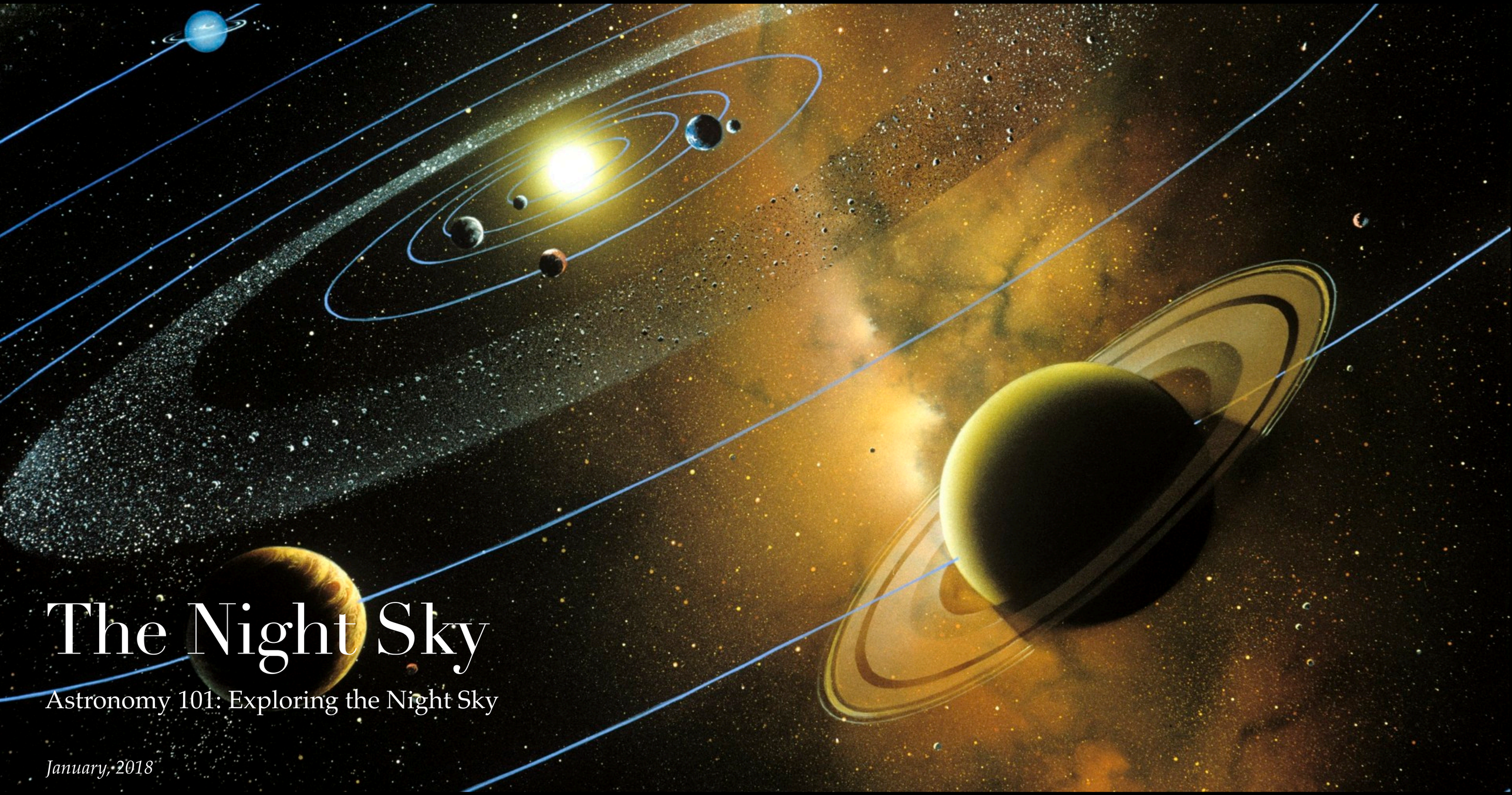


The Night Sky

Astronomy 101: Exploring the Night Sky

January, 2018

What is visible in the night sky

Largest & Closest

Which of these stars is the largest star? Which of them is the closest to us?

Brightness Magnitudes

Brightness is measured in a quantity called “magnitude” that works on a logarithmic scale.

10x brighter = -2.5 magnitude
100x brighter = -5 magnitude

The m=0.0 point is the star Vega, so all brightness is measured relative to Vega.

e.g. Uranus is about 100x dimmer than Vega

Object	Max Magnitude
Sun	-26.7
Moon	-12.6
Venus	-4.89
Mars	-2.91
Jupiter	-2.94
Saturn	-0.49
Uranus	5.32
Neptune	7.78

Brightness Magnitudes

With excellent vision, a human can see m~6.5, of which there are <10k stars with this magnitude or smaller (smaller = brighter!).

With telescopes, we can see all the way to brightness m~31.

Visible to typical human eye[1]	Apparent magnitude	Bright-ness relative to Vega	Number of stars brighter than apparent magnitude[2] in the night sky
Yes	−1.0	250%	1 (Sirius)
	0.0	100%	4
	1.0	40%	15
	2.0	16%	48
	3.0	6.3%	171
	4.0	2.5%	513
	5.0	1.0%	1602
	6.0	0.4%	4800
	6.5	0.25%	9096[3]
No	7.0	0.16%	14 000
	8.0	0.063%	42 000
	9.0	0.025%	121 000
	10.0	0.010%	340 000

Example

A star has an apparent magnitude of 4.6. What would be the magnitude of a star that is 10 times brighter?

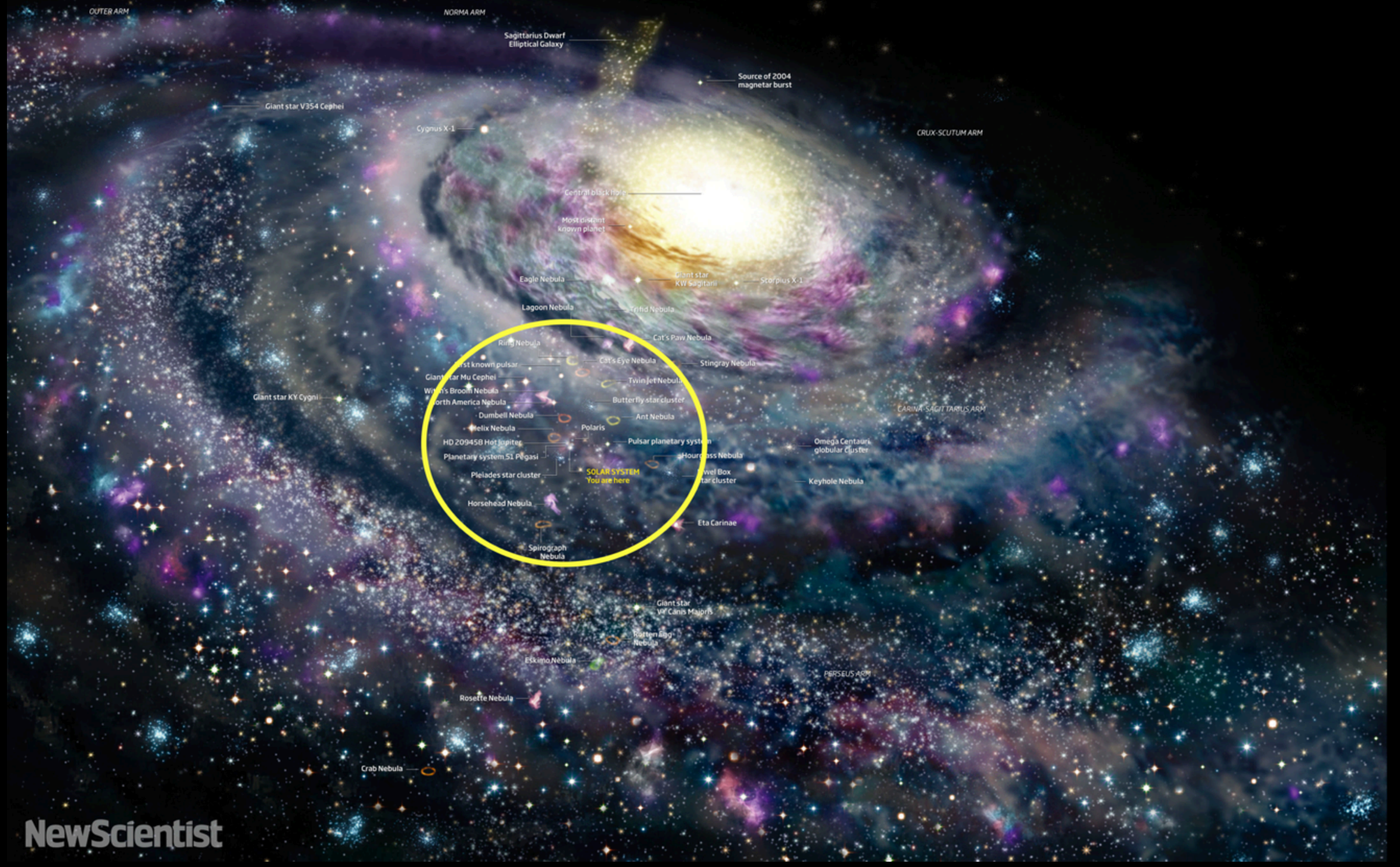
10x brighter = -2.5 magnitude

4.6 + (-2.5) = 2.1

The apparent magnitude of the brighter star is 2.1.

The Milky Way

DIGITAL IMAGE OF THE MILKY WAY BY PIKAIA IMAGING (WWW.PIKAIA-IMAGING.CO.UK)



All stars individually visible in the night sky to the unaided eye reside within this circle.

Stars and Constellations

Question: How many constellations are there in Western astronomy?

A. 283

B. 88

C. 12

D. 1316

E. Infinity

Mapping out the Night Sky

How do you tell someone else where to look in the sky? How do you communicate locations across a vast map of darkness speckled with tiny pinpoints of light?

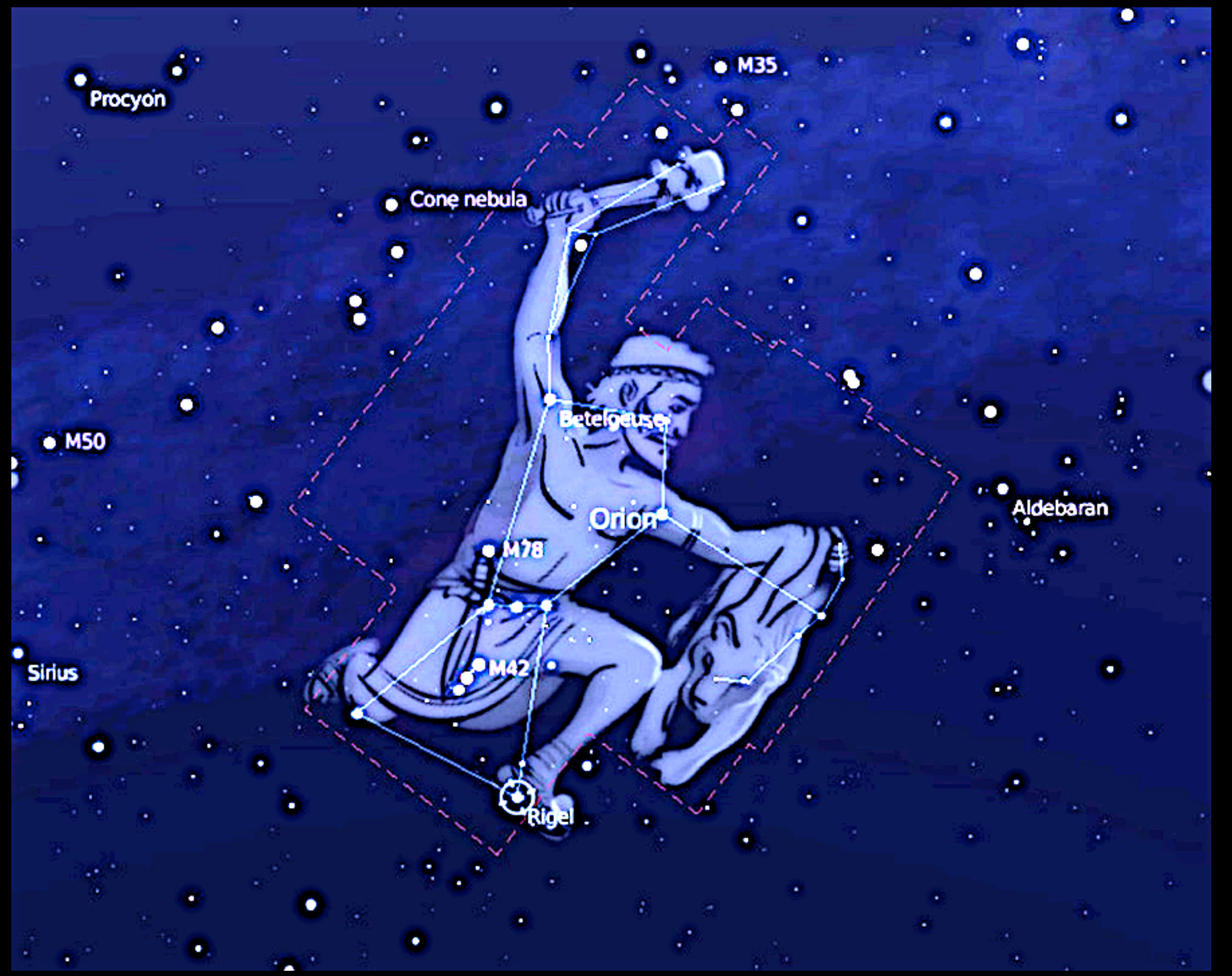
Constellations were useful for mapping out the night sky, to give some reference to locations.

Constellations

One of the best known constellations is Orion. Its 3-star belt is easily distinguishable in the night sky.

Many cultures mapped out patterns in the night sky, seeing shapes from the collections of points of light.

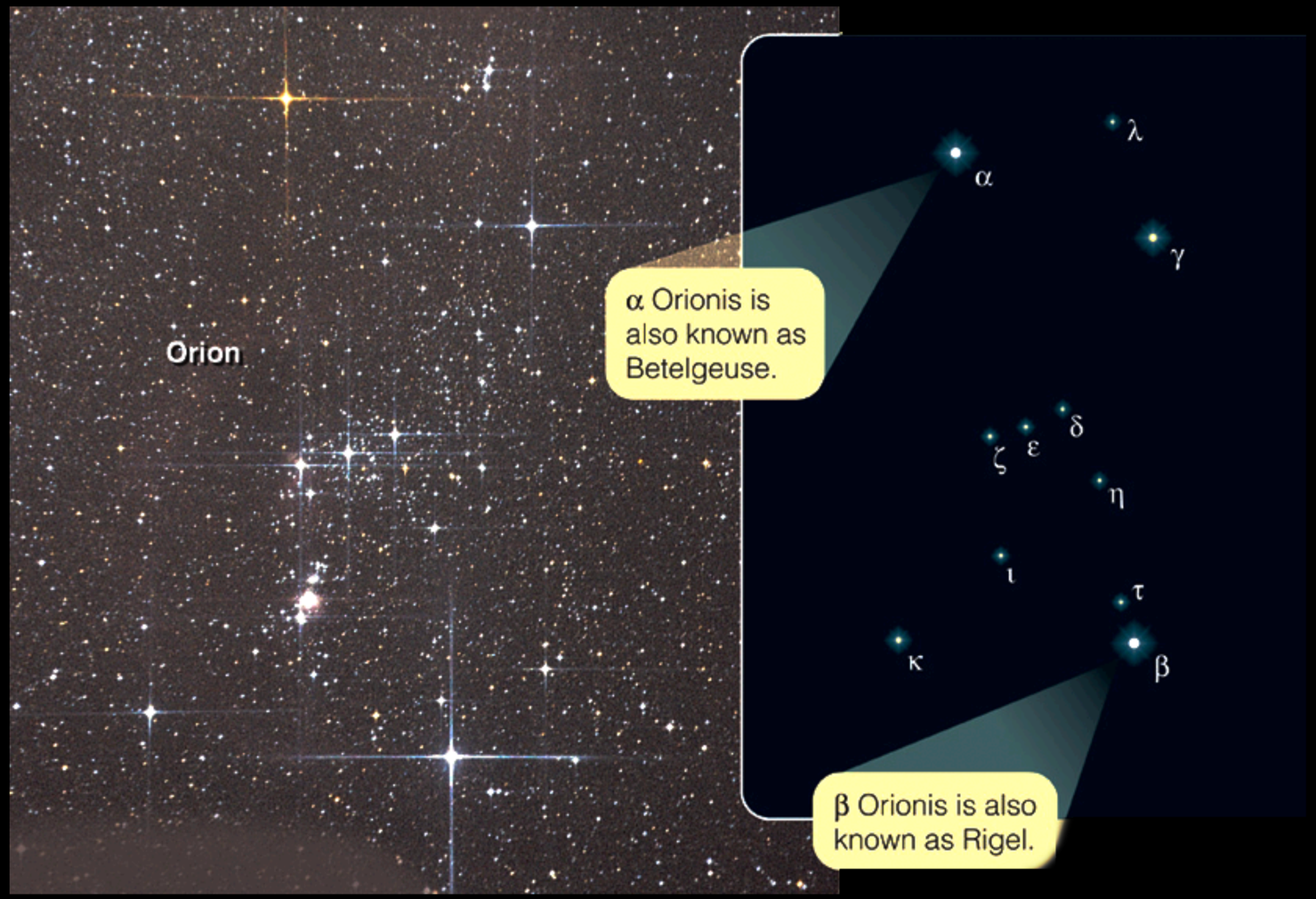
Western views of constellations are dominated by Greek & Babylonian origins.



Stars of the Constellations

The stars of a constellation are named based on their apparent magnitude.

Brightest - Alpha
Next - Beta
Next - Gamma
Next - Delta
etc.

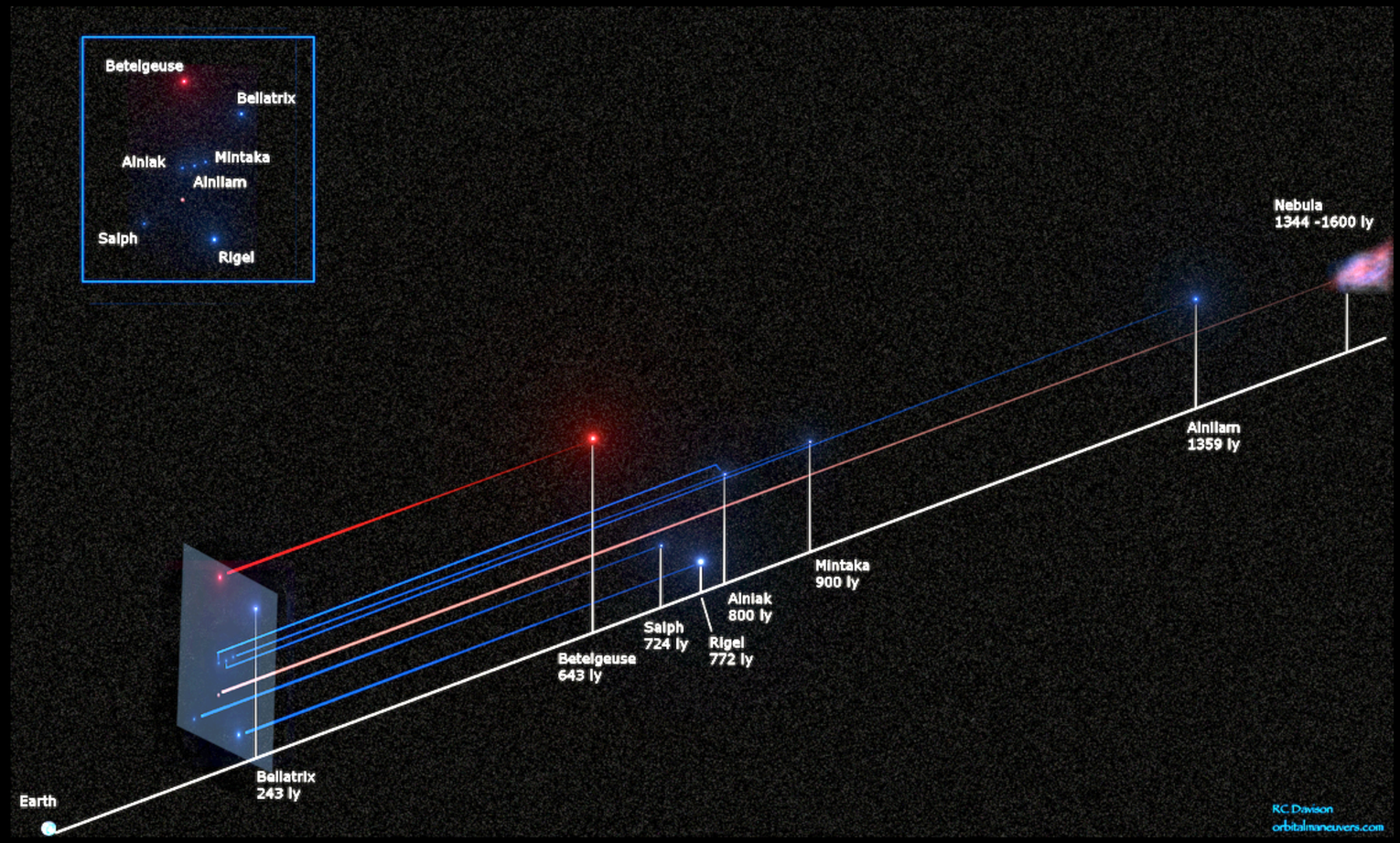


Celestial Sphere

Stars are too far away for depth perception.

