Middle School Version

Measuring the world

MIT Edgerton Center
UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Institut de Ciències de l'Educació
THAU Sant Cugat

How tall are you?

03:00

YOU CAN

- Groups of 3 to 6 people
- Use anything on the classroom

YOU CANNOT

- Use rulers or measured objects

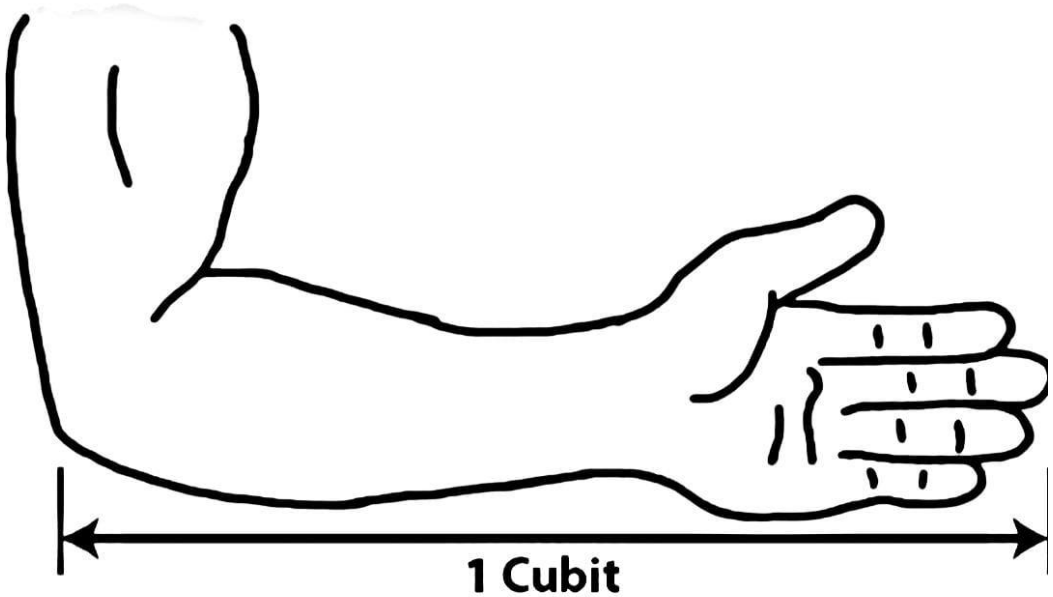
What did you use?

“I’m five pencils and a half tall! I’m taller than you!”

“I’m four pencils tall!”

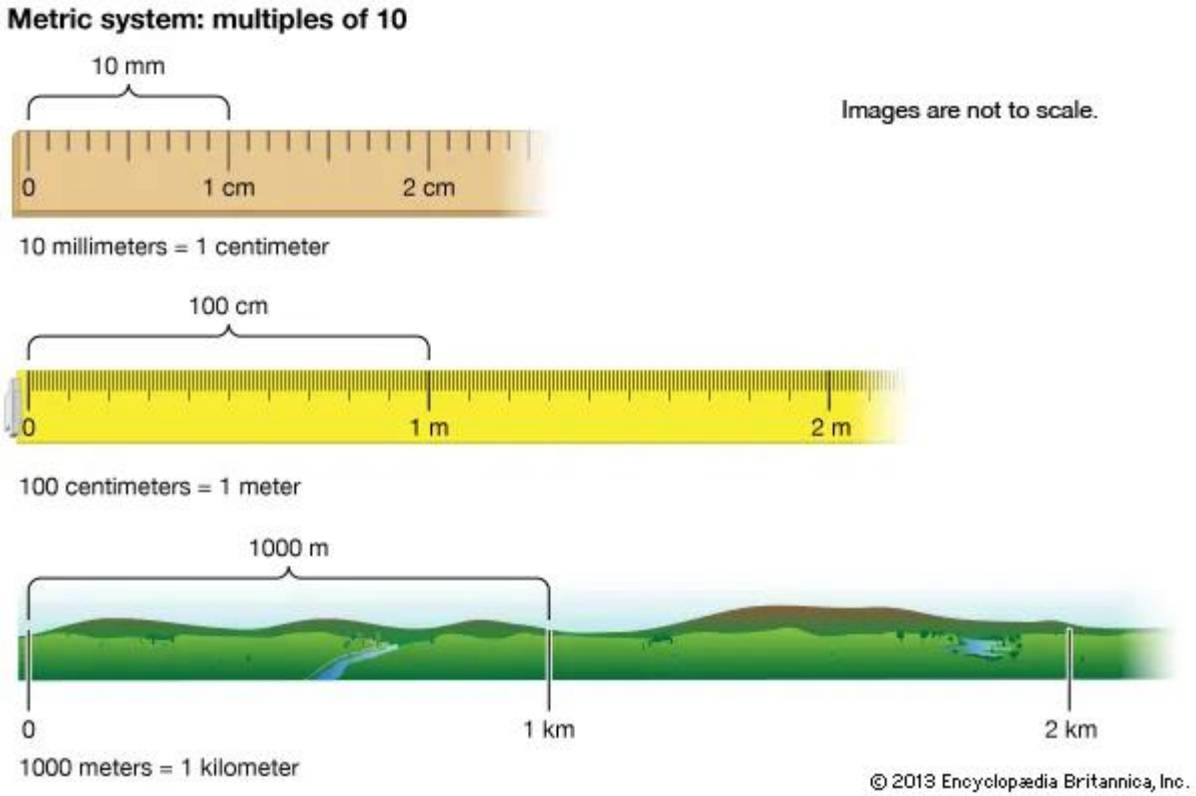
“Wait, they look the same height?!”

