National Aeronautics and Space Administration

The Heliophysics Big Year

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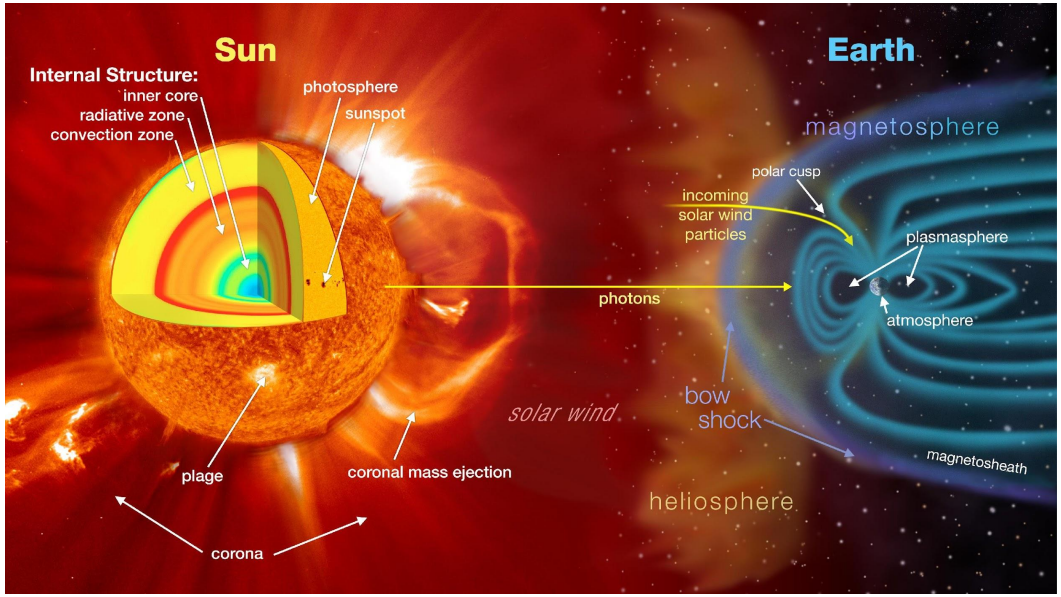
NASA Heliophysics Education Activation Team

April 2024: What is Heliophysics?

Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

It also studies how the Sun varies over time and how those changes can sometimes pose a hazard to humans on Earth and in space.



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Heliophysics Big Year Timeline

Annular Eclipse

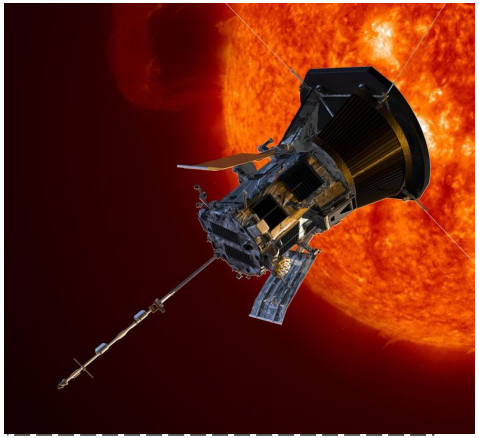
October 14, 2023

Total Eclipse

April 8, 2024

Solar Parker Probe Perihelion

December 24, 2024



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Heliophysics Big Year Themes

2023

- ☑ **October-** Annular Solar Eclipse
- ☑ **November-** Mission Fleet
- ☑ **December-** Citizen Science

2024

- ☑ **January-** The Sun Touches Everything
- ☑ **February-** Fashion
- ☑ **March-** Experiencing the Sun
- **April-** Total Solar Eclipse
- **May-** Visual Art
- **June-** Performance Art
- **July-** Physical and Mental Health
- **August-** Back to School
- **September-** Environment / Sustainability
- **November-** Bonus Science
- **December-** Parker's Perihelion

https://www.nasa.gov/science-research/heliophysics/nasa-announces-monthly-themes-to-celebrate-the-heliophysics-big-year/

