

Phystus 201 -
Lecture 31

Relativity, Continued!

Time Dilation

"Moving clocks run slower"

$$t_{\text{moving observer}} = \gamma t_{\text{stationary observer}}$$

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

Example: Let's take a trip to the nearest star, and see if there is any life there!

Proxima Centauri (it has at least one planet, according to recent exoplanet searches!)

How far away is it?

→ 4.4 light years

?
what's this.

1 ly \equiv distance traveled by light in one year

$\downarrow \downarrow$
 $= vt$

$35 \times 24 \times 60 \times 60$
 \downarrow

$$= (3.0 \times 10^8 \text{ m/s}) (3.15 \times 10^7 \text{ s})$$

$$1 \text{ ly} = 9.45 \times 10^{15} \text{ m}$$

$$\text{so } 4.4 \text{ ly} = 4.15 \times 10^{16} \text{ m}$$

How fast can we travel?

Current Best: Parker Solar Probe
(launched in 2018)

Expected final speed in 2024

$$= 430,000 \text{ mph}$$

$$= 430,000 \frac{\text{miles}}{\text{hour}} \times \frac{1609 \text{ m}}{\text{mile}}$$

$$\times \frac{1 \text{ hour}}{3600 \text{ s}}$$

$$= 1.19 \times 10^5 \text{ m/s}$$

$$\boxed{\frac{v}{c}} = \frac{1.19 \times 10^8 \text{ m/s}}{3.0 \times 10^8 \text{ m/s}} = \underline{0.0004}$$

(i.e. 0.04 % of the speed of light)

How long to Proxima Centauri?

$$t = \frac{d}{v} = \frac{4.15 \times 10^{16} \text{ m}}{1.19 \times 10^8 \text{ m/s}}$$

$$= 3.49 \times 10^8 \text{ s}$$

$$= \boxed{11,000 \text{ years} \dots\dots\dots}$$

9545 AD

$$\boxed{v = 0.5 c}$$

$d \rightarrow m$

$$d = v t$$

$$t \rightarrow s$$

$$v \rightarrow m/s$$

↑ ↑ ↑
ly fraction
 of
 speed
 of light.

$$\therefore d = 4.4 \text{ ly}$$

$$v = 0.5c$$

$$t = ?$$

$$t = \frac{d}{v} = \frac{4.4 \text{ ly}}{0.5}$$

$$t = 8.8 \text{ years.}$$

OK

Relativity:

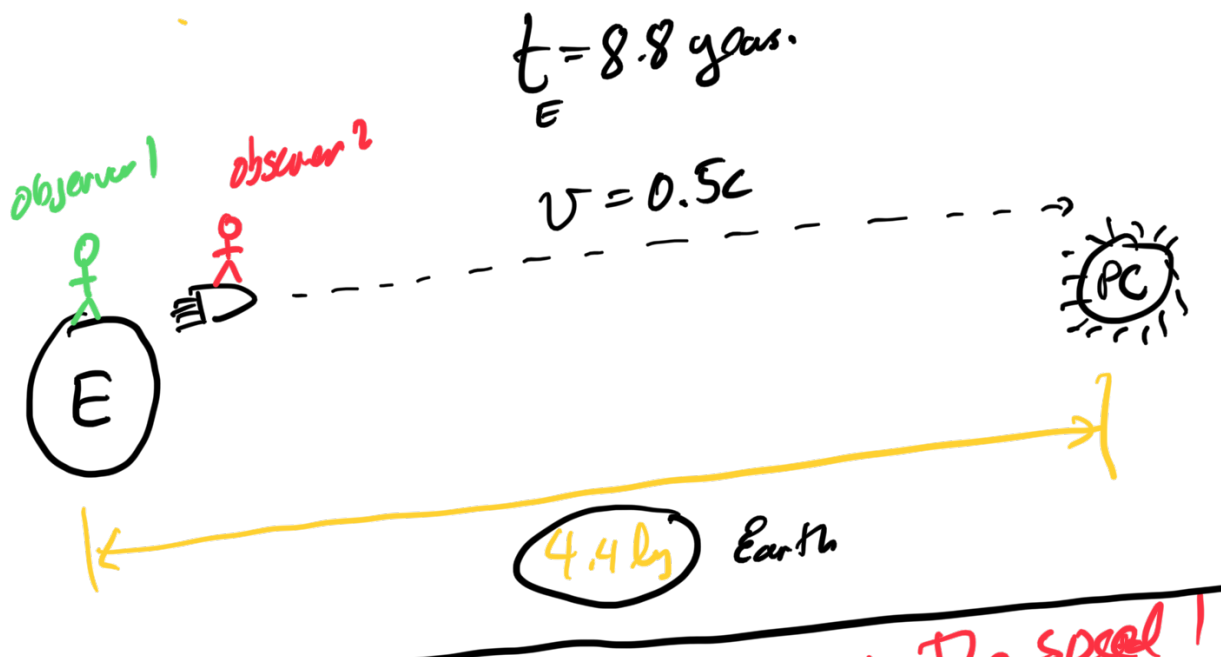
$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1 - \left(\frac{0.5c}{c}\right)^2}}$$