Measuring at home



“The Cubit”
Used by the Egyptians

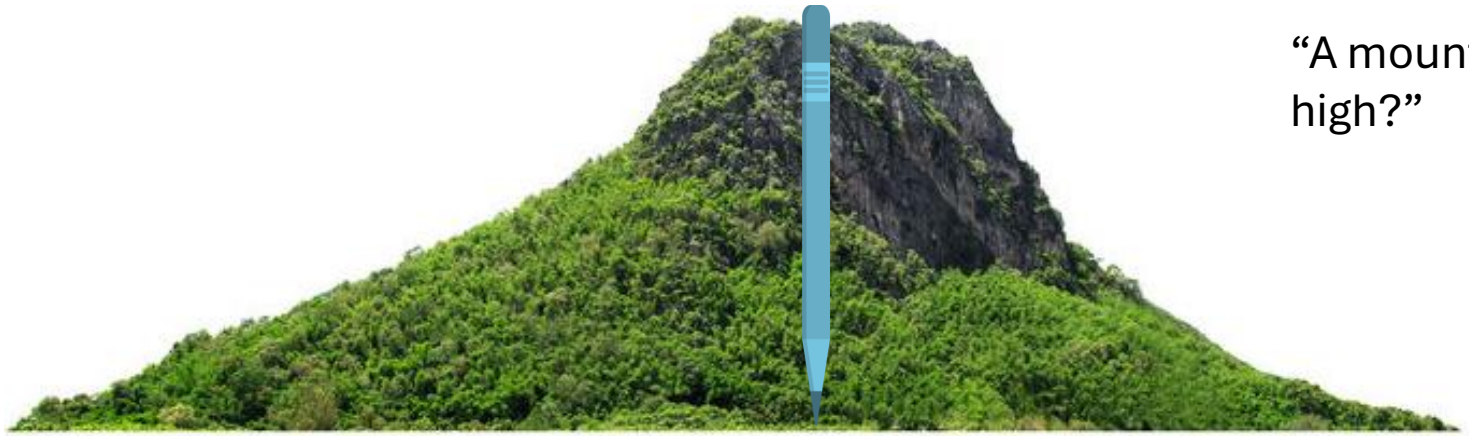
Measuring at home



“The meter”
Proposed by Gabriel Mouton in 1670

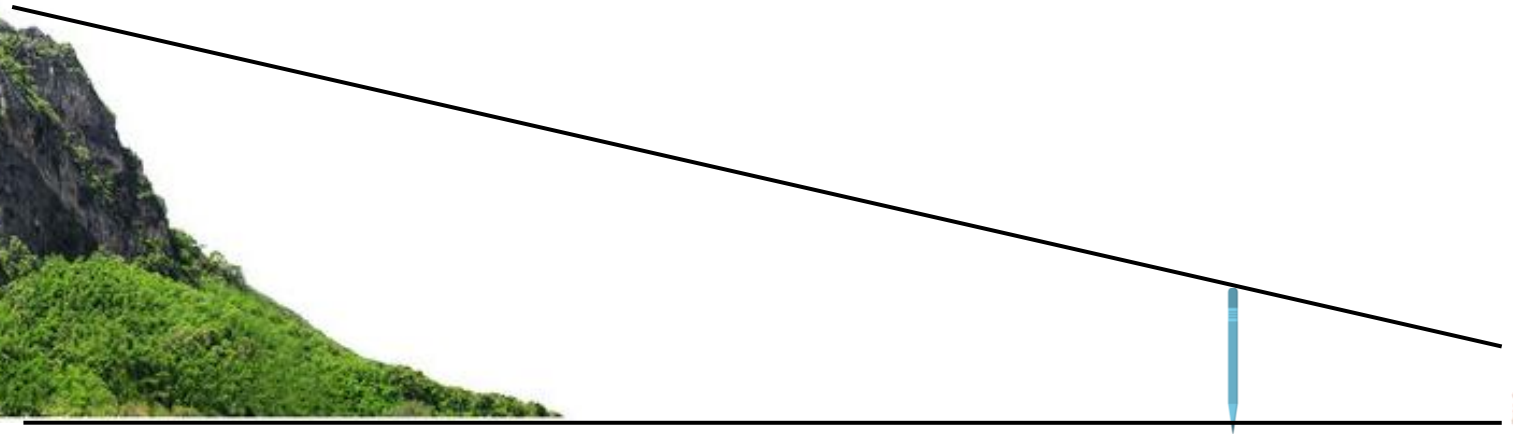
How can we measure the height of a mountain?

Measuring Earth



“A mountain is a pencil high?”

Measuring Earth



Very far away!

Try measuring how tall is a tree.

03:00

YOU CAN

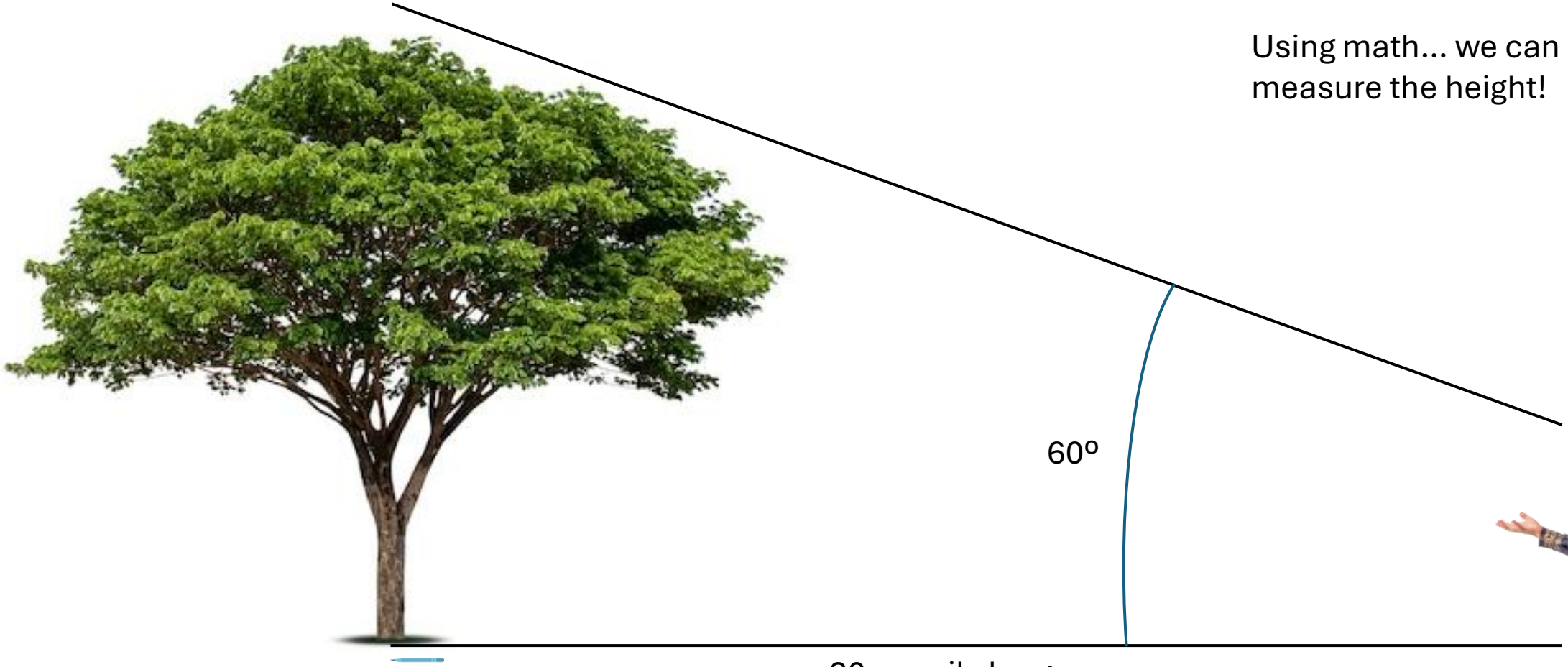
- Groups of 3 to 6 people
- Use anything on the classroom

YOU CANNOT

- Use rulers or measured objects

What did you do?

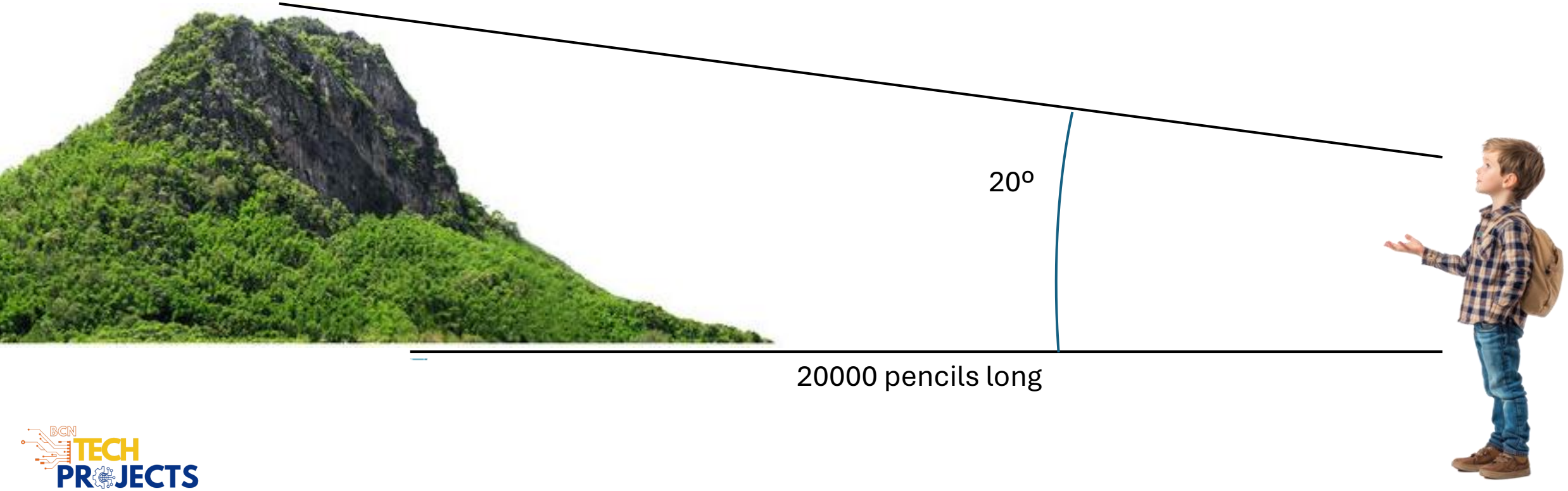
What did you do?



BCN TECH PROJECTS

What did you do?

Using math… we can measure the height!



