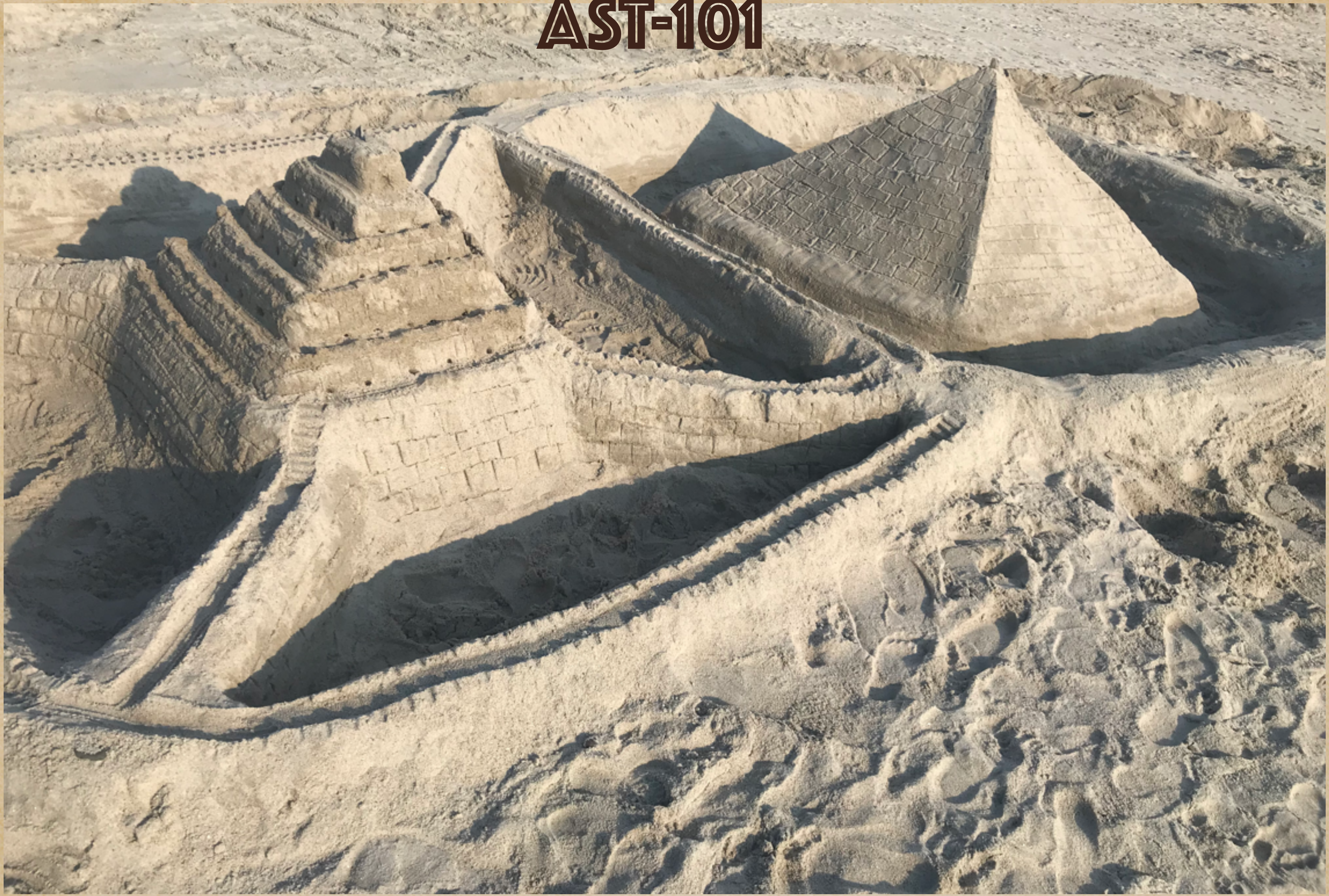
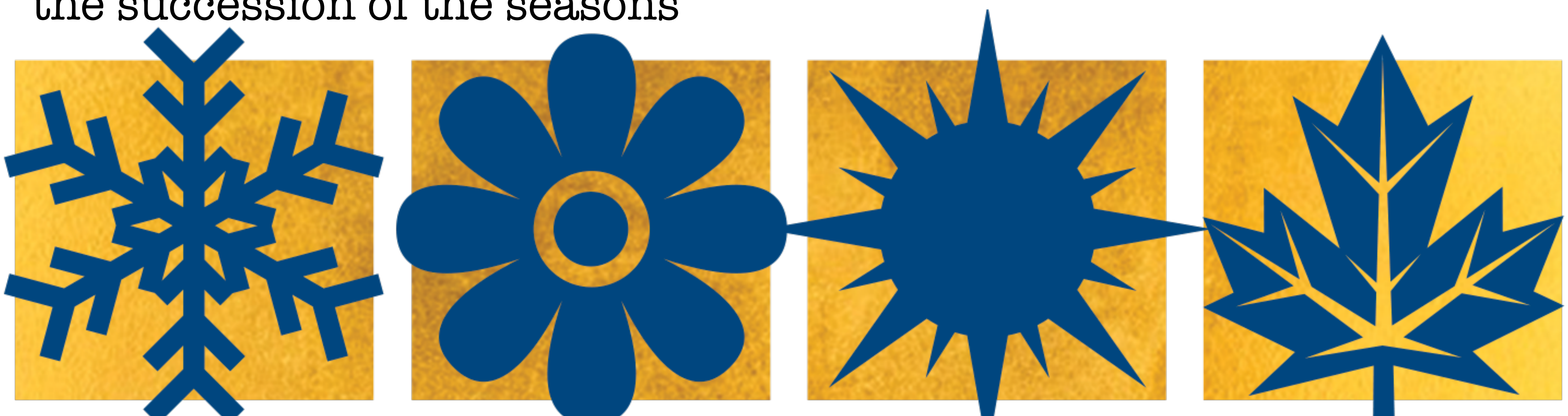


Astronomy before the common era

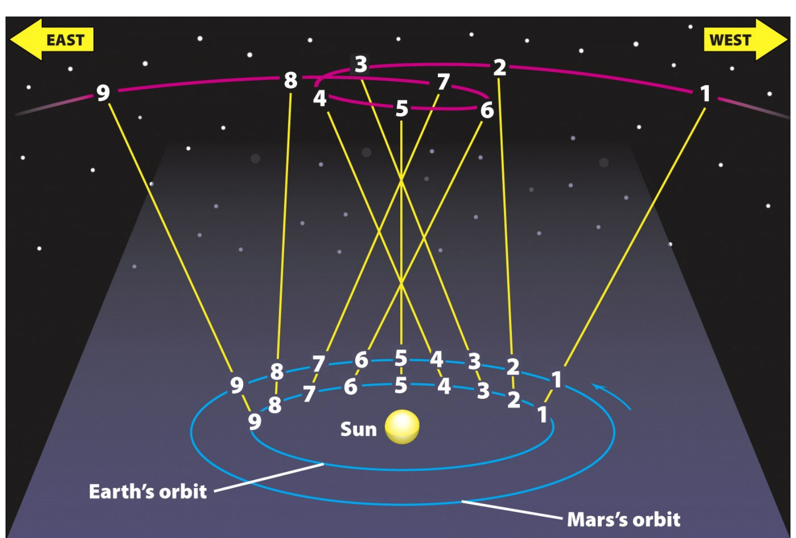
Luis Anchordoqui

The alteration between day and night

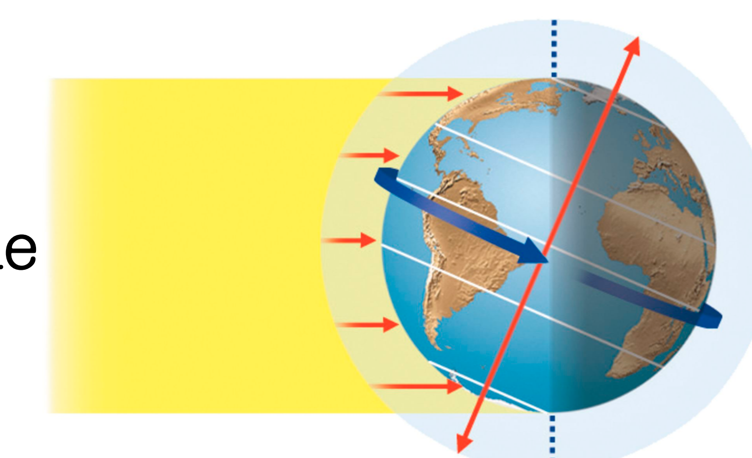
the succession of the seasons



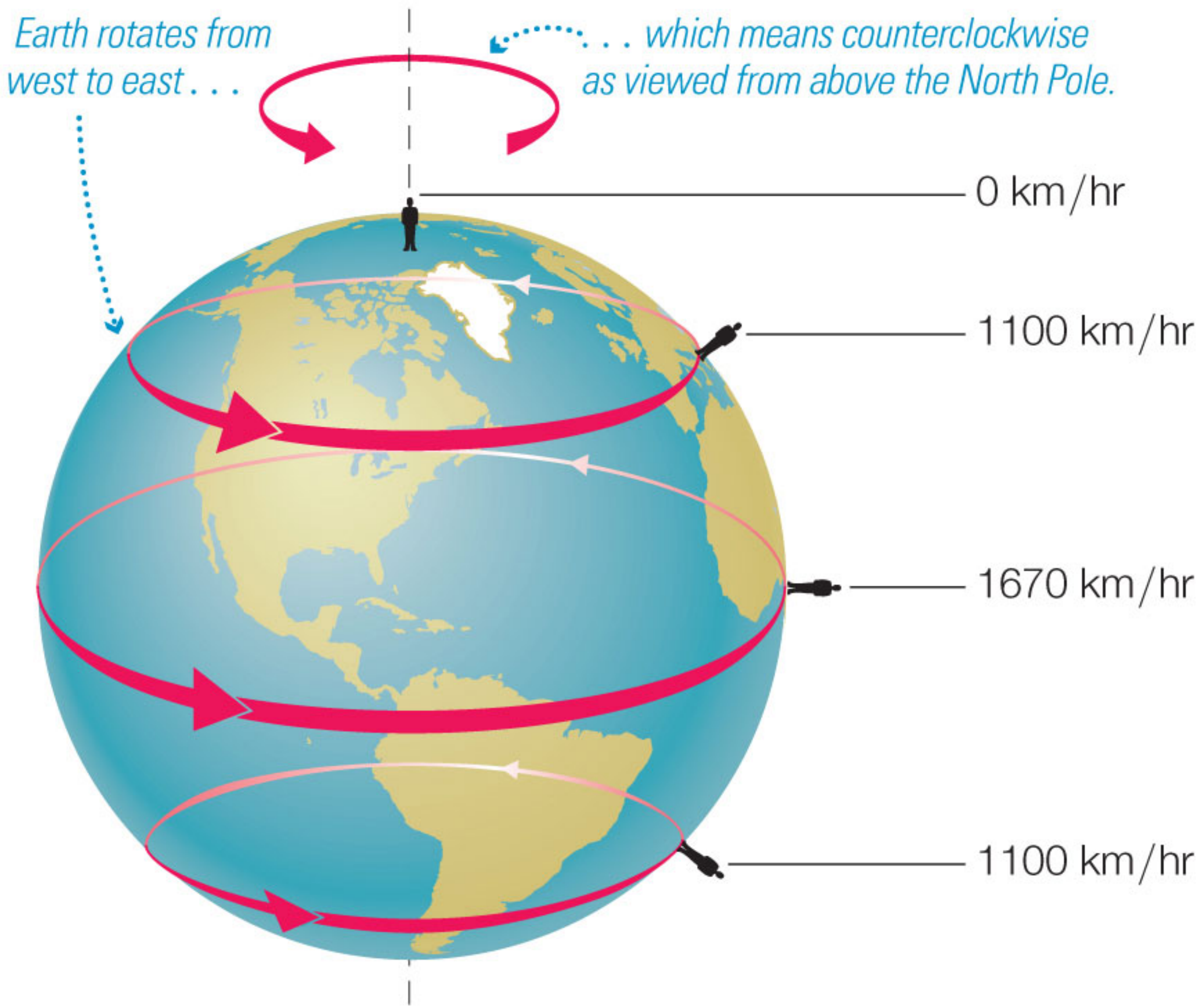
and the observation of the celestial bodies and their movements in the sky

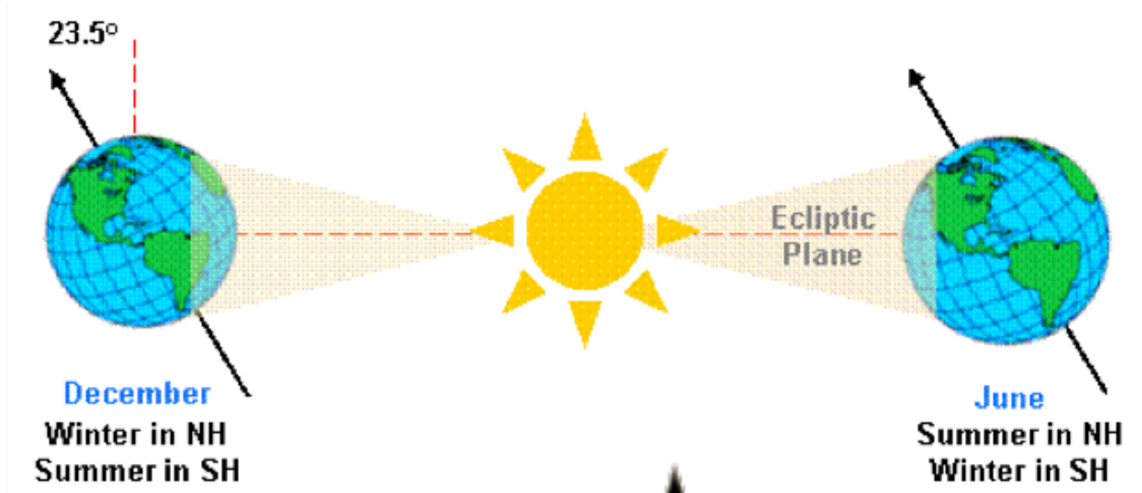


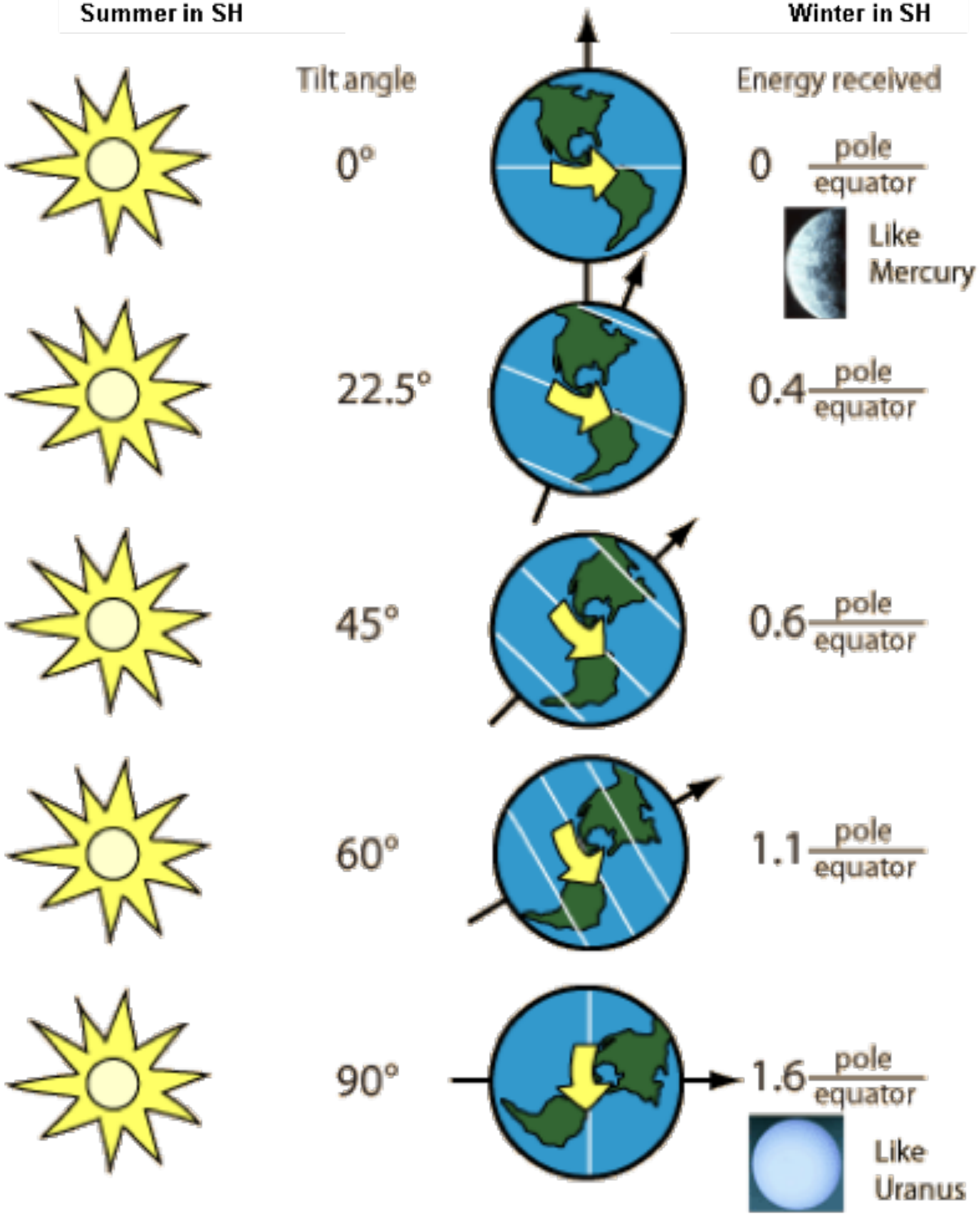
introduced the notion of time



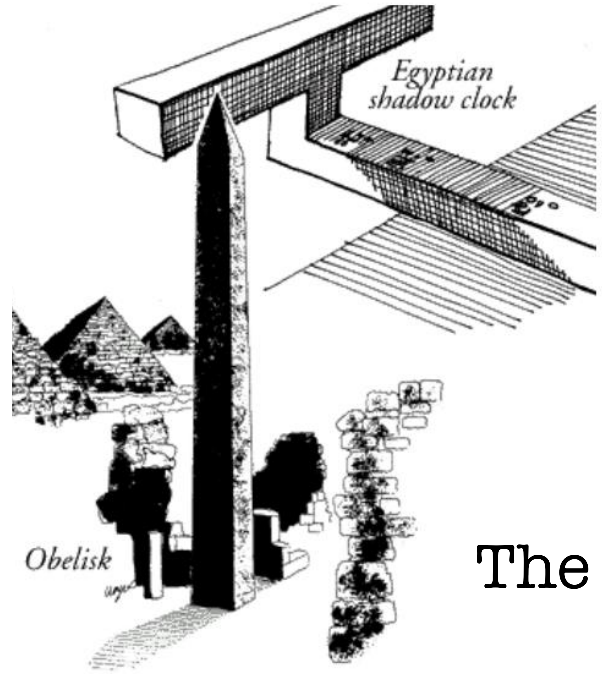
- We now know that we experience day and night because of Earth's rotation around itself
- We experience seasons because of tilt of Earth's axis of rotation as Earth moves around Sun in a year
- Precise understanding of these phenomena came about through careful observations