$$\gamma = 1.155$$

$$t_{\text{moving observer}} = \gamma t_{\text{stationary observer.}}$$

↑
Earth
↑
Spaceship



→ Both observers agree on the γ .

→ spaceship is moving - relative to observer 1 !!!

→ spaceship is stationary relative to observer 2.

$$t_{\text{Earth}} = \gamma t_{\text{spaceship}}$$

$$\boxed{8.8 \text{ years}} = (1.155) t_{\text{spaceship}}$$

$$t_{\text{spaceship}} = \frac{8.8 \text{ years}}{1.155}$$

$$t_{\text{spaceship}} = \boxed{7.6 \text{ years.}}$$

$$\boxed{v = 0.99 c}$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = 707$$

$$t_{\text{earth}} = \gamma t_{\text{spaceship}}$$

$$(8.8 \text{ years}) = 707 t_{\text{spaceship}}$$

$$t_{\text{spaceship}} = 0.012 \text{ years}$$

$$= 0.15 \text{ months}$$

$$t_{\text{spaceship}} = 4.5 \text{ days.}$$



Spaceship

$$v = 0.5c$$

$$t_s = 7.62 \text{ years}$$

$$d_s = v \cdot t_s$$

$$= (0.5c)(7.62 \text{ years})$$

Earth

$$= \boxed{3.81 \text{ ly.}} !!$$

$$v = 0.5c$$

$$t_E = 8.8 \text{ years.}$$

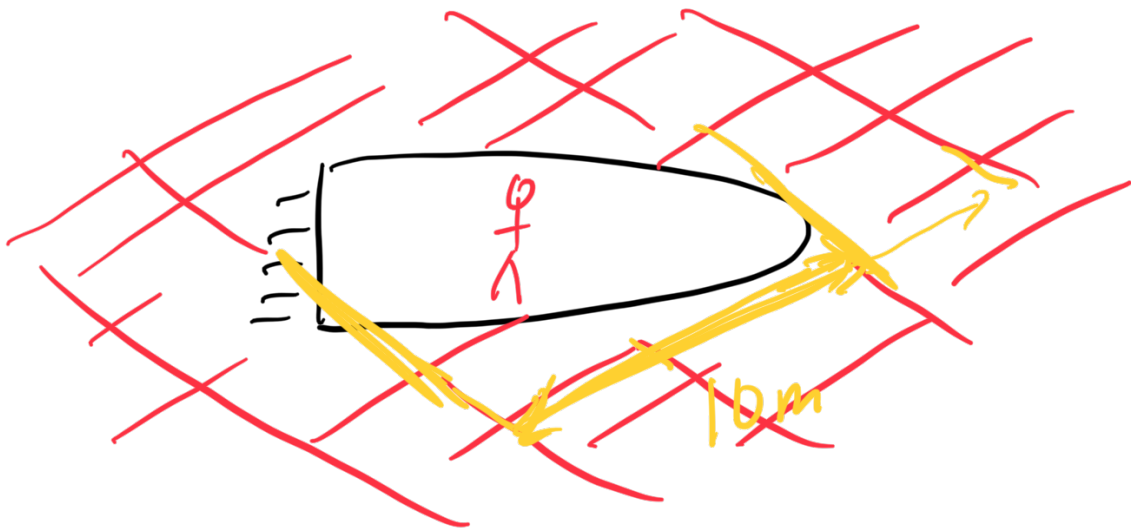
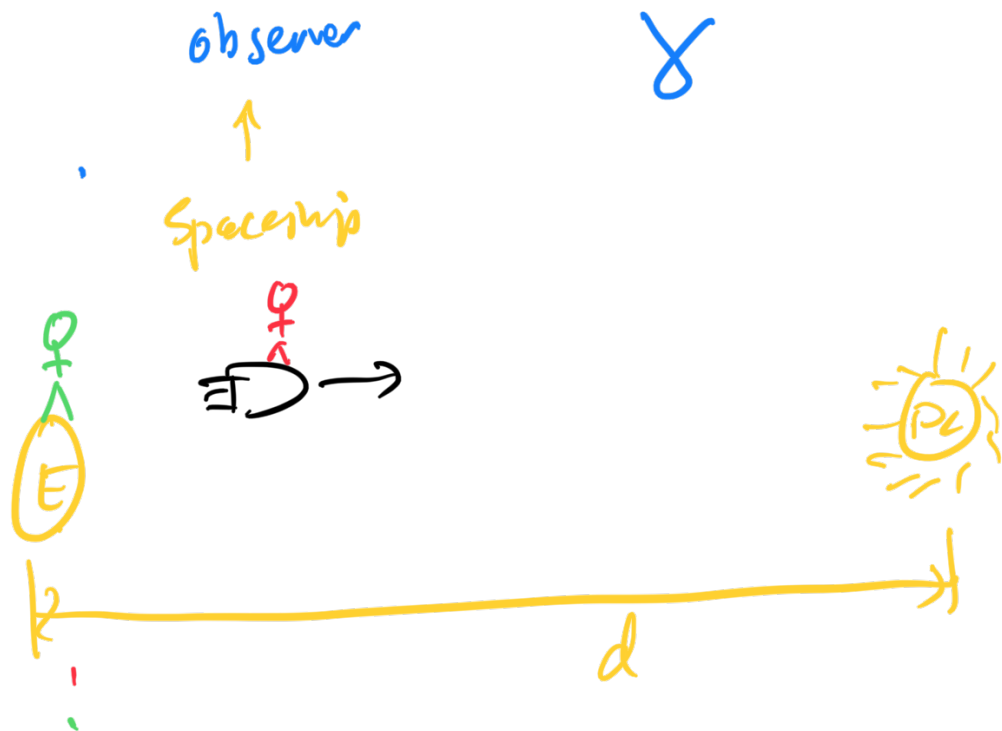
$$\begin{aligned} d_E &= v \cdot t_E \\ &= (0.5c)(8.8 \text{ years}) \\ &= \boxed{4.4 \text{ ly.}} !! \end{aligned}$$

