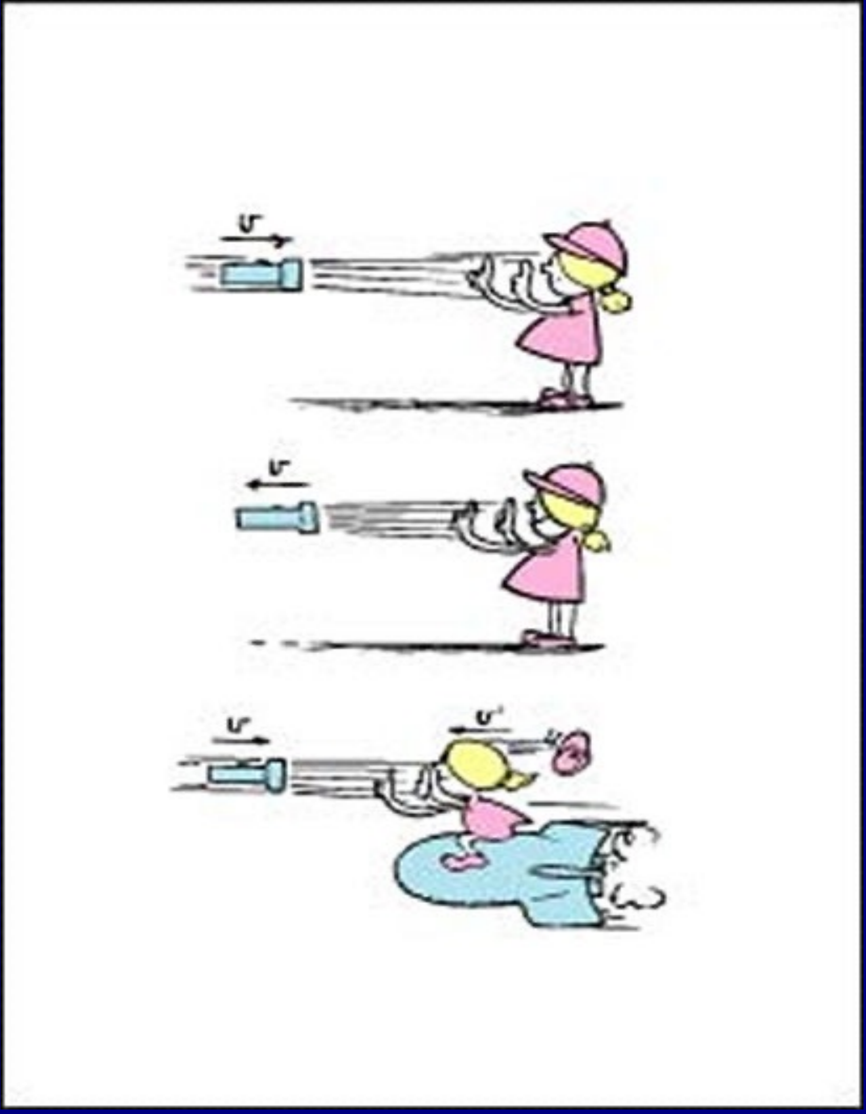
The Speed of Light

- How does the measured speed of light vary in each example to the right?