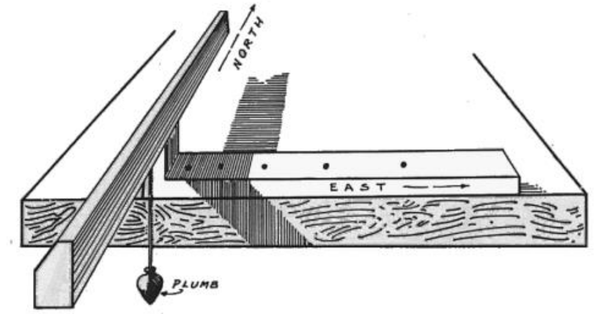



23.5°
Ecliptic
Plane
December
Winter in NH
Summer in SH
June
Summer in NH
Winter in SH


Tilt angle
Energy received
0°
0 pole/equator
Like
Mercury
22.5°
0.4 pole/equator
45°
0.6 pole/equator
60°
1.1 pole/equator
90°
1.6 pole/equator
Like
Uranus

Astronomy has its roots in the work done by the Babylonian and Egyptian civilizations



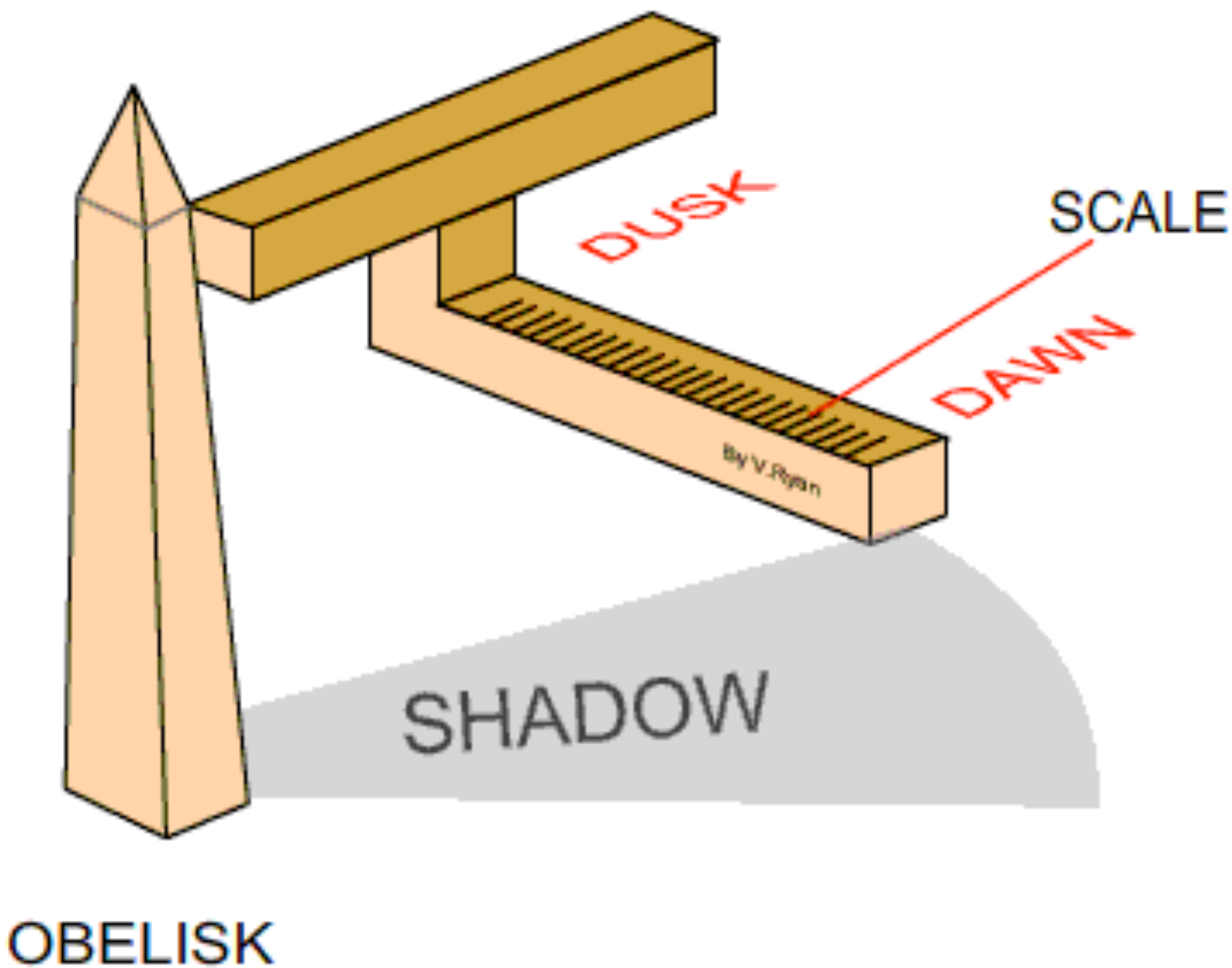


The oldest dial known 1500 BCE

The sundial is considered to be the first scientific instrument

Over a thousand years BCE the Babylonians already had extensive astronomical records with good measurements of time and of Moon positions as well as stars and planets in the sky from which we inherit both our systems of angular and time measurement: the 360° circle and the time units of 24 hrs, 60 minutes, and 60 seconds

Egyptian Sun Clock



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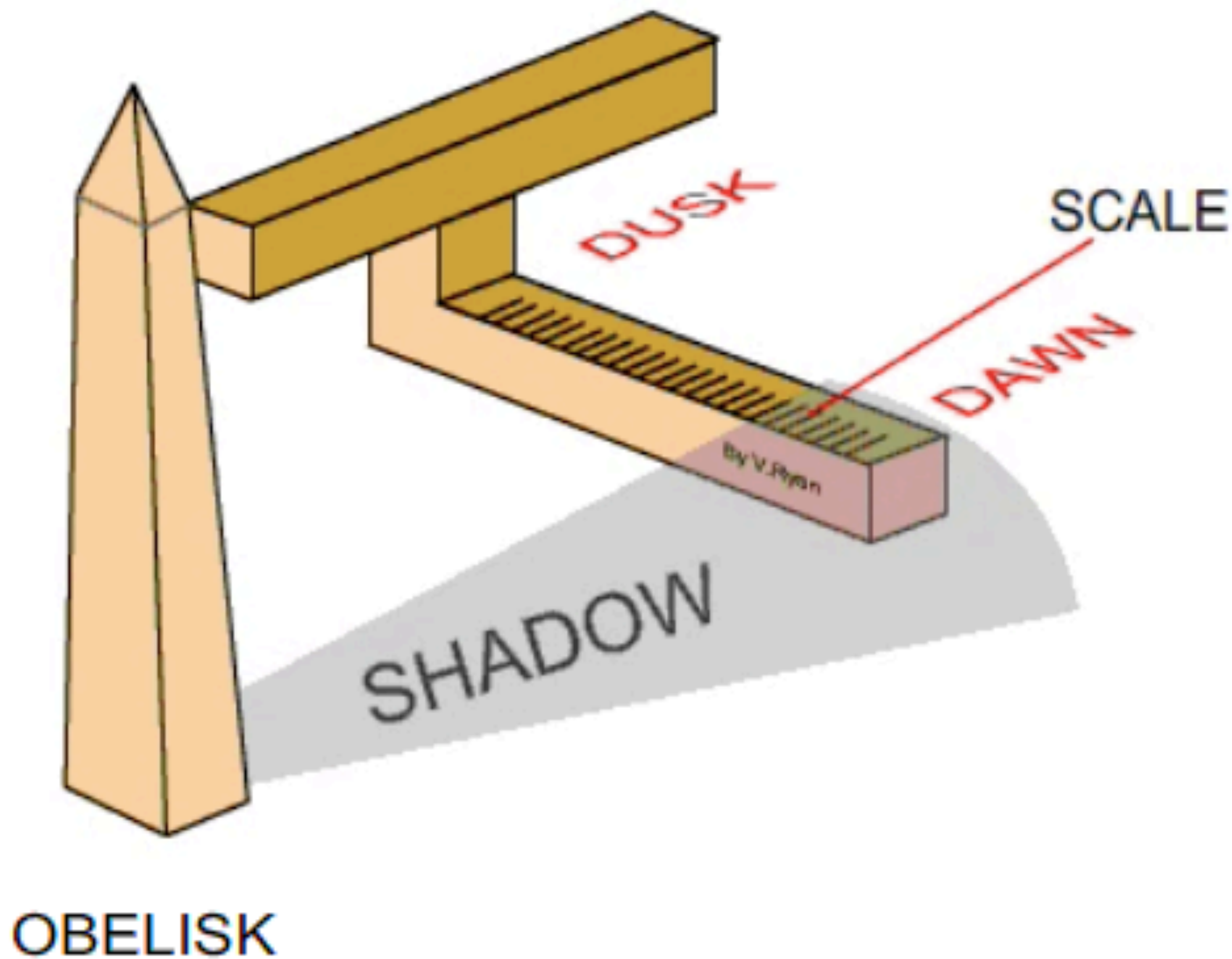

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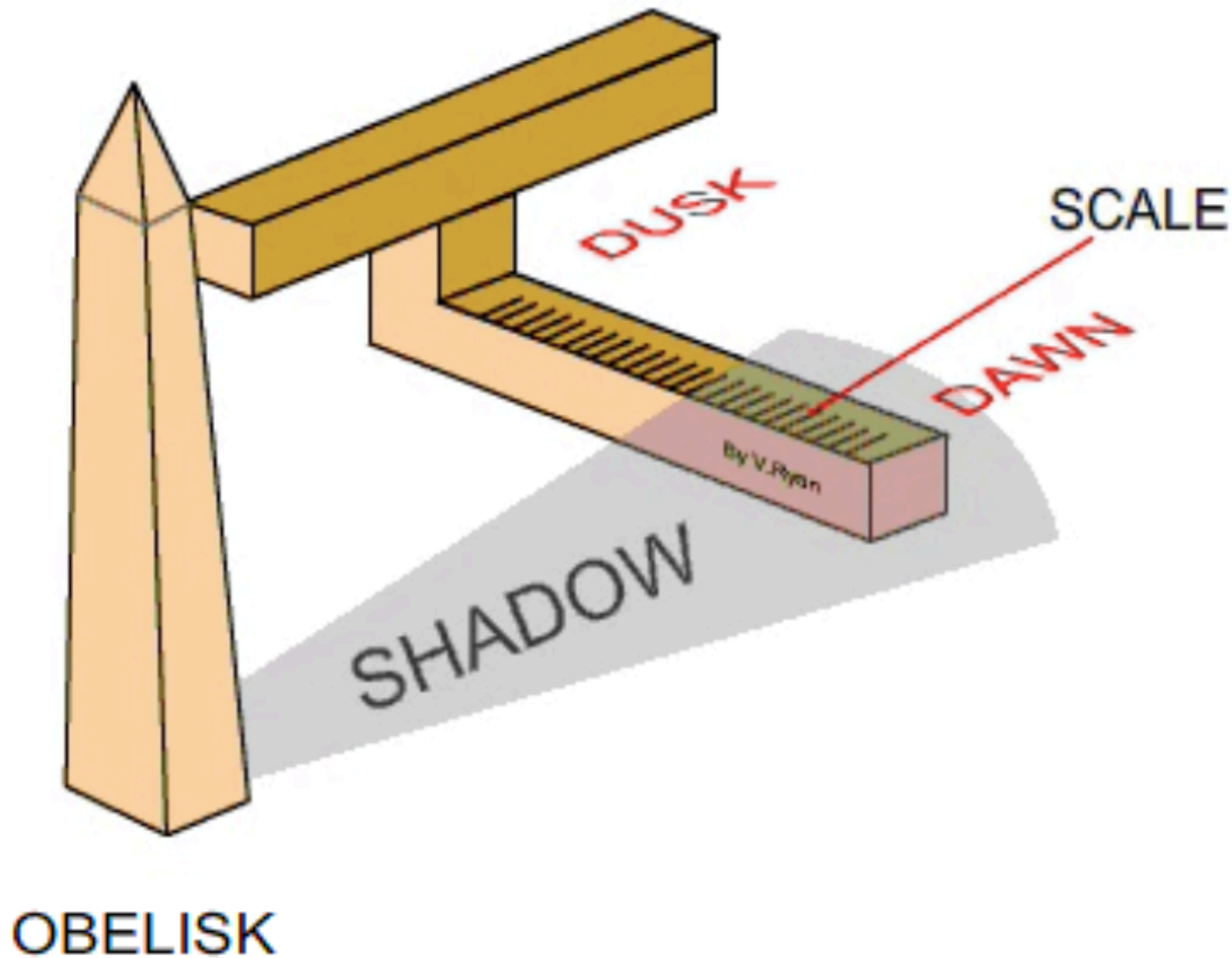
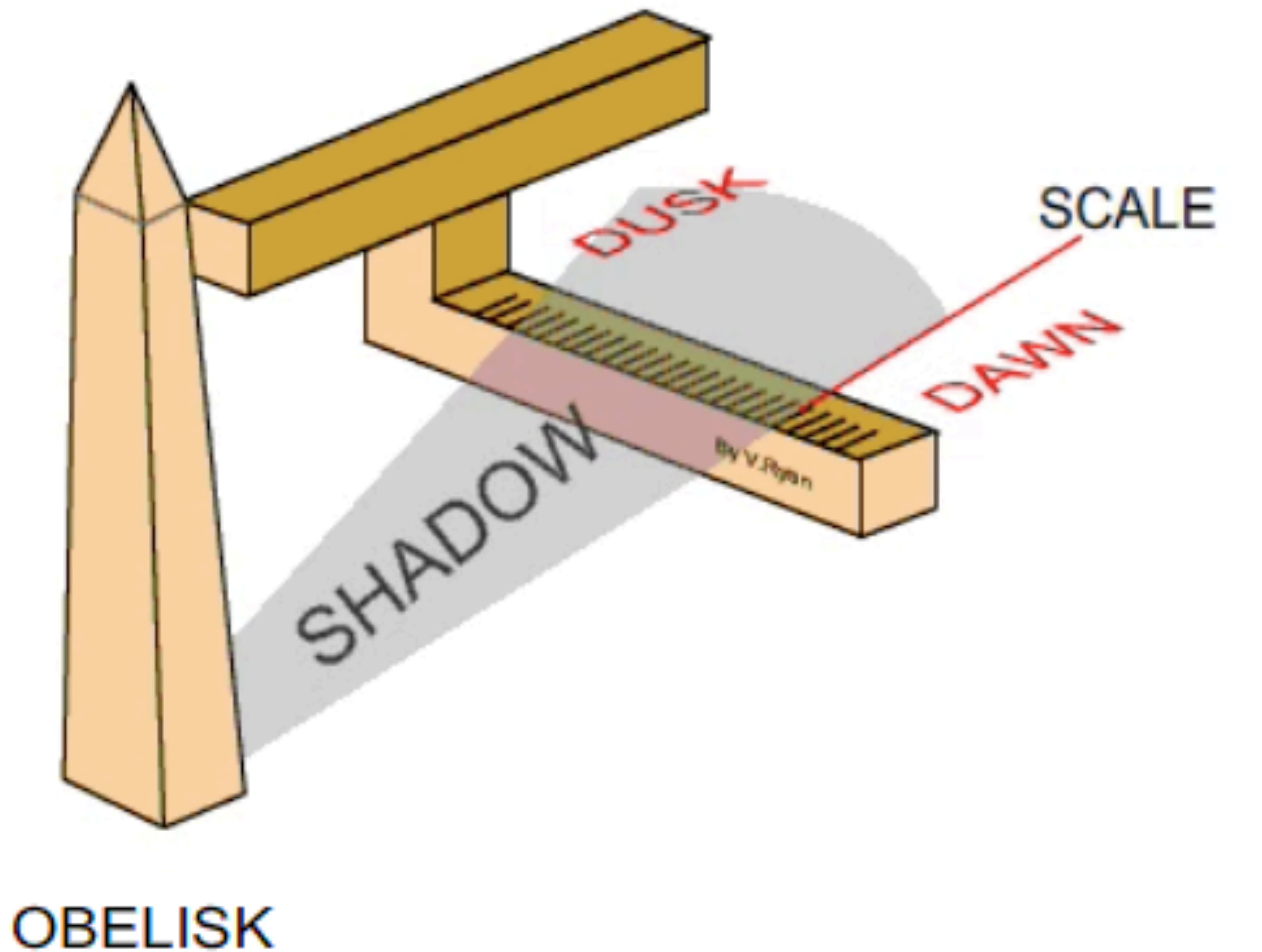