April 2024 : NASA's Big Questions

1. What causes the Sun to vary?
2. How do the Earth and the heliosphere respond?
3. What are the impacts on humanity?

These Big Questions form the basis for the

Framework for Heliophysics Education

https://science.nasa.gov/learn/heat/big-ideas/

How to Teach Heliophysics

Framework for Heliophysics Education

3 Heliophysics Investigatory Questions

↓

3 NGSS-aligned Big Ideas per Question

↓

3 Guiding Questions per Idea
-1 Question per Level-

↓

Heliophysics Resource Database

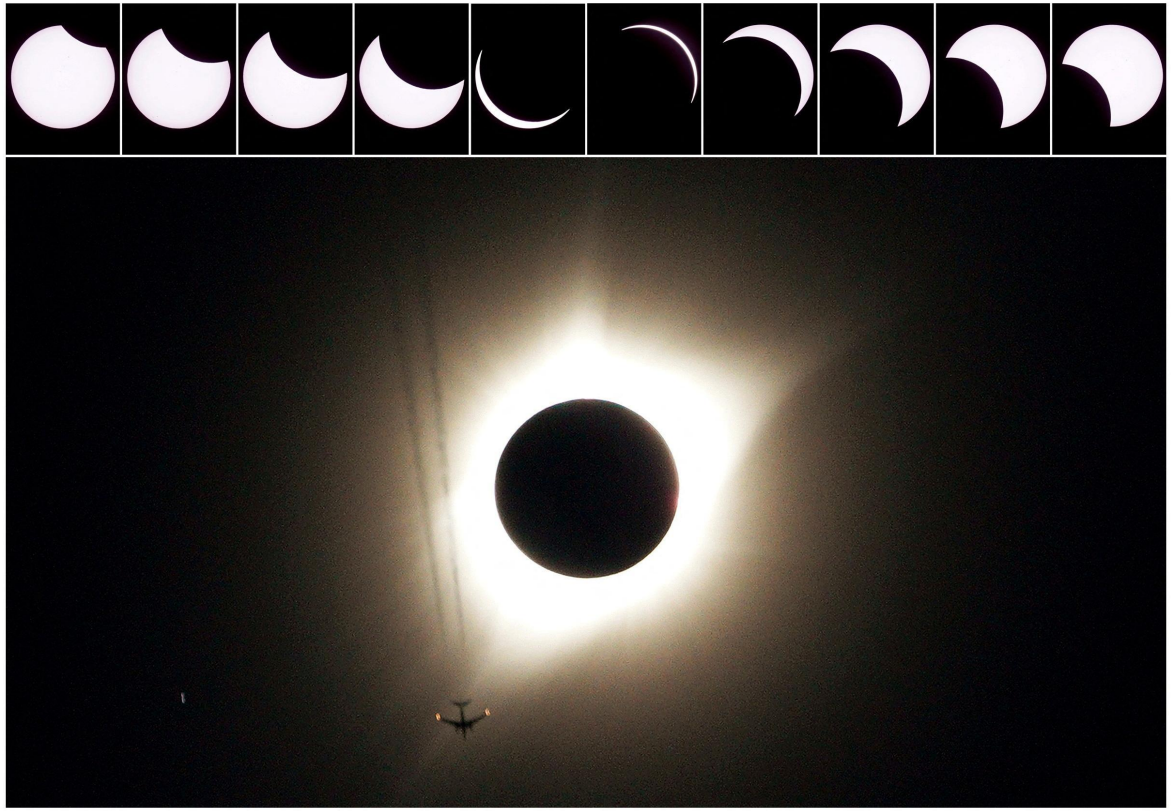
1. **What causes the Sun to vary?**
   1.1 The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)
   1.2 The Sun is active and can impact technology on Earth via space weather. (PS1,PS2, PS4, ESS2, ESS3)
   1.3 The Sun's energy drives Earth's climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

1. **How do Earth, the solar system, and the heliosphere respond to changes on the Sun?**
   2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)
   2.2 The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)
   2.3 The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

1. **What are the impacts of changes on the Sun on humans?**
   3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)
   3.2 Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)
   3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

April 2024 – Total Solar Eclipse

April 8, 2024.

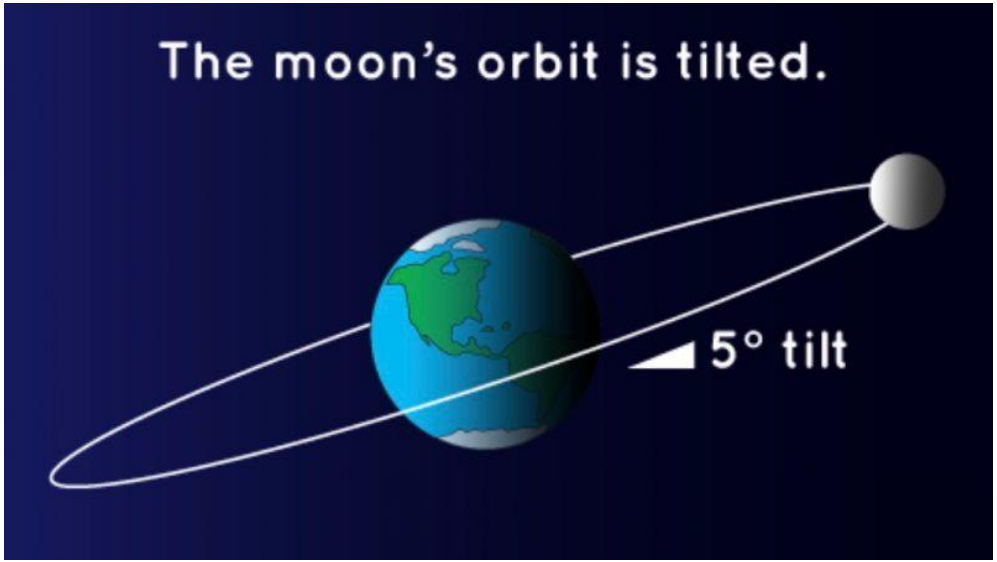


(Credit: Reuters)