Takeaways from this part

- **My arm is not the same size as yours.**
- **We need common units!**
- **1 meter is the same here, in Boston and in China!**

BCN TECH PROJECTS

High School Version

The Cosmic Distance Ladder

Adapted from Terence Tao (UCLA)'s Version

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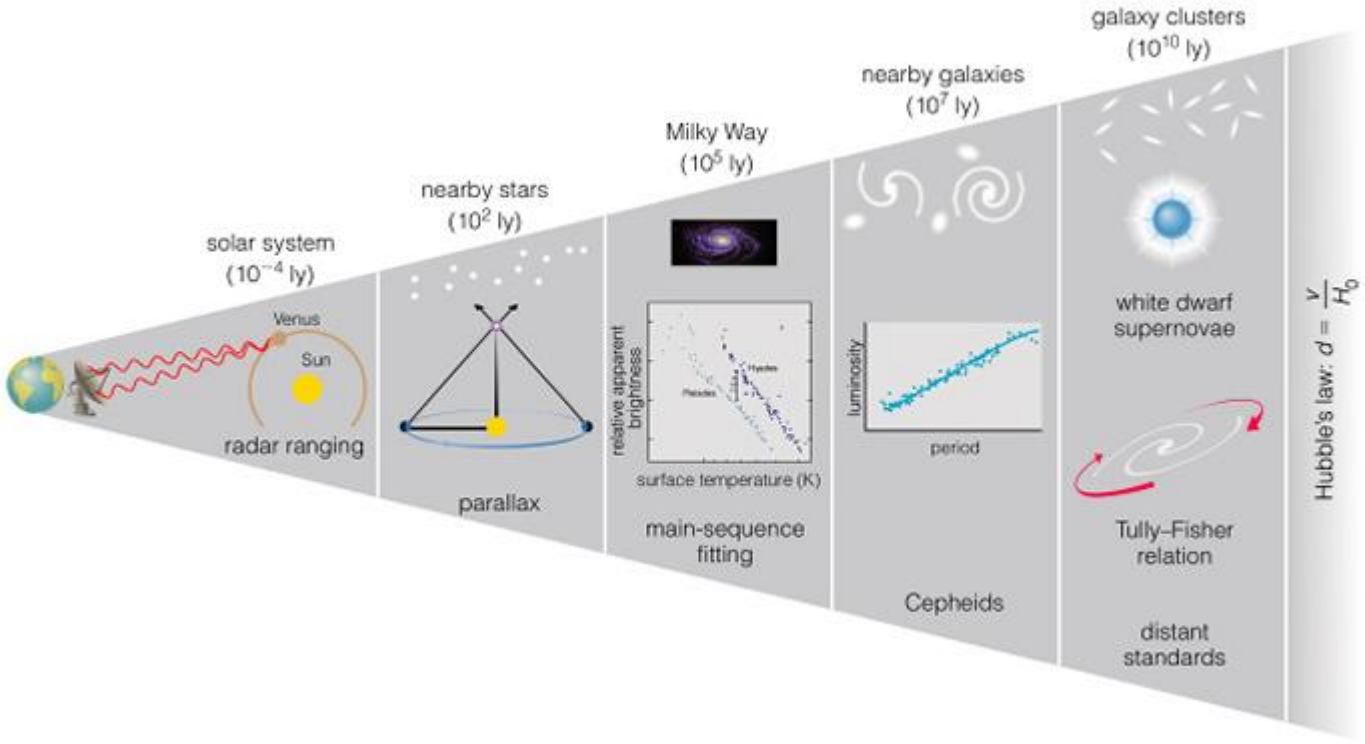
The Cosmic Distance Ladder

How do we know how far away things are?



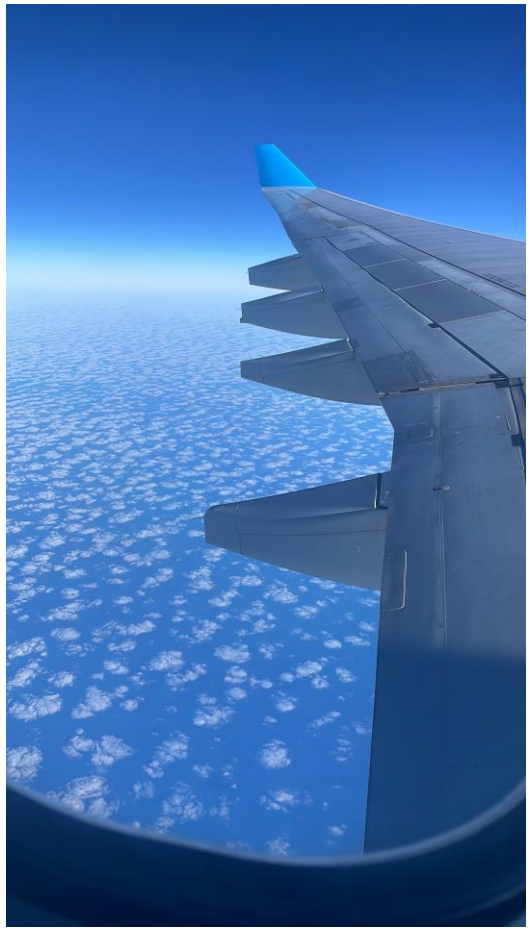
How do we measure the circumference of the earth?

How do we even approach this?

Ideas?
Thoughts?

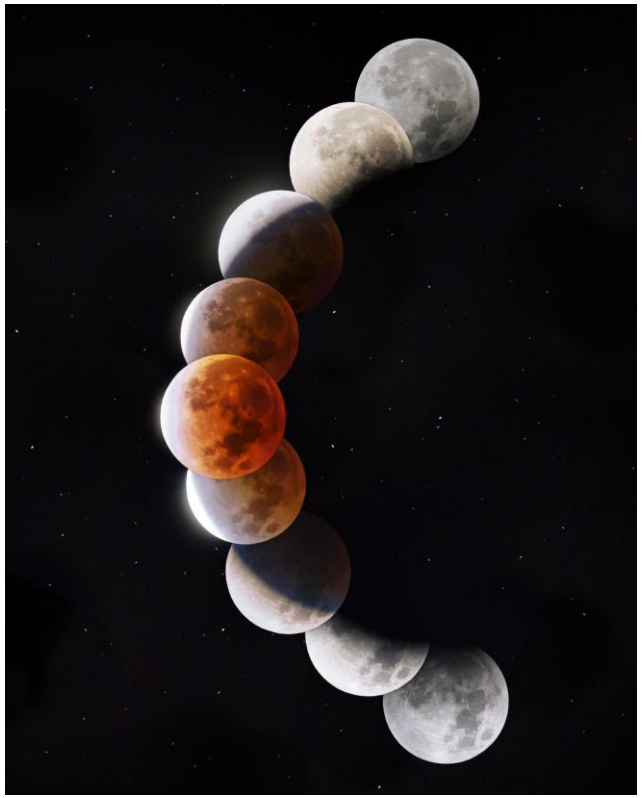
First, how do we even know what earth looks like?

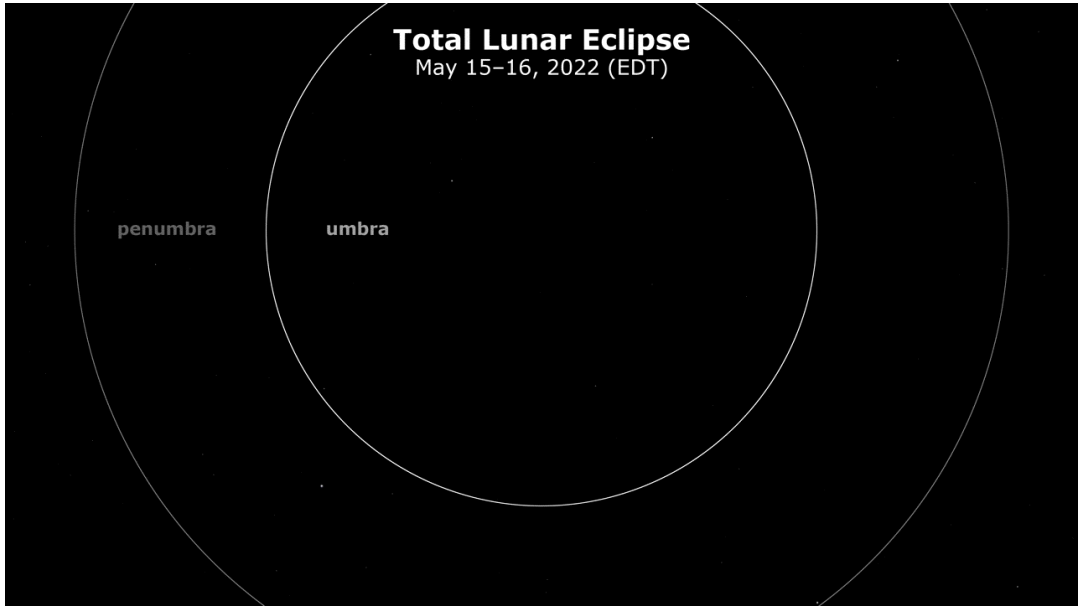
Harvard Bridge, BOS, MA. 12.14’ tall (3.7m)



Plane over the Atlantic @ ~33,000 feet (10km)

We know what the earth's projection on the moon looks like!