Ancient peoples believed that they were points of light on a vast sphere that surrounded the Earth.

This was called the Celestial Sphere.

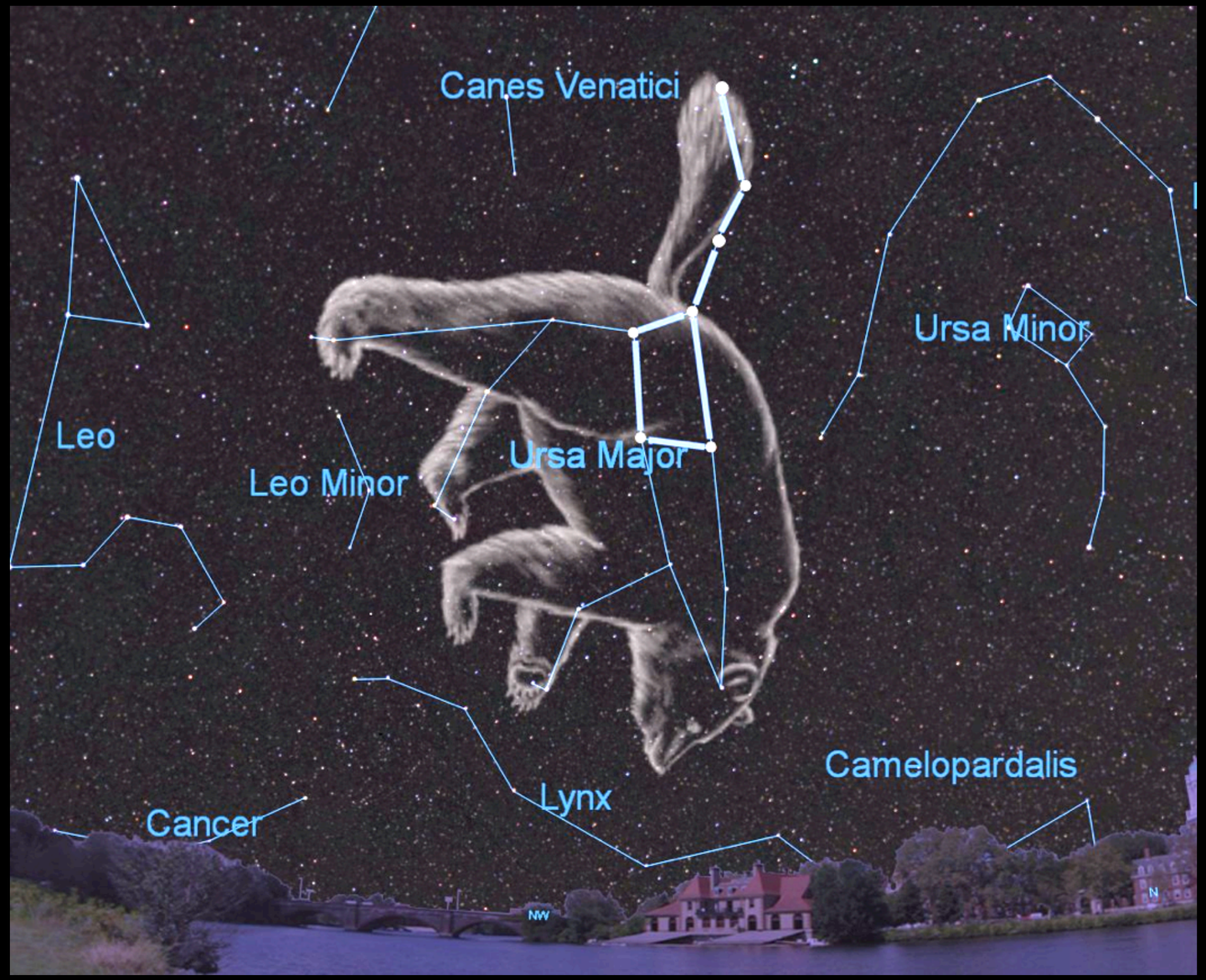


Asterisms

Some well known shapes
are not actually constellations.

Asterism is the term for shapes
that are not officially
recognized as constellations.

The “Big Dipper” is one such
shape. It is part of Ursa Major.

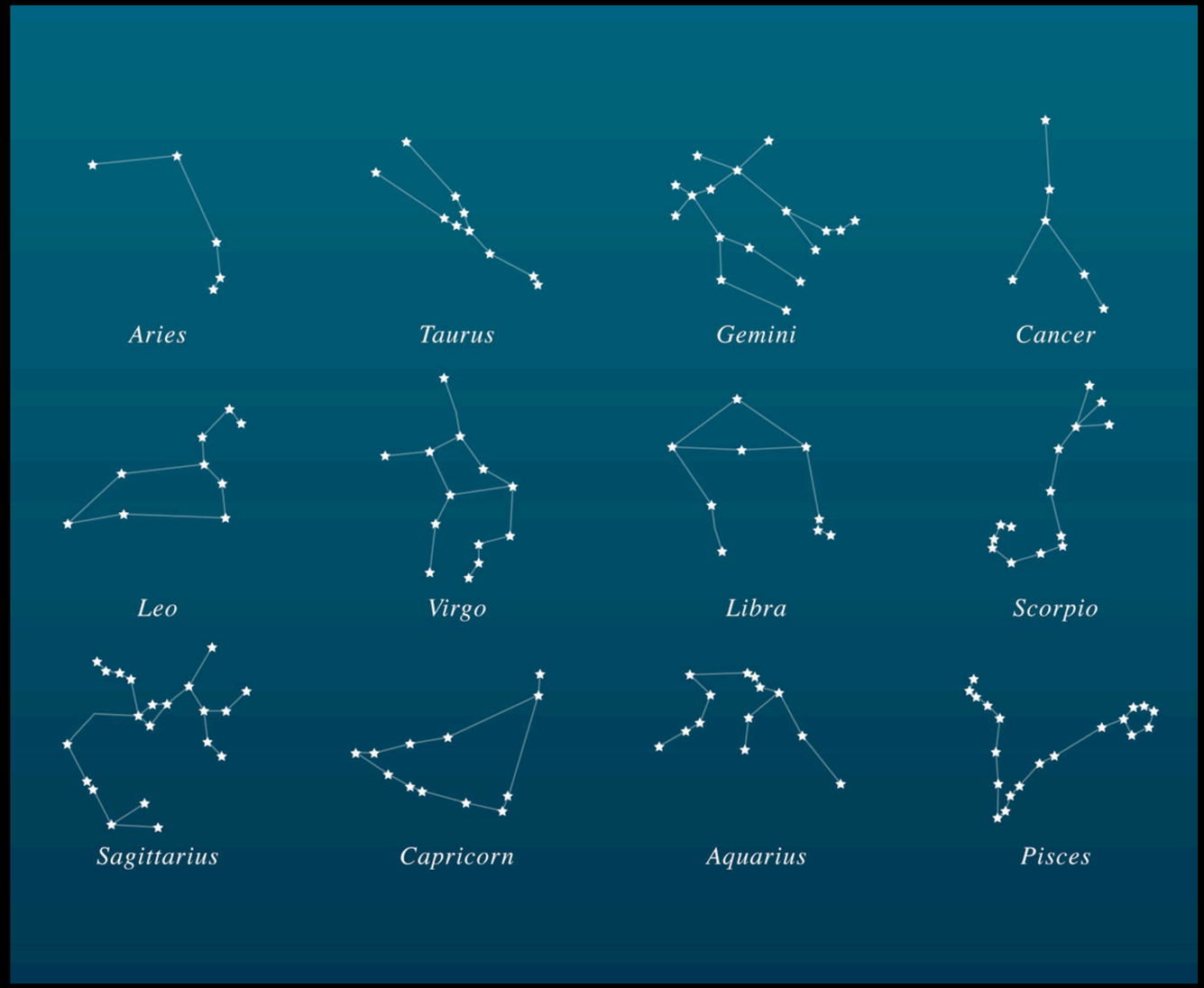


Zodiac Constellations

The best known constellations are the Zodiac Constellations that are tied in to Astrology.

There are, in fact, 13 zodiac constellations.

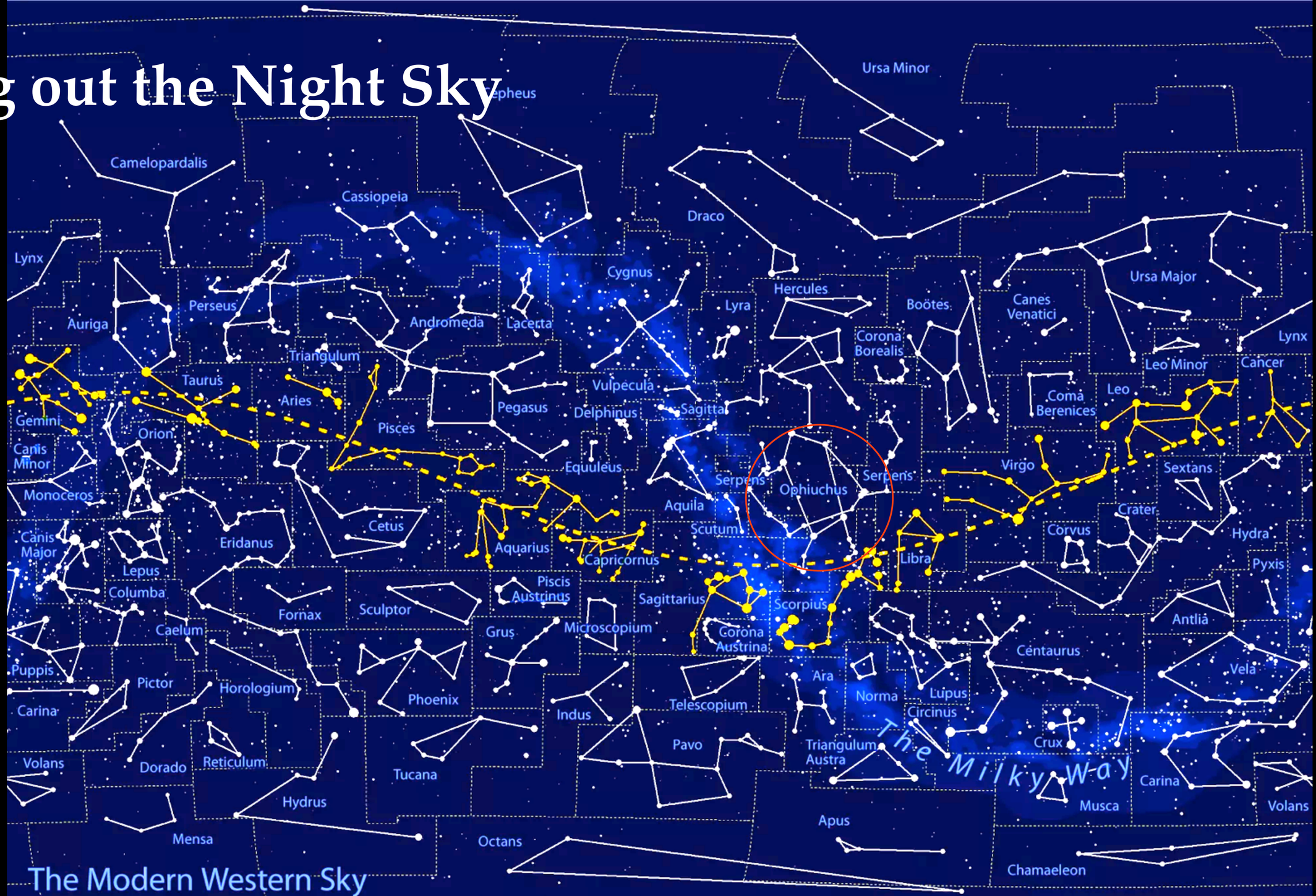
(More evidence that Astrology is bogus!)



Mapping out the Night Sky

The sky has been divided into 88 official regions / constellations.

The zodiac constellations are the constellations that follow the path of the Sun through the night sky!



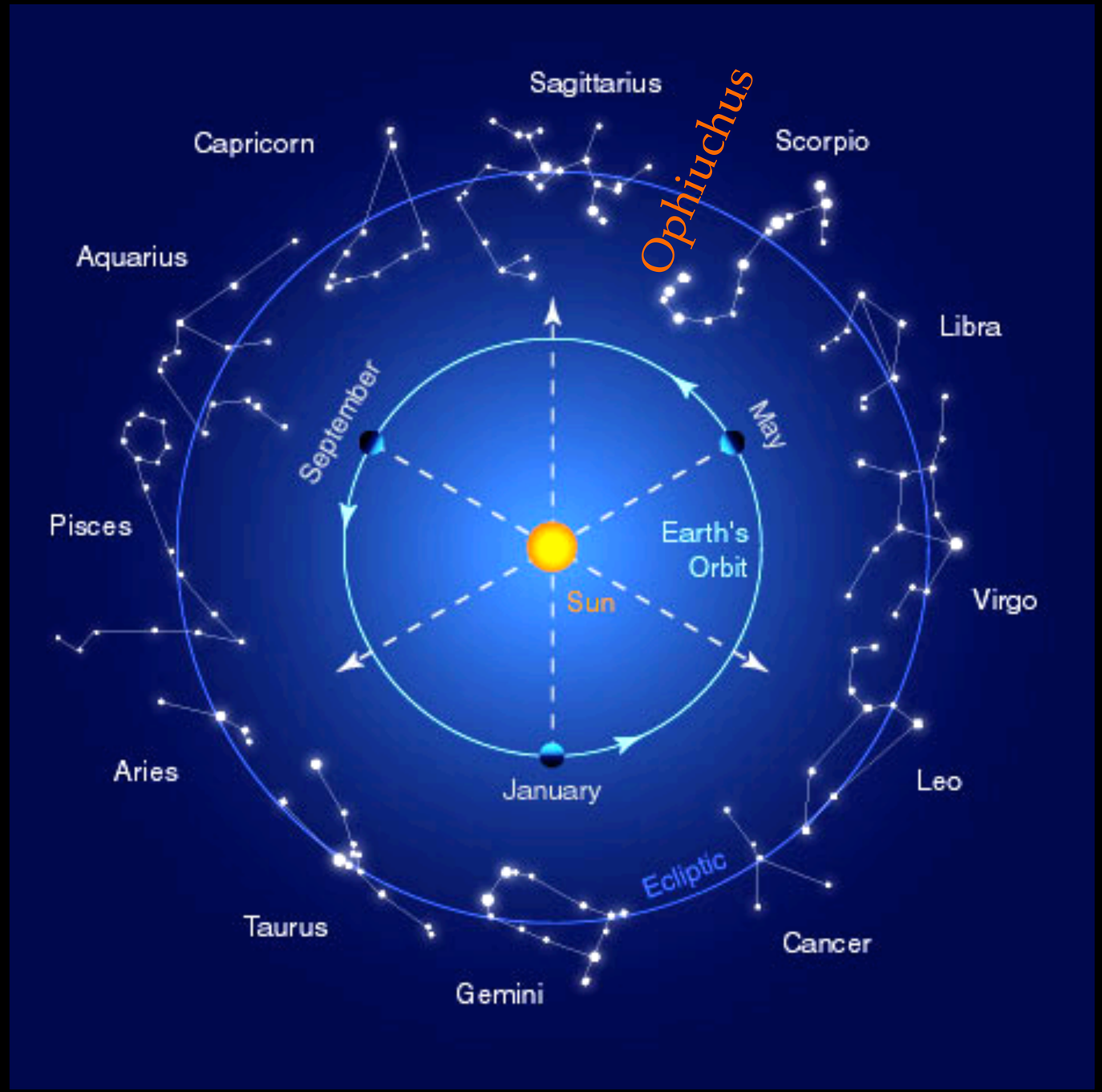
The dashed yellow line is the path of the Sun over the course of a year. Each of the regions it passes is a zodiac constellation. Except for Ophiuchus...

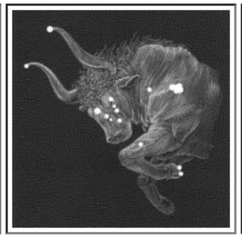
Zodiac Constellations

The month-zodiac association is the constellation that is behind the Sun.

e.g. If your astrological sign is Aries, then it is behind the Sun in April-May.

“But Aries is March - April!”
Not anymore...