April 2024 – Total Solar Eclipse

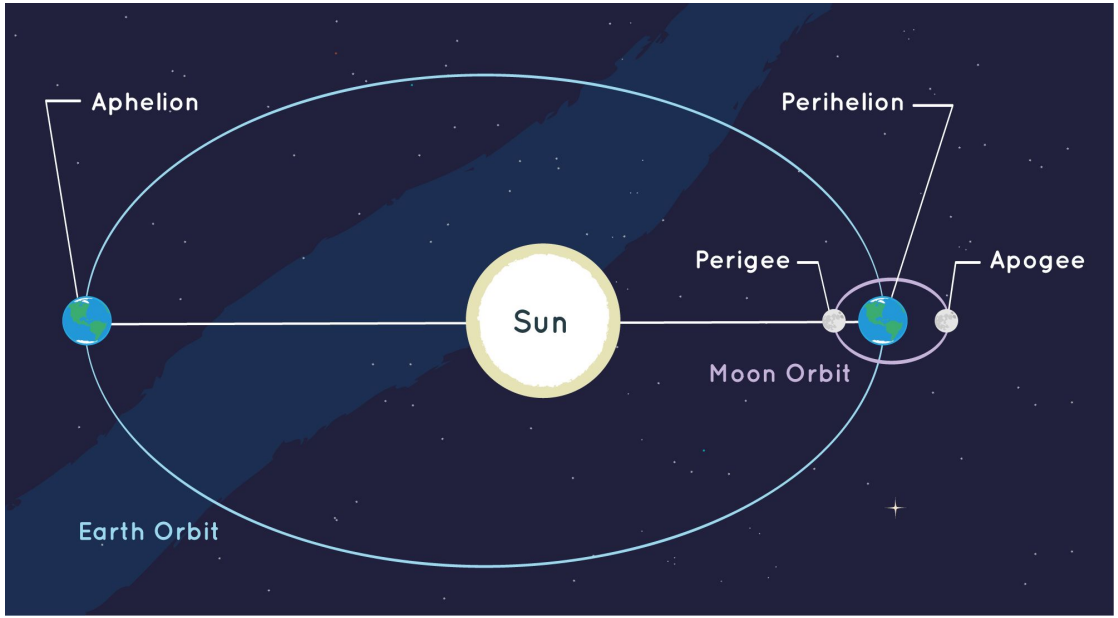
Illustration of the tilt of the Moon's orbit, with respect to the Earth-Sun plane.

It's why we don't have lunar and solar eclipses every month. Not to scale. Image via NASA SpacePlace.



April 2024 – Total Solar Eclipse

The point at which a planet is closest to the Sun is called perihelion. The farthest point is called aphelion. (Credit: NOAA)



April 2024 – Total Solar Eclipse

Lunar size

Credit John Walker

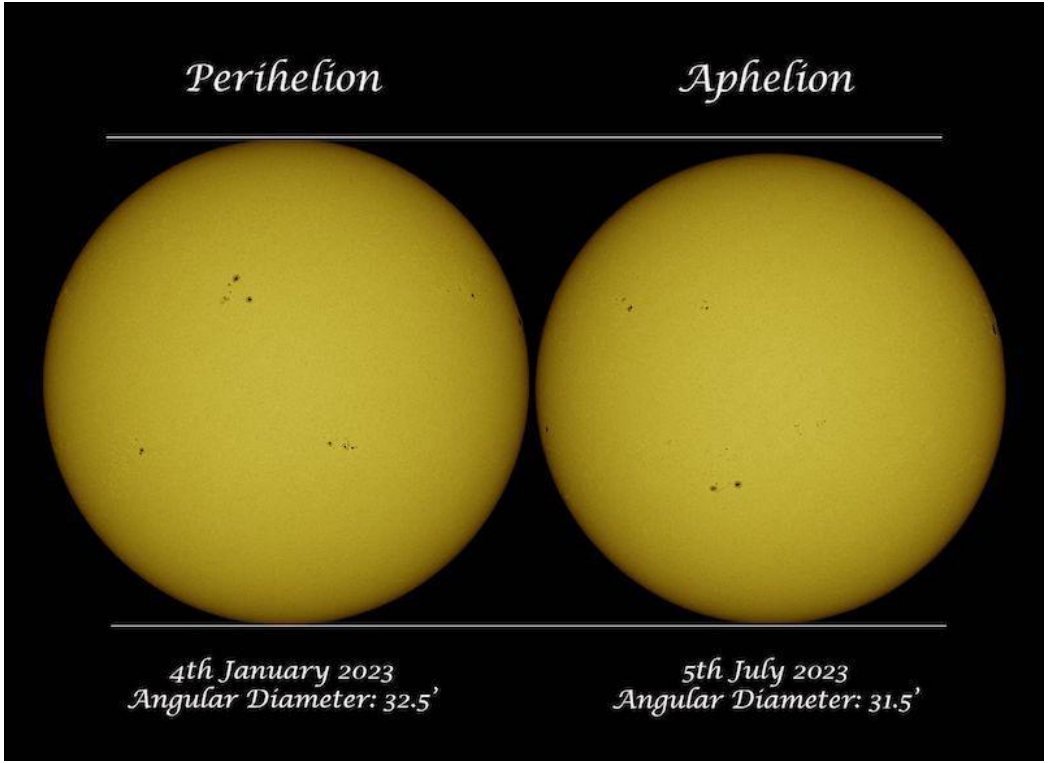
https://www.fourmilab.ch/earthview/moon_ap_per.html