No other 3D object but a sphere has a circle as a 2D projection

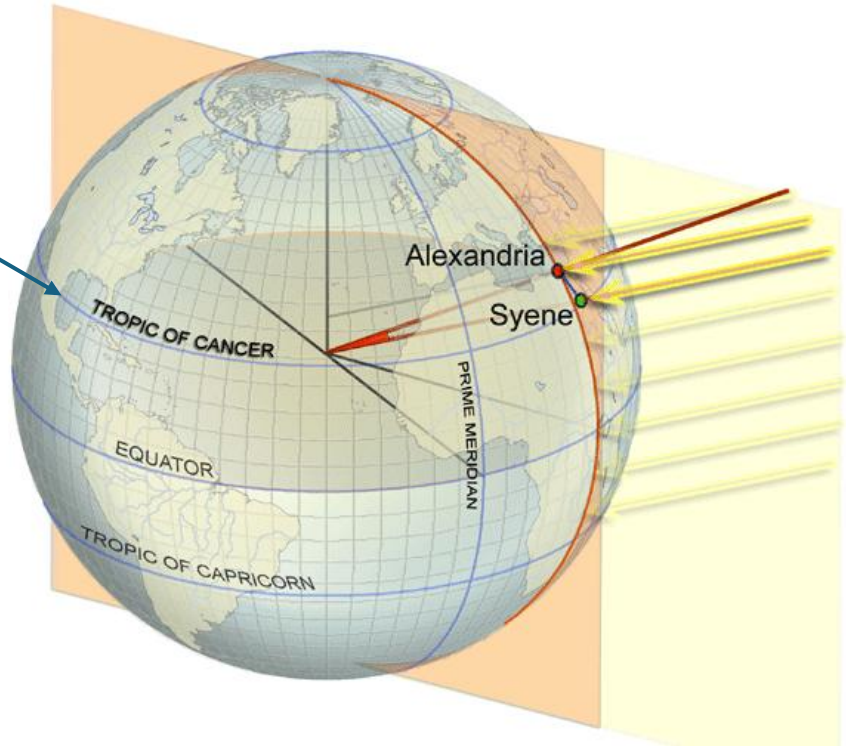
BCN TECH PROJECTS

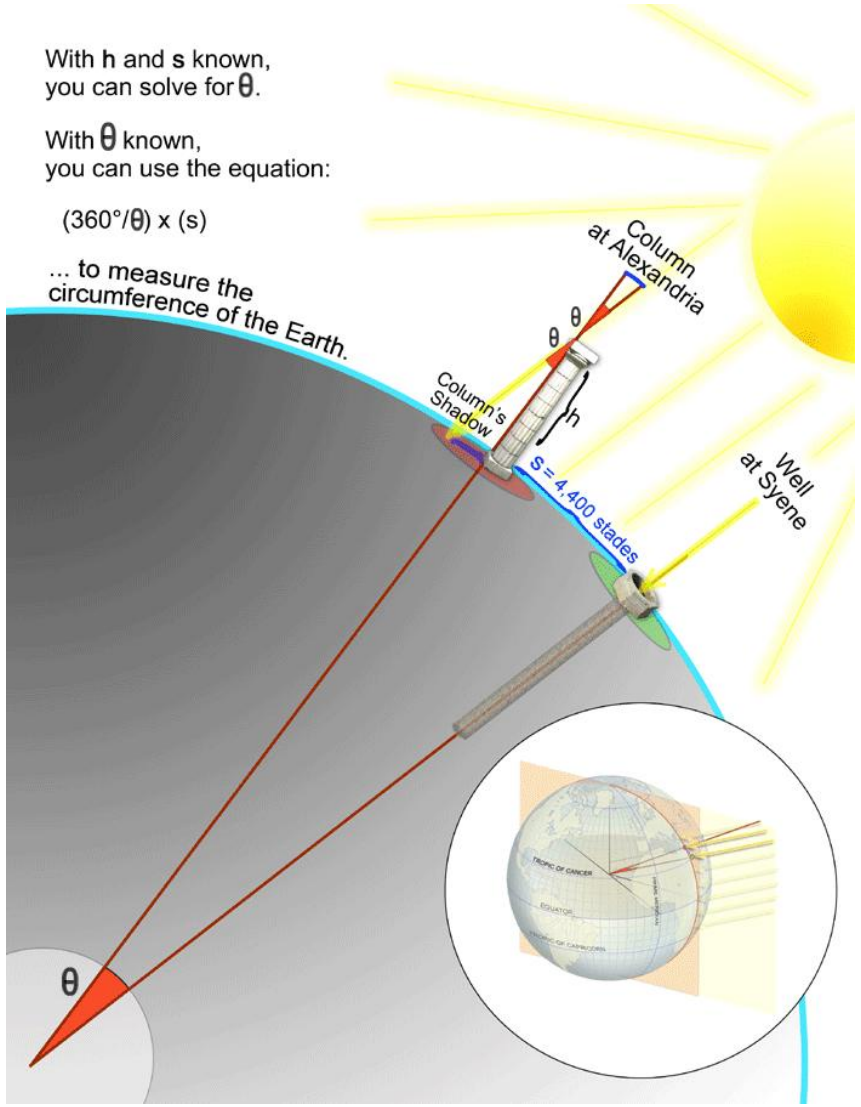
Eratosthenes (276-194 B.C.) measured it !

$$\frac{7º}{360º} = \frac{dist(Alexandria, Syene)}{Circumference\ of\ Earth}$$

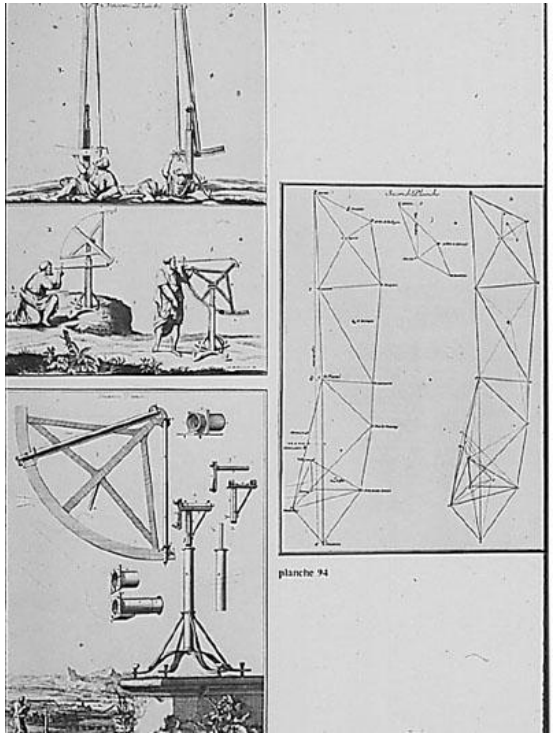
dist(Alexandria, Syene) = 5000 stadia (788.5 km)
Circumference of Earth = 40551.43 km

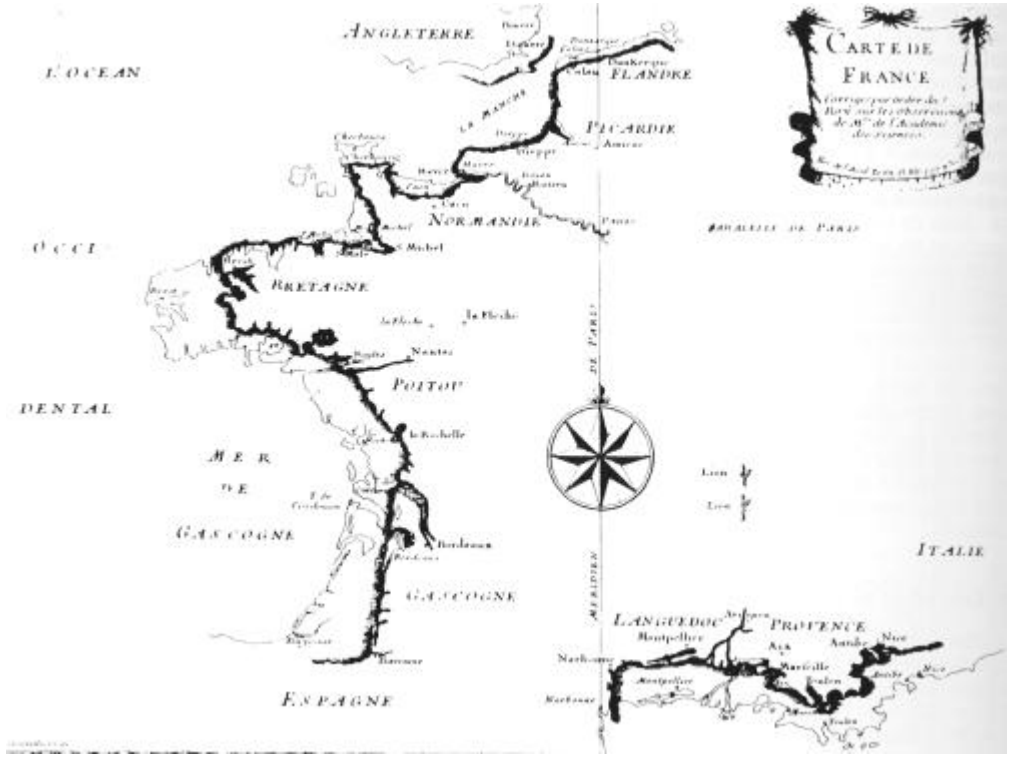
The tropic of cancer is defined as the line where sun rays are at a 90-degree angle at the summer solstice





Jean Picard measured the perimeter of earth in France back in 1793 with an error of 0.18%!