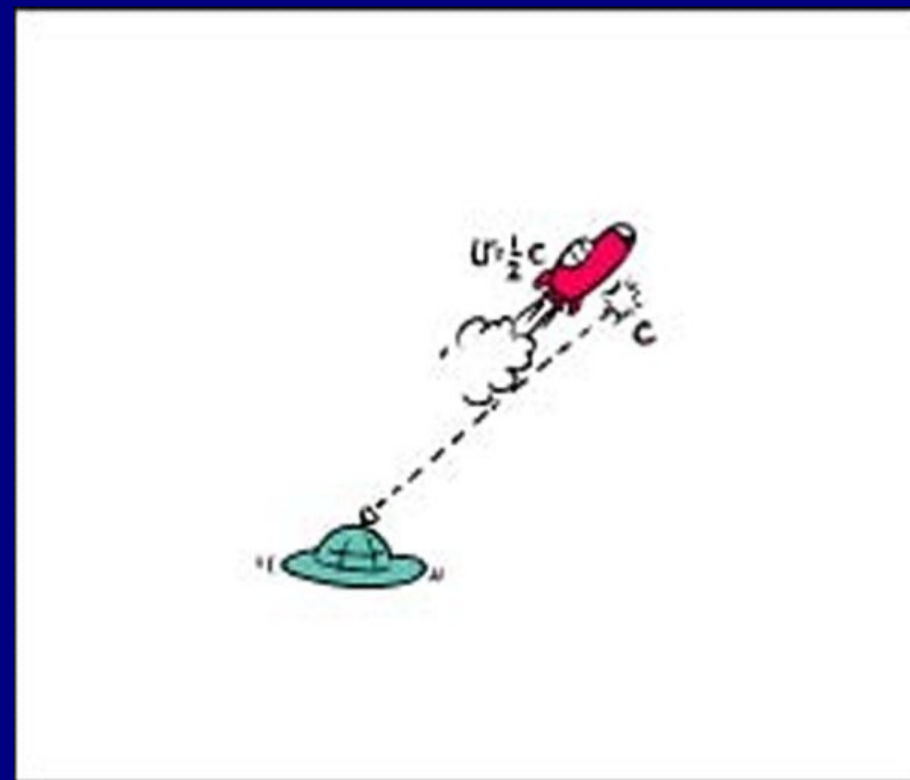
The Speed of Light

- How does the measured speed of light vary in each example to the right?
  - In each case the measured speed is the same!
- 2nd Postulate of Special Relativity
  - The speed of light is the same for all observers!



Postulates (cont.)

- 1st Postulate
  - It impossible for two observers in relative motion to determine who is moving and who is at rest!
- 2nd Postulate
  - The speed of light is the same for <u>all</u> observers!



Observers on the ground and in the rocket both measure *c*!

Relativistic Velocity Addition

- Classically: $V = v_1 + v_2$
- **Relativistically:**

$$V = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}$$

- **Ship moves away from you at 0.5*c and fires a rocket with velocity (relative to ship) of 0.5c***
  - ***How fast (compared to the speed of light) does the rocket move relative to you?***

Relativistic Velocity Addition

- Classically: $V = v_1 + v_2$
- **Relativistically:**

$$V = \frac{v_1 + v_2}{1 + \frac{v_1 v_2}{c^2}}$$

- **Ship moves away from you at 0.5*c and fires a rocket with velocity (relative to ship) of 0.5c***
  - ***You see rocket move at 0.8c***
    - ***No massize object can be accelerated to the speed of light!***
- ***If instead the ship fires a laser at speed c, what speed do you measure for the light?***

Relativistic Velocity Addition

- Classically: $V = v_1 + v_2$
- **Relativistically:**

$$V = \frac{v_1 + v_2}{1 + \dfrac{v_1 v_2}{c^2}}$$

- **Ship moves away from you at 0.5*c and fires a rocket with velocity (relative to ship) of 0.5c***
  - ***You see rocket move at 0.8c***
    - ***No massize object can be accelerated to the speed of light!***
- ***If instead the ship fires a laser at speed c***
  - ***You would measure c for the speed of light***

Question:

If you have a time machine and can go backwards in time, what is the maximum velocity can you achieve:

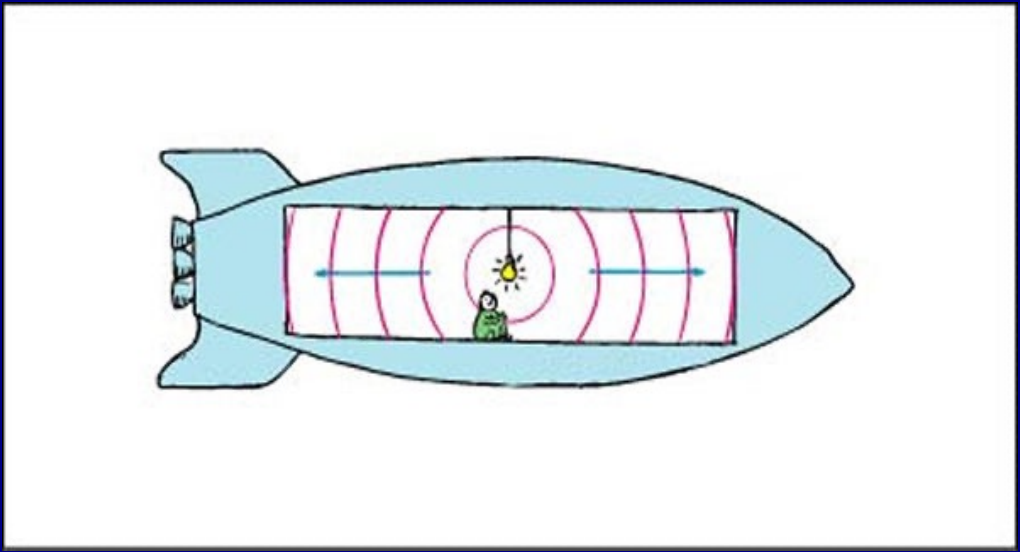
A: the speed of light

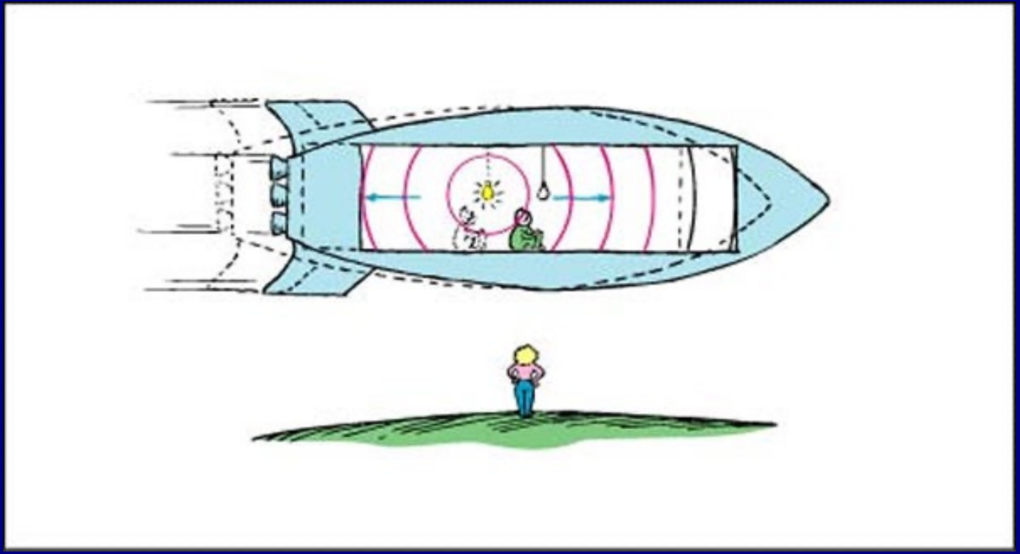
B: close to the speed of light, but not equal to it

C: infinitely large velocity

Simultaneity

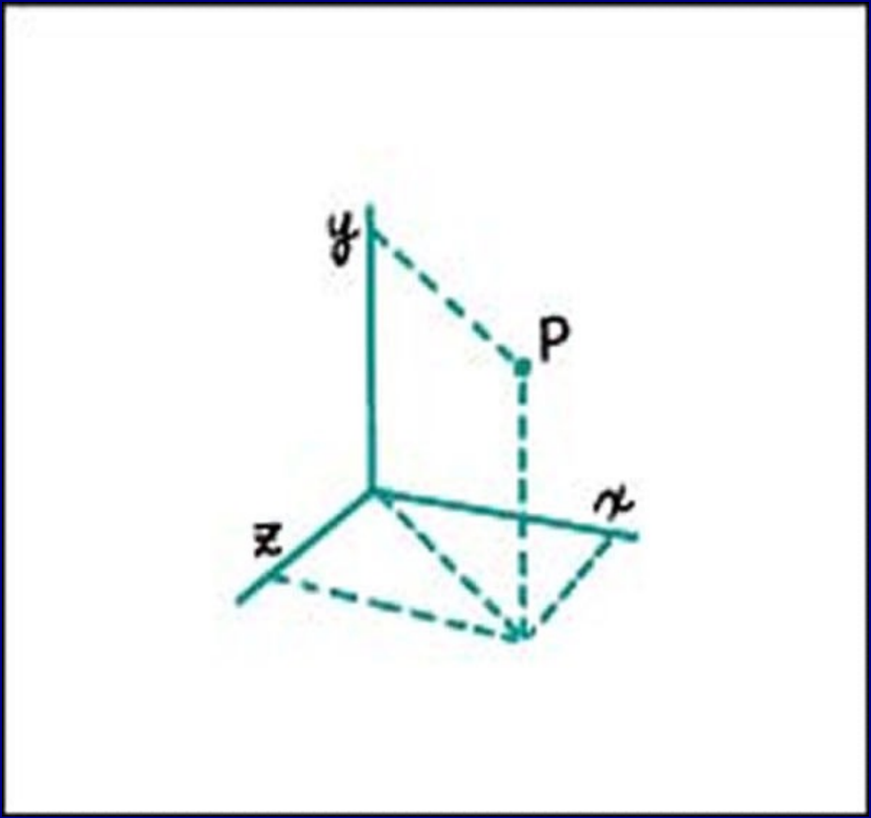
- Two events that happen at the same time in one frame of reference may or may not be simultaneous in a frame moving relative to the first.
  - Result of constancy of speed of light
  - How do the observations of the internal and external observers differ?
    - Who is right?





Spacetime

- 3-D space
  - Three numbers to locate any point
  - Objects with size: Length, width, height
- Time (fourth dimension)
  - Intimately tied to space
    - Most distant galaxies are also the youngest!
    - Seen as they were billions of years ago!