Perigee

Apogee

April 2024 – Total Solar Eclipse

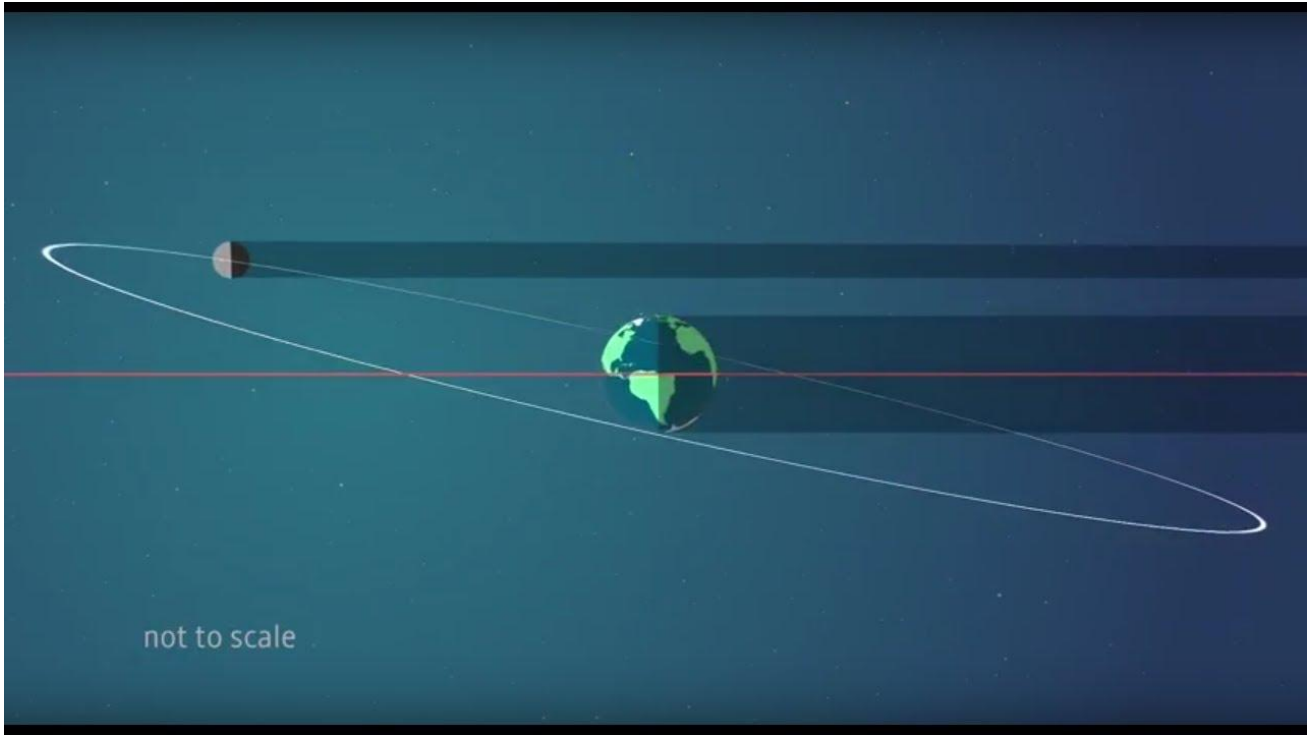
Sun size comparison



(Credit: EarthSky/ Soumyadeep Mukherjee)

April 2024 – Total Solar Eclipse

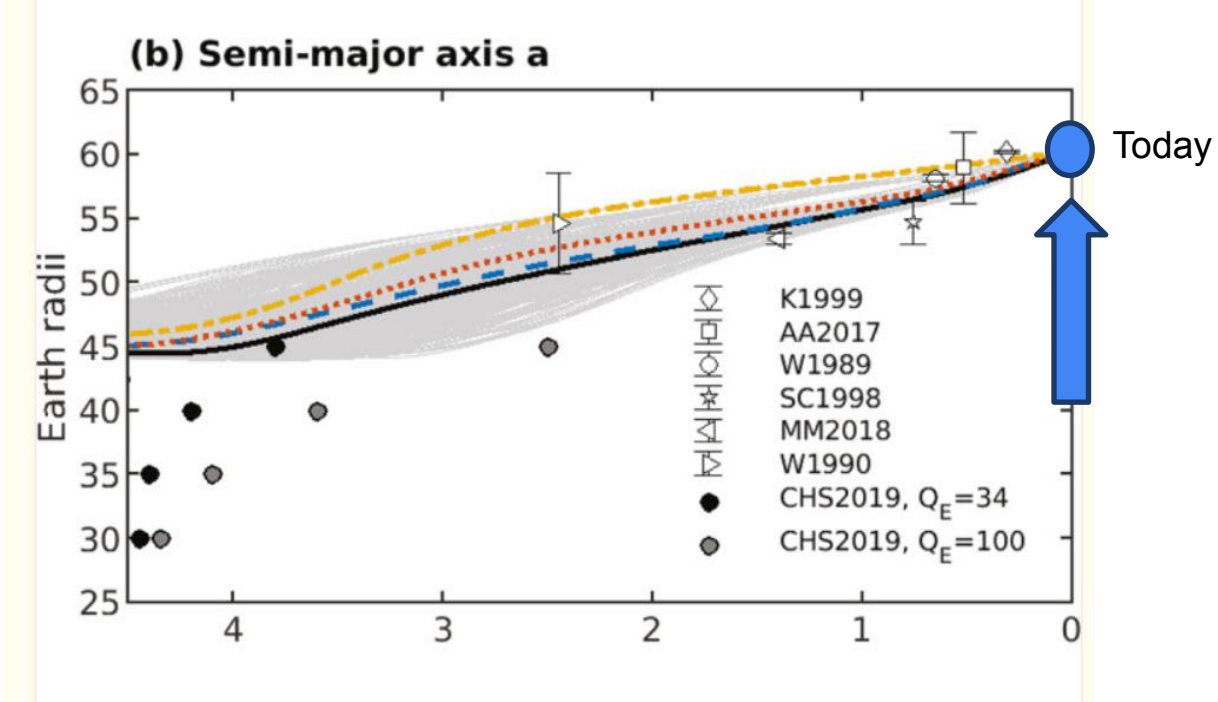
As the Moon orbits Earth, it also wobbles up and down, making total eclipses rarer than they otherwise would be. **Credit:** *NASA*



April 2024 – Total Solar Eclipse

Moon orbit drift from geology and recent lunar laser ranging.