This is how we defined the meter!

Now we can measure stuff!

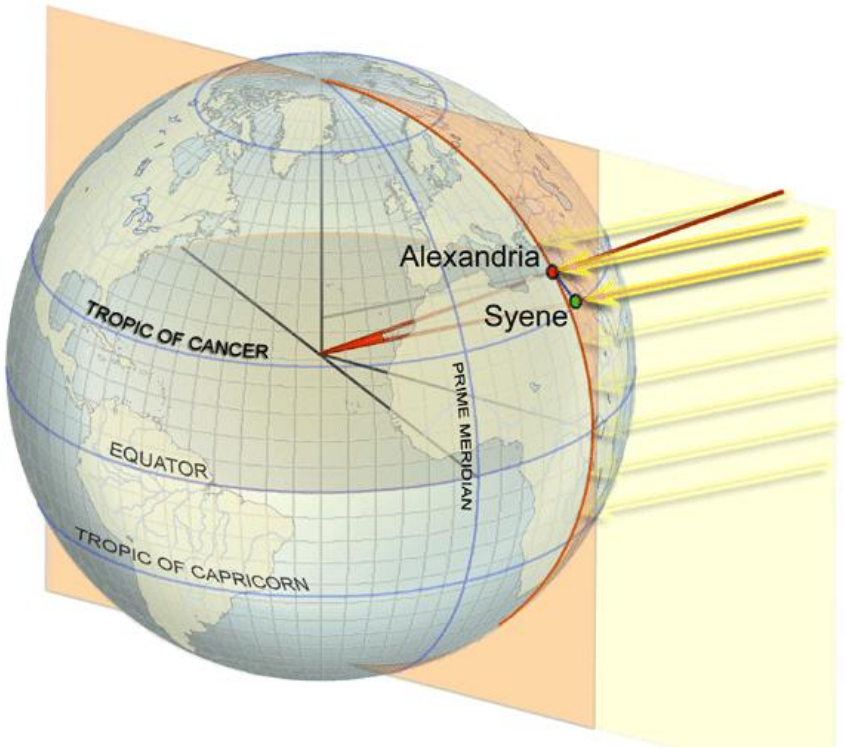
$$1 \text{ meter} = \frac{Perimeter\ of\ Earth}{4 \times 10{,}000{,}000}$$

Actually, it turned out that they made a mistake. And so, the perimeter of earth is a bit longer that it is supposed to.

BCN TECH PROJECTS

Quick side note

If the summer solstice is June 20th (The longest day and shortest night).
Why is it that it's not the hottest day of the year?



How far away is the moon?

How far away is the moon?

Ideas?

Thoughts?

How far away is the moon?

Aristarchus realized the following:

How far away is the moon?

In about 3.5 hours

So, what do we know?

$Time\ of\ one\ Lunar\ Orbit\ (28\ days), Time\ it\ takes\ to\ do\ 2\ R_{earth}\ \ (3.5\ hours)$

How far away is the moon?

In about 3.5 hours

So, what do we know?

$Time\ of\ one\ Lunar\ Orbit\ (28\ days), Time\ it\ takes\ to\ do\ 2\ R_{earth}\ \ (3.5\ hours)$

$$Circumference\ of\ Moon\ Orbit = \ 28\ days \times \frac{24\ hours}{1\ day} \times \frac{2R_{earth}}{3.5\ hours} = 2\ 457\ 600\ km$$

$$Circumference\ of\ Moon\ Orbit = 2\pi D_{moon} \Rightarrow D_{moon} = {\sim}391\ 139\ km$$

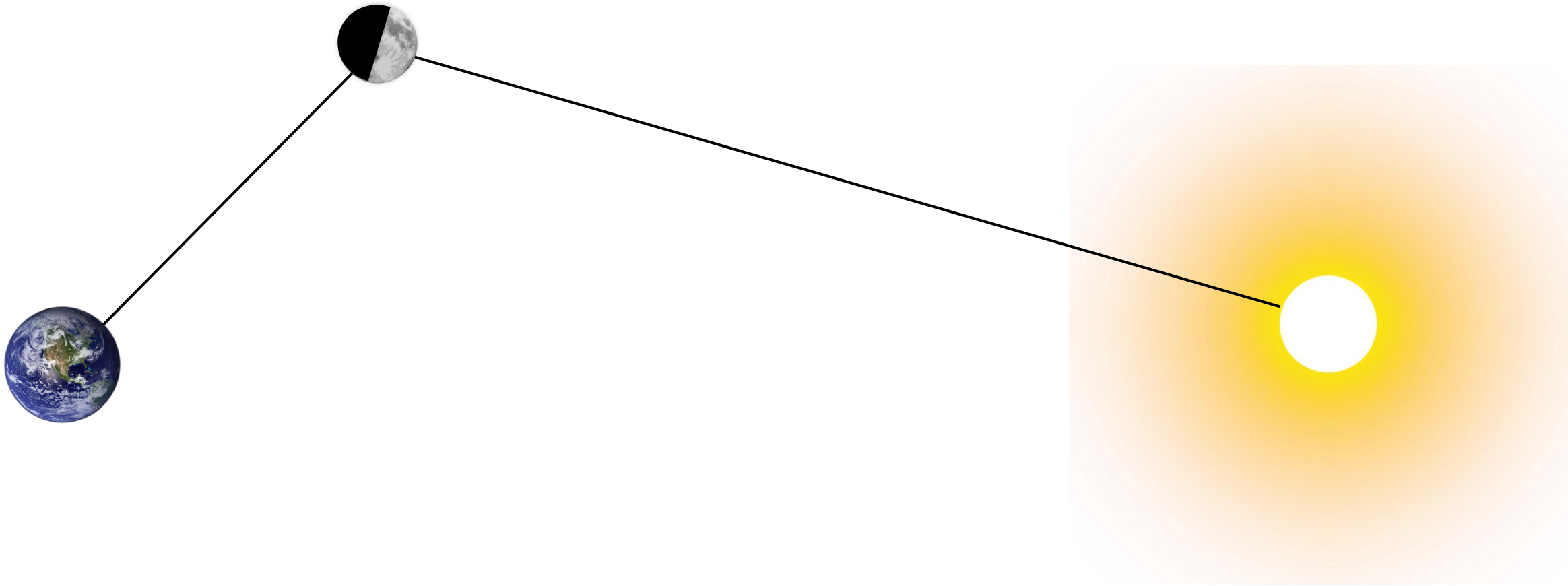
How far away is the sun?

How far away is the sun?