Egyptian Sun Clock



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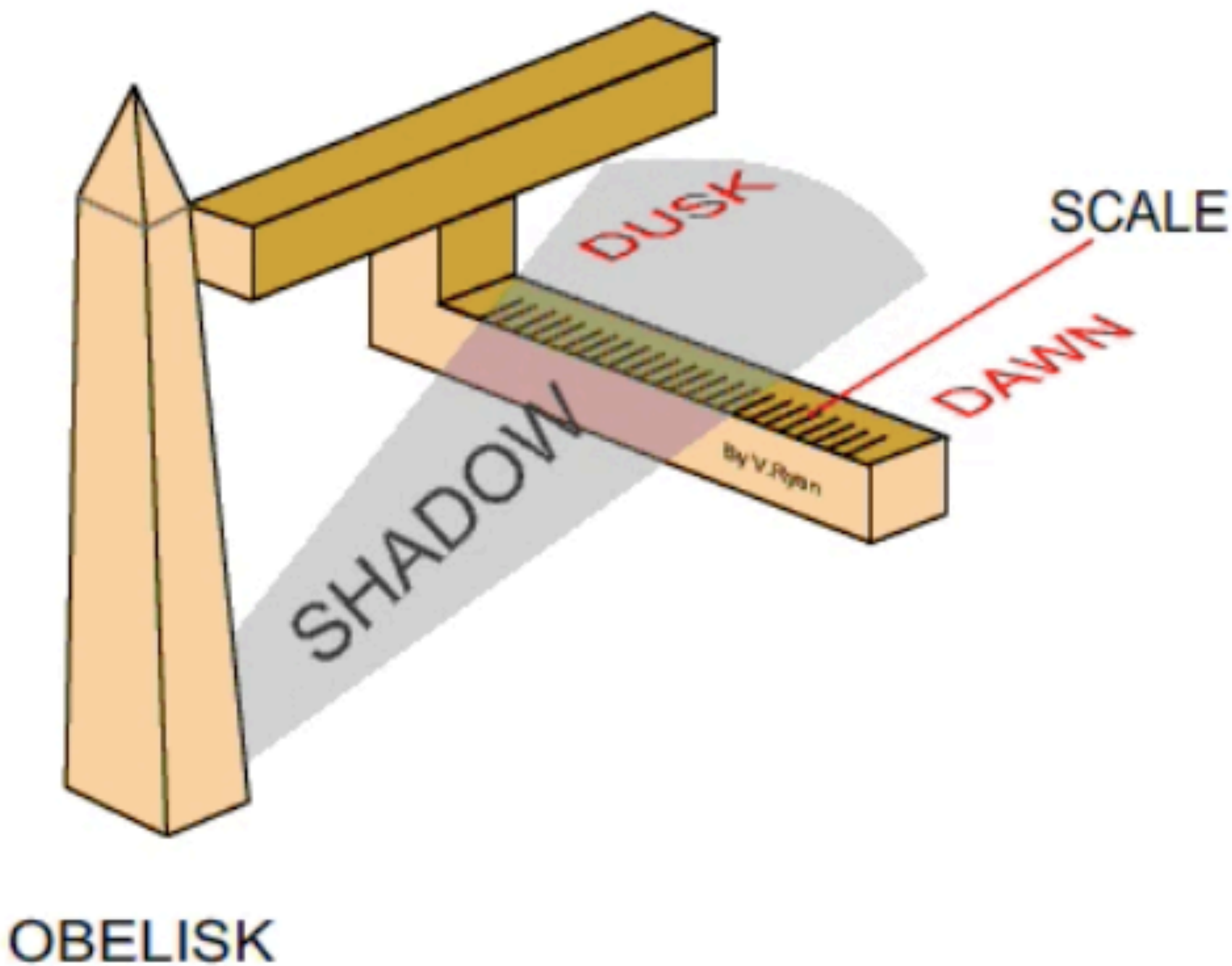
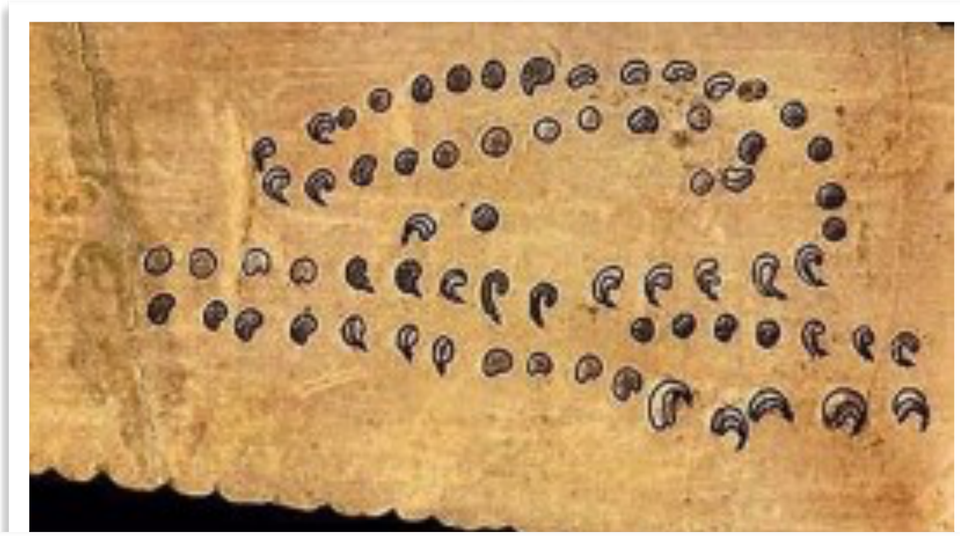


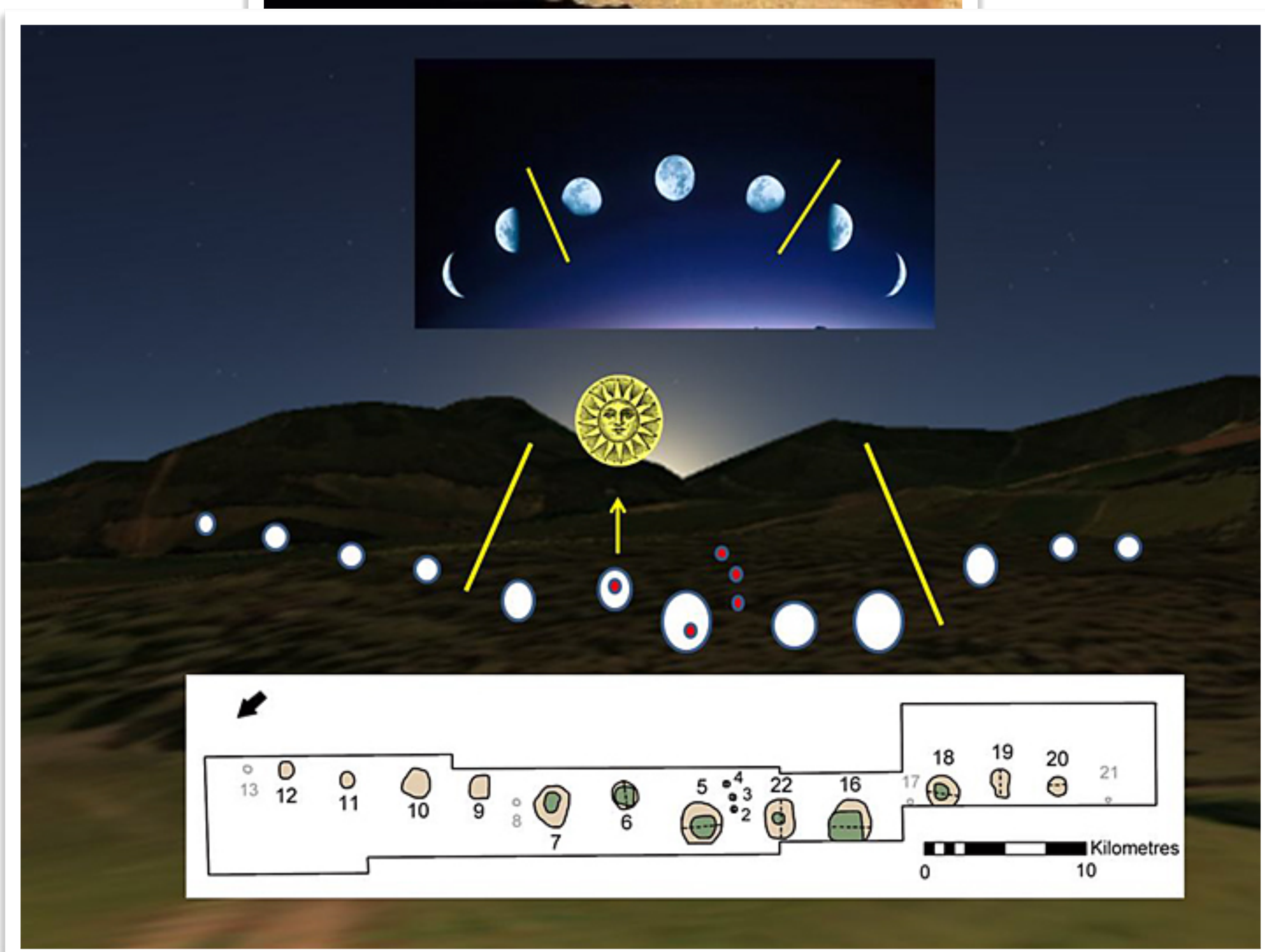
The Babylonian Calendar was a lunisolar Calendar based on the lunar phases

It was used in Babylon and surrounding regions for administrative, commercial, and ritualistic purposes

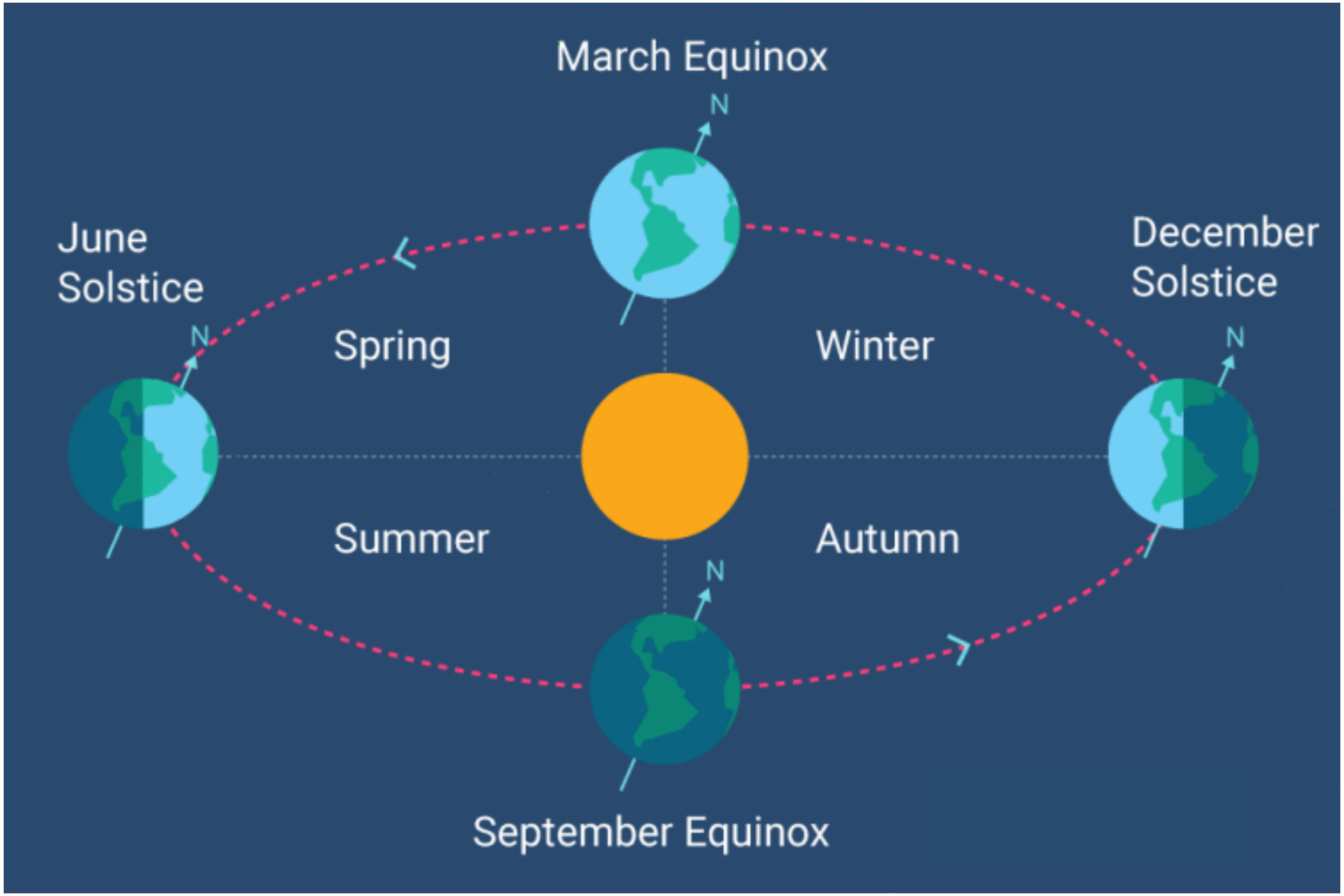
7

Babylonian year consisted of 12 lunar months each beginning on the evening (after sunset) of the first observed (or computed) lunar crescent after the astronomical new moon





The year began around the spring equinox and to keep the calendar in step with the seasons an intercalary month was inserted at (semi-)regular intervals



At first the intercalary months were inserted at irregular intervals based on the observed discrepancies between the calendar and the seasons but after about 500 BCE a regular intercalation scheme consisting of seven intercalary months in a 19-year cycle was adopted

Just like Earth, the Moon rotates on its own axis and experiences daylight and dark cycles

The Moon's day and night cycles are a little longer than Earth's:

the Moon spins on its axis once every 27.3 days

The Moon's period of rotation matches the time of revolution around Earth

This implies that it takes the Moon the same length of time to turn once on its axis as it takes it to go once completely around the Earth