Spacetime (cont.)

- Two side-by-side observers agree on all space and time measurements
  - Share same spacetime
- Two observers in relative motion disagree on space and time measurements
  - But always same ratio!
    - Differences imperceptible at low speeds
    - Important at speeds near *c (relativistic speeds)*

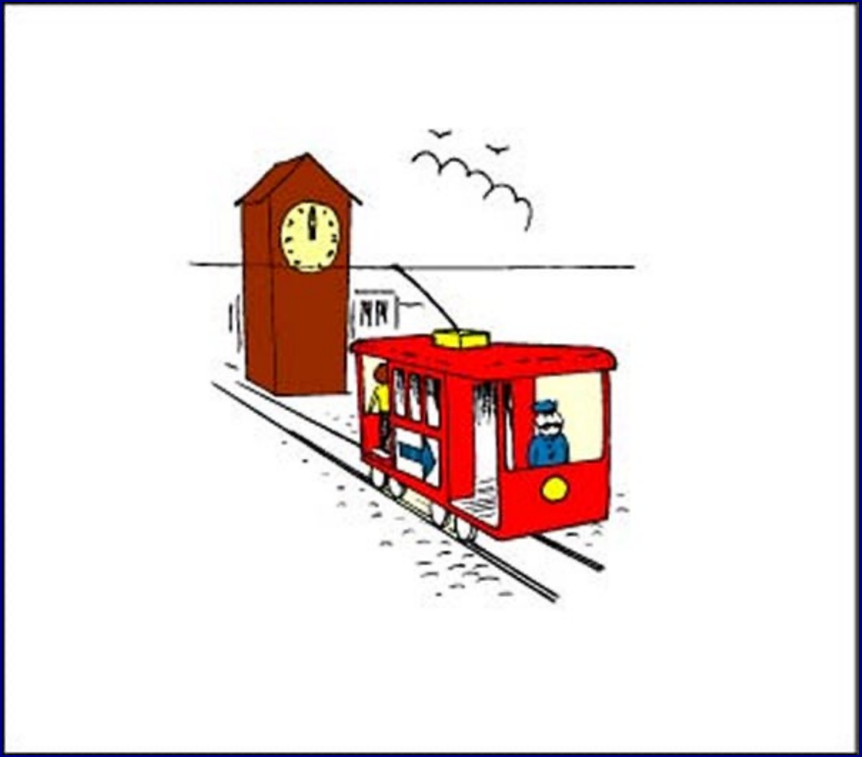
Observers in relative motion experience space and time differently, but speed of light is always constant!

Time Dilation Worksheet

How long does it take Alex to travel 1 light-hour and back at the speed of light?

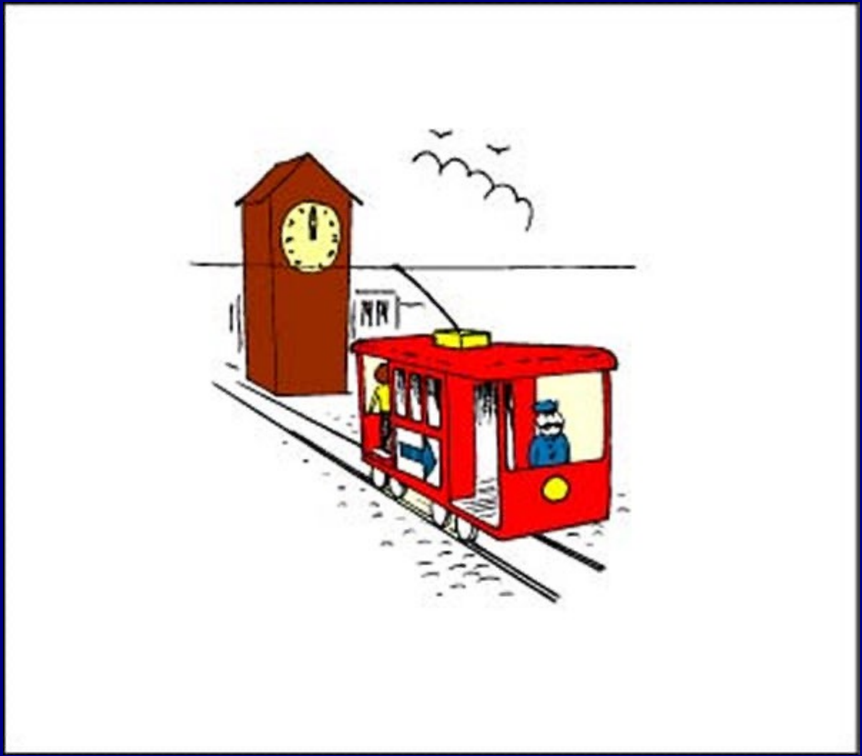
Alex departs from the clock at noon.