	ASTROLOGICAL	ASTRONOMICAL	
Constellation	**Dates**	**Constellation**	**Dates**
Aries	March 21 - April 20		April 19 - May 13 (25 days)
Taurus	April 21 - May 21		May 14 - June 19 (37 days)
Gemini	May 22 - June 21		June 20 - July 20 (31 days)
Cancer	June 22 - July 22		July 21 - August 9 (20 days)
Leo	July 23 - August 23		August 10 - September 15 (37 days)

https://physics.weber.edu/palen/clearinghouse/labs/Planisphere/sign.html

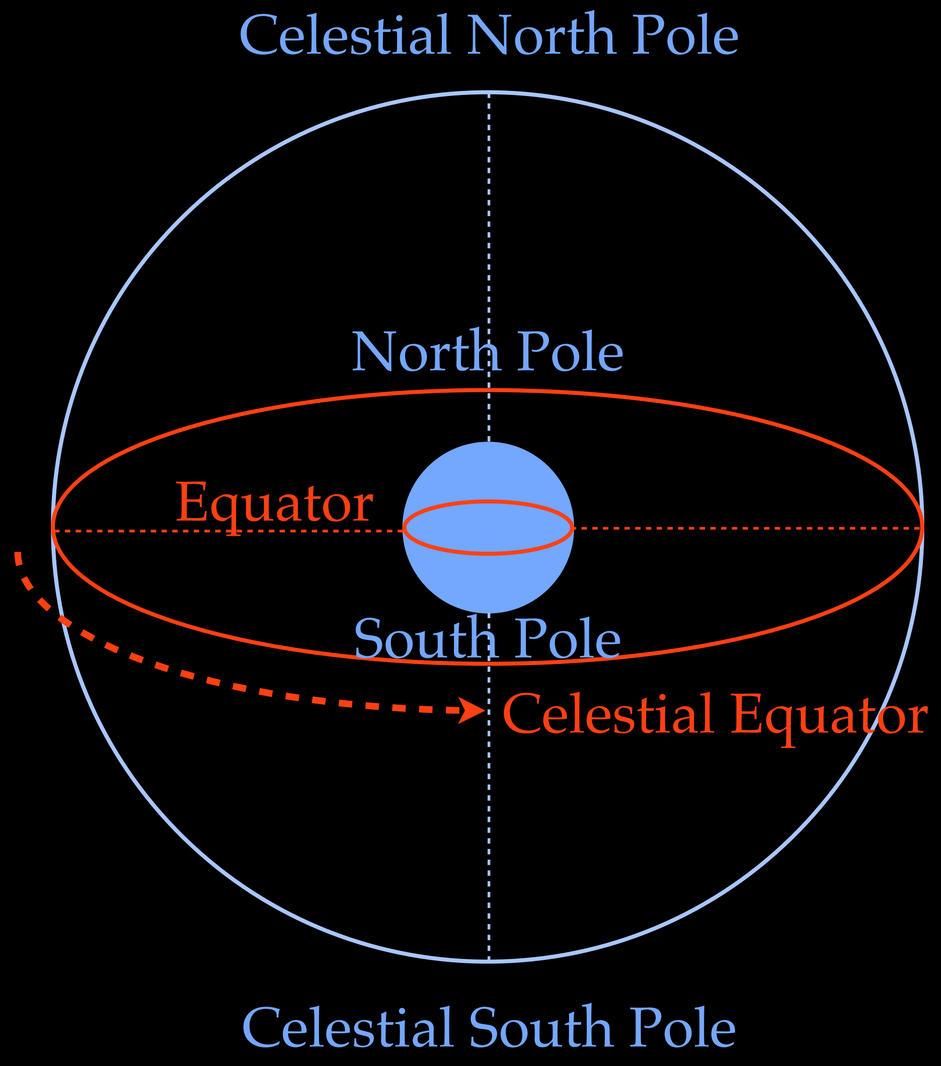
Motion of the Earth

Celestial Sphere

It appears as if everything moves around us.

Stars move across the sky, as does the Sun.

The point in the sky directly above the North/South pole appears to be stationary.



Celestial Pole

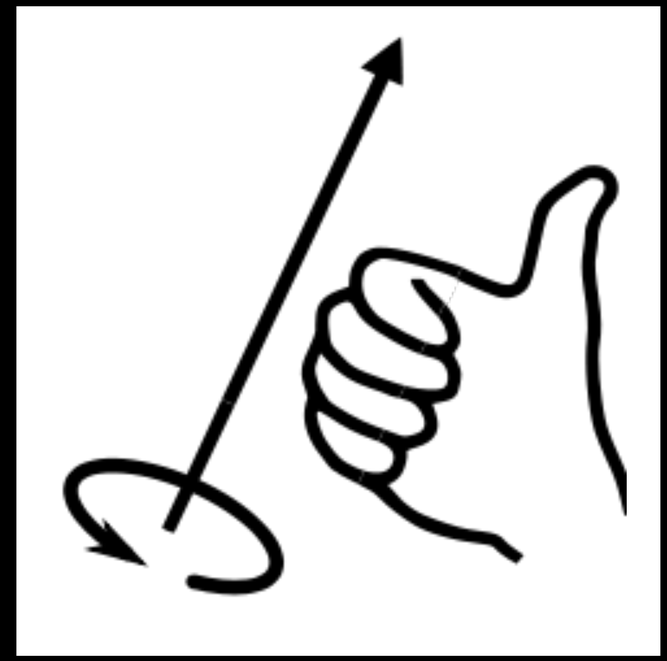
The further stars are from the poles, the faster they appear to be moving.

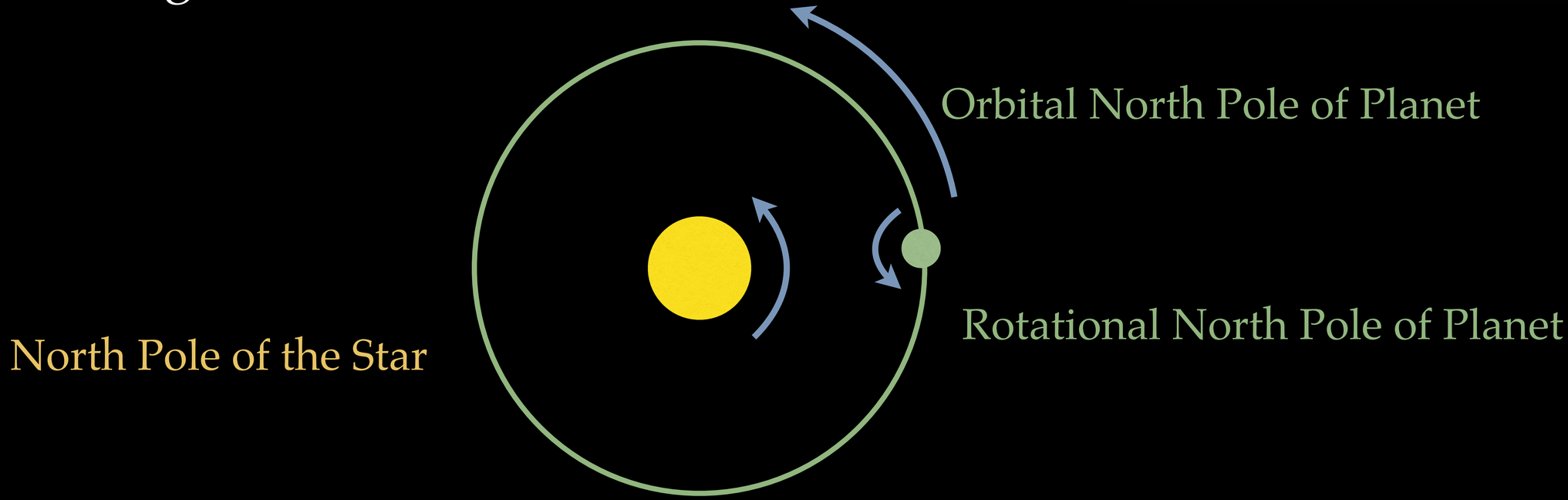
But they all rotate at the same angular rate:
$0.25^{o}/\text{min}$

North vs South

Counter-clockwise rotation is positive rotation, which we call with the “North Pole”.

If you see rotation in a counter-clockwise direction, you are looking at the “North Pole” of the rotation.

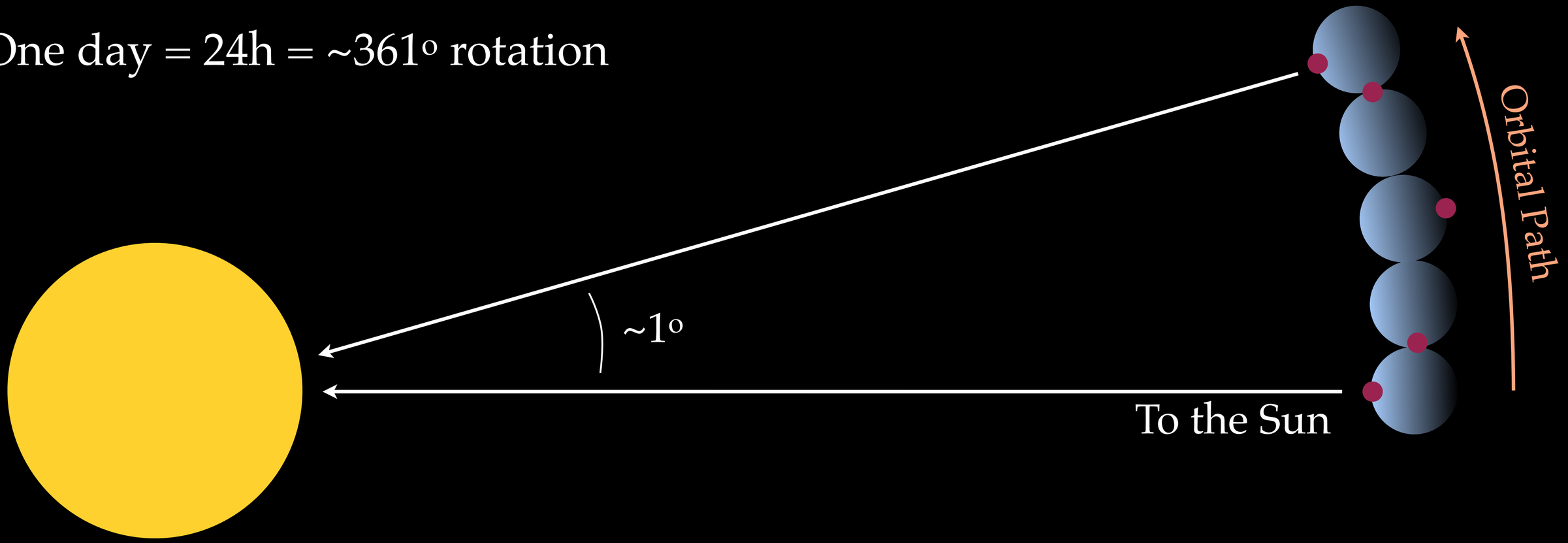




The “Day”

A “day” is commonly understood as the time taken for the Sun to return to the same position overhead. This is the “Solar Day”

One day = 24h = ~361^{o} rotation

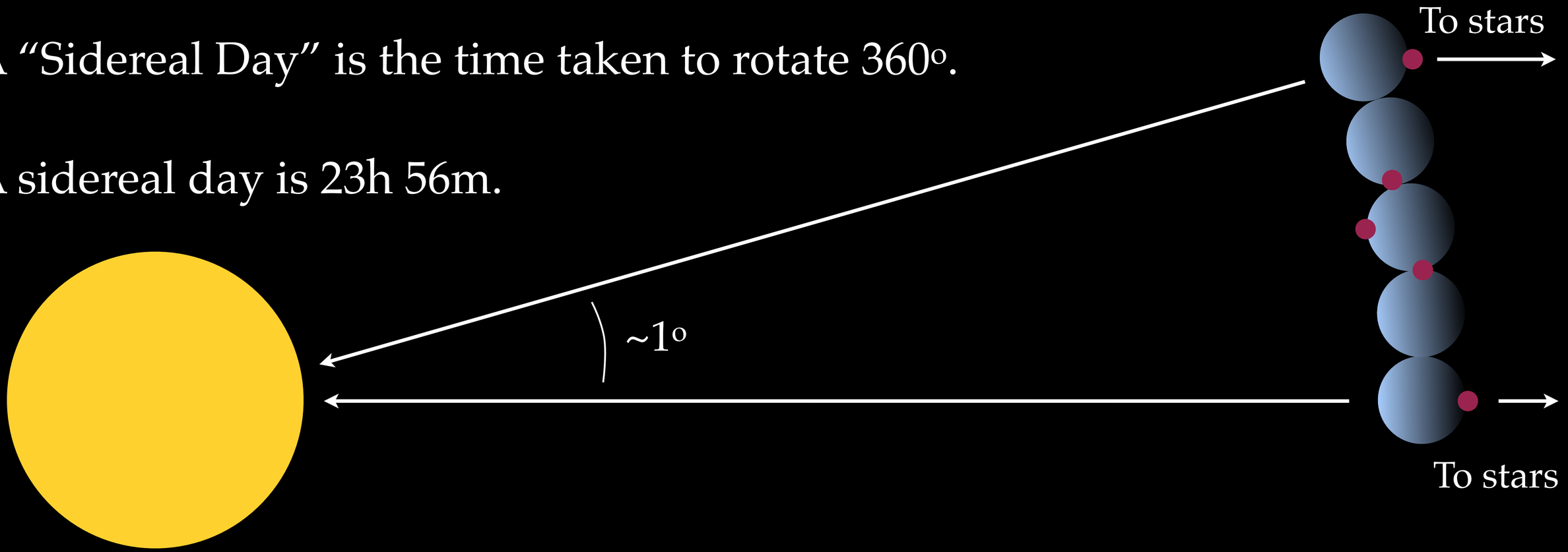


An Alternative “Day”

Because the Earth orbits the Sun, the Sun is NOT a good reference to determine rotation. Use the stars for that, instead.

A “Sidereal Day” is the time taken to rotate 360^{o}.

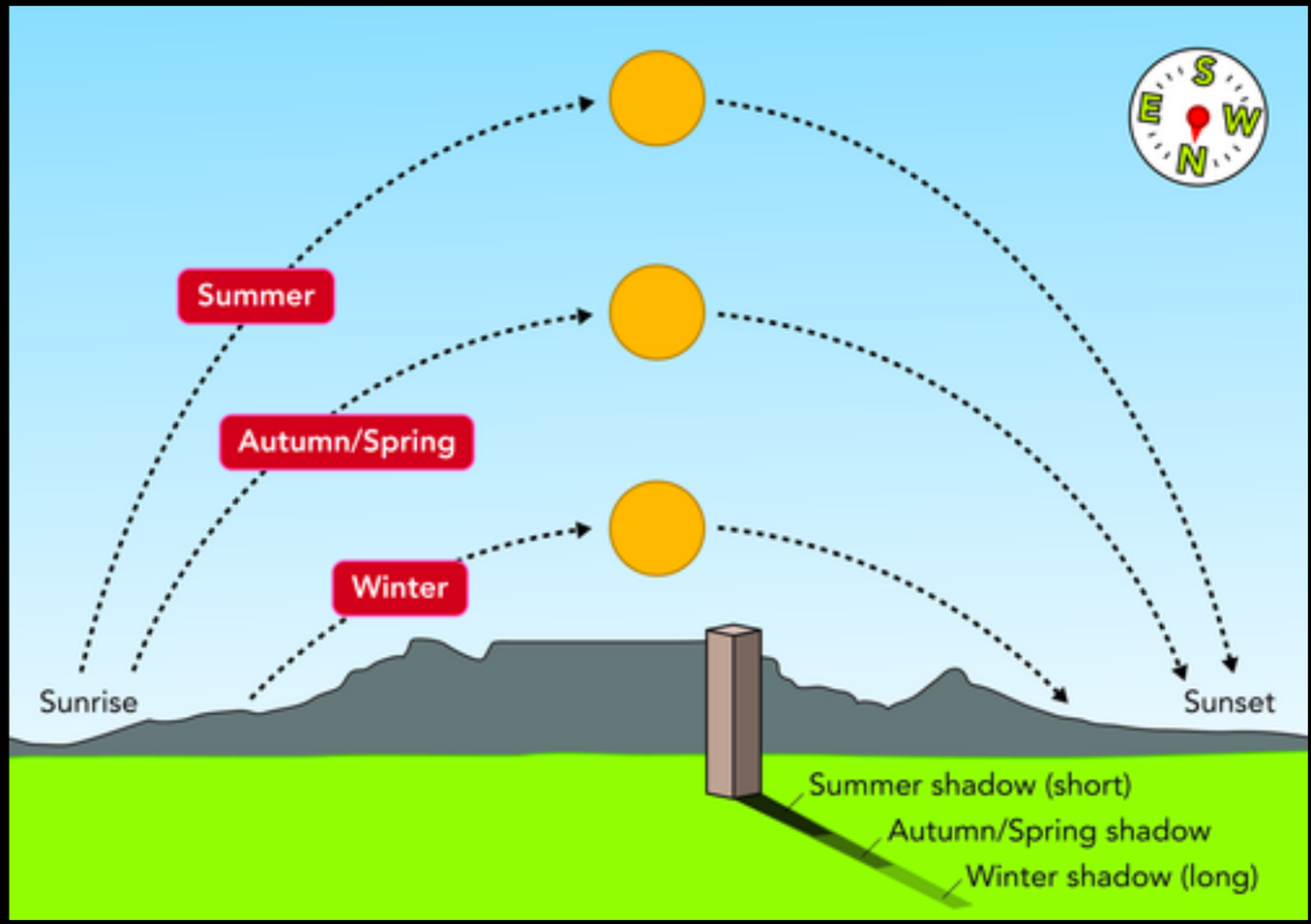
A sidereal day is 23h 56m.