Current rate is 3 cm/year



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April 2024 – Total Solar Eclipse

Conclusions

There was a time when the Moon was so close it completely blocked the disk of the Sun.

There will come a time when the Moon's disk will always appear too small to fully block the Sun.

This means that one day, there will be an end to Total Solar Eclipses.

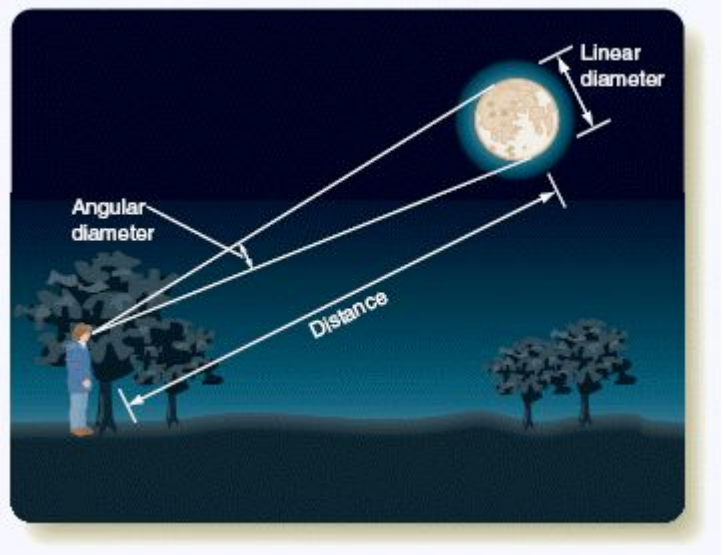
April 2024 – Beginners: Angular size

We see things as they appear to be to our eyes and brain.

We may know that a car is 10-feet long, but when we see it at a distance it appears smaller.

Our Moon is 3,475 km in diameter, but at a distance of 363,000 km from Earth, it is only about as big as a child's fingernail at arms-length.

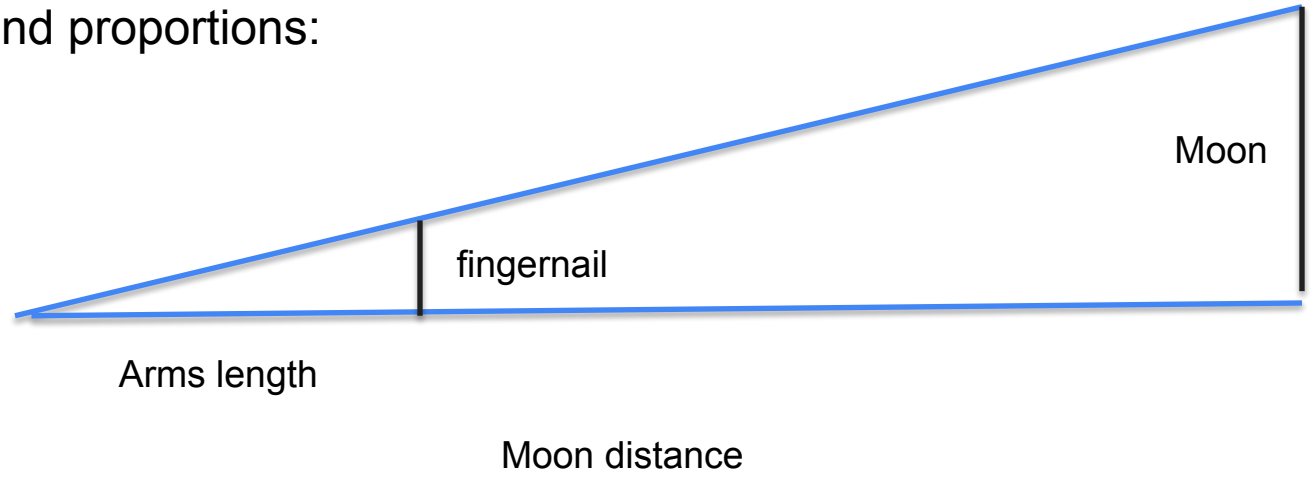
We can see how this works using 'similar triangles'.



Seeds Foundations of Astronomy, 9th edition

April 2024 – Beginners: Angular size

Similar Triangles and proportions:



April 2024 – Beginners: Angular size

Proportions: Show that the thumb has about same proportion to the Moon and so its angle is the same.