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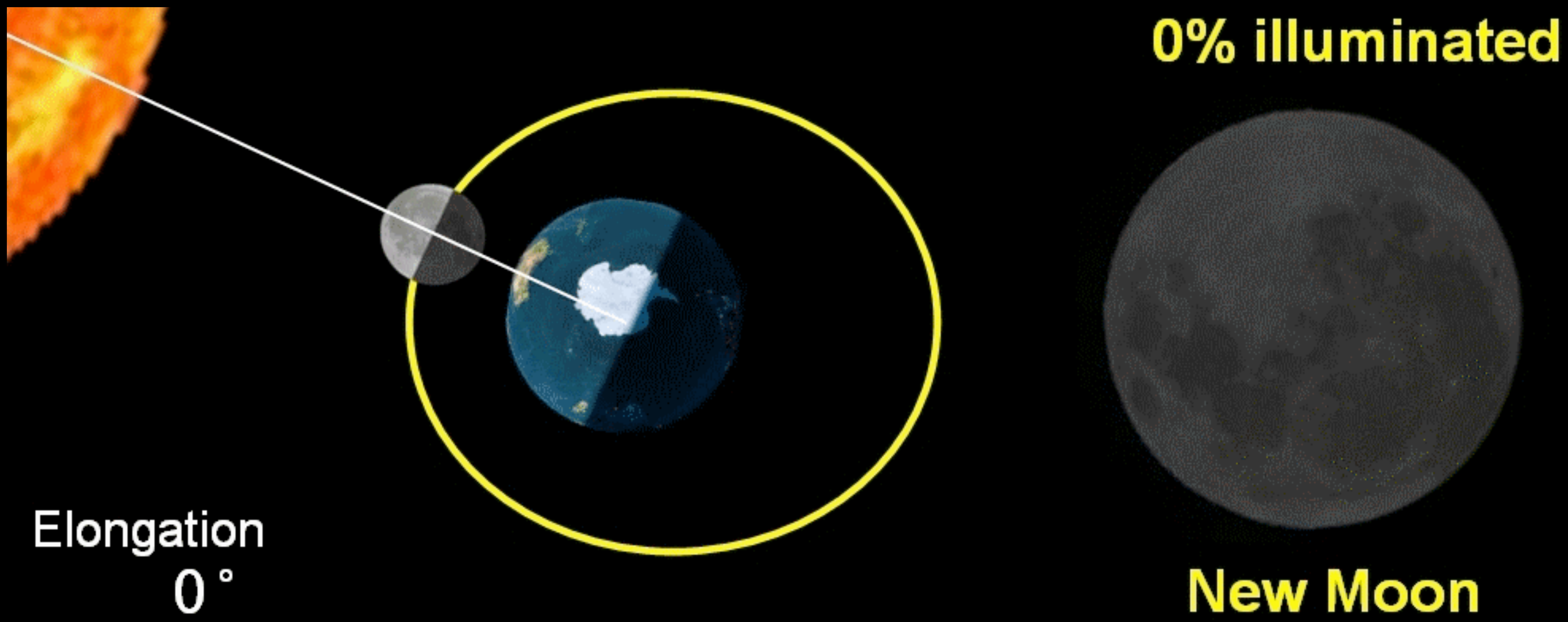
This means that Earth observers always see the same side of the Moon (called the "nearside")

The side we do not see from Earth, called the "farside," has been mapped during lunar missions

The Moon looks different during its revolution around the Earth



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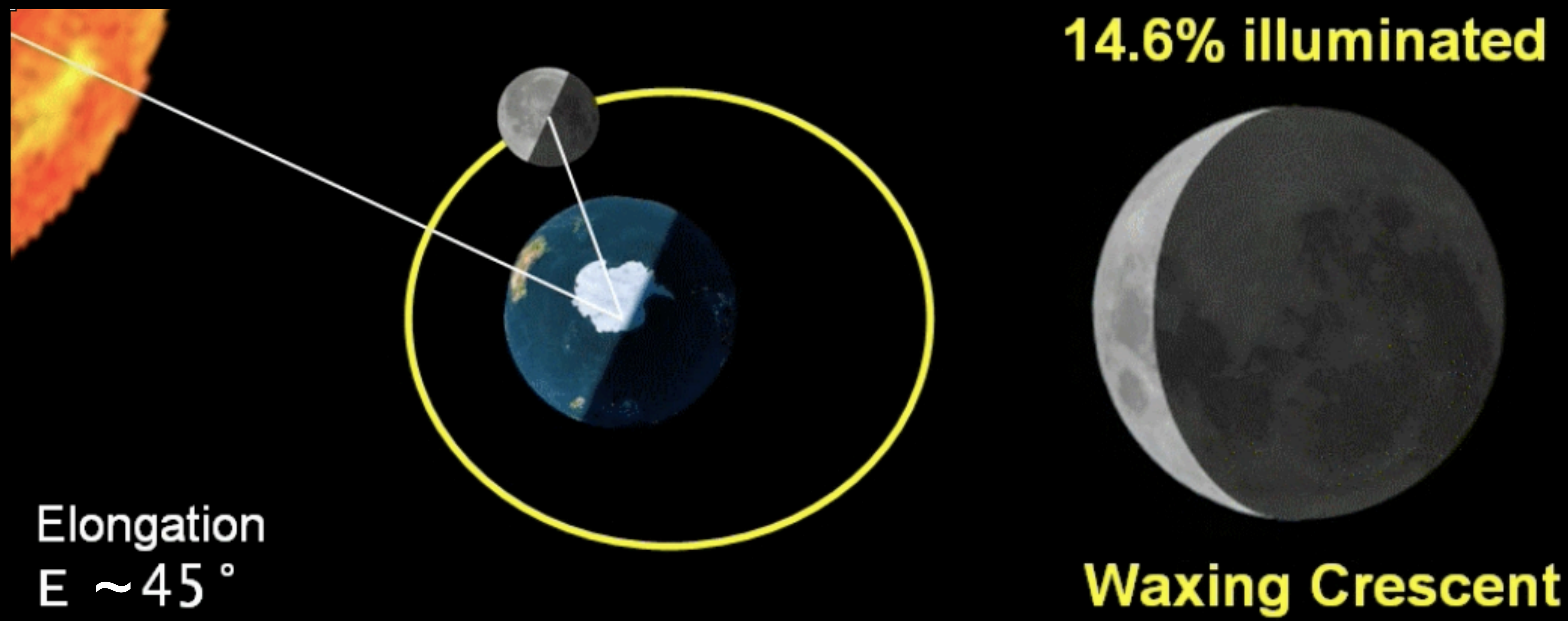

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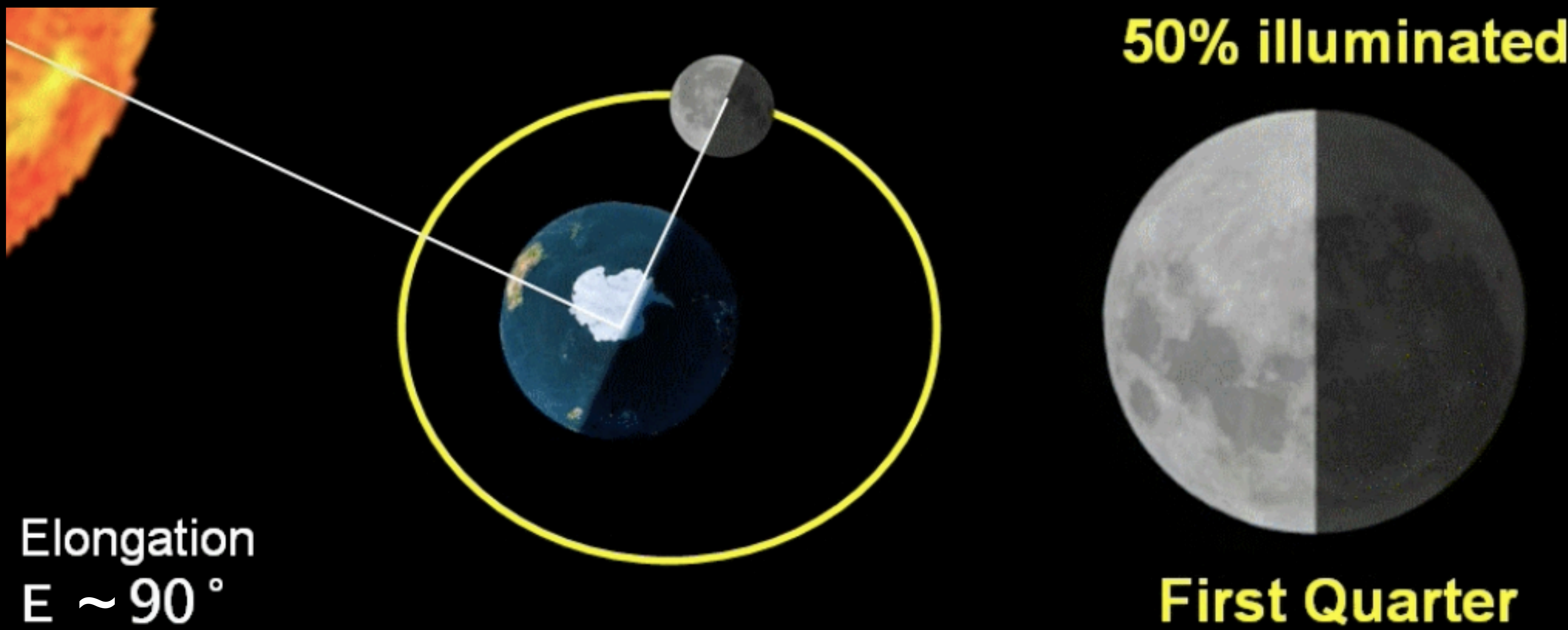

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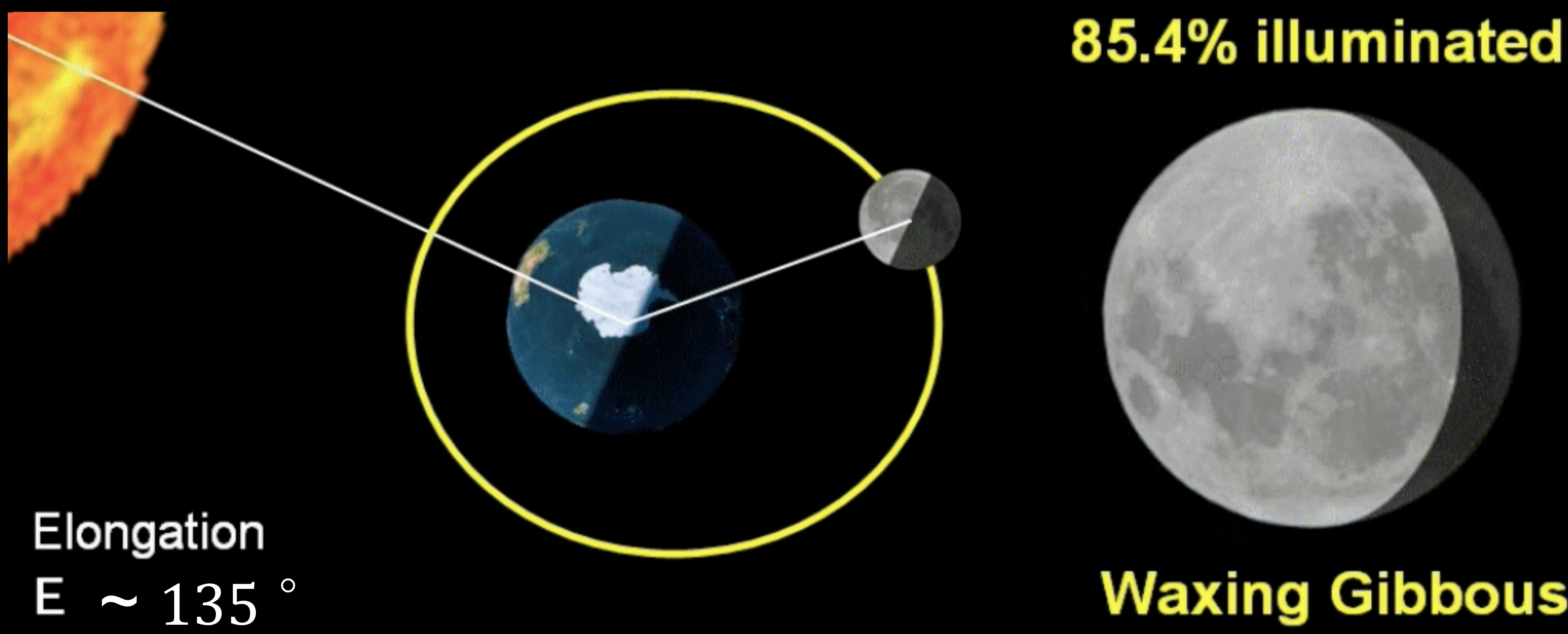

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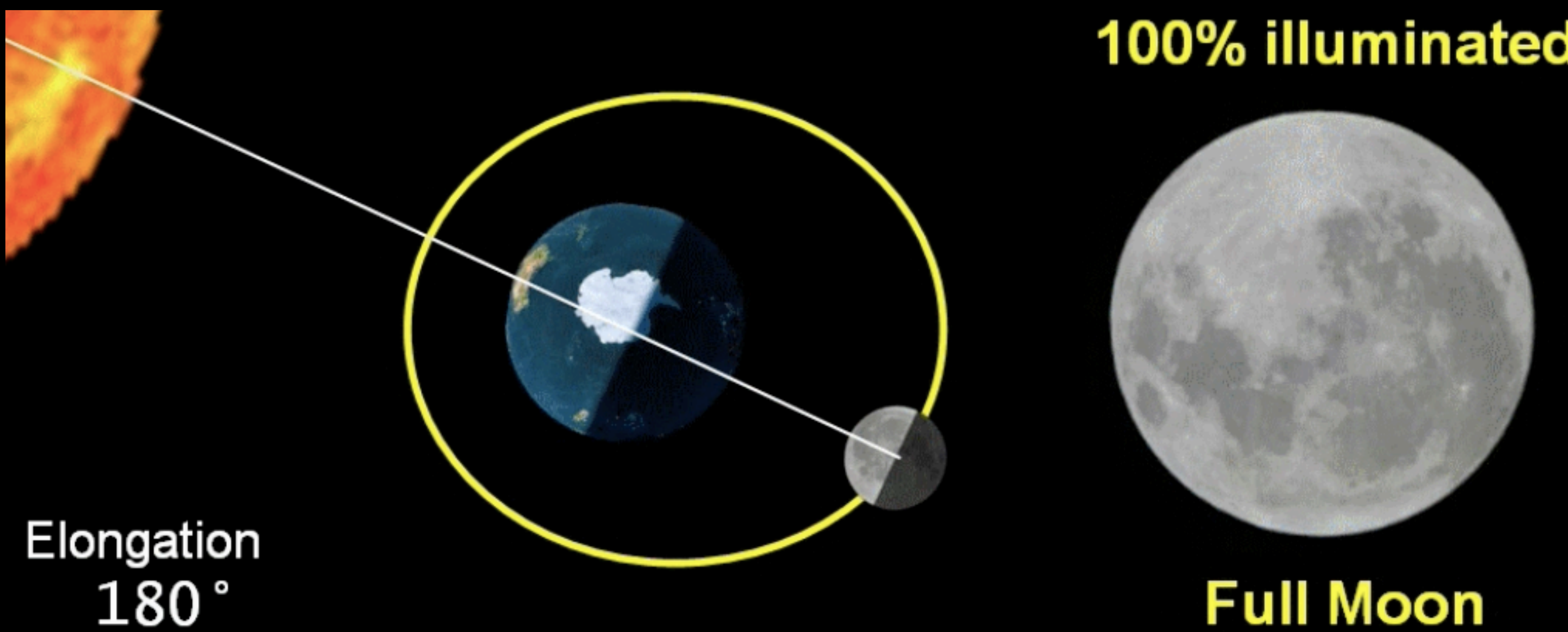

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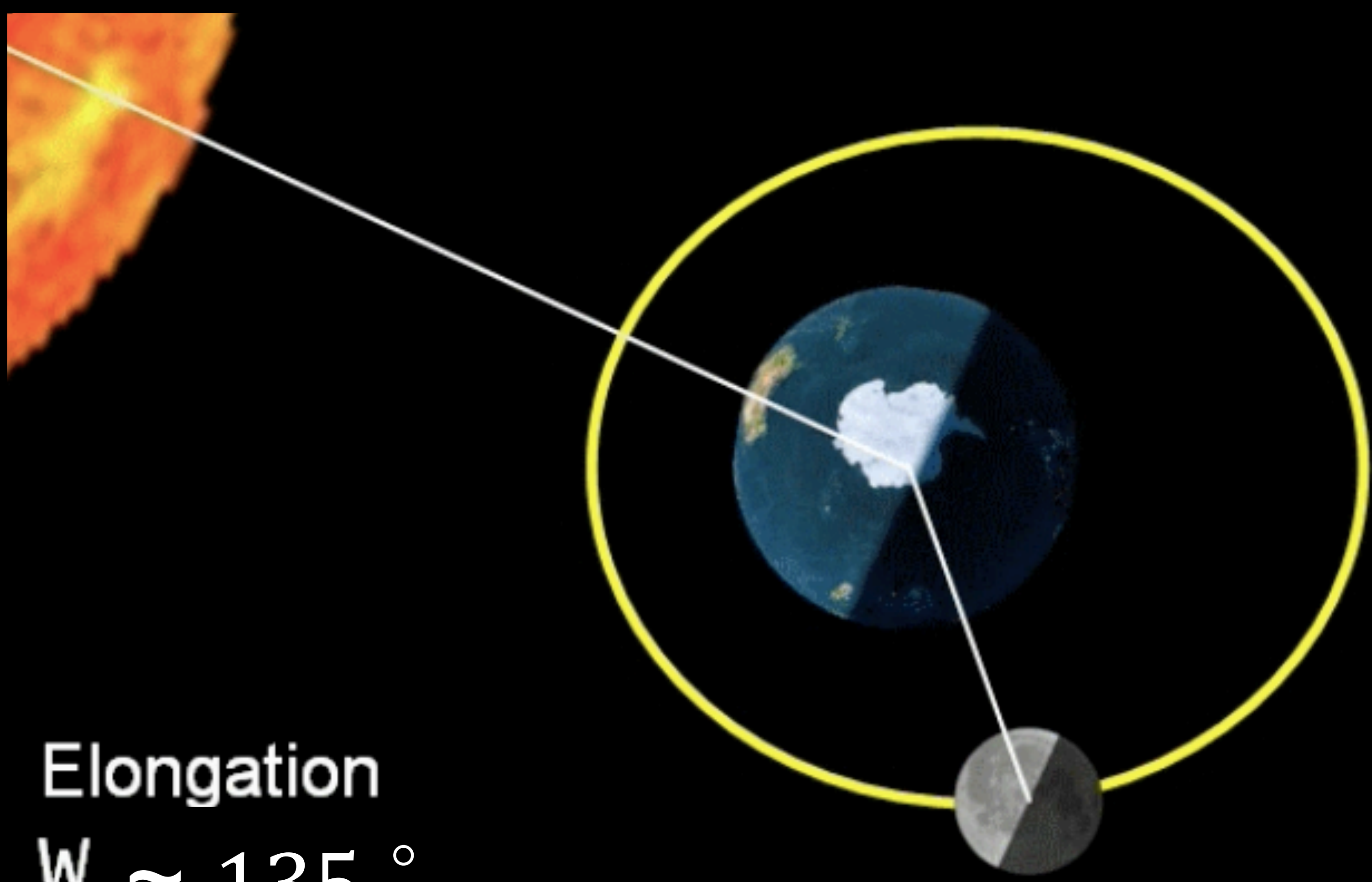