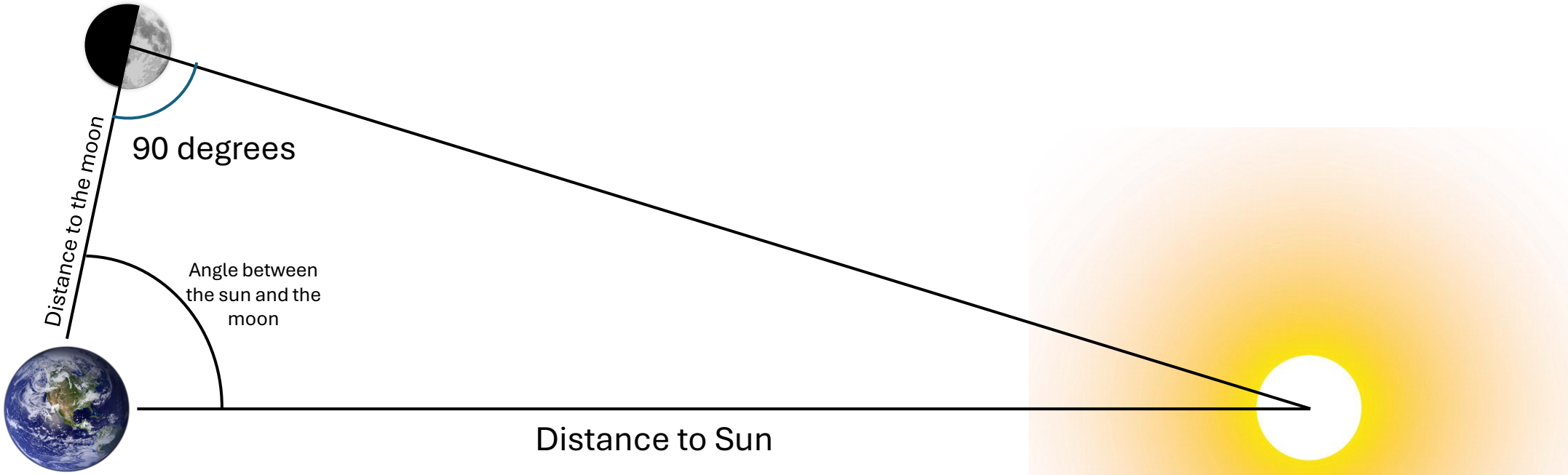
Ideas?

Thoughts?

How far away is the sun?

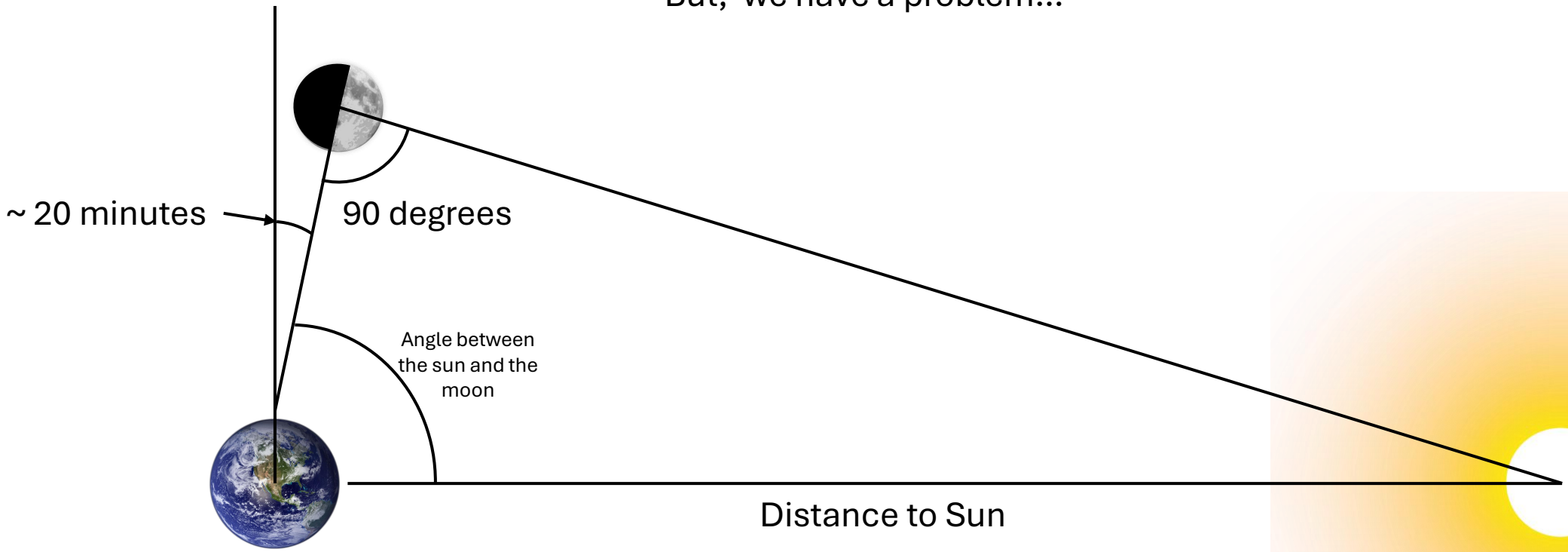


How far away is the sun?



How far away is the sun?

But, we have a problem...



This angle is super small!!

$$20\,\text{min} \times \frac{1\ hour}{60min} \times \frac{360\ degrees}{24\ hours \times 30\ days} = 1/6\ degree$$

$$\cos\left(90 - \frac{1}{6}\right) = \frac{Distance\ to\ moon}{Distance\ to\ Sun}$$

$$Distance\ to\ sun = \sim 344 \times Distance\ to\ moon$$

Quick Sum Up

$$Radius\ of\ Earth = \frac{40000\ km}{2\pi} = \sim 6366\ km$$

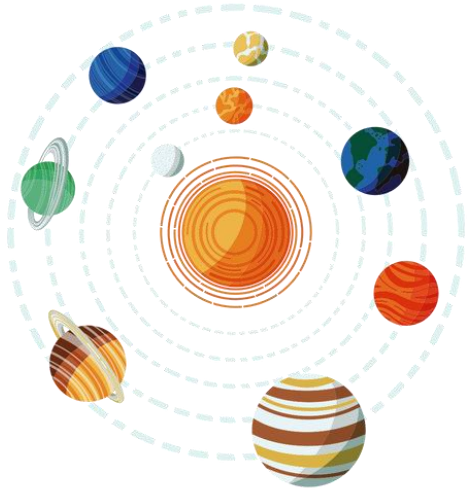
$$Distance\ to\ moon = \sim 61 \times Radius_{earth} = \sim 388\ 326\ km$$

$$Distance\ to\ sun = \sim 344 \times Distance\ to\ moon = \sim 1\ Astronomical\ Unit = \sim 133\ 584\ 144\ km$$

What's Next?

How far away are other stars?

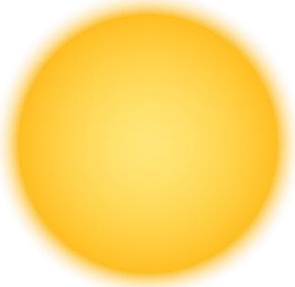
How far away are other stars?



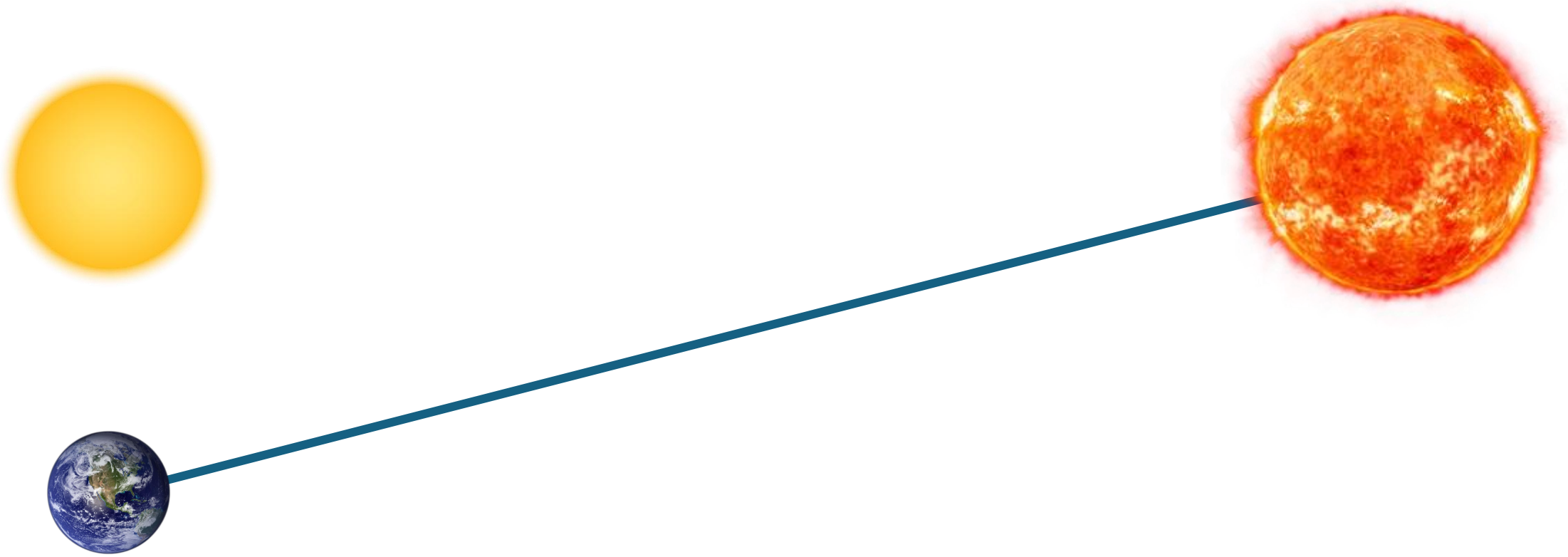
Ideas?