- Alex travels at speed of light for one hour towards Juan and stops
  - What does the clock tower read when Alex stops? Does Alex read the same time as the stationary observer
  - (Juan)?



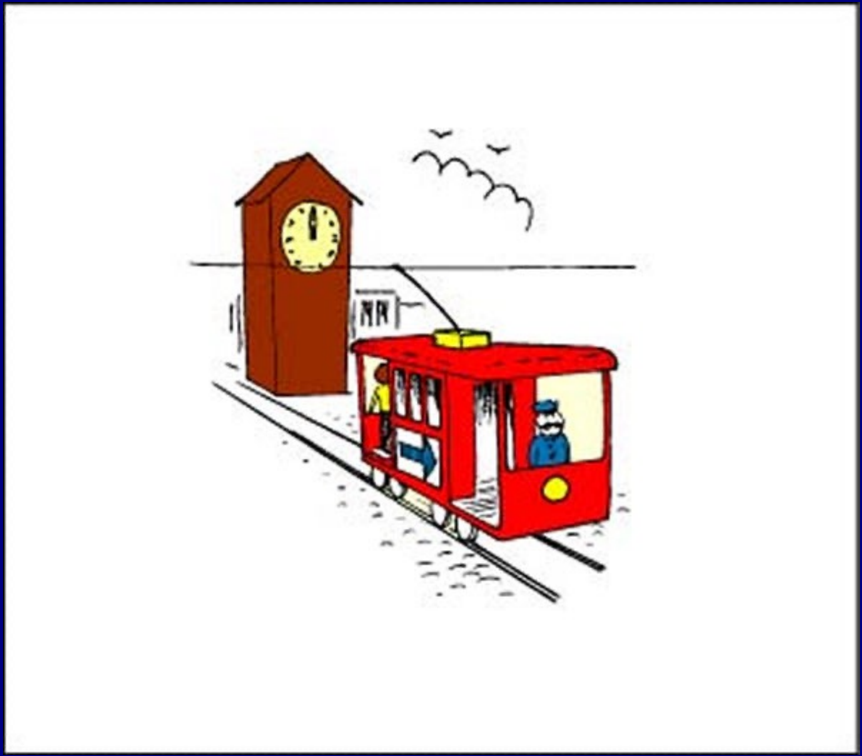
Time Dilation

- Juan sees Alex parked next to the clock at noon.
  - Travel at speed of light for one hour towards observer and stop
    - What does Alex read at the end of his trip?
      - Both read 12pm
      - Time stood still for Alex!
    - So if Alex travelled at speed < *c what would he observe?*



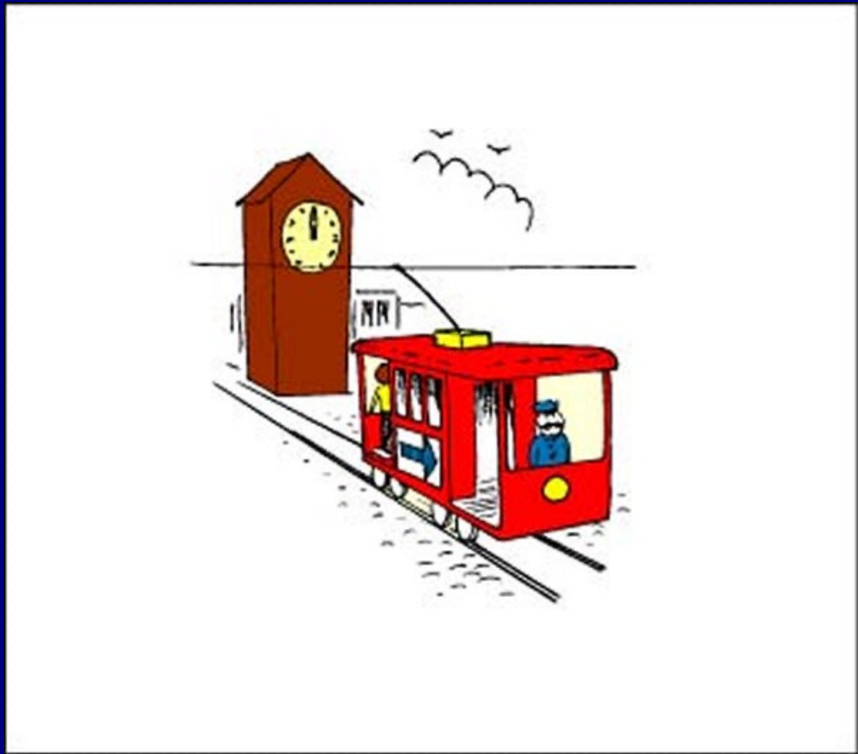
Time Dilation

- If clock reads 12pm, Juan, 1 light hour away reads 11am at that instant.
  - Travel at speed of light for one hour towards observer and stop
    - What does Alex read at the end of his trip?
      - Both read 12pm
      - Time stood still for Alex!
  - So if Alex travelled at speed < *c what would he observe?*
  - *Now Alex travels at high speed back towards clock*
    - *Sees tower clock speed up!*
    - *Will the two effects cancel?*