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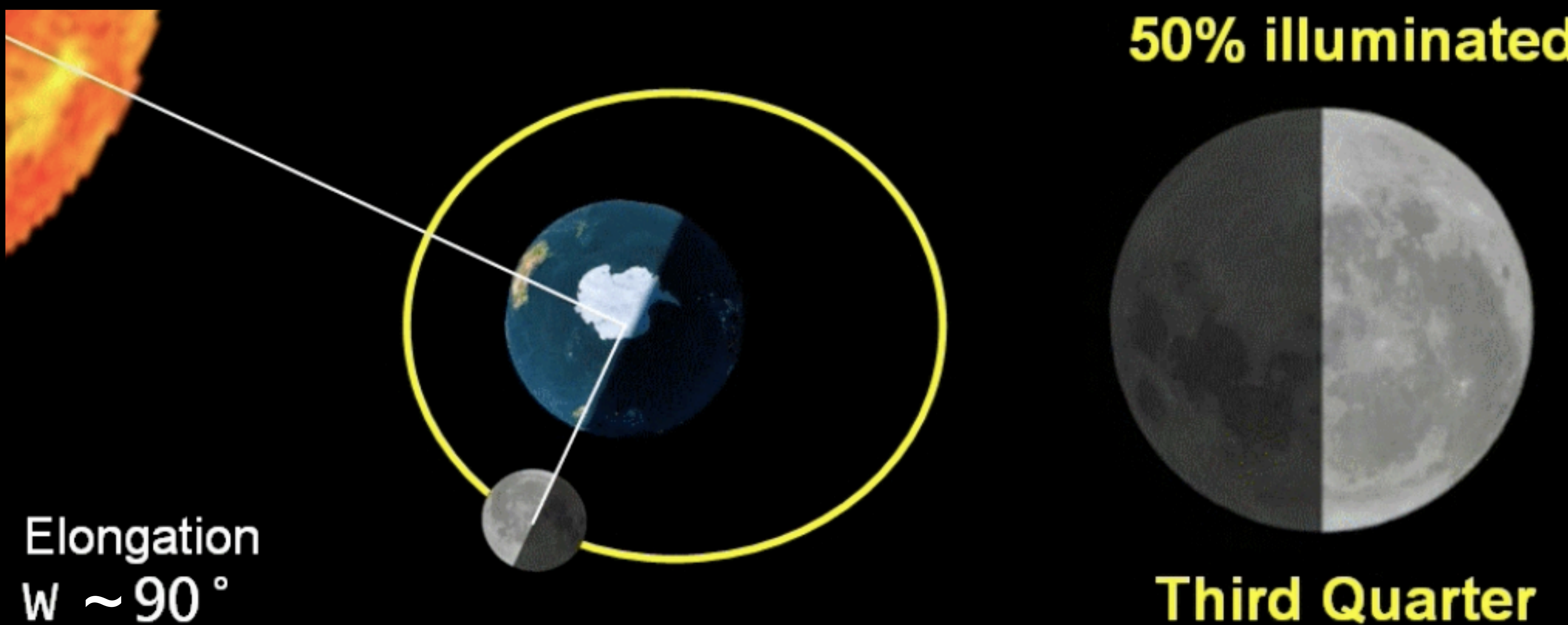

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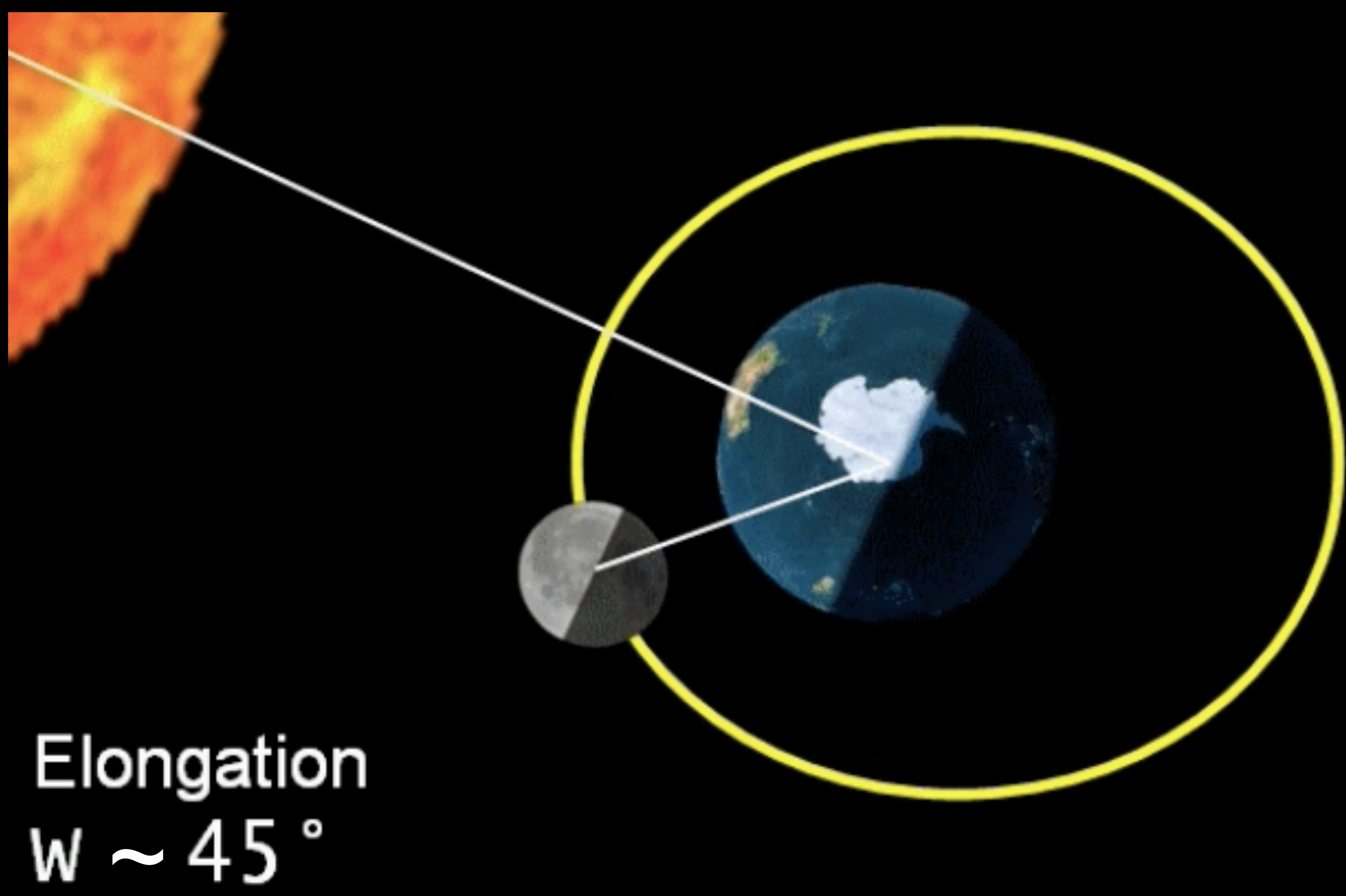


Phases of the Moon

- The center ring shows the moon as it revolves around the Earth, as seen from above the north pole
- Sunlight illuminates half the Earth and half the moon at all times
- But as the moon orbits around the Earth, at some points in its orbit the sunlit part of the moon can be seen from the Earth, and at other points, we can only see the parts of the moon that are in shadow
- The outer ring shows what we see on the Earth during each corresponding part of the moon's orbit

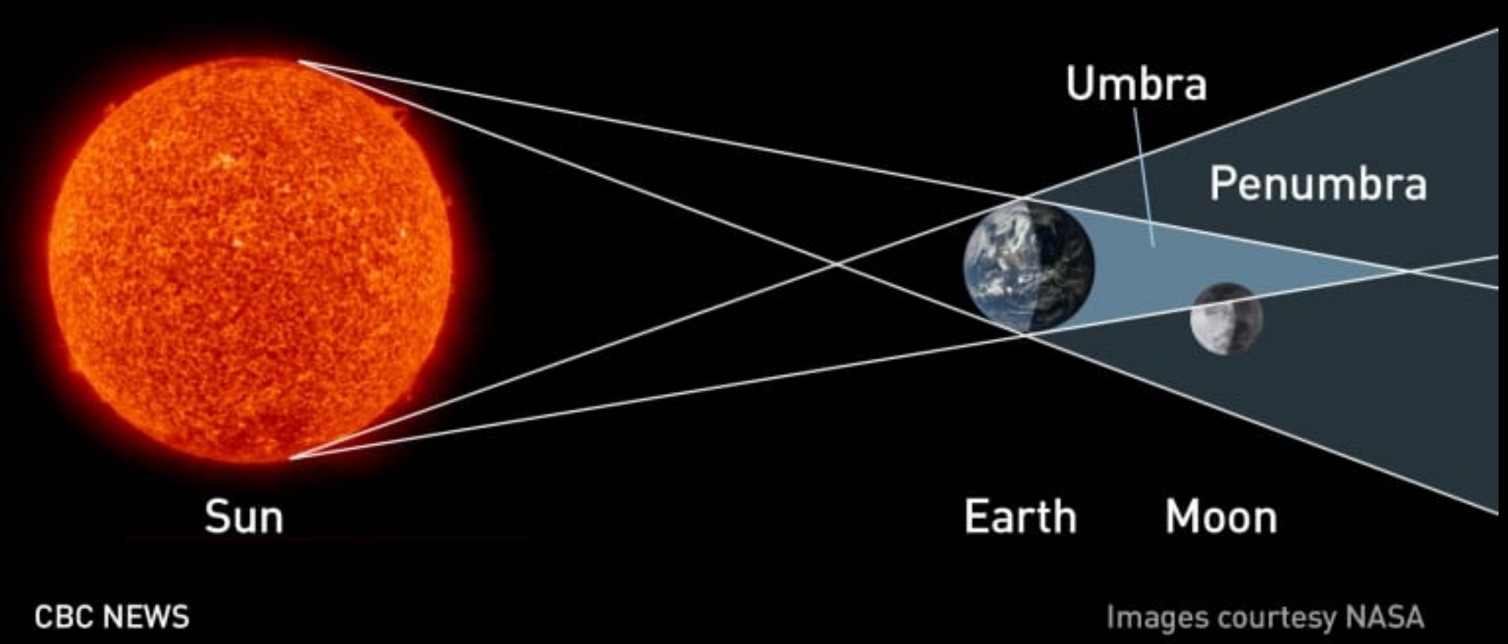
The Moon's sidereal orbital period (the sidereal month) is roughly 27.3 days

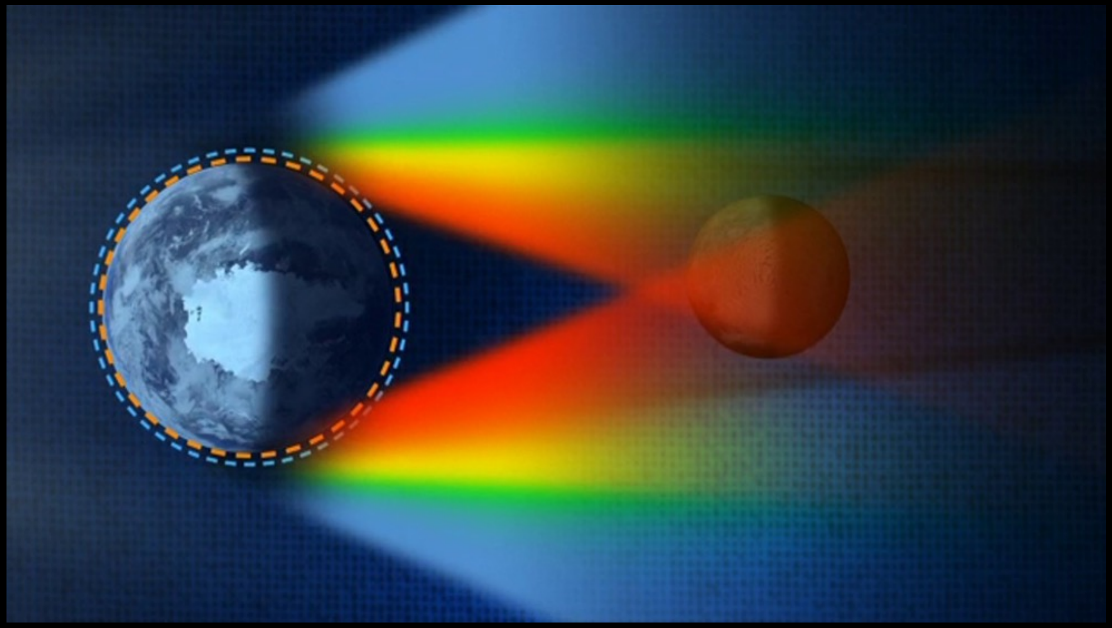
Time interval that the Moon takes to orbit 360° around the Earth relative to the "fixed" stars

Period of lunar phases (the synodic month -> full moon to full moon period) is about 29.5 days

This is because while Moon is orbiting Earth -> Earth is progressing in its orbit around the Sun

Lunar Eclipse





- Earth’s atmosphere scatters blue light
- Red light is refracted and falls onto the Moon

As we've already mentioned ☛ lunar eclipse always happens at a Full Moon

However ☛ not every Full Moon comes with a lunar eclipse

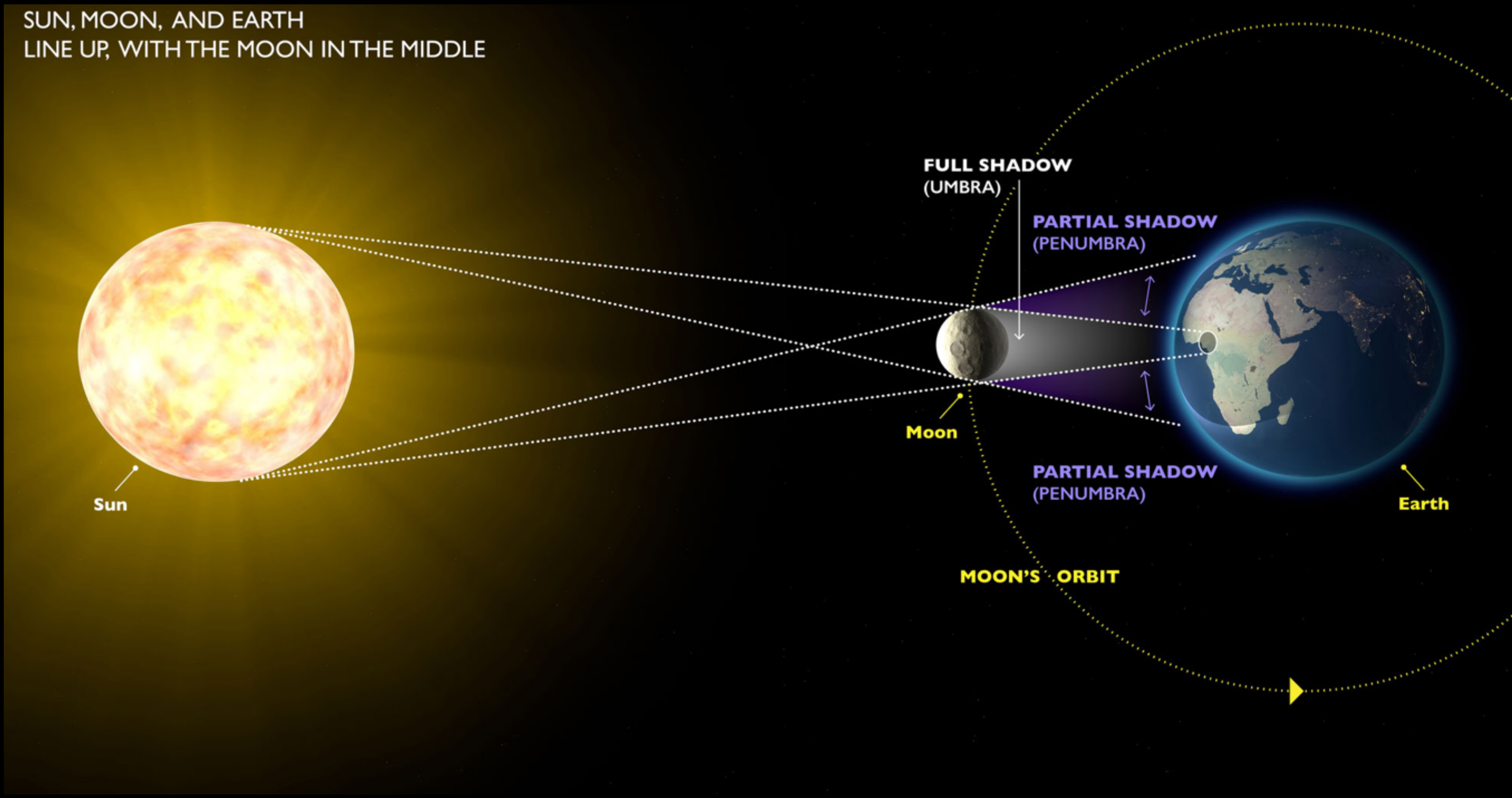
Here is why ☛ Moon's orbit is tilted at about five degrees to the Earth's orbit, so our natural satellite usually passes above or below the Earth's shadow at aFull Moon.