Arm = 24-inches

Fingernail = ¼-inch 0.25-inch / 24-inches = **0.01** angle = 0.6°

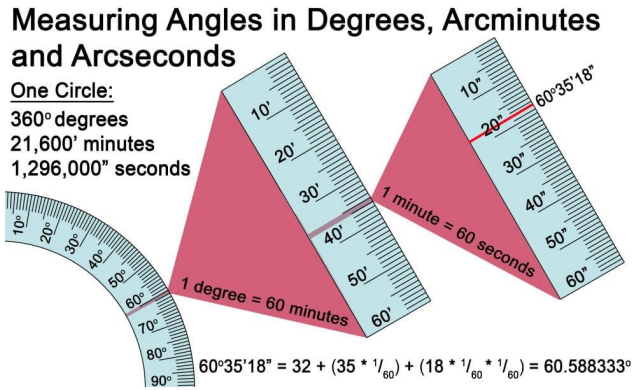
Moon = 3,500 km

Distance = 363,000 km 3,500 km / 363,000 km = **0.01** angle = 0.6°

April 2024 – Intermediate: Lunar distance

The Moon's angular size is given by

$$\Theta = 57.3^{o} \times \frac{\text{Linear diameter (km)}}{\text{Distance (km)}}$$



Example: For a diameter = 3,500 km and D = 363,000 km

$\Theta = 57.3^{o} \times 3500/363000 = 0.55^{o}$

We prefer to use arc-sec measure where $1^{o} = 3600$ " so

$\Theta = 0.55 \times 3600 = 1988$"

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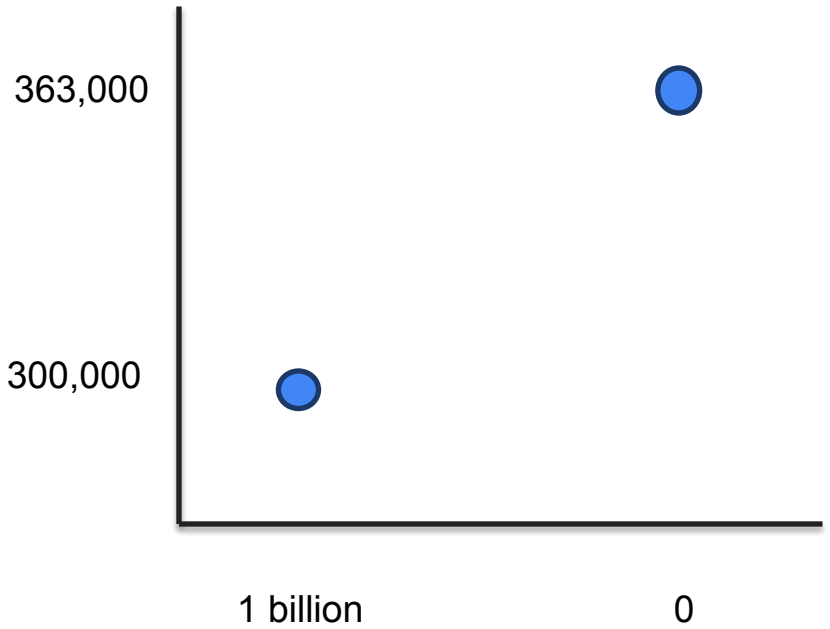
April 2024 – Intermediate: Lunar Distance

Over the last one billion years, the lunar distance has increased from 300,000 km to 363,000 km.

What linear equation models this change in distance?



April 2024 – Intermediate: Lunar Distance

Over the last one billion years, the lunar distance has increased from 300,000 km to 363,000 km.

What linear equation models this change in distance?

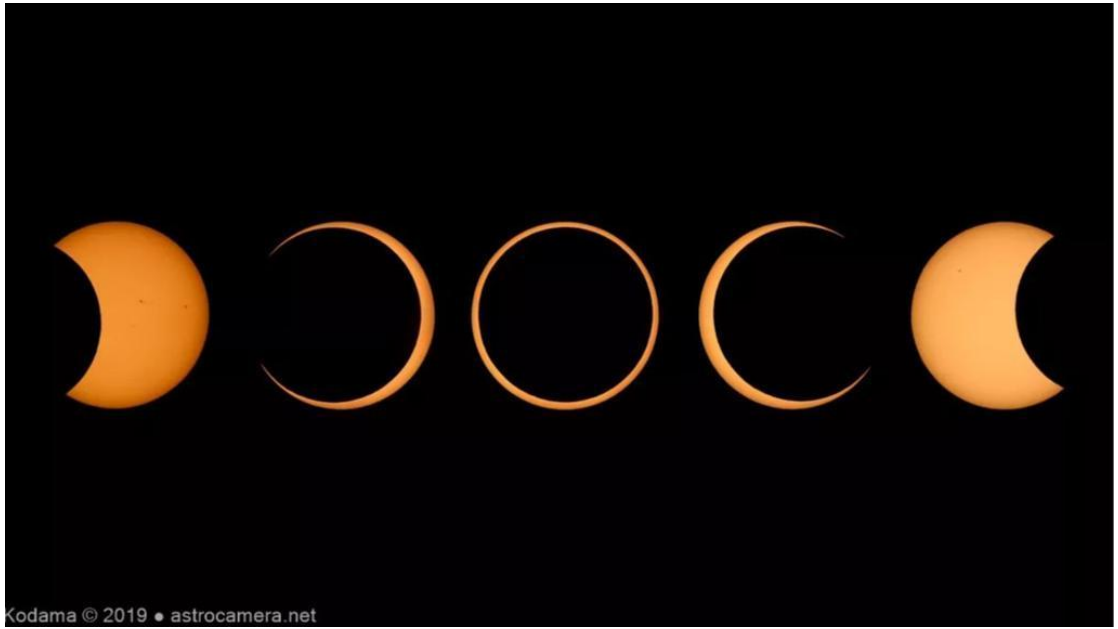
Slope = (363000-300000)/1000 million years = 63 km/Myr

D = 300,000 + 63 T

Where T is in millions of years.