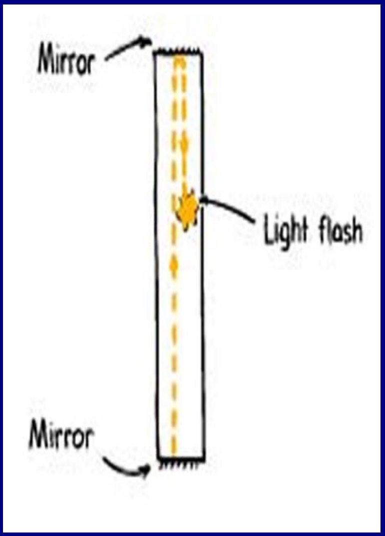
Time Dilation

- If clock reads 12pm, Juan, 1 light hour away reads 11am at that instant.
  - Travel at speed of light for one hour towards observer and stop
    - What does Alex read at the end of his trip?
      - Both read 12pm
      - Time stood still for Alex!
  - So if Alex travelled at speed < c *what would he observe?*
  - *Now Alex travels at high speed back towards clock*
    - *Sees tower clock speed up!*
    - *Will the two effects cancel?*

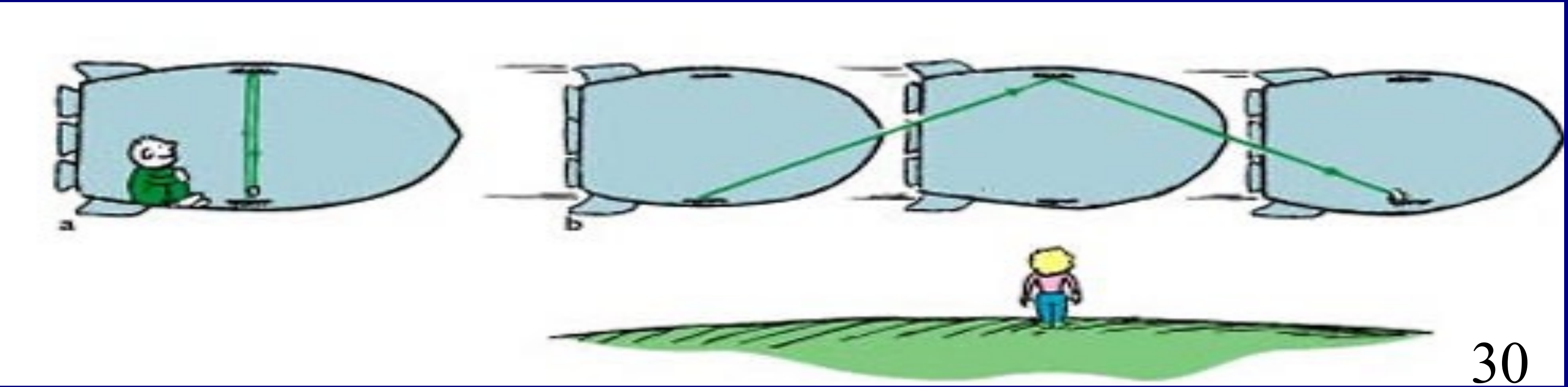


Yes! But Alex's wristwatch will disagree with town clock! How?

Time Dilation (cont.)



- Moving clocks run slow!
  - Light clock: time between mirrors = 1 tick
  - Observer moving with clock: no dilation!
  - External observer: Light travels longer path
    - But, speed of light constant => each tick takes longer!
- True for all clocks! Property of spacetime!