It's not just time that is
relative, distance is as well!

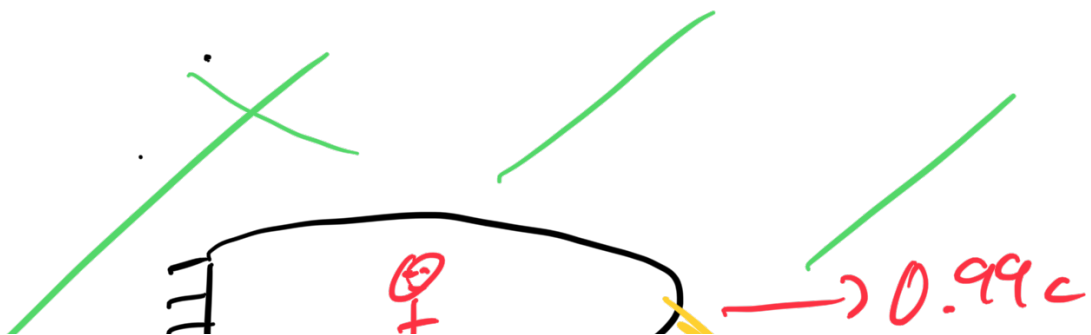
Length Contraction:

$$d_{\text{moving}} = \frac{d_{\text{stationary observer}}}{\gamma}$$

earth
↓



Space is like a ruler