Thoughts?

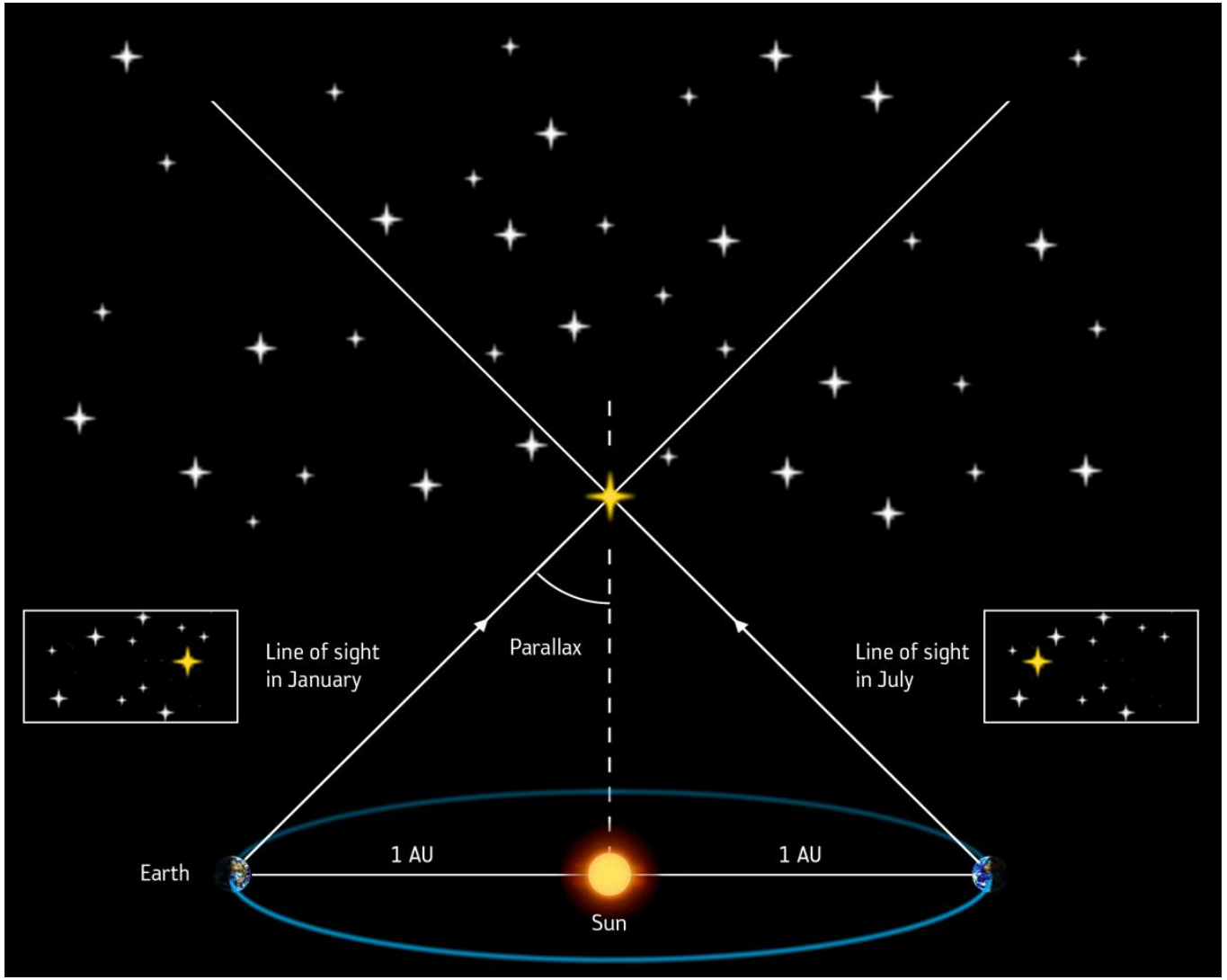
How far away are other stars?

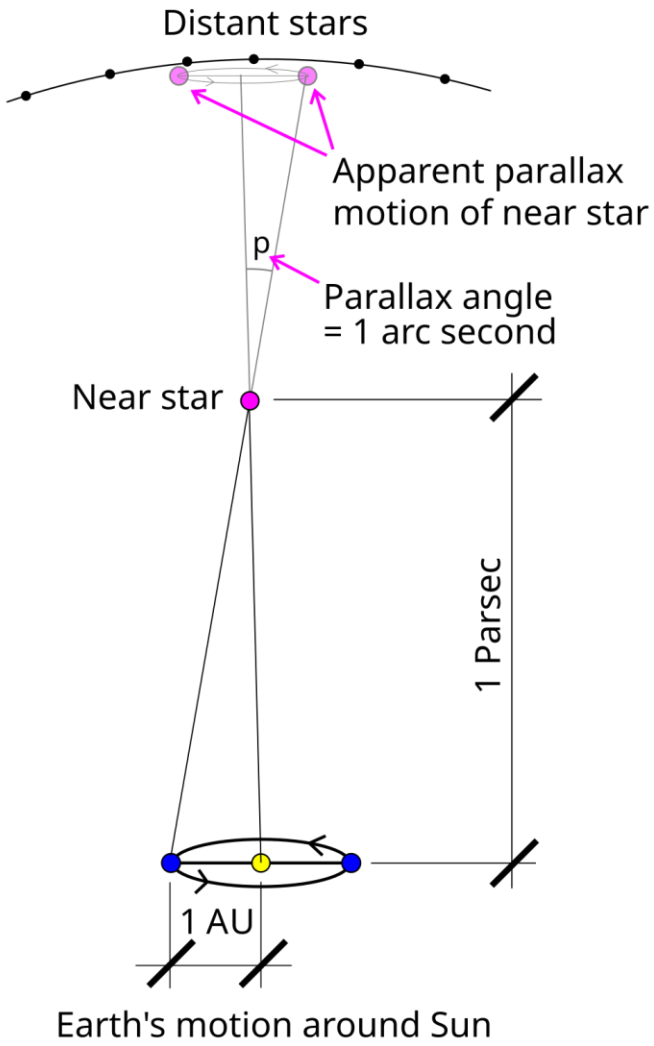


Measuring Galaxies and very far away stars



How far away are other stars?