Time Dilation Animated

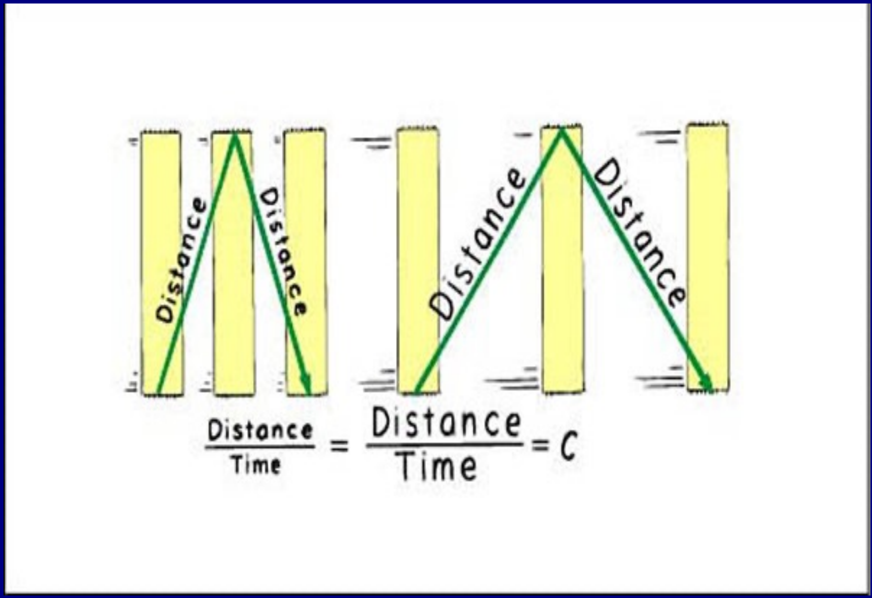
- Time between ‘ticks’ = distance / speed of light
- Light in the moving clock covers more distance…
  - …but the speed of light is constant…
  - …so the clock ticks slower!

- Moving clocks run more slowly!

Time Dilation (cont.)

- Experimentally confirmed
  - Particle accelerators
  - Atomic clocks: Jets & GPS

- *Only relative velocity matters!*
  - *Observer moving with clock would see external clocks run slower! How can this be?*



Truck and Garage Paradox

- Suppose you have a truck 20 ft long and you want to park it in a Garage that is only 10 ft deep. Is there a way to make it fit?
- Yes! If you move the truck in at 0.865c then it will be contracted in length to just 10 feet. At 0.99c it will measure just 2.8 feet and fit easily (until it hits the wall of the garage).

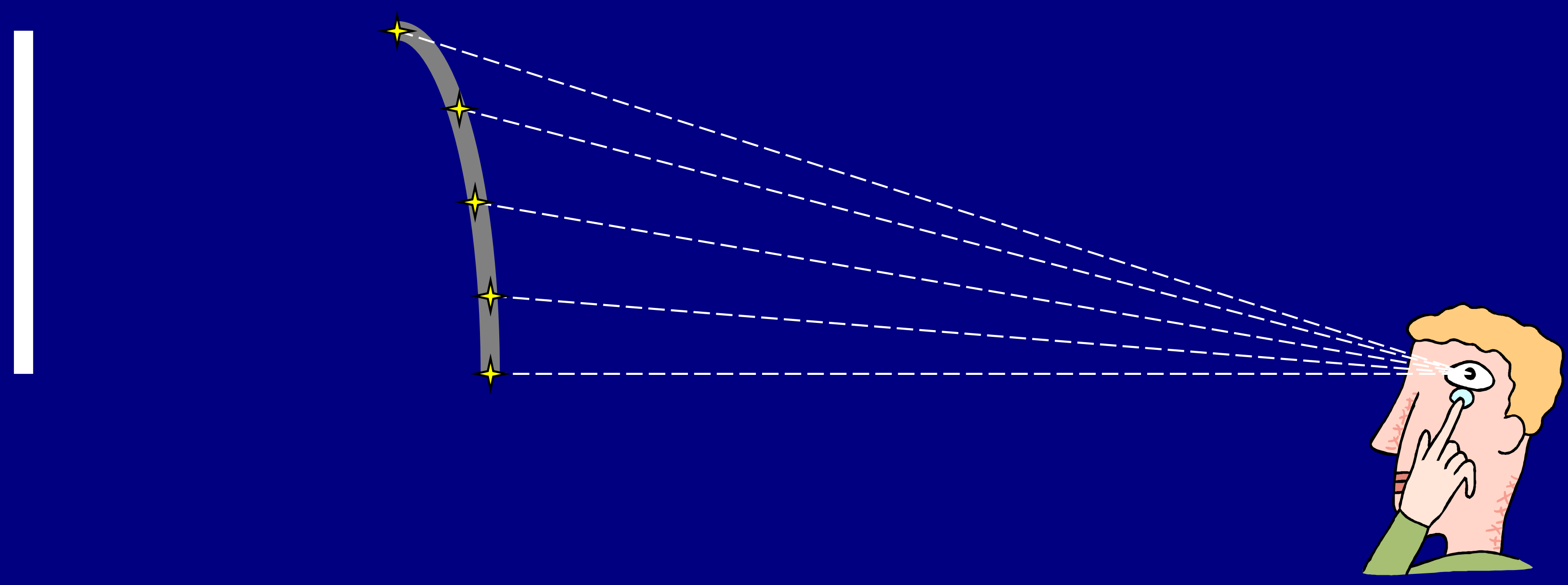
Relativistic Mass

- There is an increase in the effective mass of an object moving at relativistic speeds given by:

- $m = \gamma m_0$ where $$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

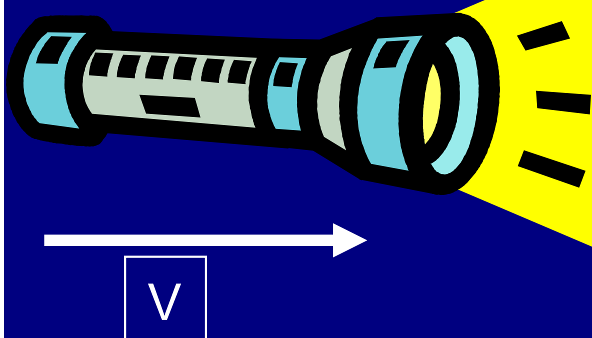
- you have to reach 0.14c to change the mass by 1%
- at 0.99c the mass is 7.14 times greater than rest mass
- at 0.9999c the mass is 70 times greater than rest mass

Lorentz Transformations



- Light from the top of the bar has further to travel.
- It therefore takes longer to reach the eye.
- So, the bar appears bent.
- Weird!

Doppler Boosting



- Beam becomes focused.
- Same amount of light concentrated in a smaller area
- Flashlight appears brighter!

Relativistic Doppler Equation

$z = \Delta\lambda/\lambda$

$$1 + z = \sqrt{\frac{1 + \beta}{1 - \beta}} \quad \text{or} \quad \beta = \frac{(1 + z)^2 - 1}{(1 + z)^2 + 1}$$

Where $\beta = v/c$

Question:

Photons (packets of light) move at the speed of light. Their rest mass is therefore:

A: the same as their relativistic mass

B: much greater than their relativistic mass

C: less than their relativistic mass

D: zero

Question:

The speed of protons in a big accelerator must be:

A: equal to the speed of light

B: greater than the speed of light

C: less than the speed of light

D: zero

Relativistic Summary

- time dilation : $t = t_0\gamma$
- length contraction: $L = L_0/\gamma$
- mass increases: $m = \gamma\, m_0$
- where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- 0.14c --> $\gamma = 1.01$
- 0.99c --> $\gamma = 7.14$
- 0.998c --> $\gamma = 15$

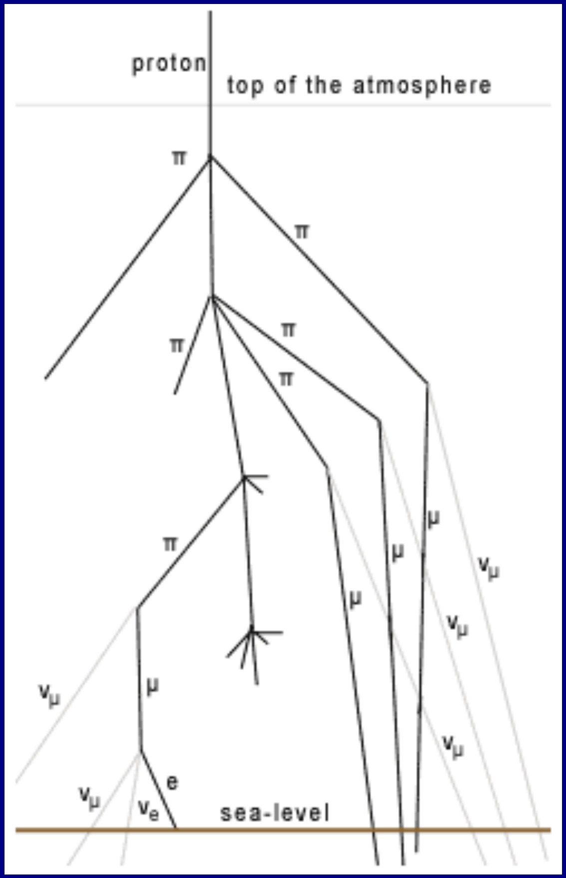
Question:

Suppose a muon is created 5 km up in the atmosphere. If it is moving at 0.998c and has a lifetime of 2×10^{-6} seconds, can it reach the ground?

A: No

B: Yes

C: can’t say



Twin Paradox

- Suppose there are two twins, Al and Bill age 10. Al goes to summer camp 25 light-years away. If he travels at 0.9999c then it takes 25 years each way and Bill is age 60 when Al gets back. But Al is only 10 and a half because time for him was moving slower. But from Al's point-of-view Bill was the one moving so how did Bill get so old?