April 2024 – Intermediate:

If the Sun's diameter is 0.5° today, in how many million years will the Moon's diameter start to be less than the Sun's diameter?



April 2024 – Intermediate:

If the Sun's diameter is 0.5 today, in how many million years will the Moon's diameter start to be less than this?

$$\Theta = 57.3^{o} \frac{3{,}500\ km}{D} = 0.5^{o}$$

$$D = (57.3/0.5) \times 3500\ km = 401{,}000\ km.$$

Then:

401,000 km = 363,000 +63T

T = 600 million years.

Image Credit: Detlev Van Ravenswaay

April 2024 – Advanced: Everything Changes!

The Sun's radius is changing

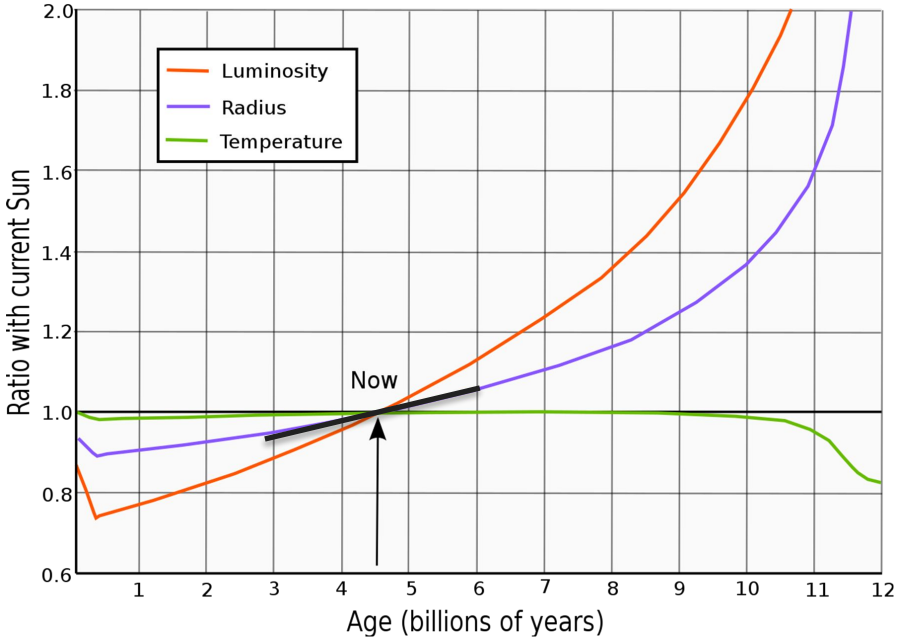
1 billion yrs ago = 95% of today
1 billion yrs from now = 105% of today

What is a linear equation that models the diameter change in time units of 1 million yrs if the radius today is 696,000 km?

The lunar distance is changing too.

Perigee distance:
D = 363,000 + 63T km

Apogee distance:
D = 405,000 + 63T km



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April 2024 – Advanced: Everything Changes!

The Sun's diameter is changing

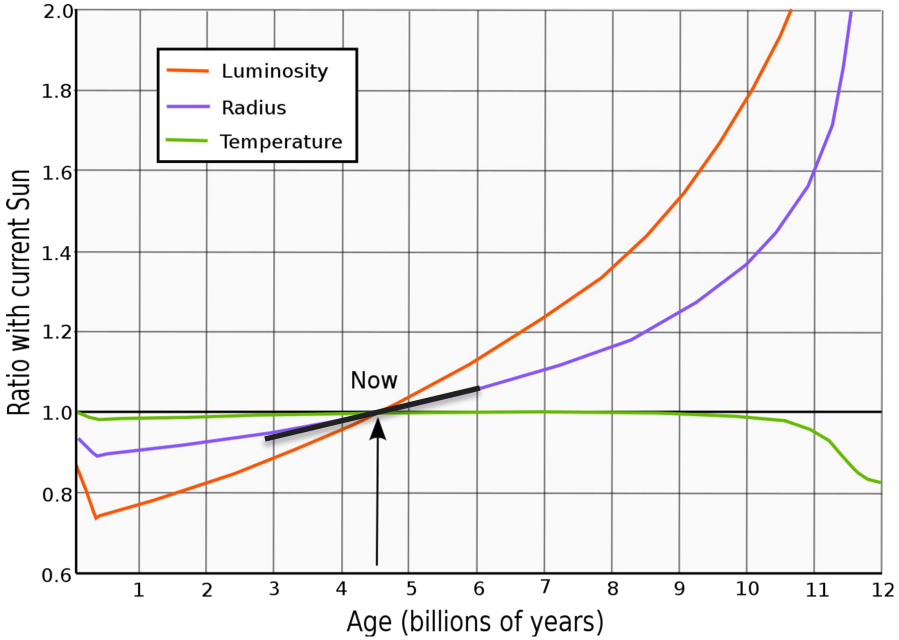
1 billion yrs ago = 95% of today
R = 696,000 x 0.95 = 661,000 km
T = -1000 Myrs

1 billion yrs from now = 105% of today
R = 696,000 x 1.05 = 730,800 km
T = +1000 Myrs

Slope = (730800-661000)/(1000-(-1000))
= 69800k m/2000 Myr
= +35 km/Myr.

R = 696,000 + 35 T km

Diameter = 1,392,000 + 70T km



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April 2024 – Advanced: Everything Changes!

What are the formulae for the angular size of the Sun and Moon assuming the distance to the Sun is fixed at 150 million km?