On average ☛ there are two lunar eclipses per year

The maximum number of lunar eclipses in one year is five ☛ though it happens quite rarely

The last time five lunar eclipses occurred in one calendar year was in 1879 and the next time such an event will happen is in 2132

Solar Eclipse

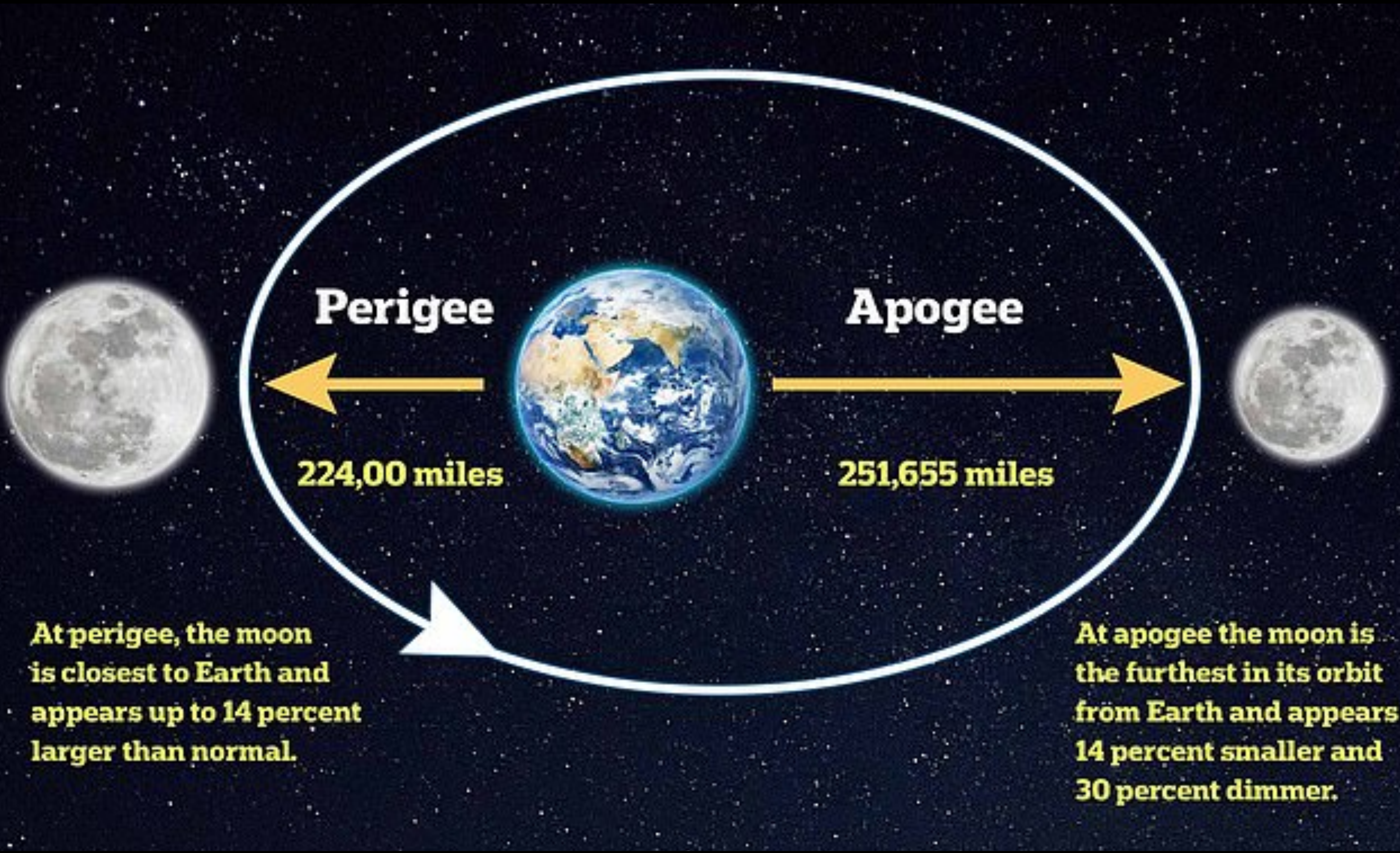


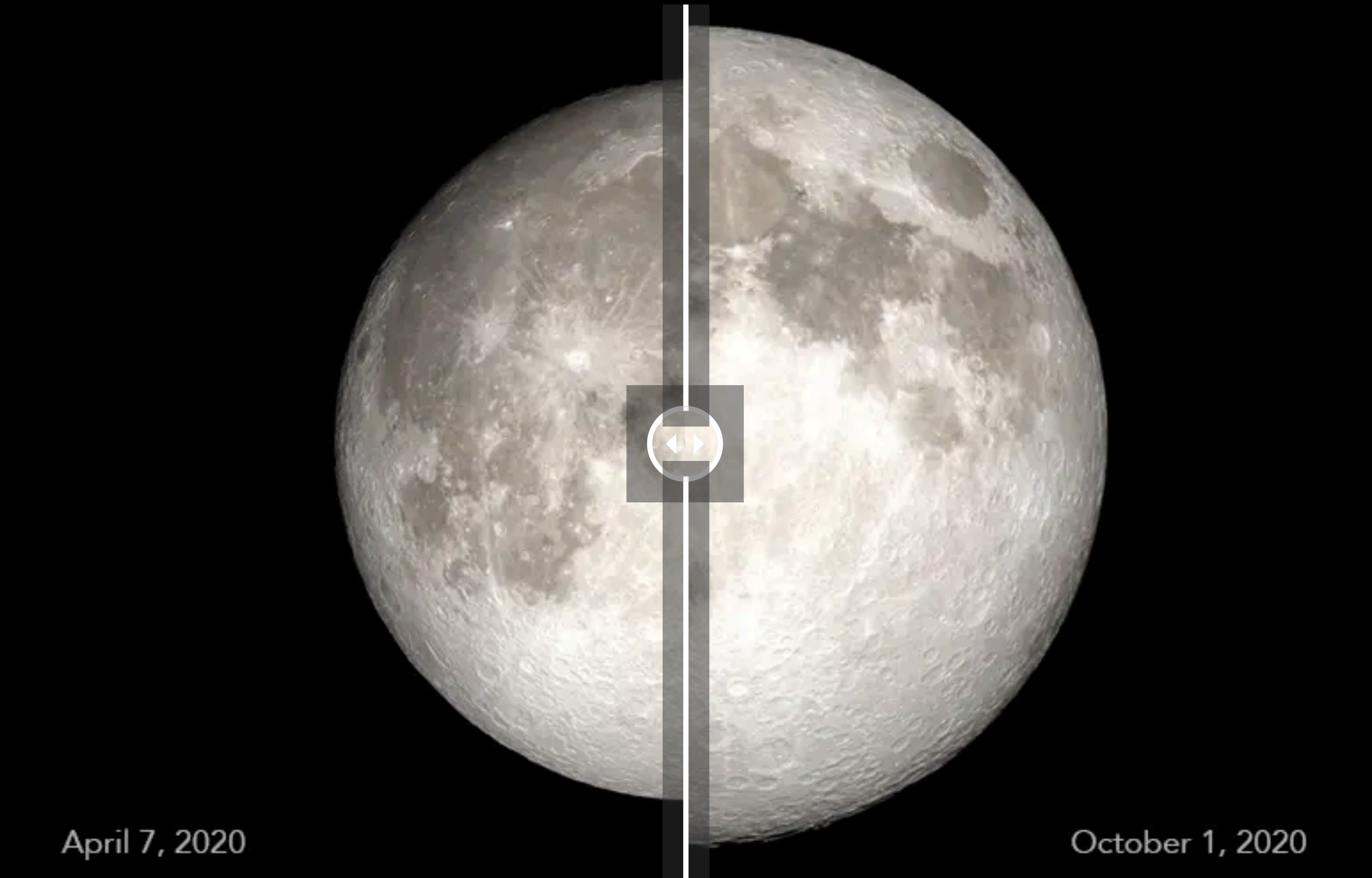
- Most calendar years have two solar eclipses

- The maximum number of solar eclipses that can take place in the same year is five, but this is rare

- Only about 25 years in the past 5,000 years have had five solar eclipses

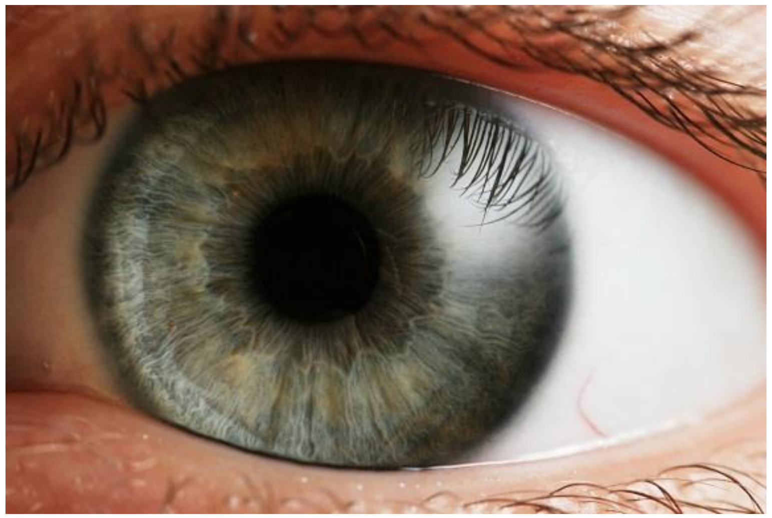
- The last time this happened was in 1935, and the next time will be in 2206

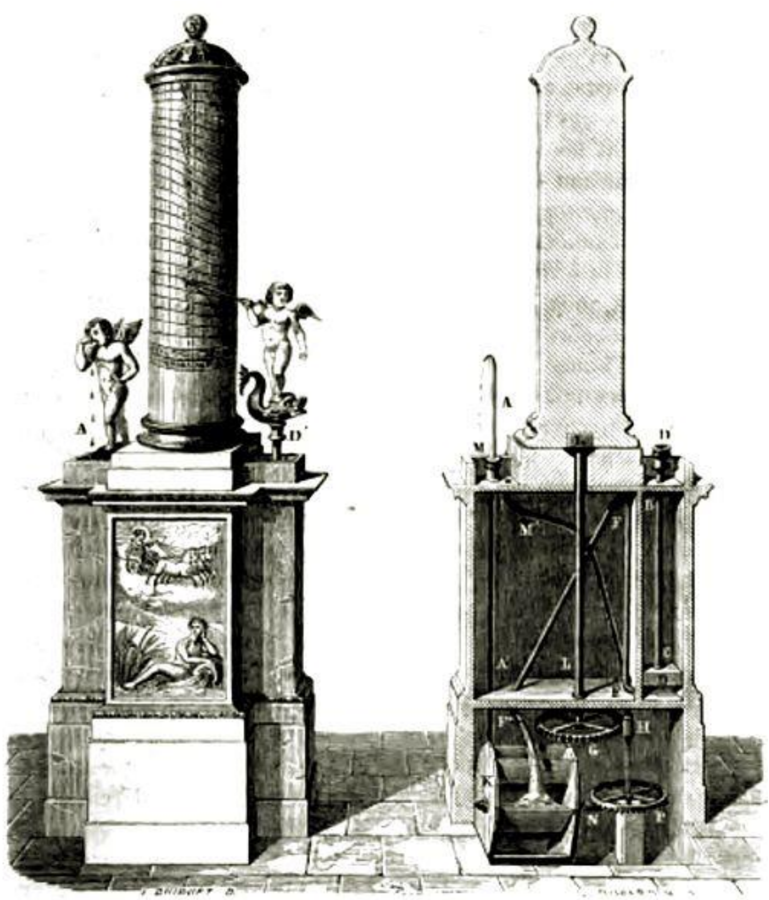

Perigee
Apogee
224,00 miles
251,655 miles
At perigee, the moon is closest to Earth and appears up to 14 percent larger than normal.
At apogee the moon is the furthest in its orbit from Earth and appears 14 percent smaller and 30 percent dimmer.