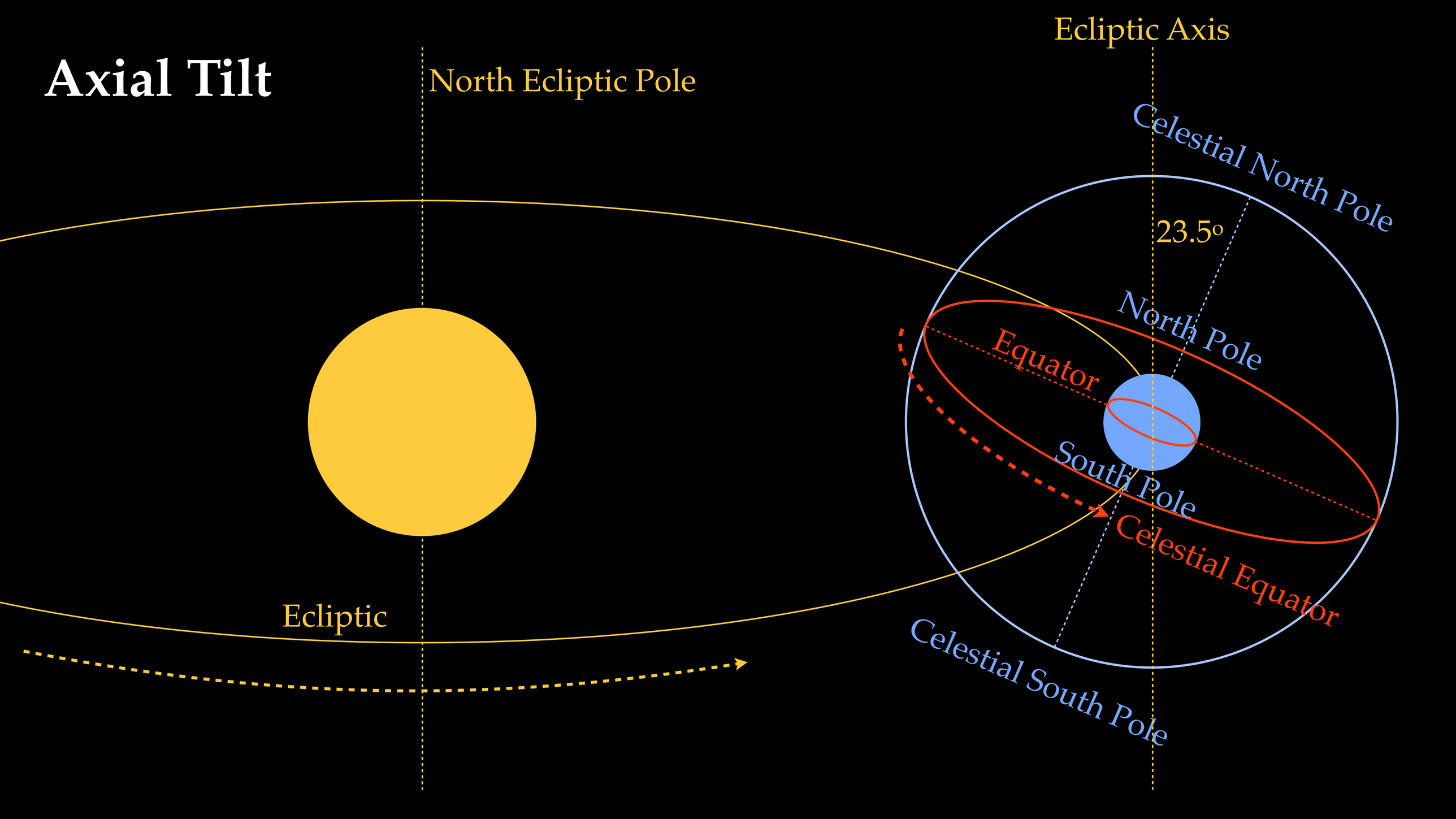
Motion of the Sun

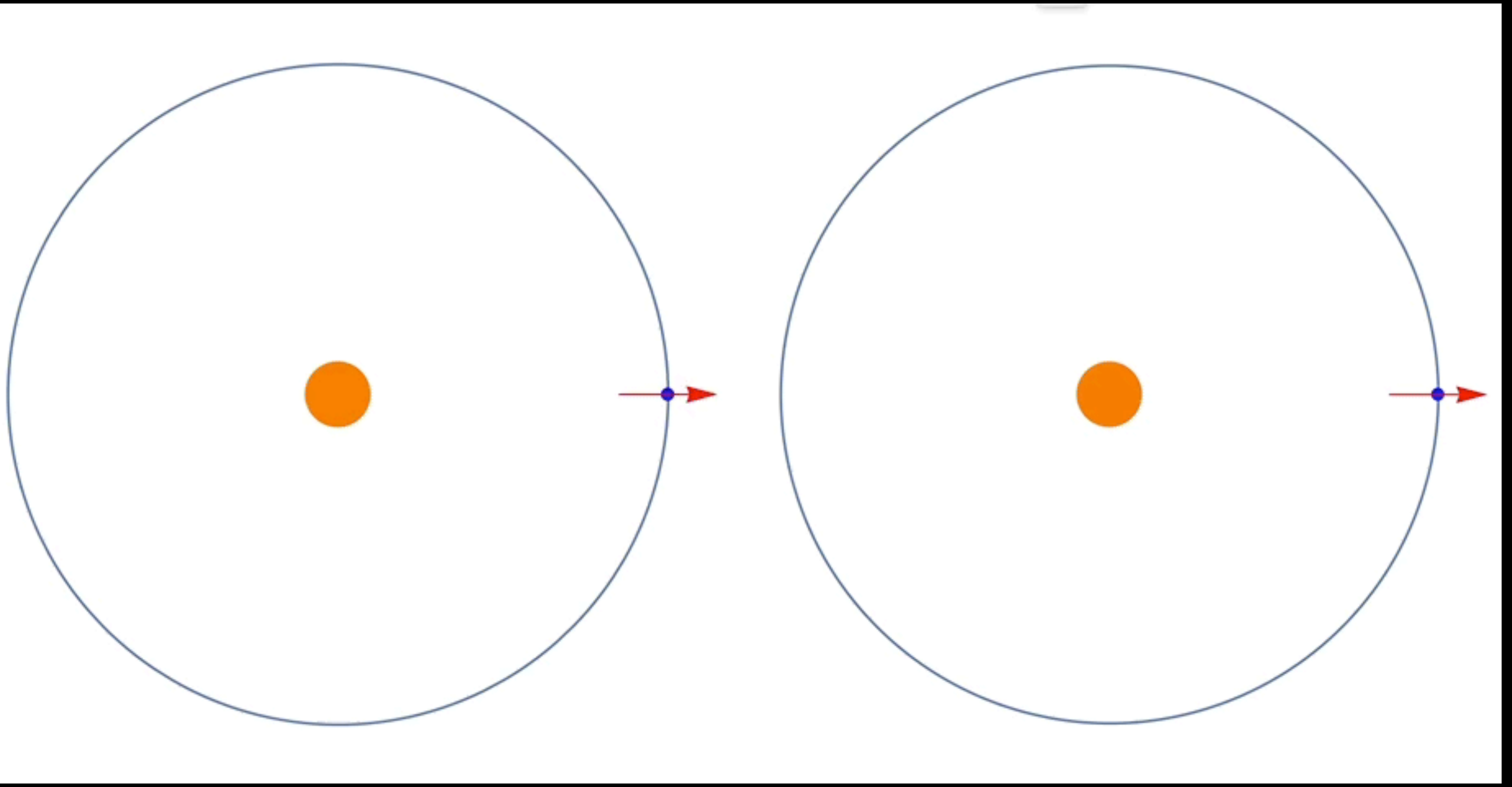
The Sun does not follow a uniform path. Its height above the horizon changes over the seasons.

This is due to Axial Tilt: Earth's rotation and Earth's orbit do not line up!

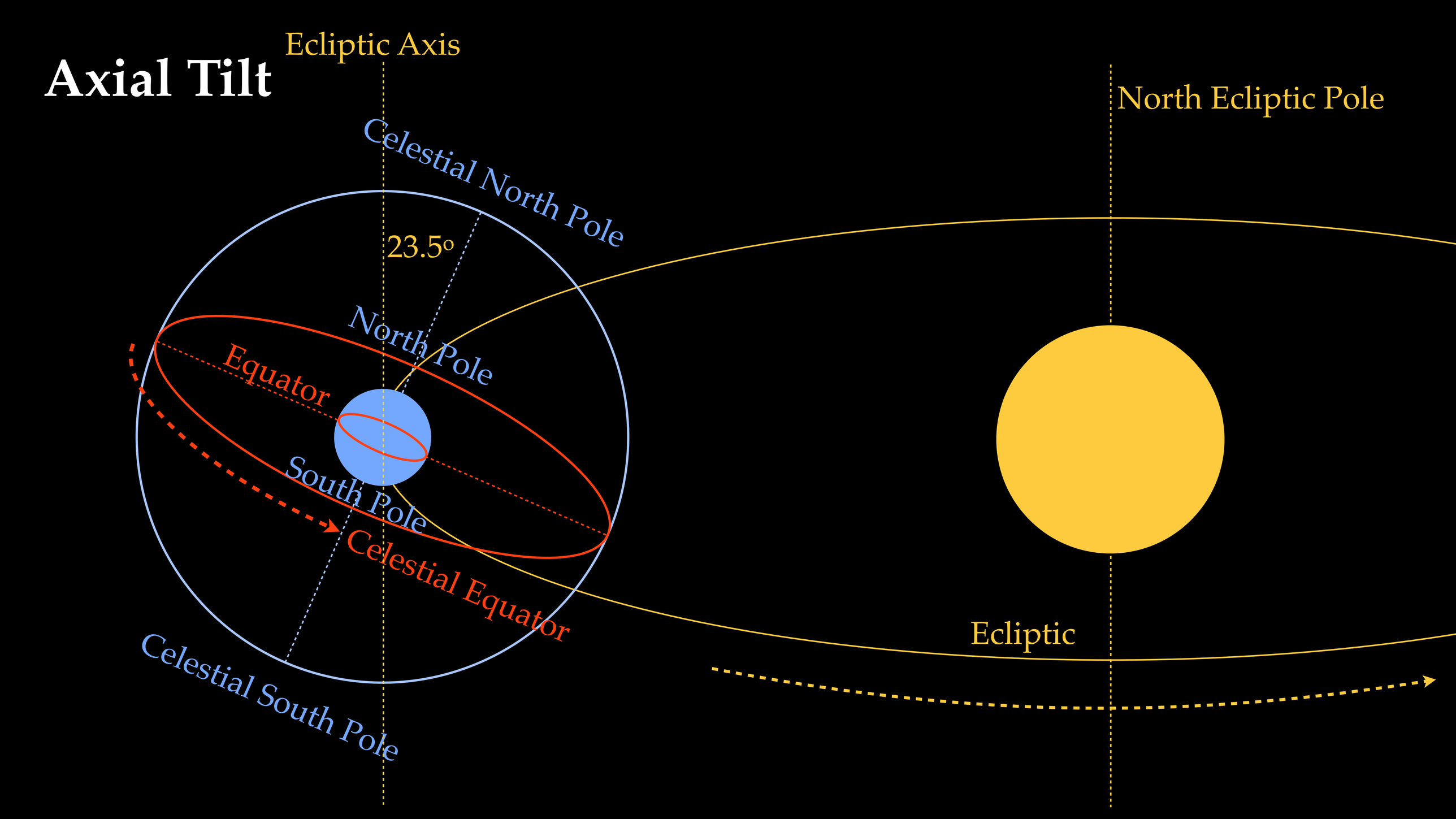


Axial Tilt


Ecliptic Axis
North Ecliptic Pole
Celestial North Pole
23.5°
North Pole
Equator
South Pole
Celestial Equator
Ecliptic
Celestial South Pole



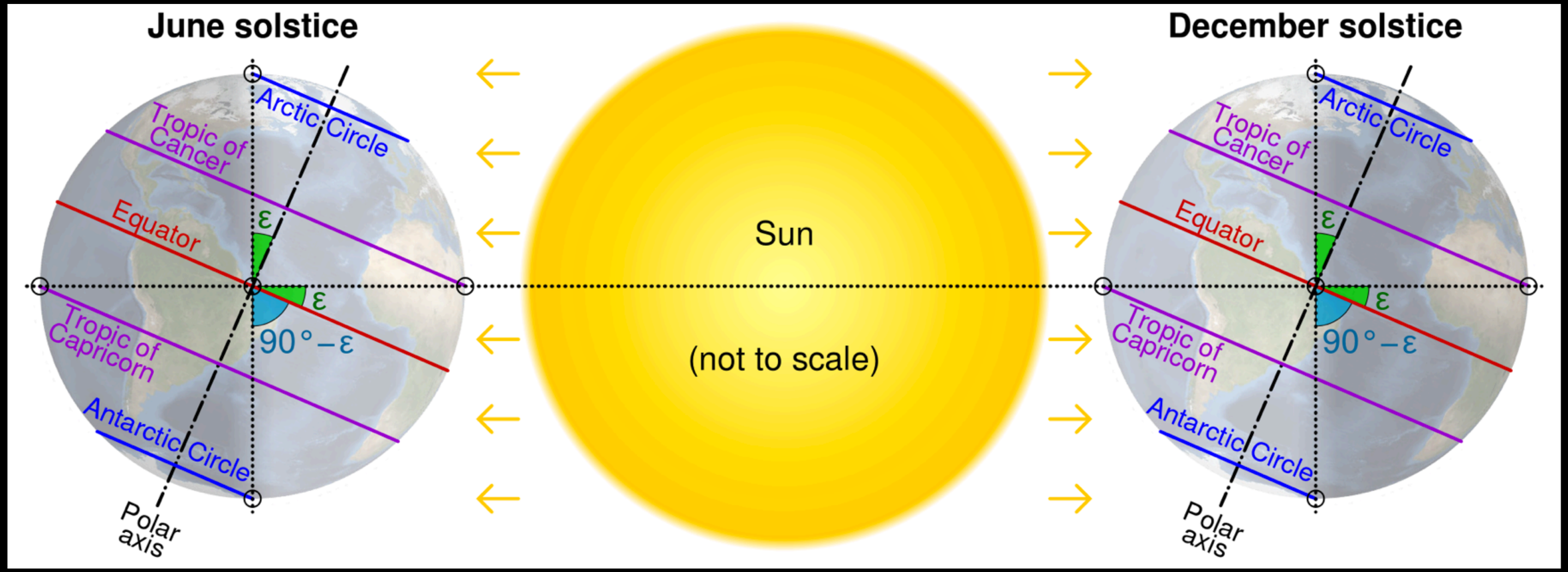
Axial Tilt


Ecliptic Axis
Celestial North Pole
23.5°
North Pole
Equator
South Pole
Celestial Equator
Celestial South Pole
North Ecliptic Pole
Ecliptic

https://gfycat.com/briefforsakenelver

Axial Tilt

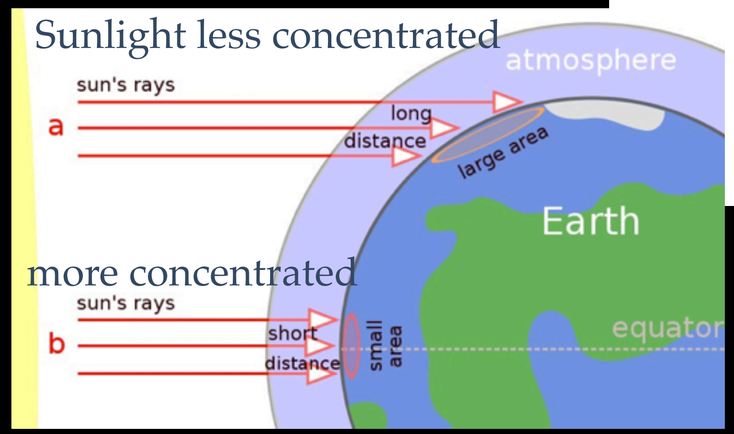
The axis of rotation always points in the same direction, no matter where the planet is relative to the Sun. This is the primary cause of our seasons.

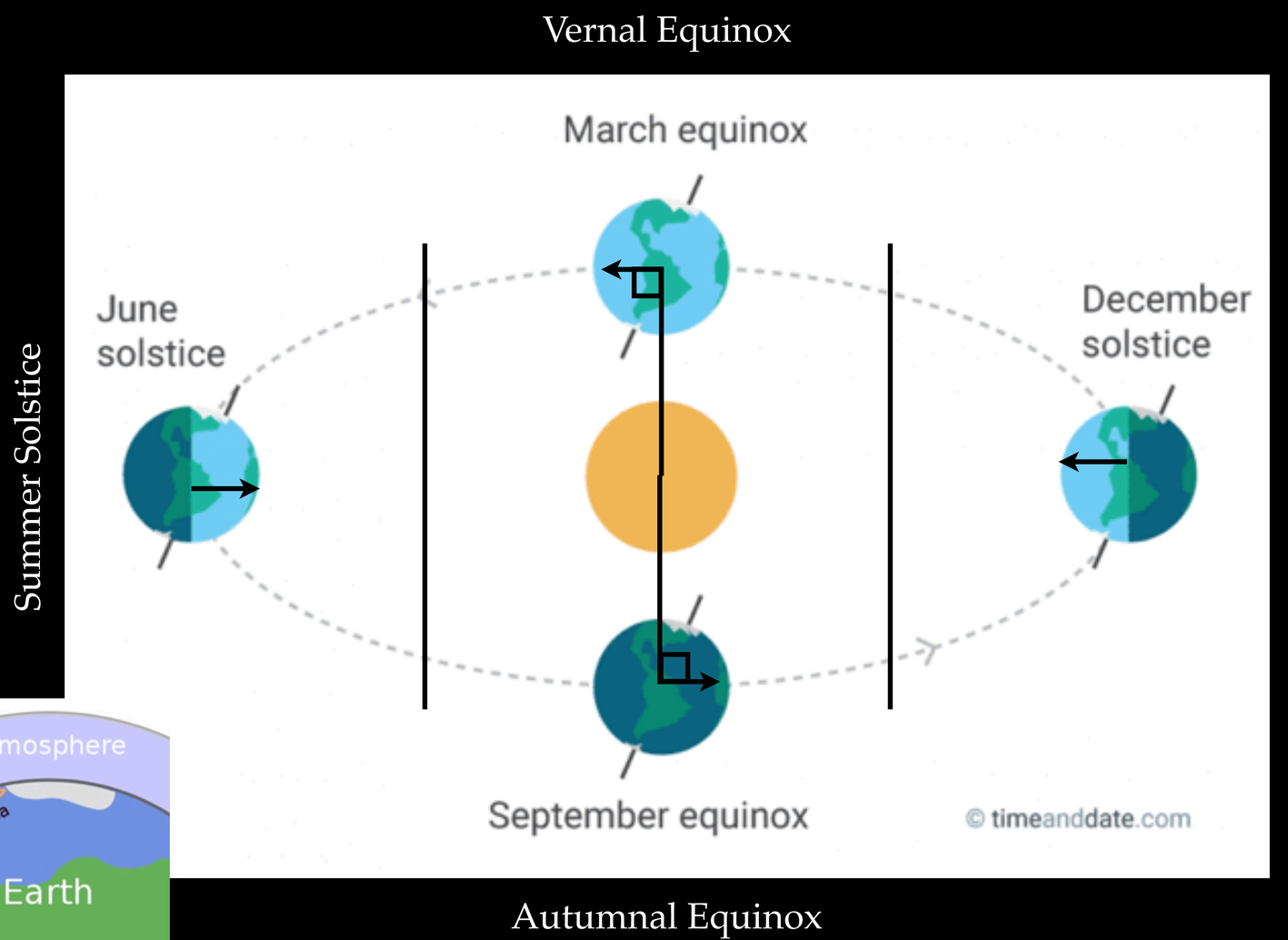


Solstices and Equinoxes

Solstices occur when the axial tilt aligns with the Sun.

Equinoxes occur when the axial tilt is perpendicular to the line connecting Earth to the Sun.

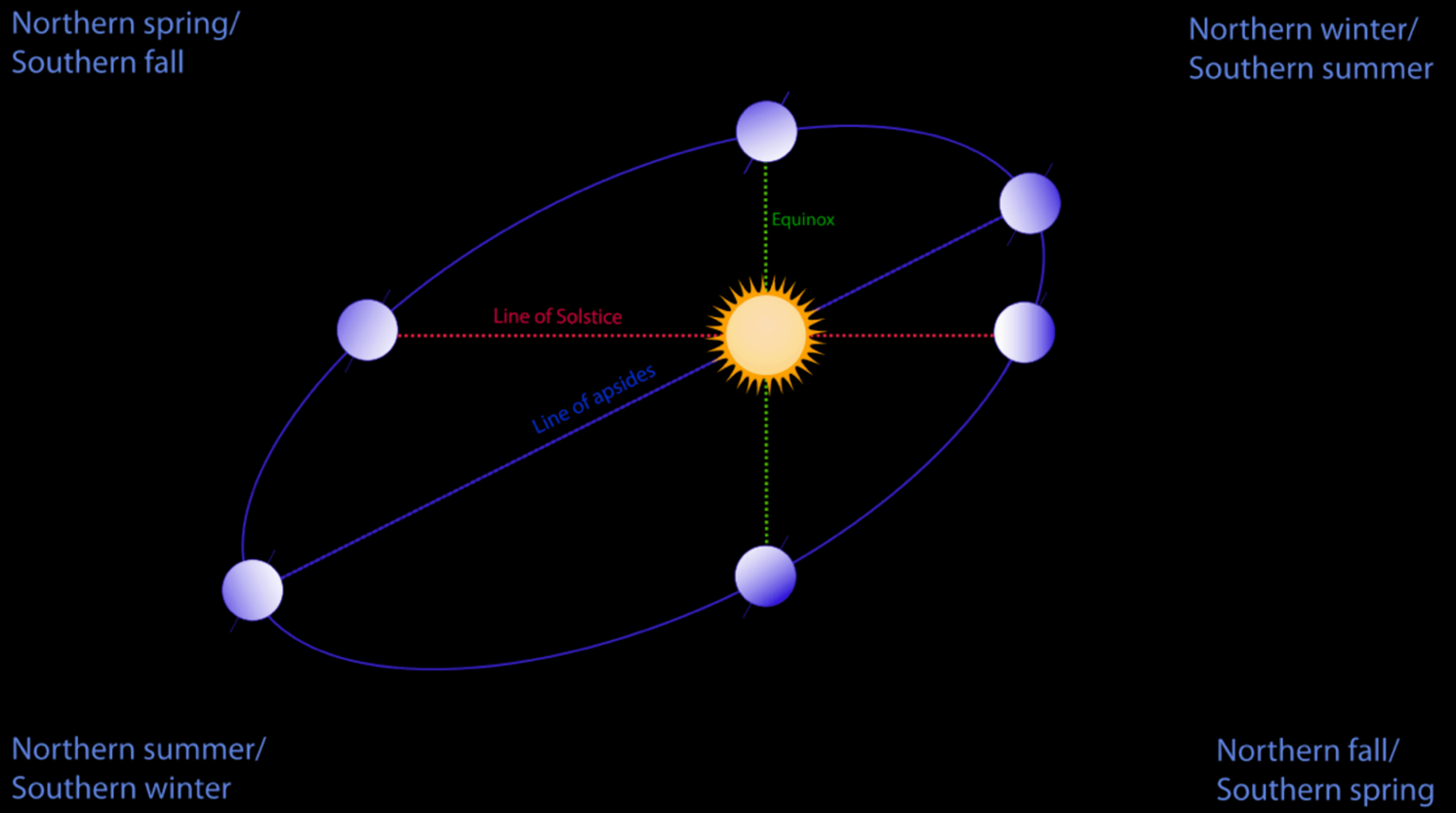




Elliptical orbit

Earth's orbit isn't perfectly circular - in addition to axial tilt, we also have an elliptical orbit.