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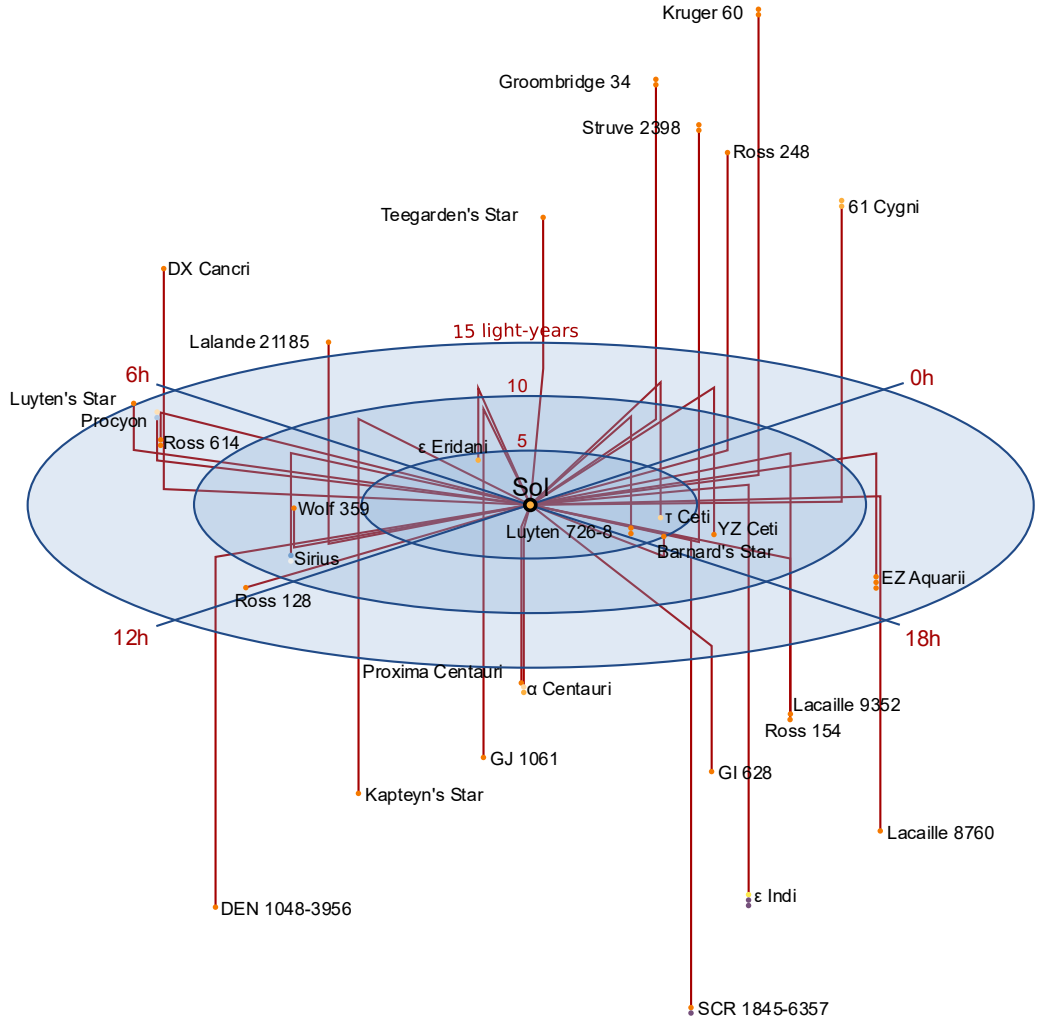
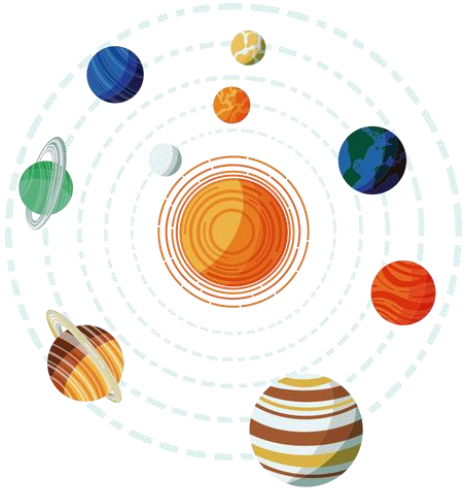


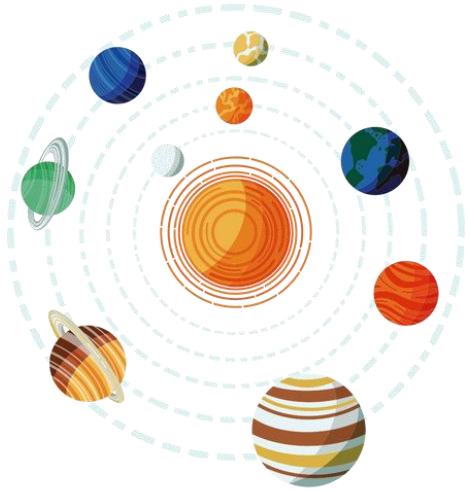
Quick Side Note

How do we know that other stars have planets orbiting around them?
The only thing we see is a point of light right?

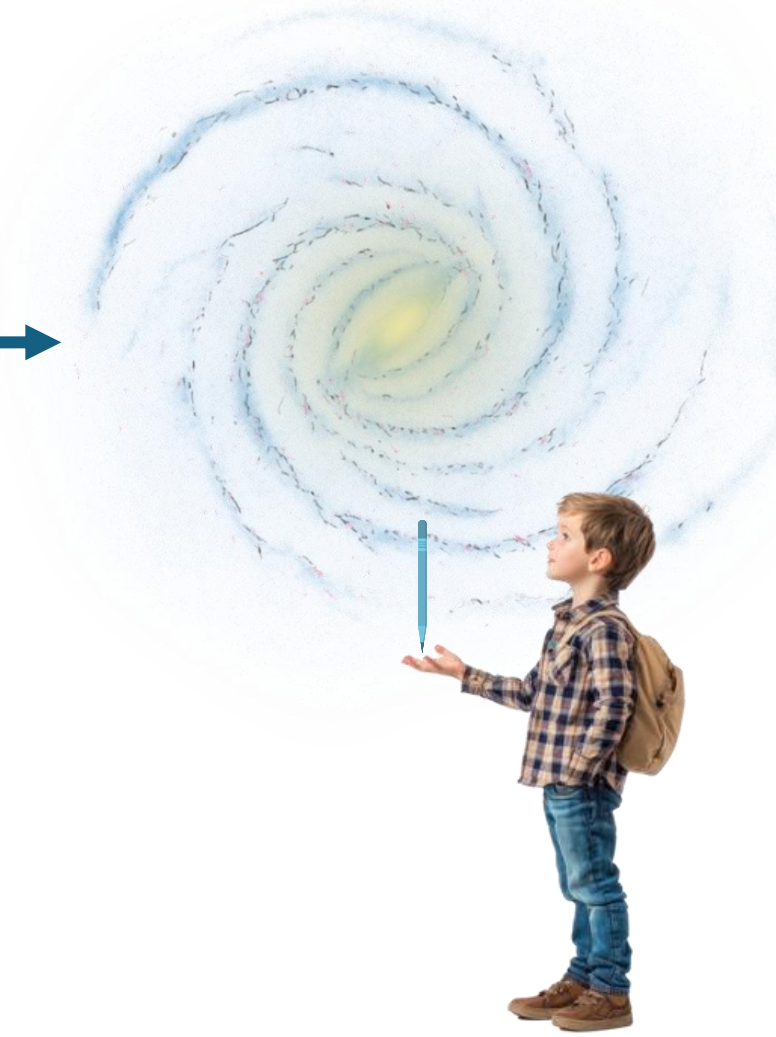


Measuring Galaxies and very far away stars

Measuring Galaxies and very far away stars

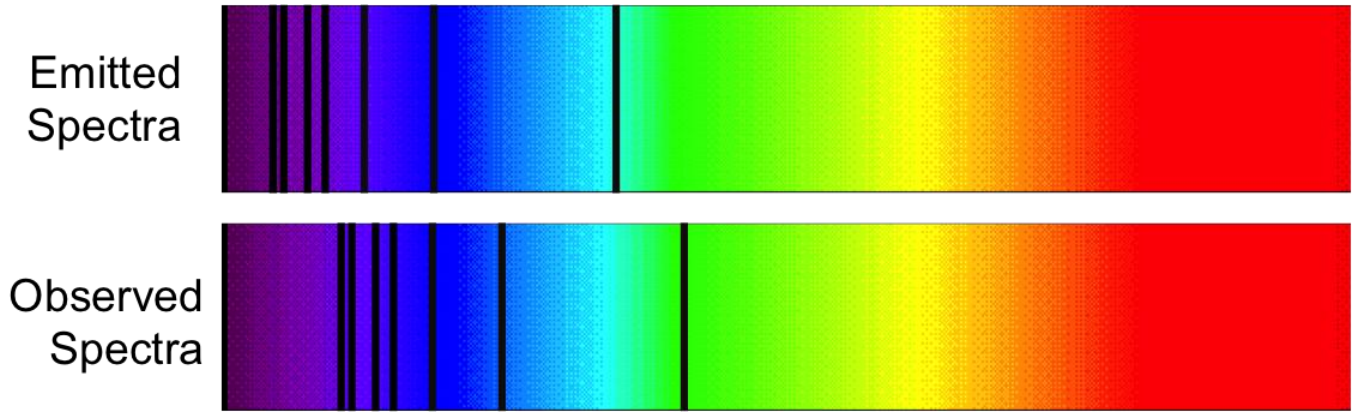


Ideas?
Thoughts?



Measuring Galaxies and very far away stars

This is a bit more complicated...



Bibliography

- Terence Tao's "The Cosmic Distance Ladder" Presentation: https://terrytao.wordpress.com/wp-content/uploads/2010/10/cosmic-distance-ladder.pdf
- Sagan, C. (1985). Cosmos. Ballantine Books.
- Grant Sanderson (3Blue1Brown)'s Cosmic Distance Ladder video series

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