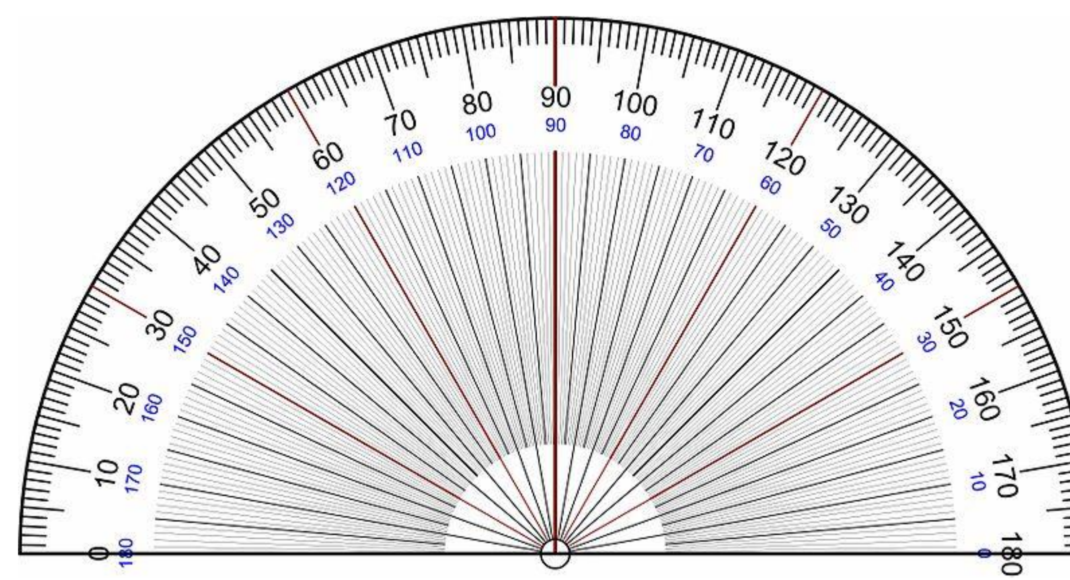


Not-So-Super Moon vs. Supermoon
Credit: NASA's Scientific Visualization Studio

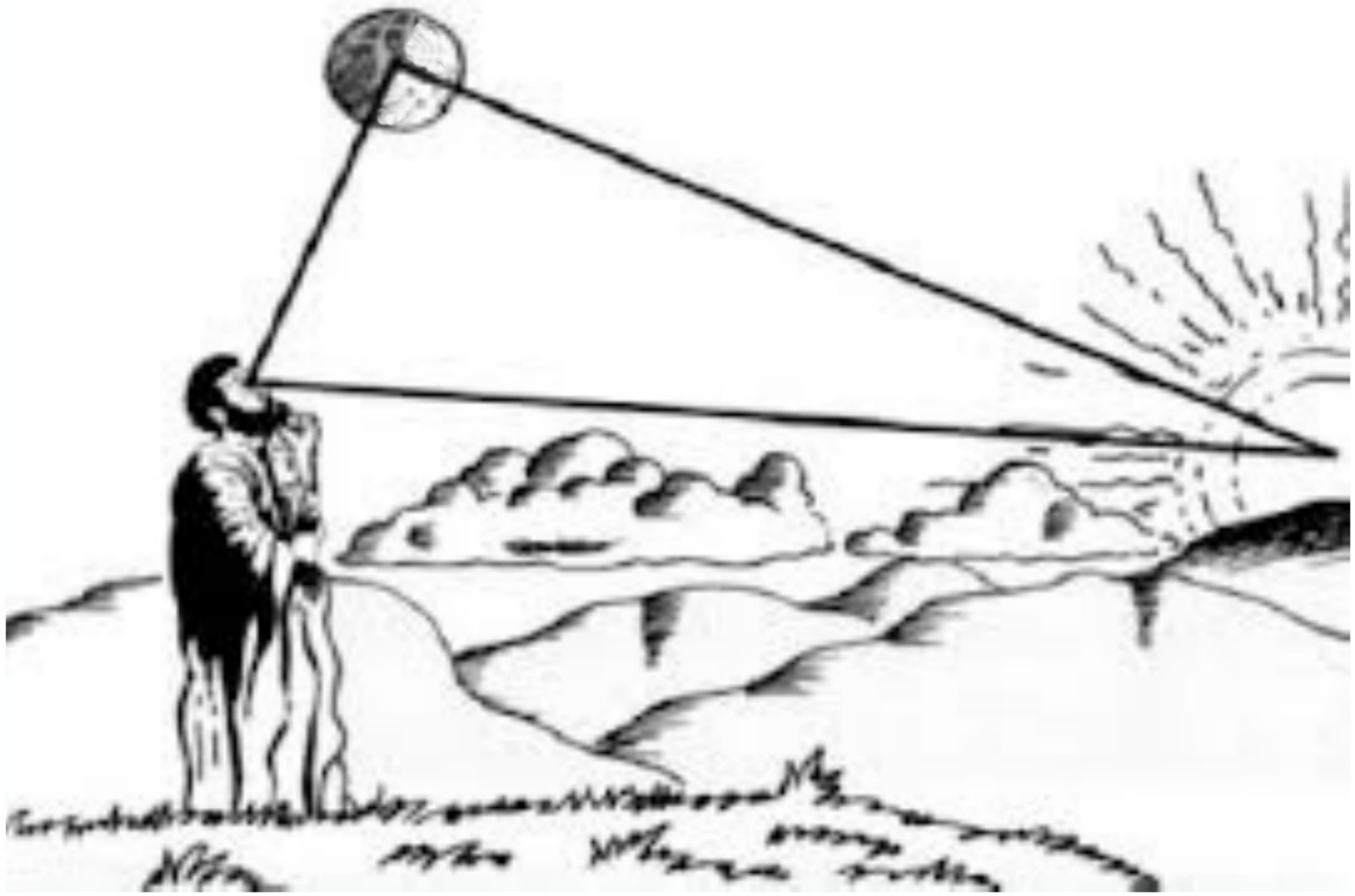
Astronomy 2500 Years Ago



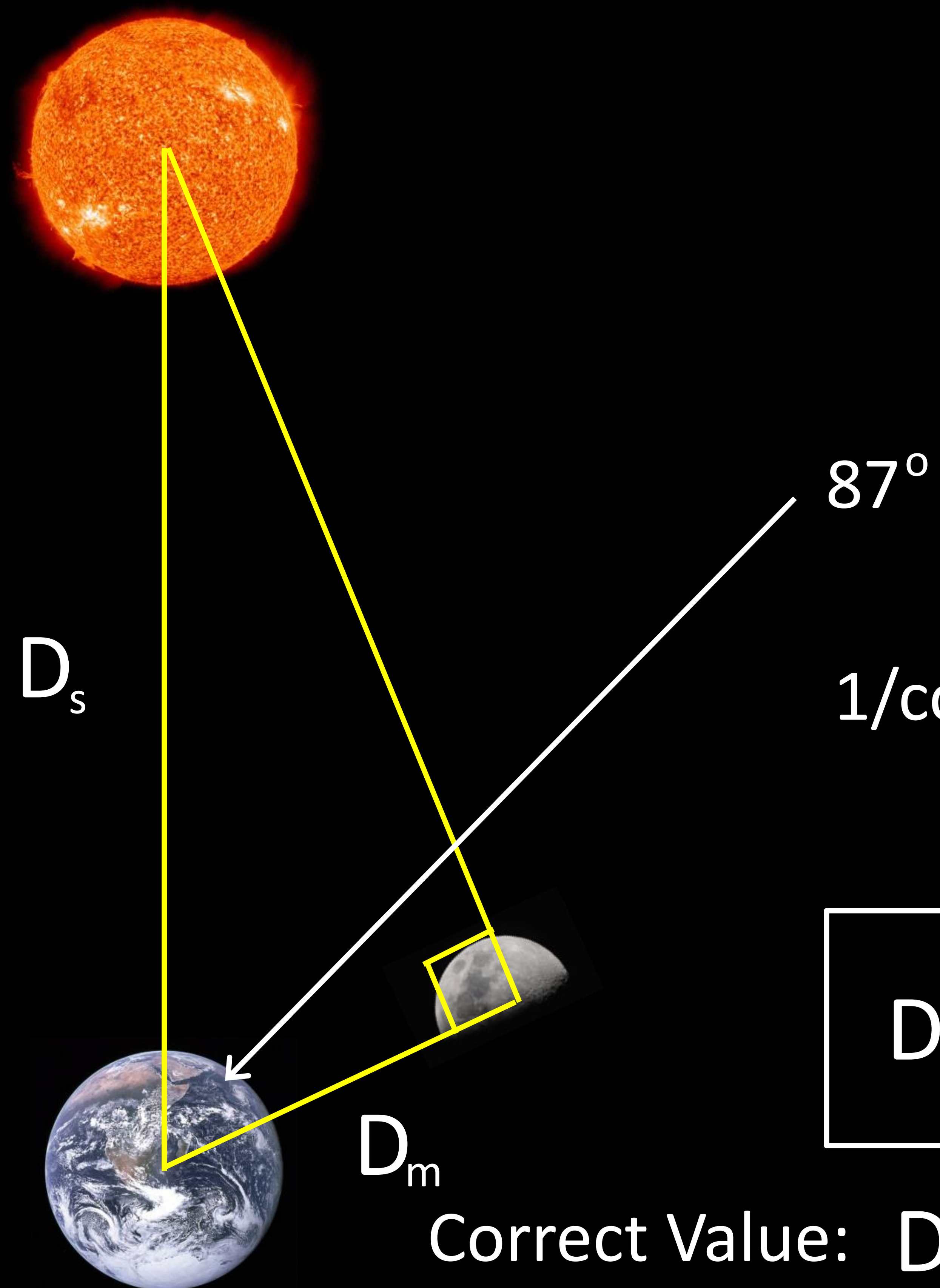




Aristarchus realized that when the Moon was exactly half illuminated
it formed a right triangle with the Earth and the Sun



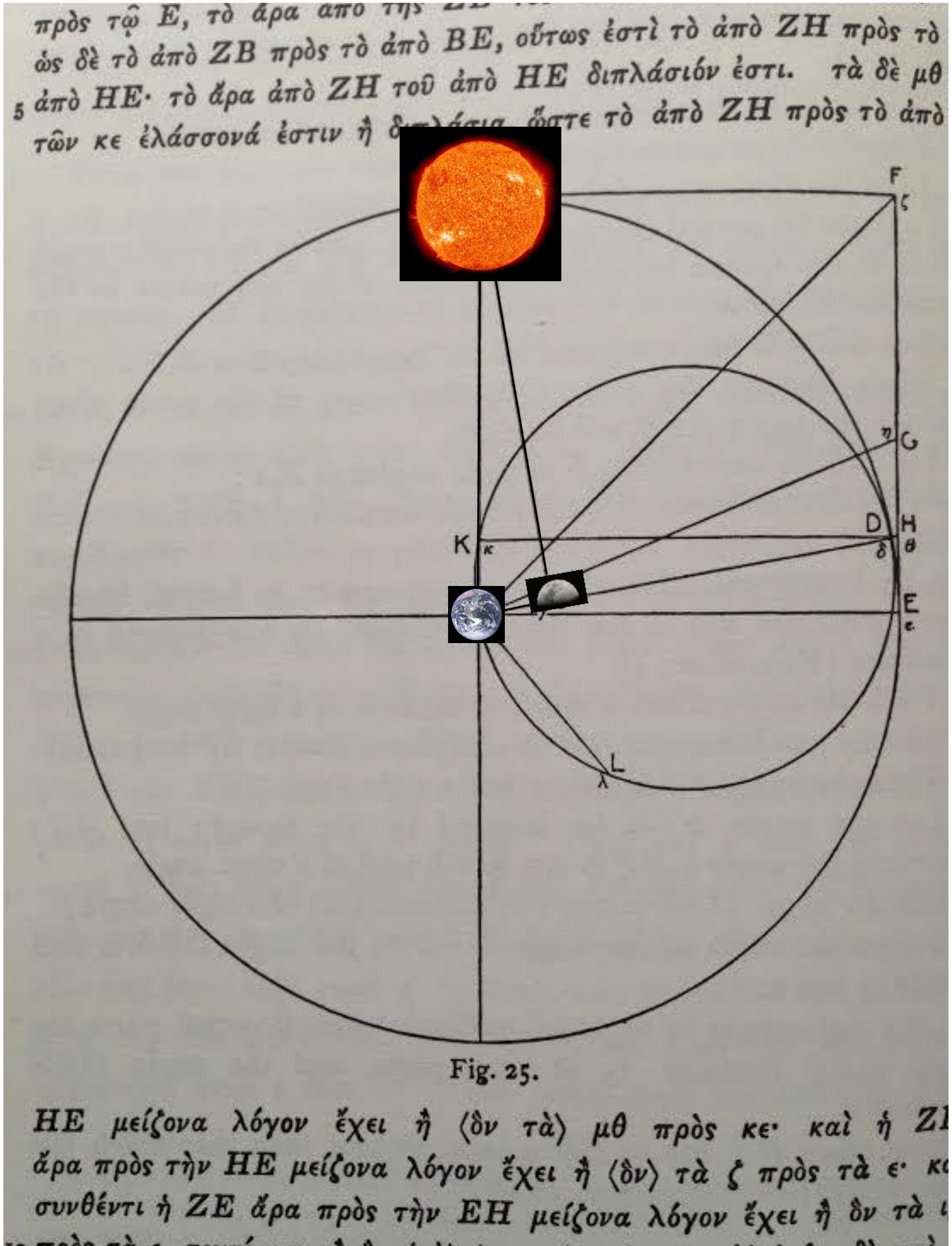
By observing the angle between the Sun and Moon
the ratio of the distances to the Sun and Moon could be deduced using a form of trigonometry



$1/\cos(87°) = 19.1$

$D_s = 19.1\ D_m$

Correct Value: $D_s = 389\ D_m$



πρὸς τῷ Ε, τὸ ἄρα ἀπὸ τῆς ΖΒ ... ὡς δὲ τὸ ἀπὸ ΖΒ πρὸς τὸ ἀπὸ ΒΕ, οὕτως ἐστὶ τὸ ἀπὸ ΖΗ πρὸς τὸ ἀπὸ ΗΕ· τὸ ἄρα ἀπὸ ΖΗ τοῦ ἀπὸ ΗΕ διπλάσιόν ἐστι. τὰ δὲ μθ τῶν κε ἐλάσσονά ἐστιν ἢ ... ὥστε τὸ ἀπὸ ΖΗ πρὸς τὸ ἀπὸ

Fig. 25.

ΗΕ μείζονα λόγον ἔχει ἢ ⟨ὃν τὰ⟩ μθ πρὸς κε· καὶ ἡ Ζ... ἄρα πρὸς τὴν ΗΕ μείζονα λόγον ἔχει ἢ ⟨ὃν⟩ τὰ ζ πρὸς τὰ ε· κ... συνθέντι ἡ ΖΕ ἄρα πρὸς τὴν ΕΗ μείζονα λόγον ἔχει ἢ ὃν τὰ ι... πρὸς τὰ ε, τουτέστιν ...

After several pages of geometry…

$$18D_m < D_s < 20D_m$$

What shape is the Earth?

Key Concepts

1. Aristotle (4th Century BCE) was the first to demonstrate the Earth is **spherical**
2. Eratosthenes (ca. 200 BCE) was the first to determine the **size** of the Earth

Aristotle (4th Century BCE): First to give reasons why the Earth is spherical

Aristotle contemplating the Bust of Homer, Rembrandt (CE 1653)

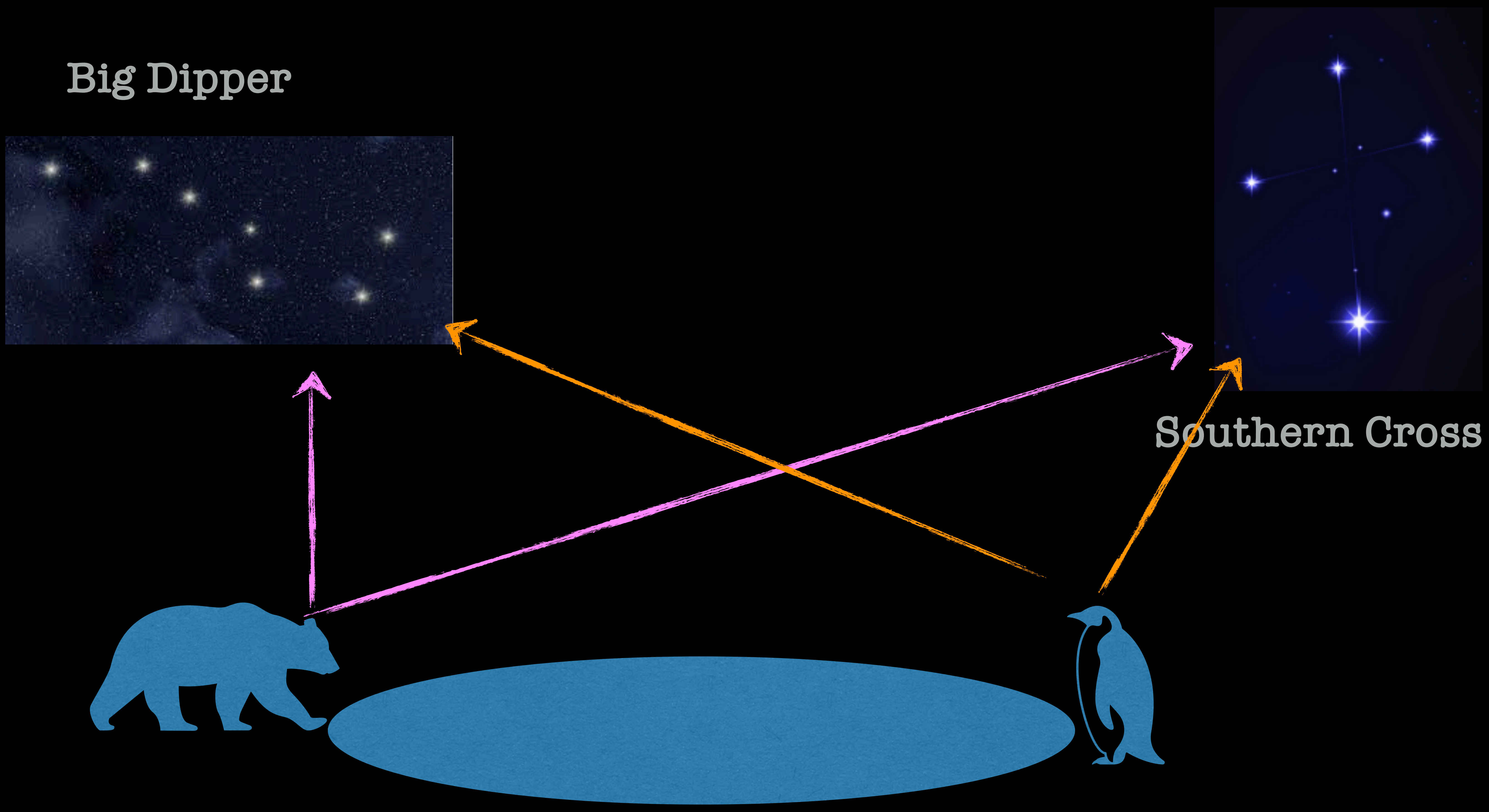
Aristotle's 1st reason

You see different stars from the south than from the north

Big Dipper

Southern Cross

If the Earth were flat (as Thales believed)