Earth is furthest from the Sun in Northern Hemisphere Summer.



The Changing Orbit

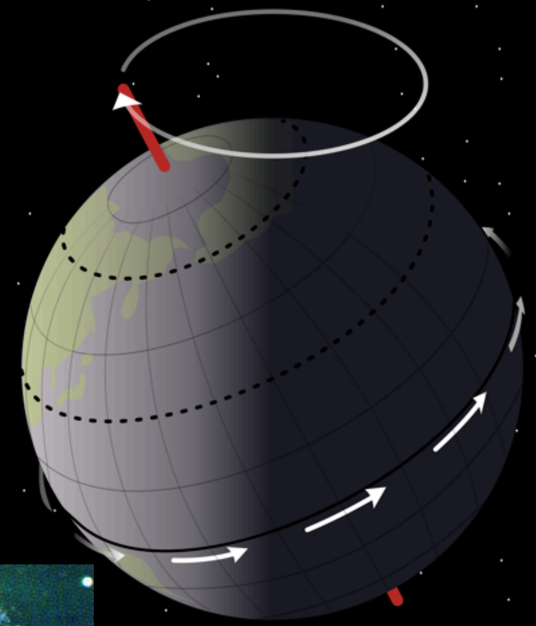
Earth's rotation axis changes direction over time!

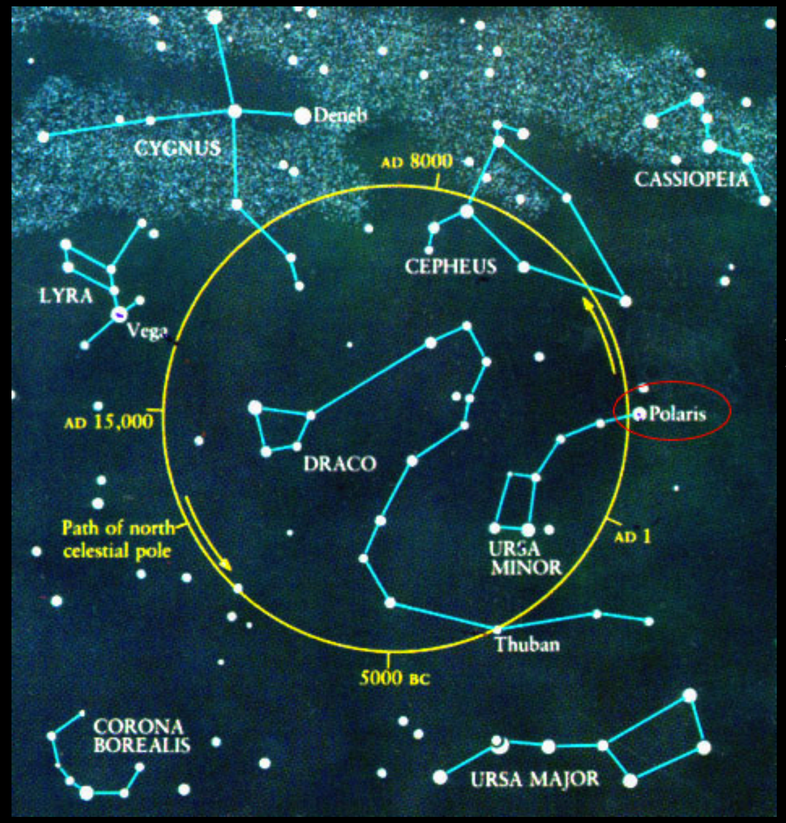
This is called "Precession".

The precessional period of Earth is 26 000 years.

3000+ years ago, Polaris was NOT the North Star!

Earth's orbit precesses, too!





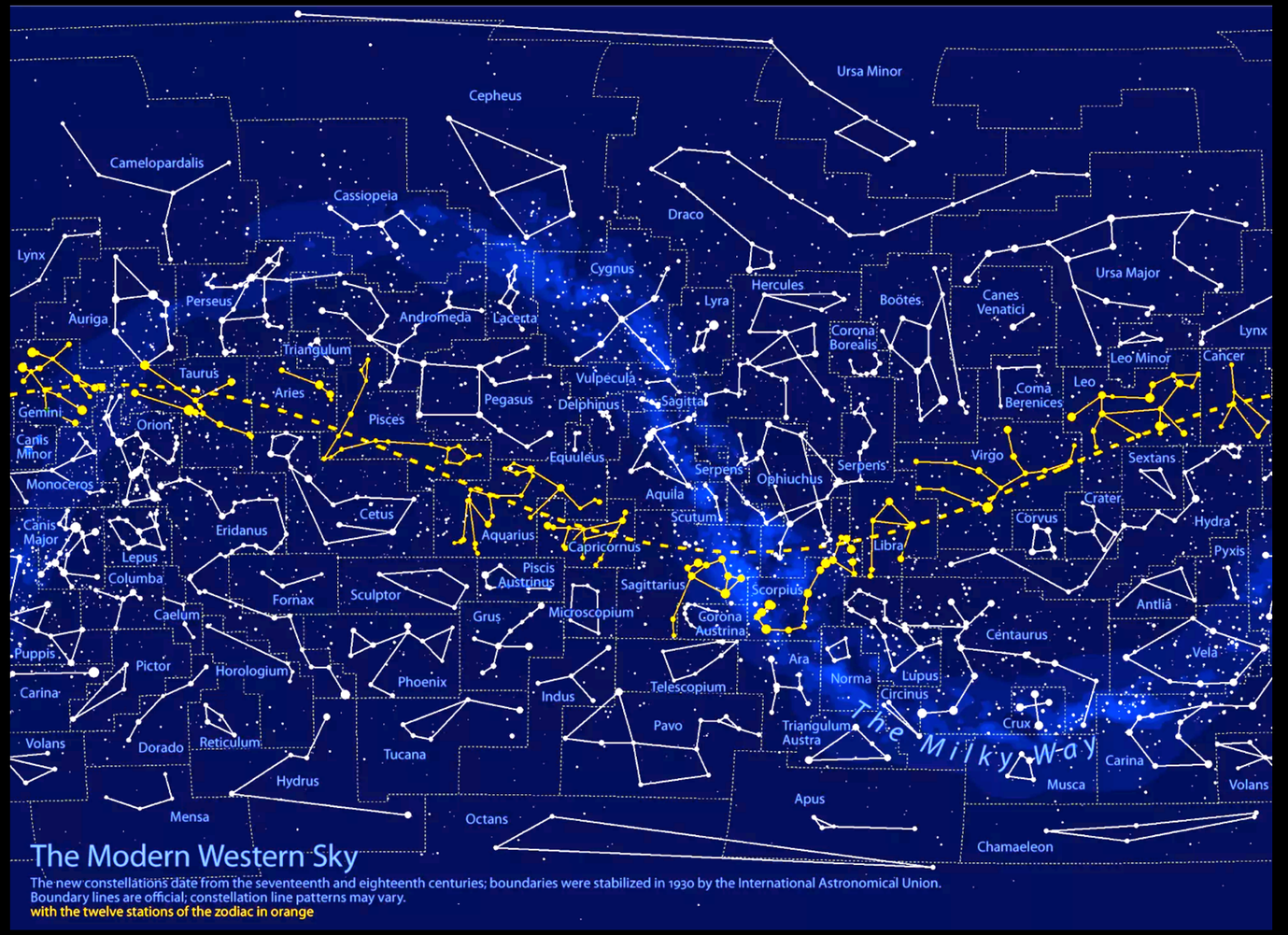
Polaris is North Star now

Thuban was North Star in 3000 BC

The Changing Orbit

The precessional changes to Earth's orbit have affected the alignment of the Sun with the zodiac constellations.

Astrology claims that celestial alignment influences life. How can that be when the alignment has changed but the theory has not?



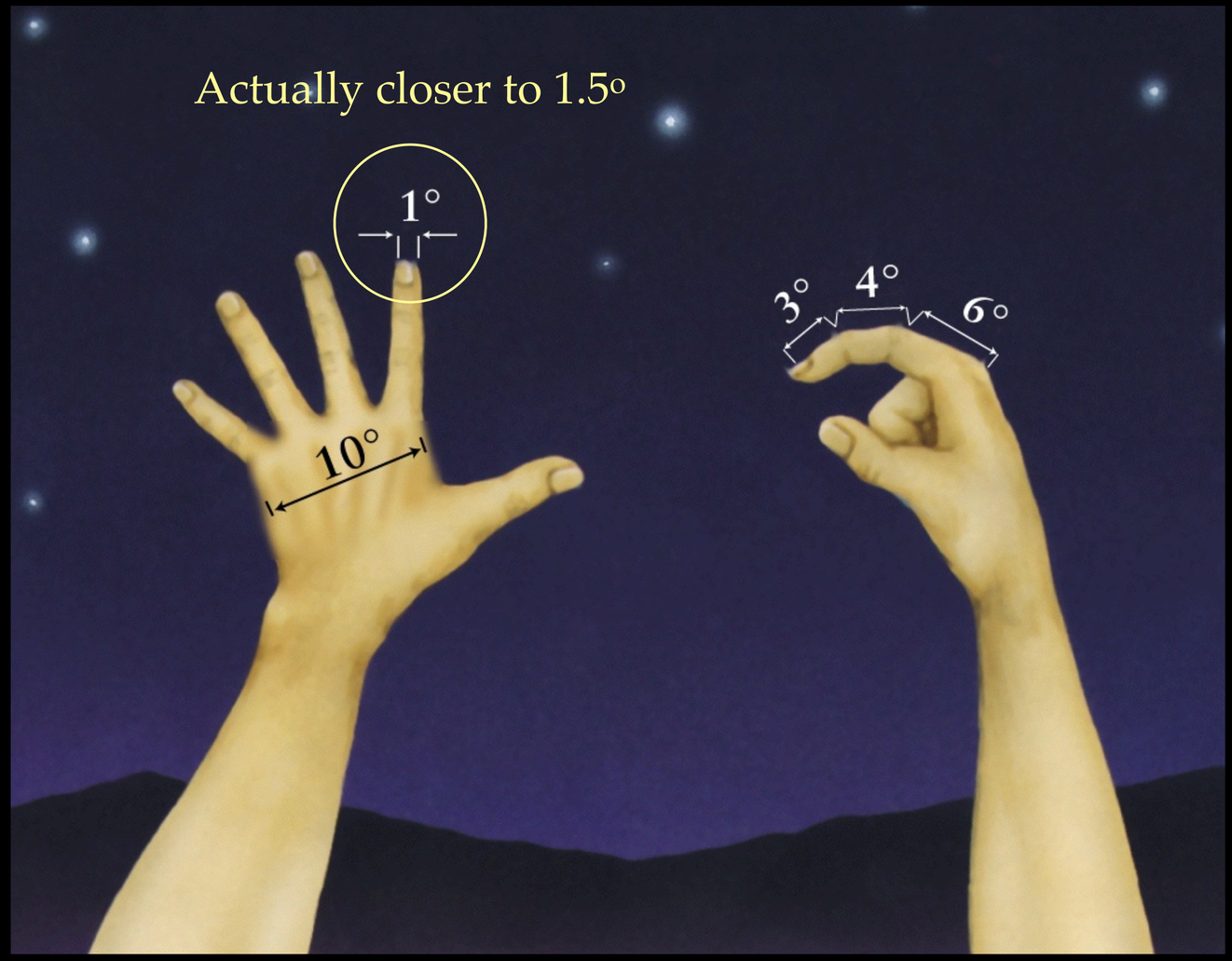
Using Angles in Astronomy

Measuring Angles

You can approximate angles by using your hands.

Recall: 360^{o} in a circle.

But you can see at most ~180^{o} of the night sky, due to the ground around you.



Measuring Angles

Decimals of degrees can be used to describe angles smaller than 1^o.

In astronomy, a different convention is often used:

Arcminute $= 1' = 1/60^o$

Arcsecond $= 1'' = 1/60' = 1/3600^o$

Above: This is 1^o.
Below: This is 0.5^o.

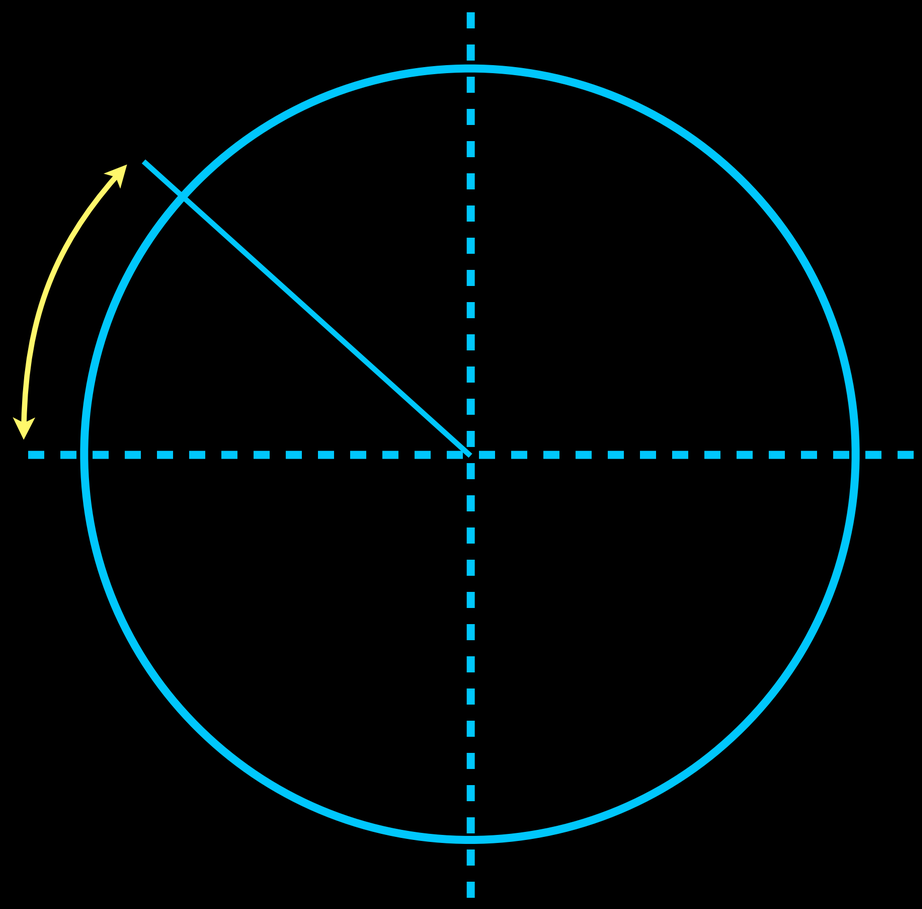
While these seem small, technology can measure angles smaller than 0.00001^o.
That is so small, I cannot illustrate it properly on a lecture slide!

Measuring Angles

To complicate matters, astronomers also commonly use HOURS to measure angles!

$360^o = 24h$, so $1h = 15^o$, and $4m = 1^o$.

There is some usefulness in this -
if the Earth rotates every ~24h,
then it clearly tells us approximately
how far something will move in the
sky in a certain amount of time.

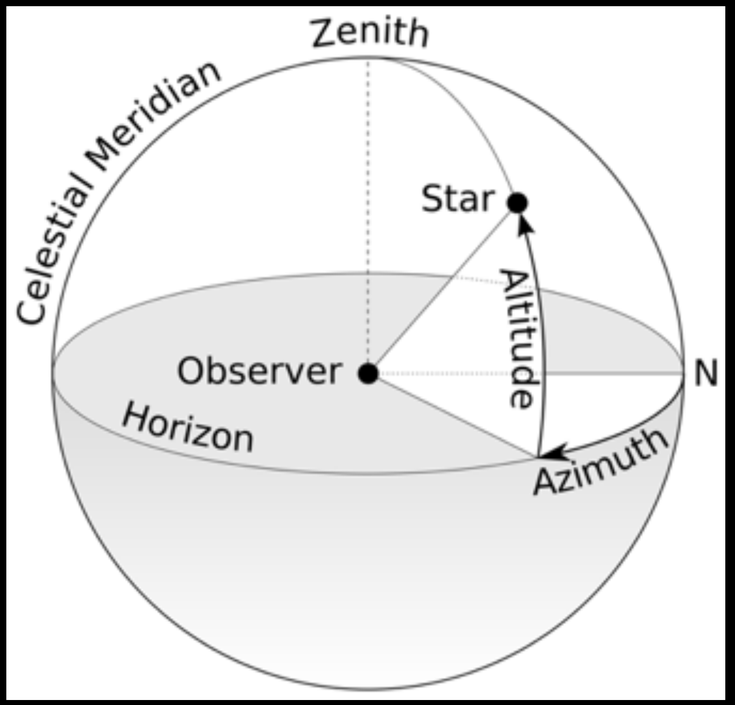


$42.34^o = 42^o\ 20'\ 24'' = 2h\ 49m\ 21.6s$

Communicating Celestial Positions

Constellations are not an accurate way of communicating celestial objects/events.

One of the earliest ways:
measure angle relative to North (azimuth)
measure angle above the horizon (altitude)



Because Earth is a sphere, must also state your Zenith (directly overhead) or Nadir (directly underneath).

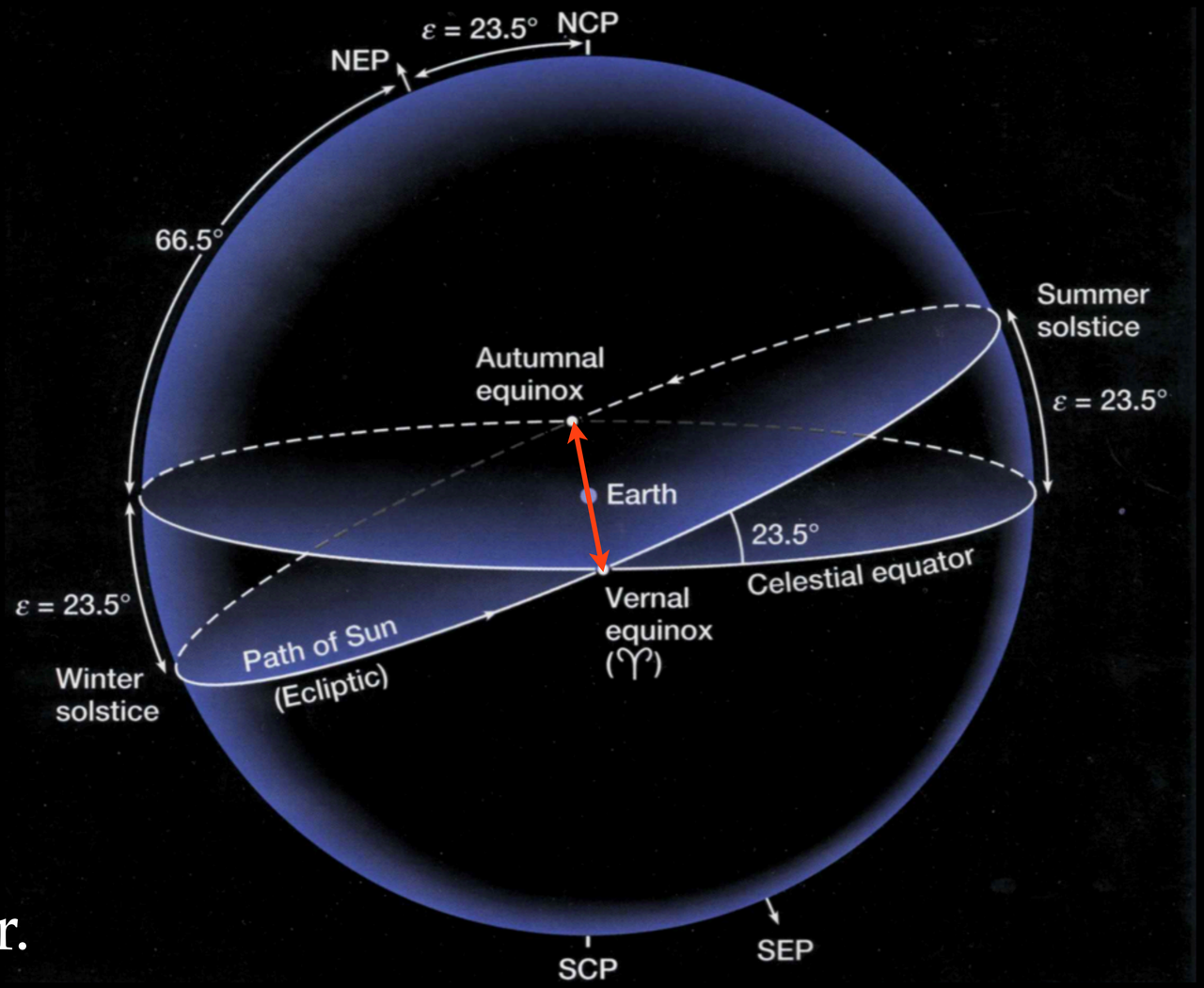
Since the Earth rotates, orbits and precesses, this is not a simple feat to track!