Q = 57.3 x (Diameter (km)/Distance (km)) degrees

Sun:
Θs = 57.3 x (1,392,000 + 70T km)/150 million km
Θs = 0.50 + 0.000027 T

Moon Apogee:
Distance = 405000+63T
Θa = 57.3 x (3,500) / (405000+63T)

Moon Perigee:
D = 363,000 + 63T km
Θp = 57.3 x (3,500) / (363,000+63T)

April 2024 – Advanced: Everything Changes!

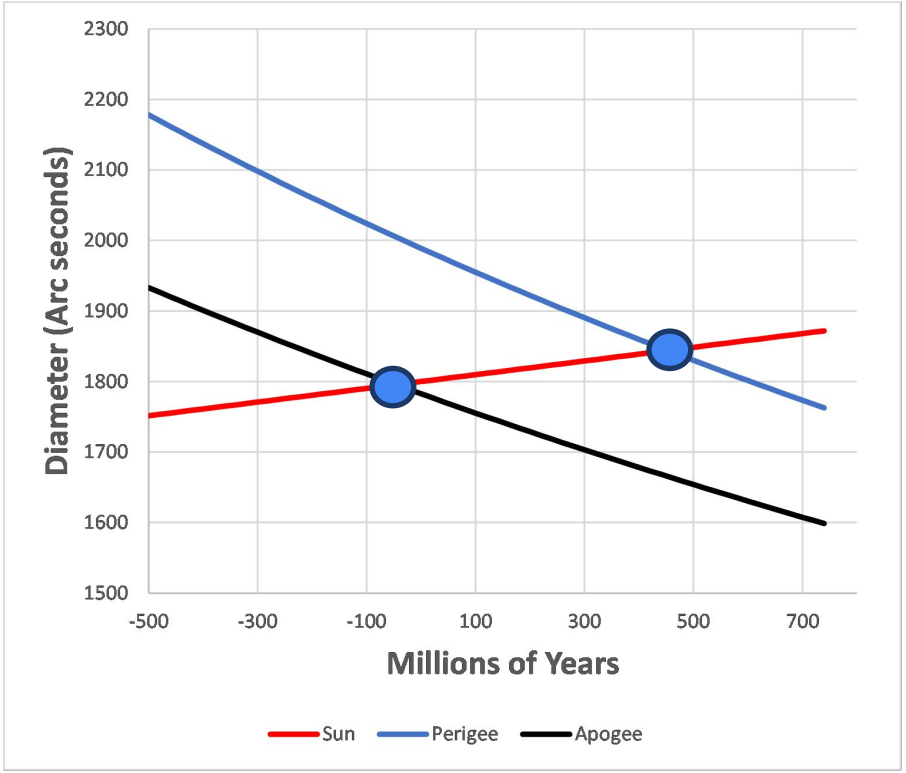
Plot the equations for Θs, Θa and Θp.

When will the first and last total solar eclipses will occur?

Point A = 40 million years ago

Point B = 460 million years from now

This assumes a linear increase in lunar distance, which is not quite accurate,



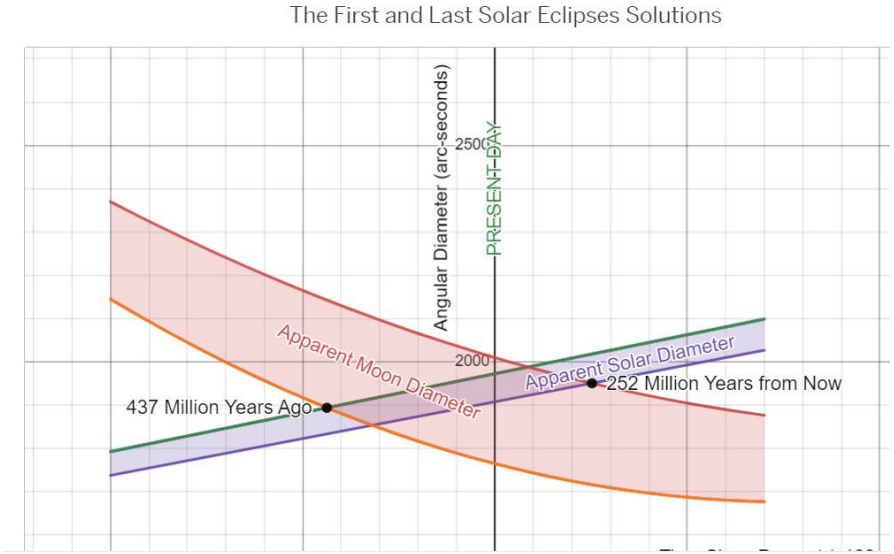
NASA HEAT

April 2024 – Advanced: Everything Changes!

A more accurate prediction is available through DESMOS which uses parabolic lunar evolution and not linear.

Point A = 437 million years ago
Point B = 252 million years from now

DESMOS provides an interactive math lab for students that plots equations and provides the appropriate NGSS and Math standards plus a guided narrative on the nature of the problem.



DESMOS Lab: Created by Luke Henke and Sten Odenwald
https://teacher.desmos.com/activitybuilder/custom/657881d995f85f6585cd3ad5

May 2024: Visual Art

Next Time!

The Sun has been depicted in art for thousands of years. This month looks at ways artists around the world are portraying the Sun, from graphic illustrations to street art to ceramics.

One of the most common beliefs is that the Sun is yellow, but it is actually white, as pictures from the ISS always show.