2^{nd} reason
Shape of Earth's shadow

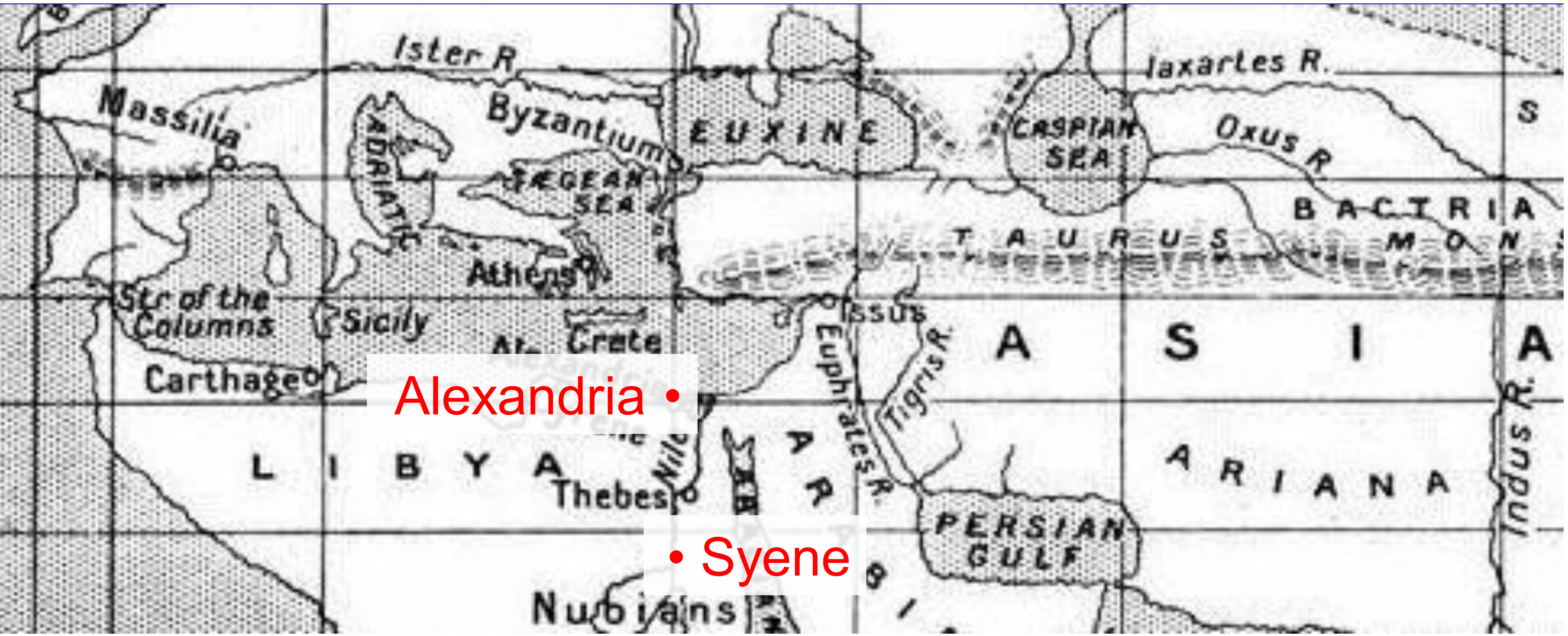
During a lunar eclipse, Earth's shadow is **always** circular

Only object whose shadow is always circular is a sphere

Eratosthenes (ca. 200 BC): First to find the **size** of the spherical Earth

Eratosthenes teaching in Alexandria, Bernardo Strozzi (AD 1635)

Eratosthenes was the head librarian of the famous Library of Alexandria

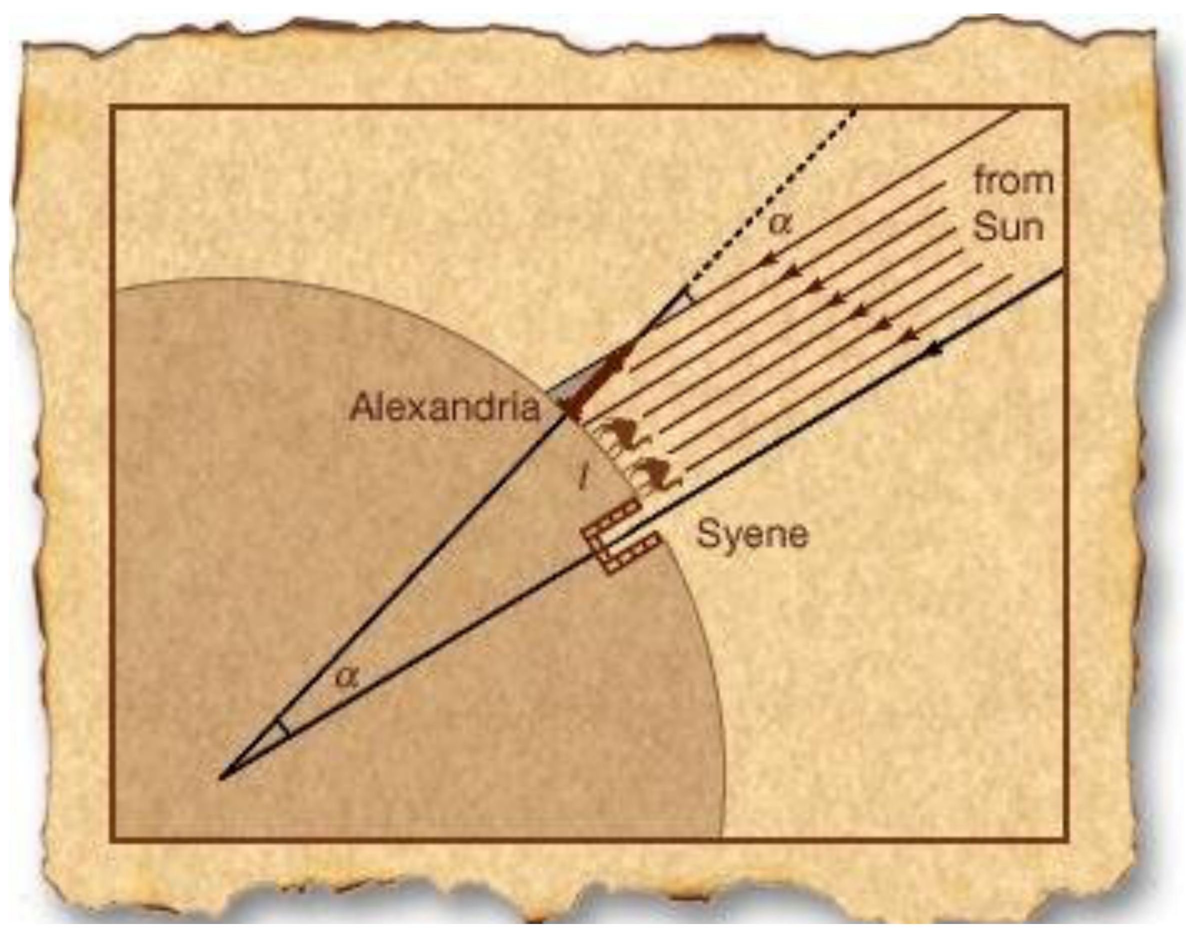


- What Eratosthenes read: At noon on June 21, Sun is at Zenith seen from Syene

- What he saw: At noon on June 21, Sun is 7.2 south of Zenith seen from Alexandria

- What he assumed: Earth is spherical; Sun is very, very far away

Eratosthenes then divided 360° by $7°12'$ and determined that $7°\ 12'$ was 1/50th of a circle
Since the distance between and Syene and Alexandria was measured to be 5,000 stades
and these two places lie on the same meridian
geometric argument -> circumference of the Earth ~ 250,000 stades



The best modern guess is that 1 stadia = 185 m Putting Eratosthenes result
In modern units -> circumference of the Earth is 46,250 km

Modern measurement -> 40,070 km

Eratosthenes estimate is only about 15% too large!

If the Earth–Moon distance were greater than the Earth–Sun distance would an observer on the Earth be able to see the Moon in its first quarter phase?

A. Yes

B. No

If the Earth-Moon distance were greater than the Earth-Sun distance would an observer on the Earth be able to see the Moon in its first quarter phase?

A. Yes

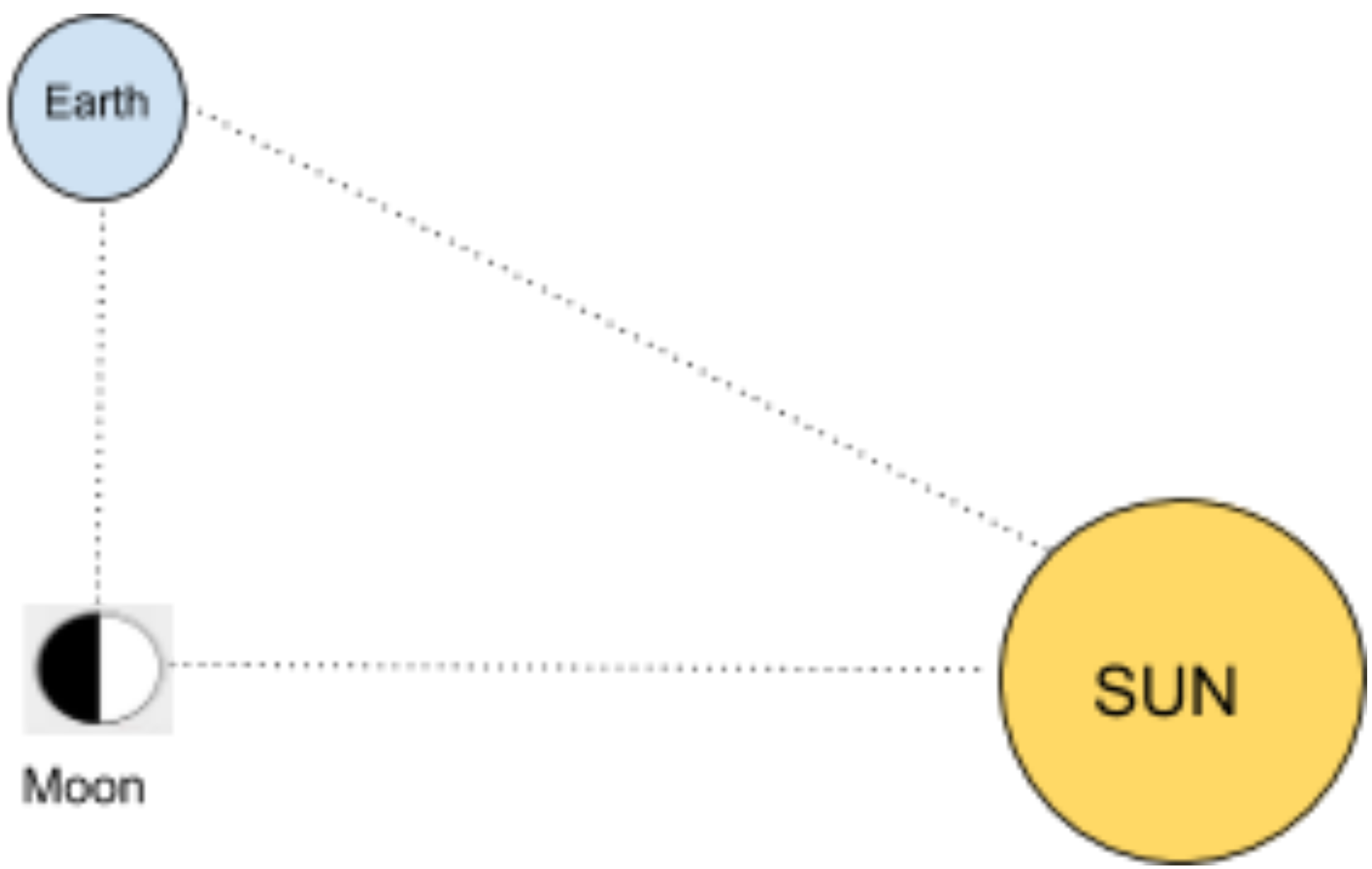
B. No

Observer on Earth would not be able to see the Moon in its first quarter phase

if Earth – Moon distance were greater than Earth – Sun distance

When we see the Moon in its first quarter phase, Earth, Moon, and Sun must be aligned such that they form a right angle with Earth – Sun distance as the hypotenuse of a right triangle

This is the only way we would be able to see first quarter Moon.



The same side of the moon always faces the Earth because:

A. The moon is not rotating about its axis.

B. Tidal forces keep the moon’s rotation and orbiting motion in sync with each other

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Which civilization developed and implemented the first lunar calendar?

A. Roman
B. Greek
C. Babylonian
D. Aztec

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Which planet seems to be turned on its side with an axis tilt of 98 degrees?

A. Uranus

B. Pluto

C. Neptune

D. Saturn

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The period from one full moon to the next is:

A. 27.3 days

B. 7 days

C. 29.5 days

D. 365 days

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Name the phase that the moon is in for each type of eclipse, lunar and solar:

A. Full moon for both phases

B. New moon for both phases

C. Full moon for lunar and new moon for solar

D. New moon for lunar and full moon for solar

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QUERY 1

Two martians, Yll and Ylla K, are located due north and south of each other on planet Mars

Yll sees Sun directly overhead (at the zenith) at noon. At same time, Ylla sees Sun 6 degrees away from the zenith. Ylla is 355 kilometers north of Yll. Compute circumference of planet Mars

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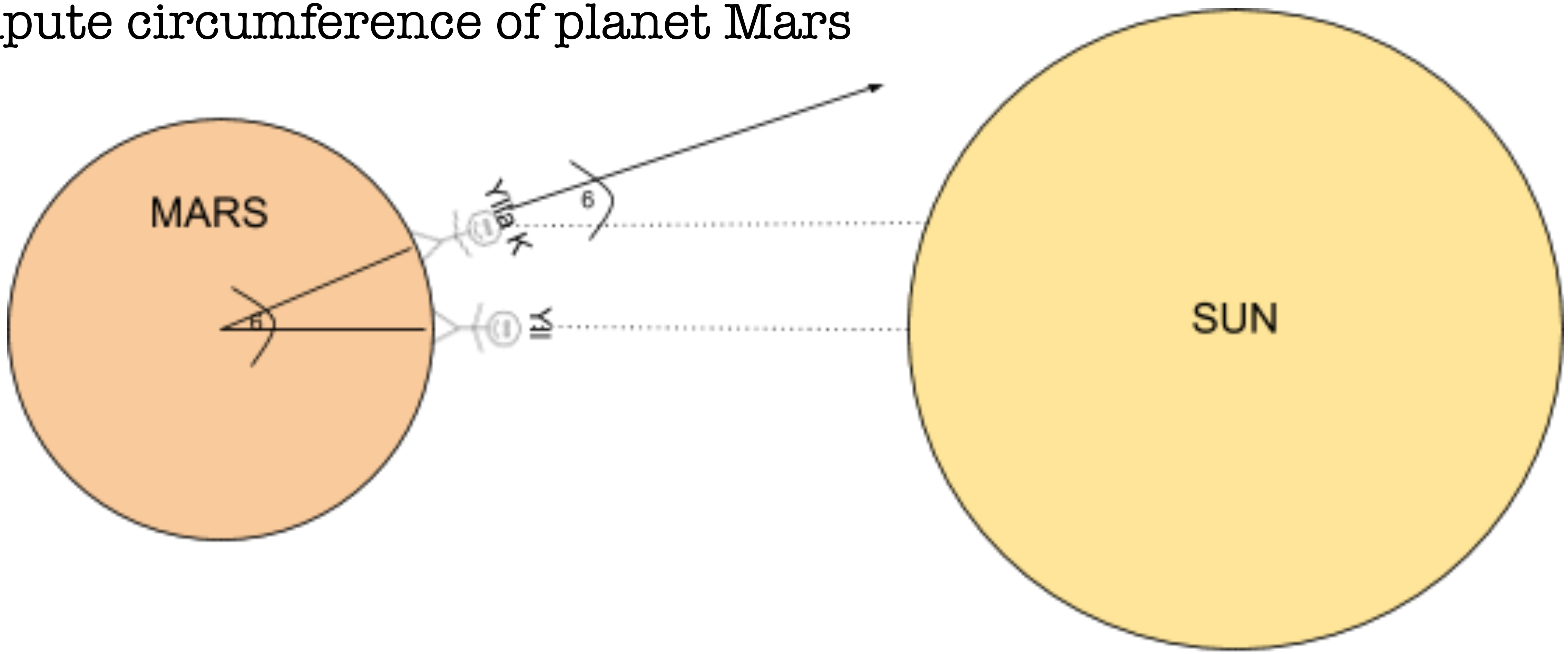

$$\frac{6^\circ}{360^\circ} = \frac{355 \text{ km}}{x} \Rightarrow x = 21,300 \text{ km}$$

QUERY 2

Given that circumference of Earth is 40,000 kilometers, what is Earth's diameter in kilometers?

Given that there are 0.621 miles per kilometer, what is Earths diameter in miles?

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$$\mathcal{C} = 40,000 \text{ km}$$

$$d = \frac{\mathcal{C}}{\pi} = \frac{40,000 \text{ km}}{\pi} = 12,732 \text{ km}$$

$$1 \text{ km} = 0.621 \text{ miles} \Rightarrow 12,732 \text{ km} = 0.621 \cdot 12732 \text{ miles} = 7,906.57 \text{ miles}$$