Communicating Celestial Positions

Modern mapping requires
a common fixed position on
the celestial sphere to reference.

We use the Vernal Equinox as
the (0,0) point.

The line between the equinoxes
is formed by the intersection of
the ecliptic plane, and our equator.



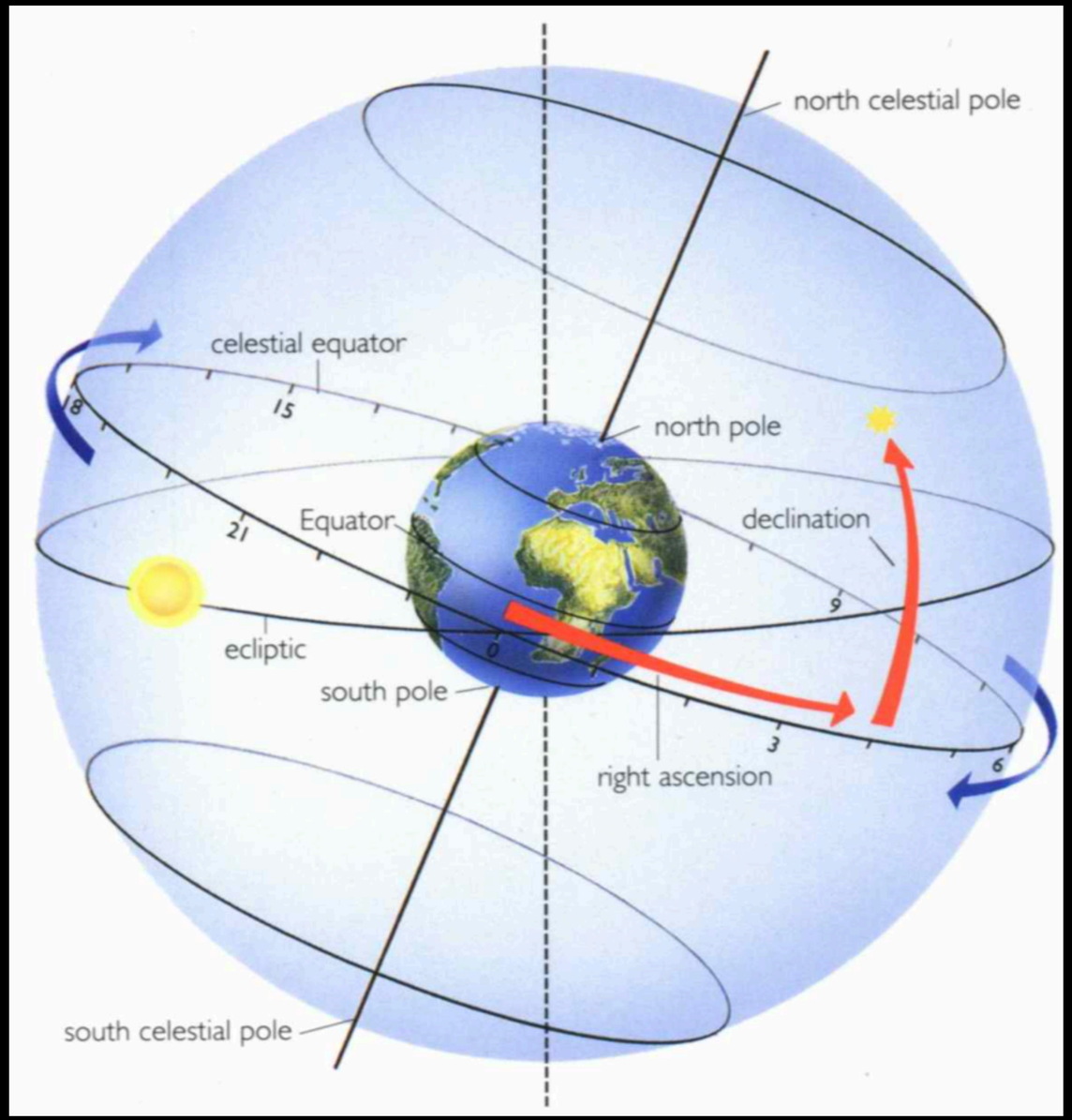
Communicating Celestial Positions

Right ascension is measured East of the Vernal Equinox.

Right Ascension maps 0h to 24h.

Declination is measured North / South of the celestial equator. Angles measured North of the equator are positive.

Declination maps -90^{o} to +90^{o}.

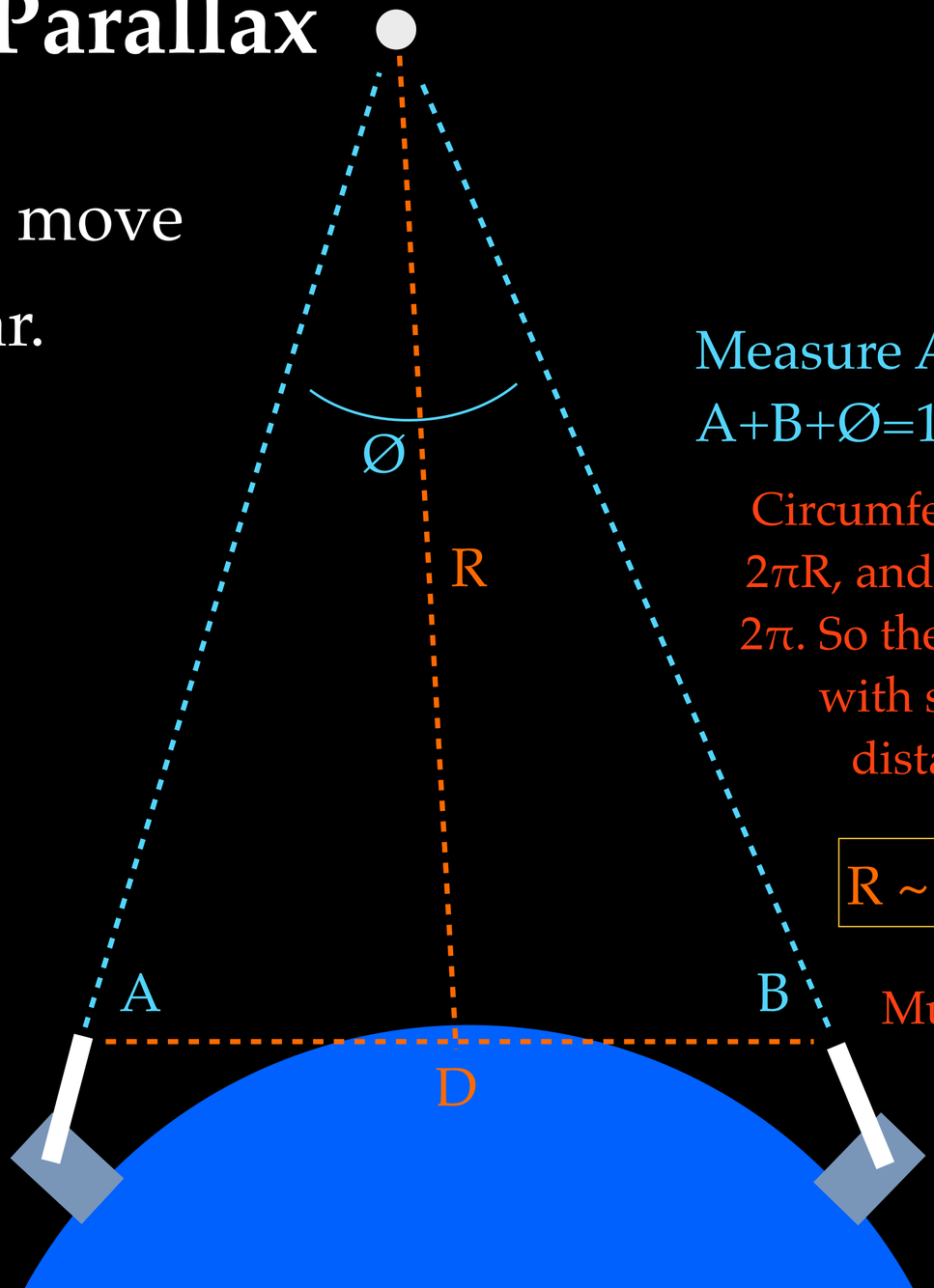


Measuring distance with Parallax

Stars appear to be stationary: they move on the order of arcseconds per year.

Triangulation is used to measure their distance!

To do this, we need to be able to measure angular positions very accurately!



Measure A & B:
$A+B+\emptyset=180^o$

Circumference of a circle is $2\pi R$, and the radial angle is 2π. So the portion of a circle with some angle has distance angle*R.

$$R \sim (180/\pi)\, D/\emptyset$$

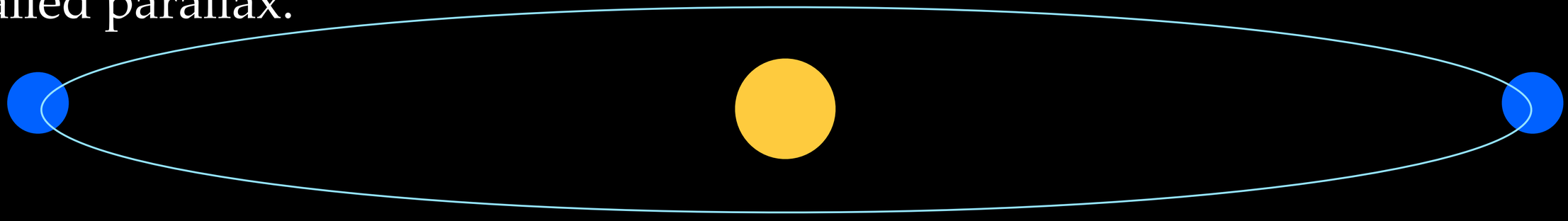
Multiply by $180/\pi$ to convert degrees to radians

Measuring Longer Distances

Highest precision angle is 0.001”, which allows measuring distances less than 0.28ly using two observatories simultaneously on Earth. That’s ~1/15th of the distance to the nearest star!

To measure distances more accurately, we use a longer baseline: The diameter of the orbit of the Earth!

The angular difference between the two positions (Ø) when doing this is called parallax.

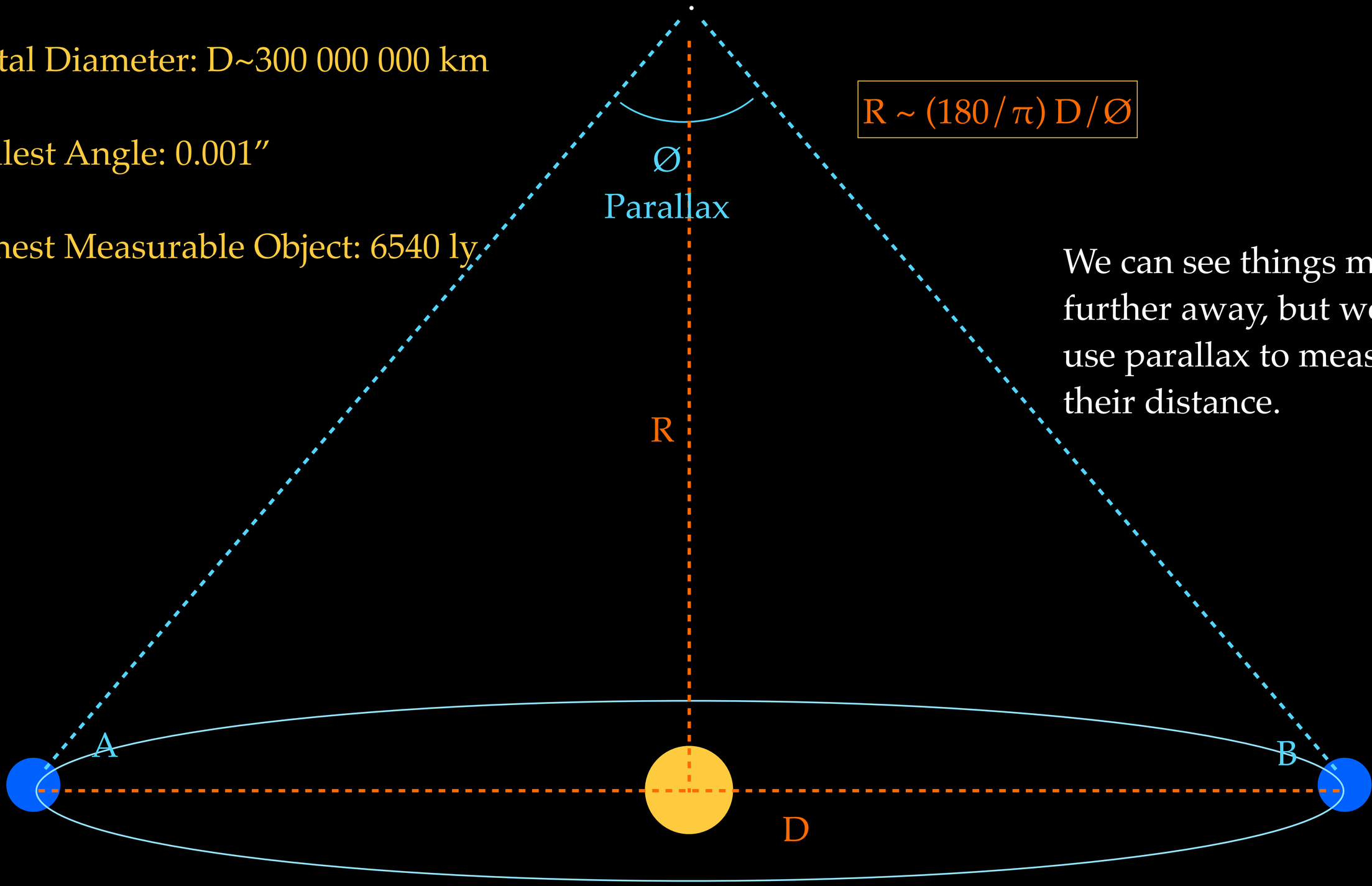


Orbital Diameter: D~300 000 000 km

Smallest Angle: 0.001”

Furthest Measurable Object: 6540 ly

$R \sim (180/\pi)\, D/Ø$



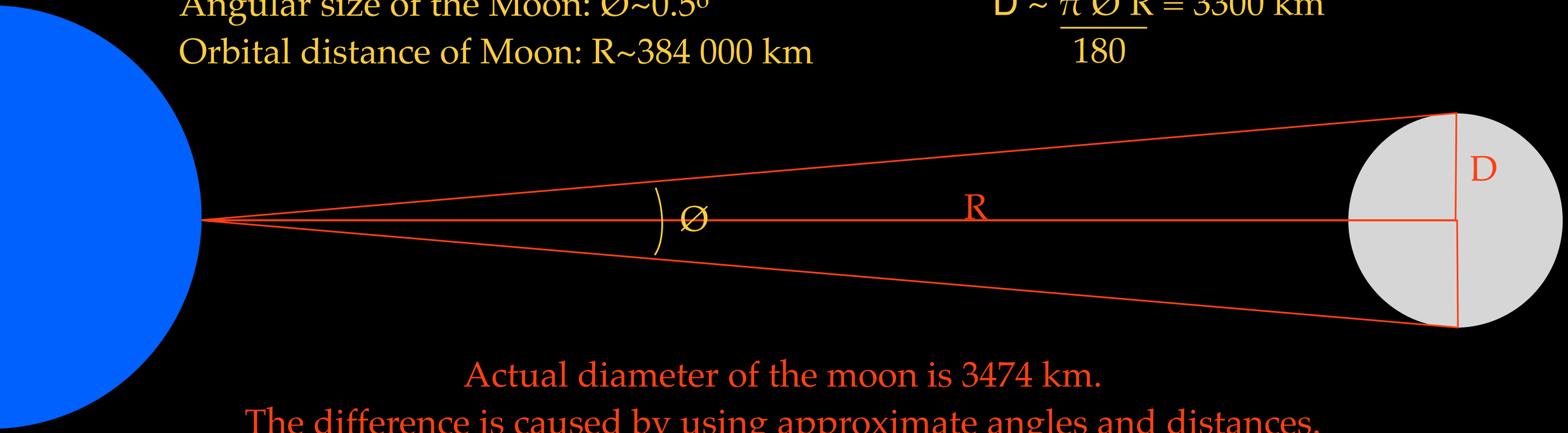
We can see things much further away, but we can’t use parallax to measure their distance.

Measuring the size of planets

We can measure the sizes of some objects using triangulation, too.