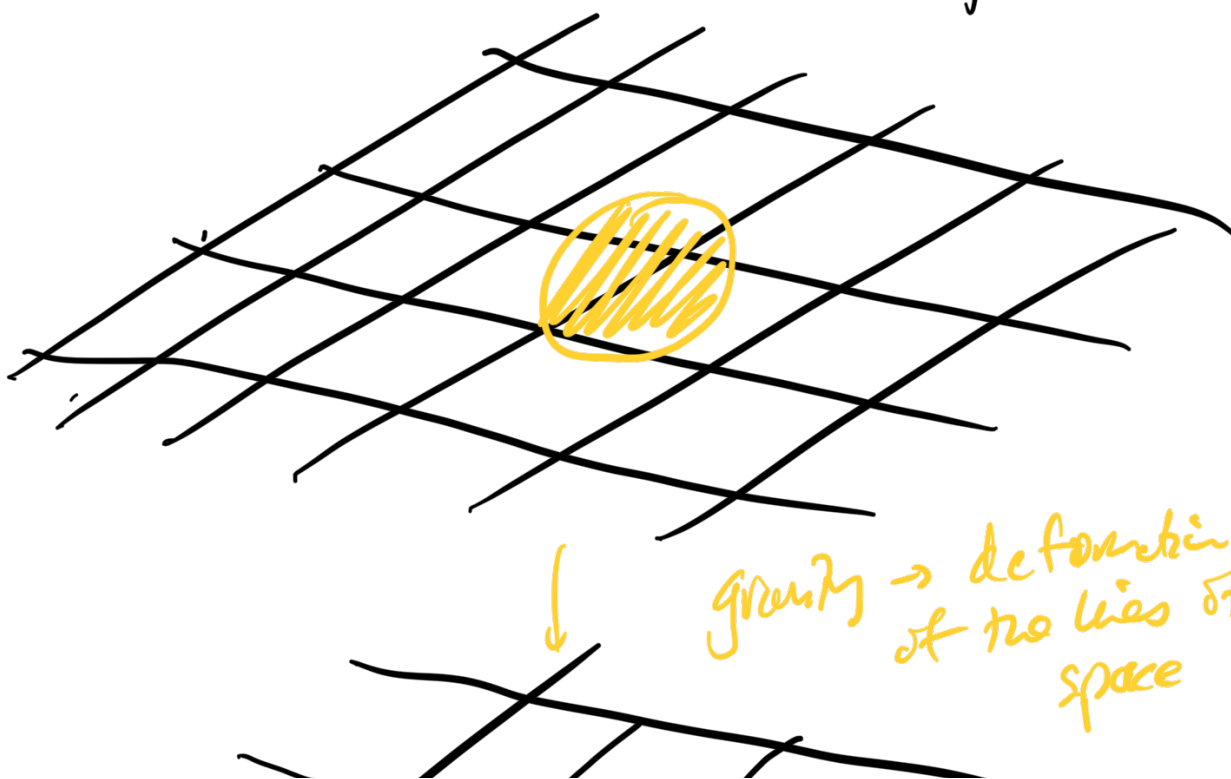


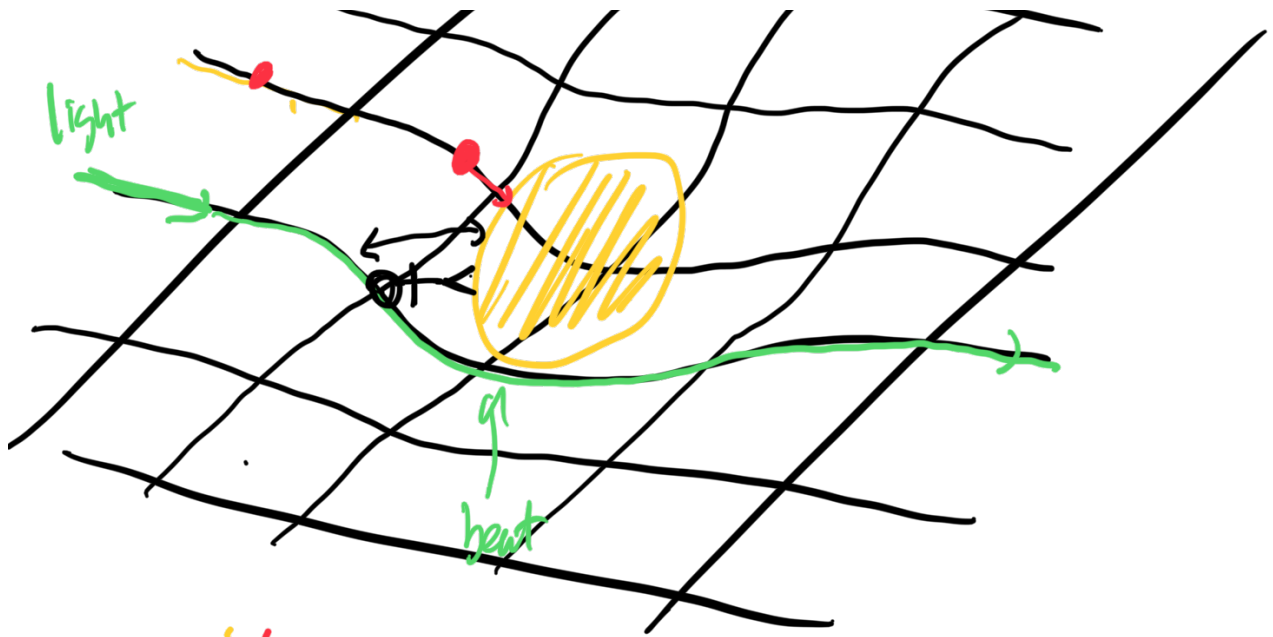


Gravity

Newton \rightarrow How.
Einstein \rightarrow Relativity \rightarrow Why

Space.





gravitational lensing.