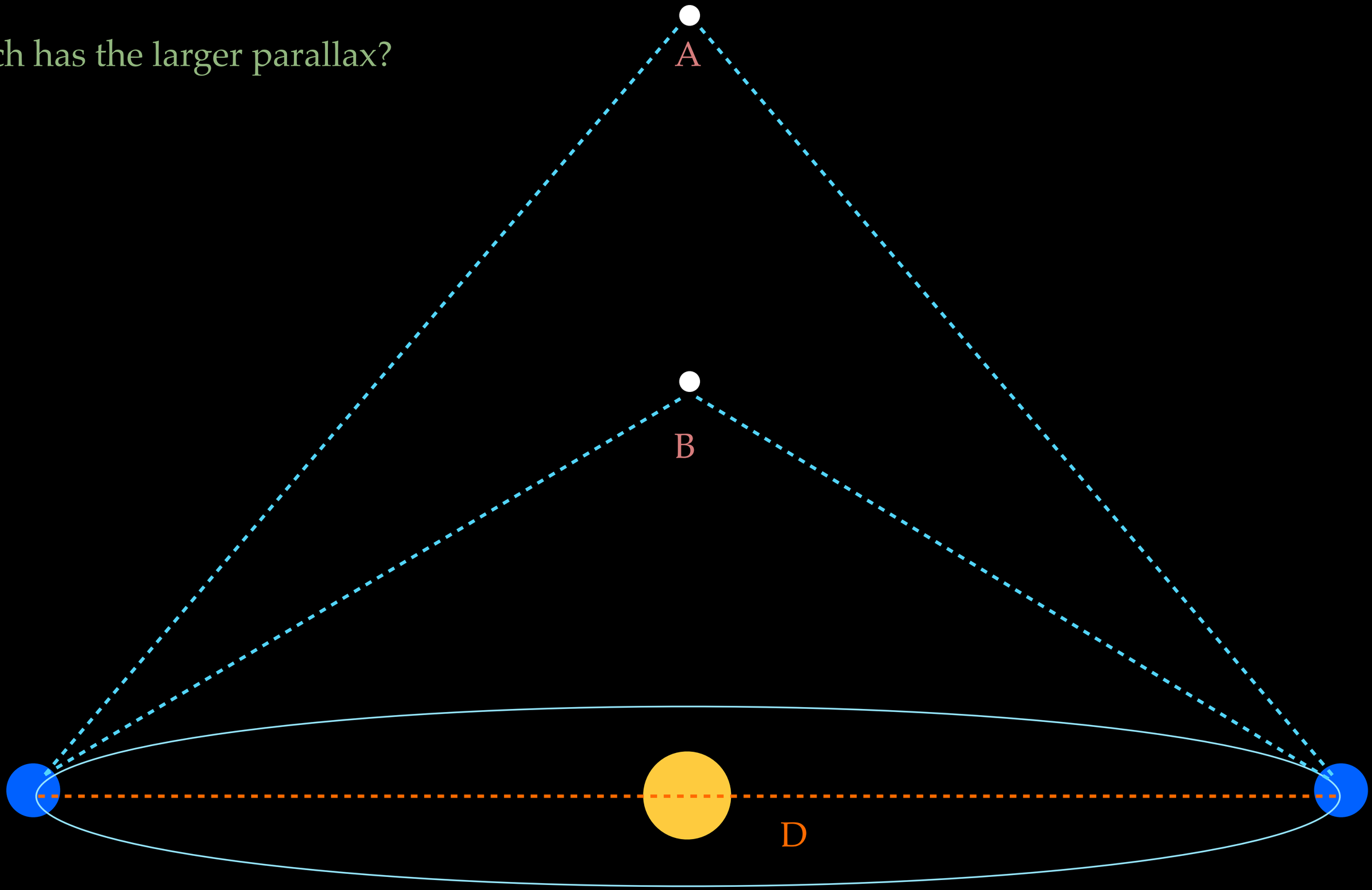
Angular size of the Moon: Ø~0.5°
Orbital distance of Moon: R~384 000 km

$$D \sim \frac{\pi \, Ø \, R}{180} = 3300 \text{ km}$$



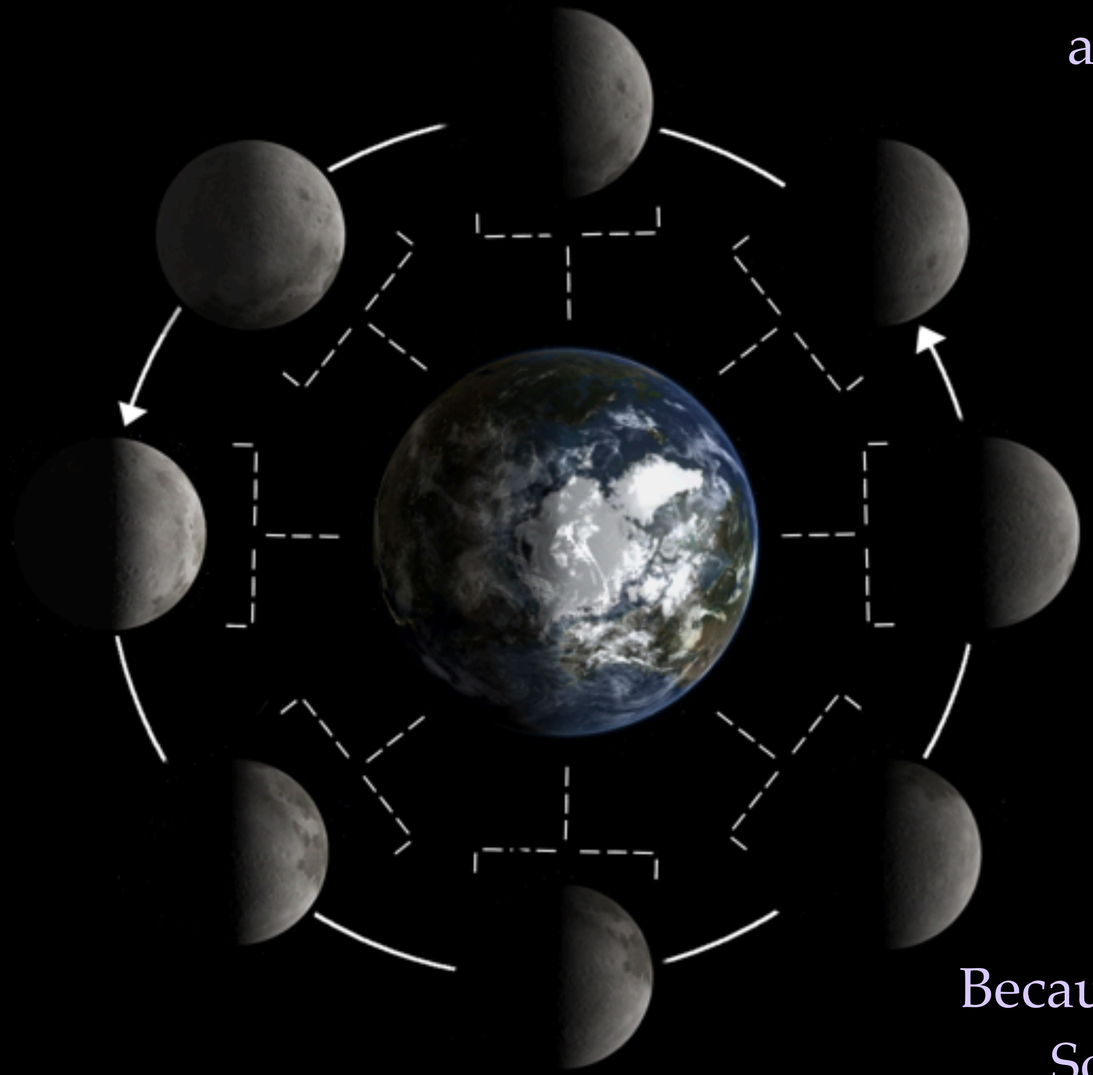
Actual diameter of the moon is 3474 km.
The difference is caused by using approximate angles and distances.

Which has the larger parallax?



The Motion of the Sun & Moon

Phases of the Moon



The Moon orbits the Earth once every 27.3 days - this is known as a Sidereal Month - the time taken for the Moon to align exactly in the same place among the stars.

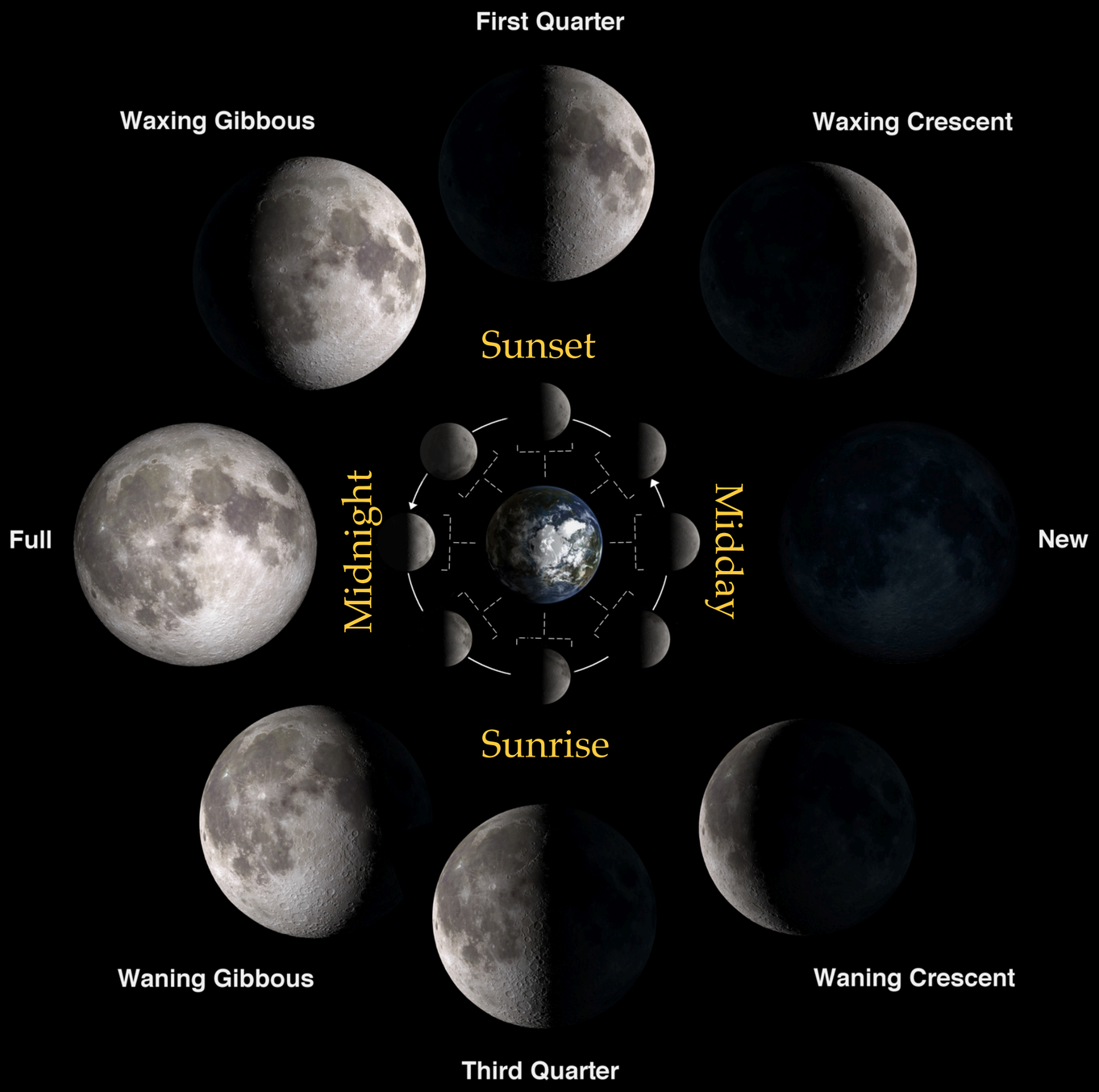
Because the Earth is orbiting the Sun, much like the Sidereal vs Solar day, the periodicity of the PHASES of the Moon is different than its orbital period.

Phases of the Moon

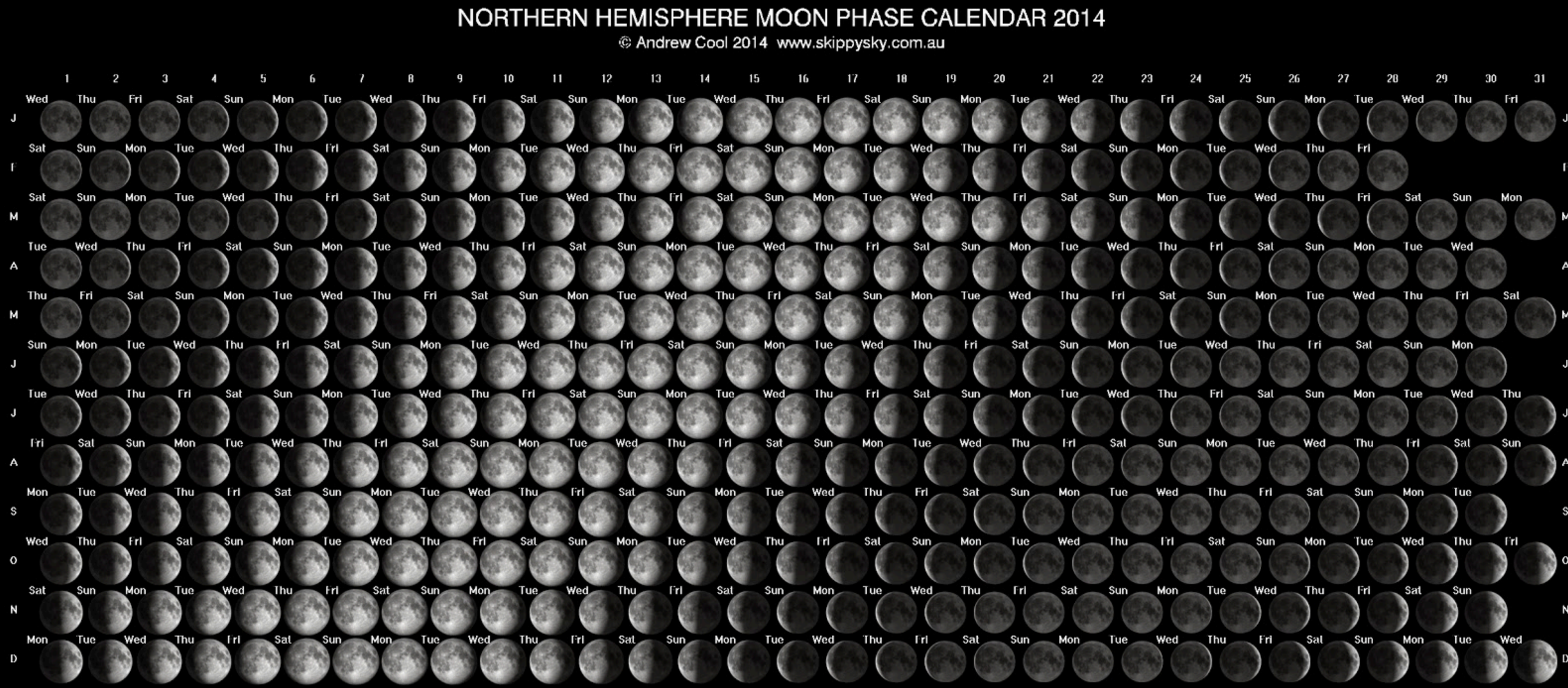
Period of Phases: 29.5 days

Many people believe that the moon influences biological processes.

Beware: “Studies show...” Meta analyses find no relationship between the Moon’s periodicity and any human pattern/ behaviour.



Phases of the Moon



Lunar Eclipse

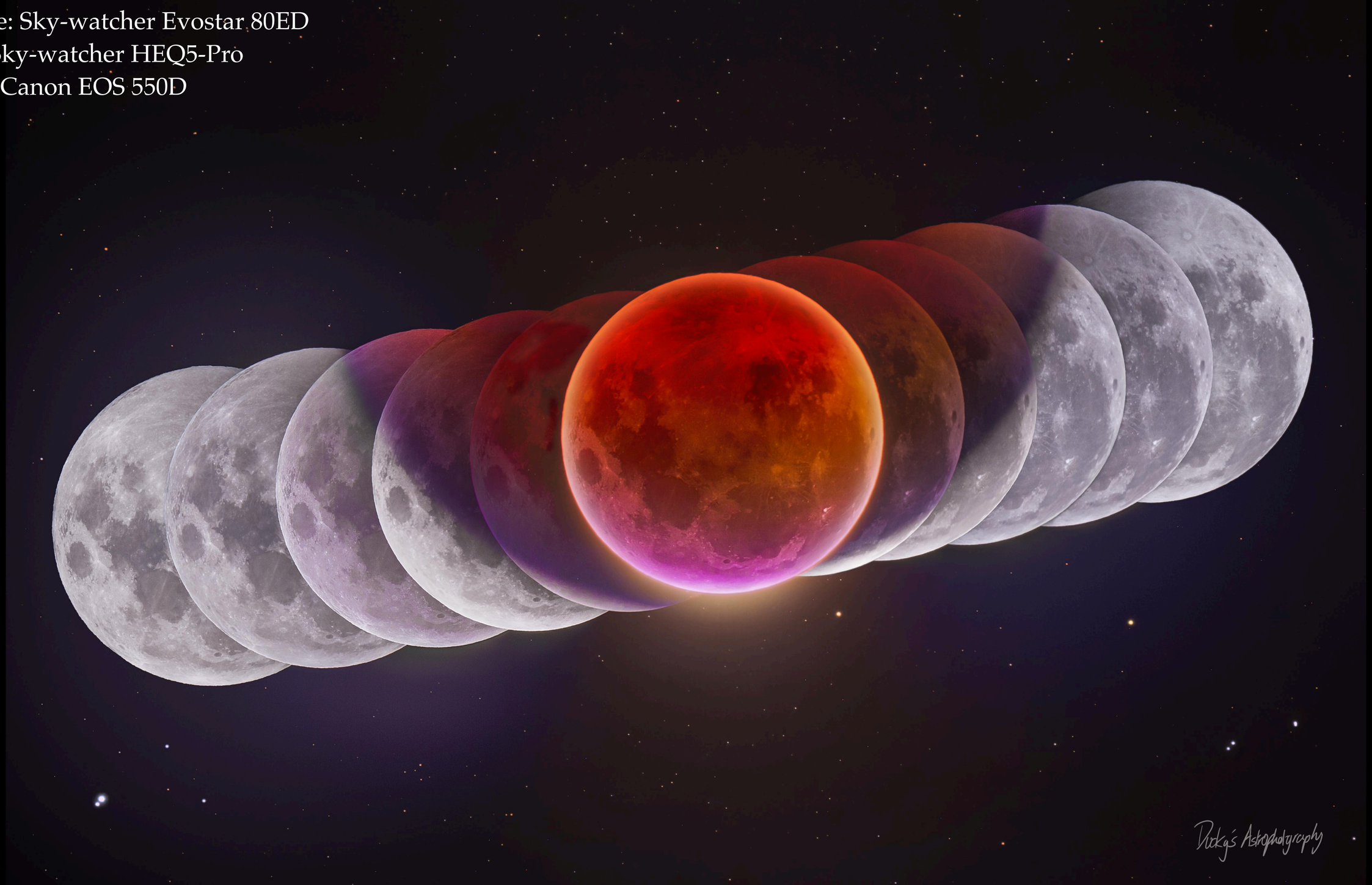
When the Moon passes behind Earth, Earth's shadow is cast on to the Moon.

There would be a reddish glow here, too, except that the bright spot overwhelms the camera.

The exposure time is turned up, so the white sliver is overexposed, but the reddish glow can be seen.

The reddish colour is caused by Earth's atmosphere acting as a lens. The amount of light is very dim, so it typically can't be seen until close to the eclipse.

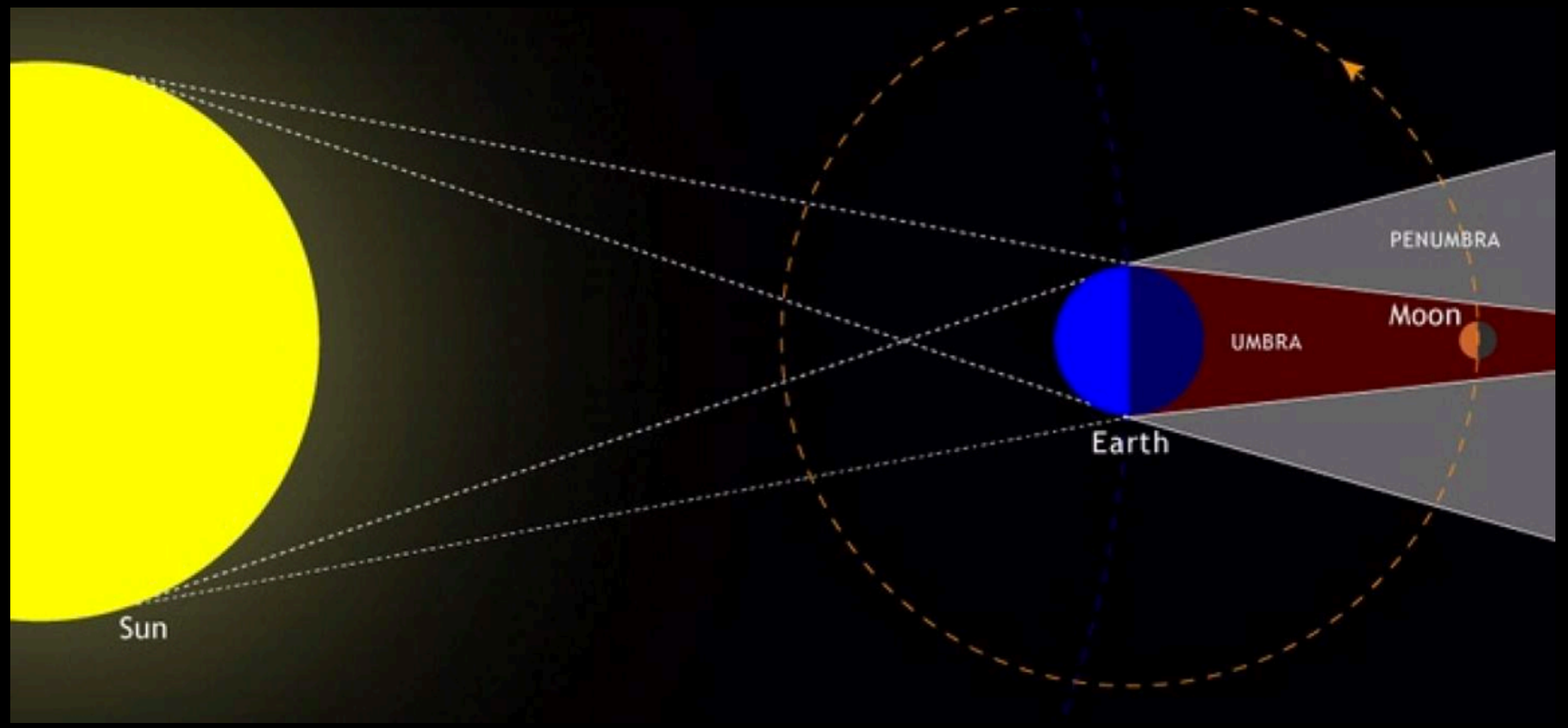
Telescope: Sky-watcher Evostar 80ED
Mount: Sky-watcher HEQ5-Pro
Camera: Canon EOS 550D



Lunar Eclipse

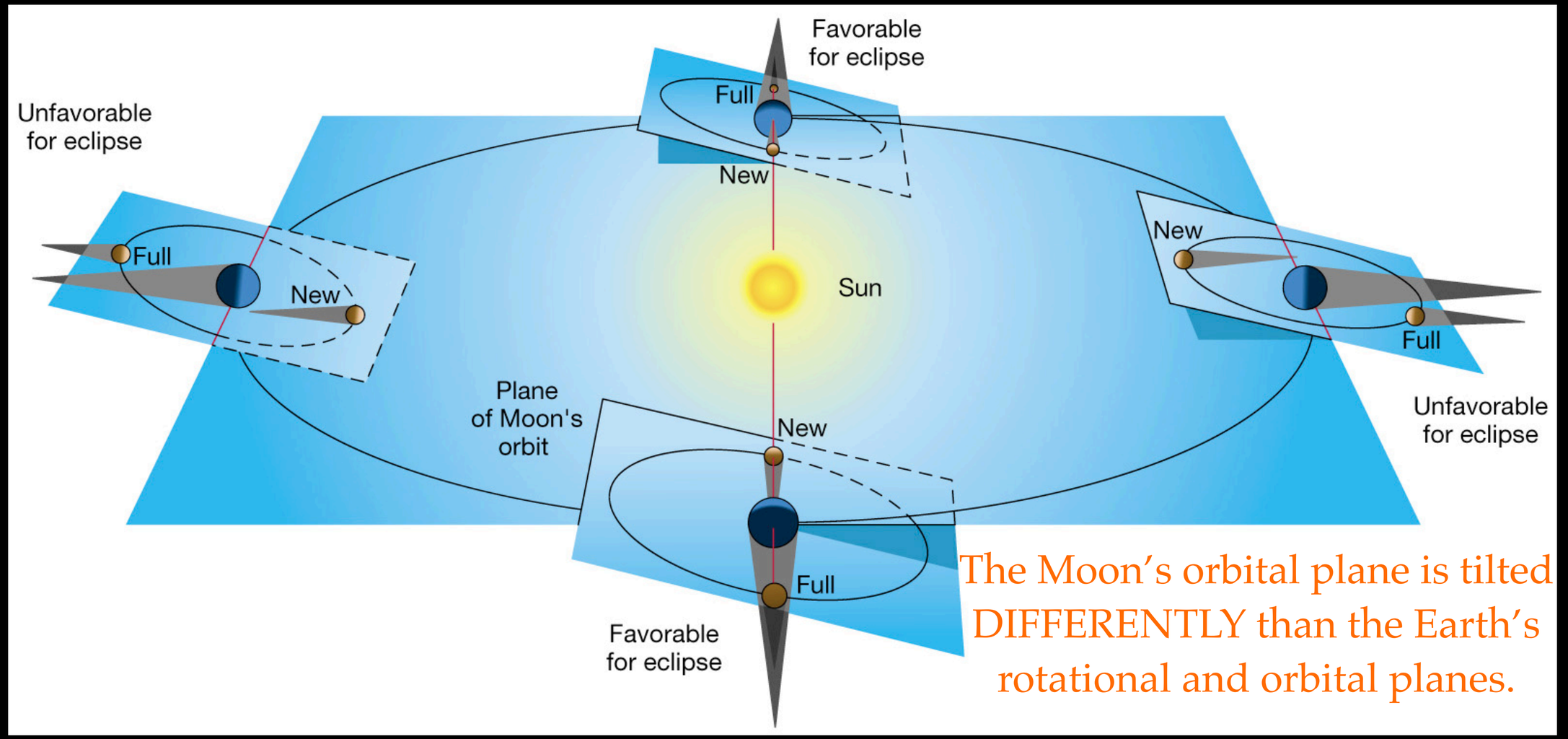
Total lunar eclipses only occur when the Moon is entirely within the Umbra - the full shadow of the Earth.

The Penumbra is the region where only some of the light from the Sun is blocked by the Earth.



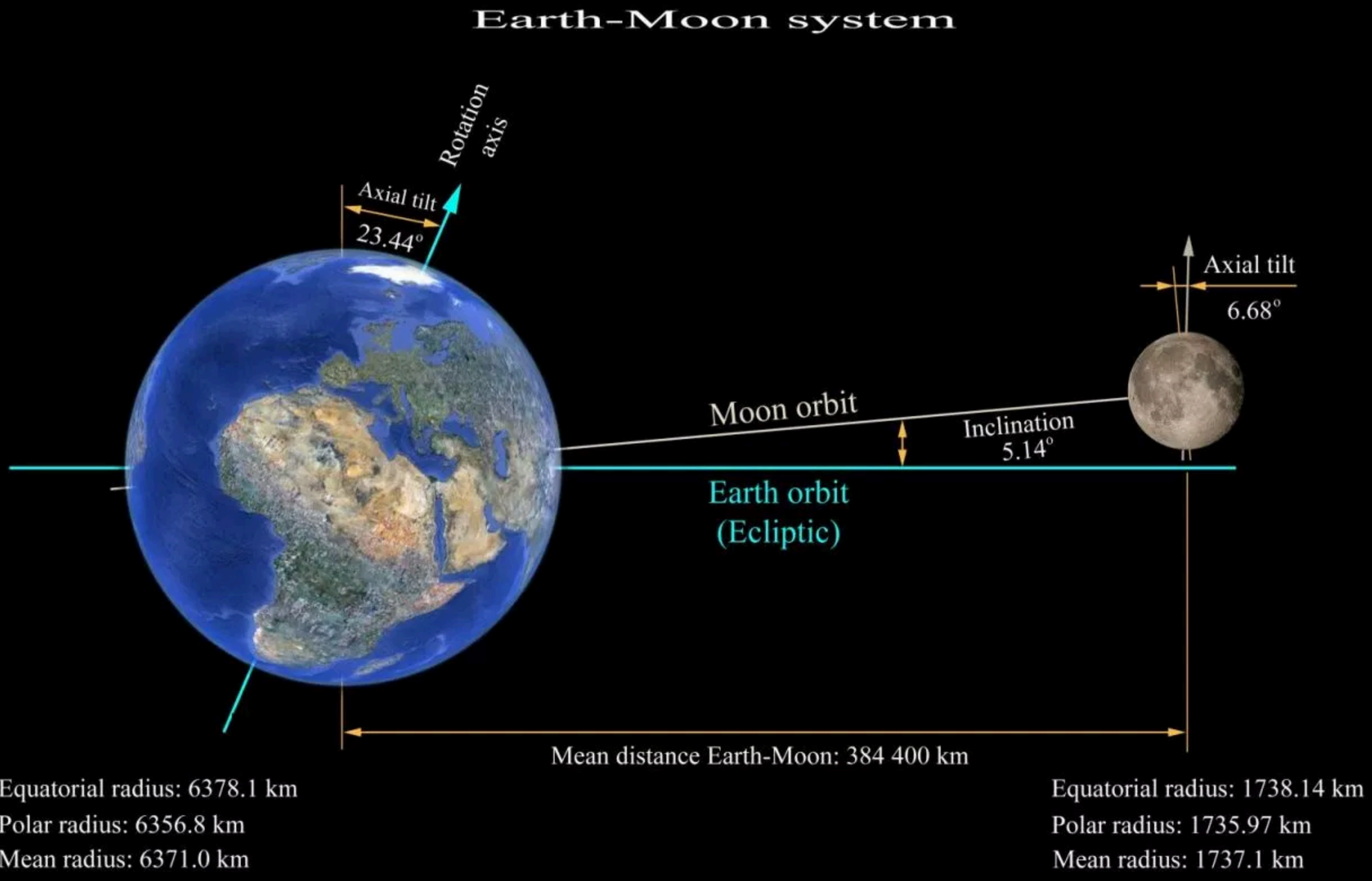
Lunar & Solar Eclipse

Eclipses only occur when the tilted lunar orbit aligns just right with the Sun.



The Moon's orbital plane is tilted DIFFERENTLY than the Earth's rotational and orbital planes.

Earth’s Orbit and Moon’s Orbit



https://gfycat.com/GlamorousLameAntbear

Moon Phases 2018

Including Libration and Position Angle

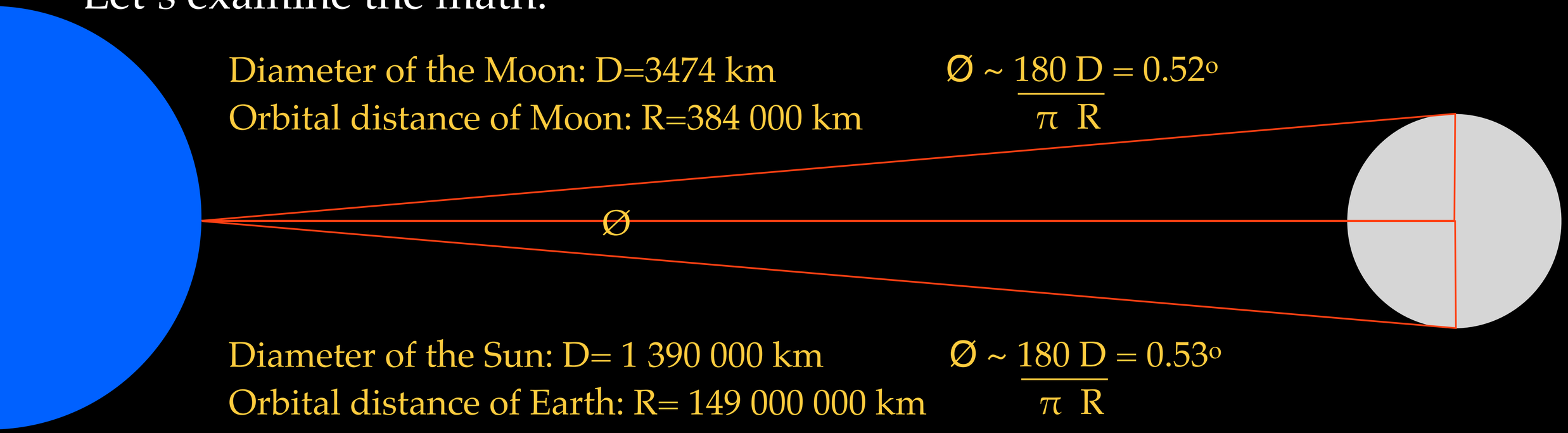
Time	10 Sep 2018 01:00 UT
Phase	0.2% (0d 06h 59m)
Diameter	1966.2 arcseconds
Distance	364531 km (28.61 Earths)
Position	11h 32m 55s, 06° 58' 35"N
Subsolar	1.063°N 179.746°E
Sub-Earth	4.865°S 3.682°E
Pos. Angle	24.330°

Solar Eclipse

Lunar eclipses occur because the Earth is much bigger than the Moon.

So why do solar eclipses occur?

Let's examine the math:



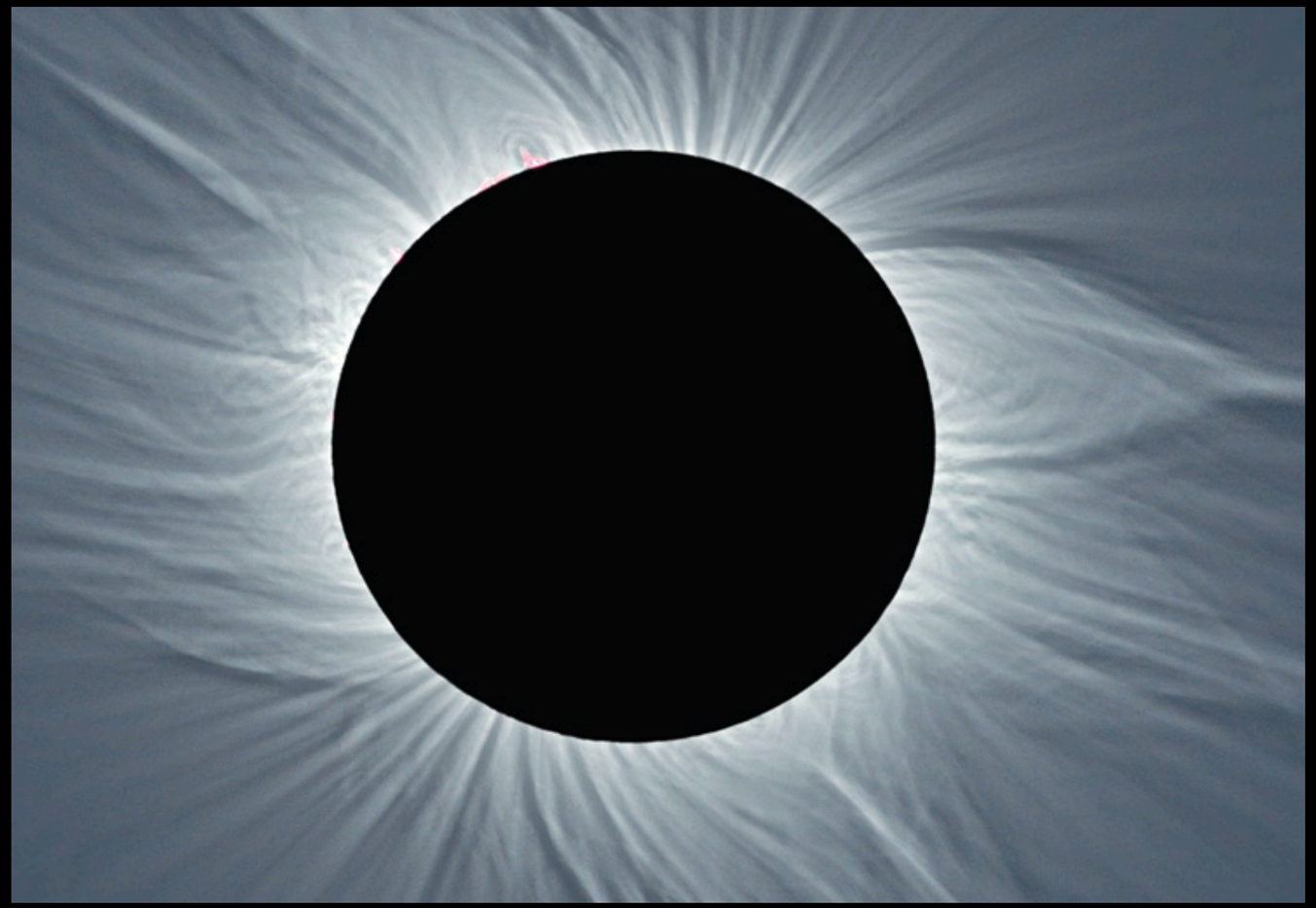
Solar Eclipse

Solar Eclipse

Solar eclipses are spectacular events for many reasons.

With the right equipment, the corona can be seen!

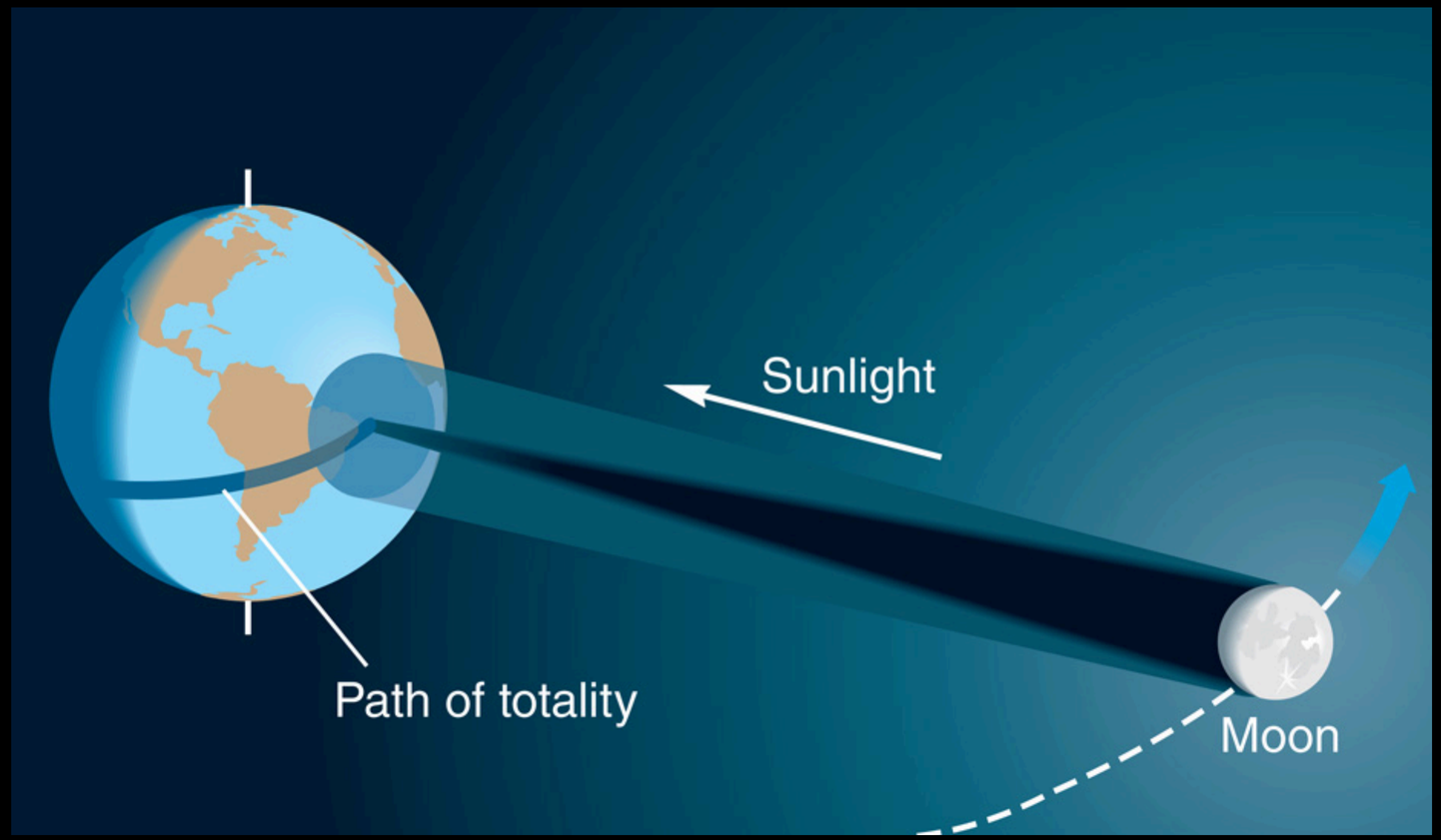
Normally, the bright Sun overwhelms the visibility of the corona.



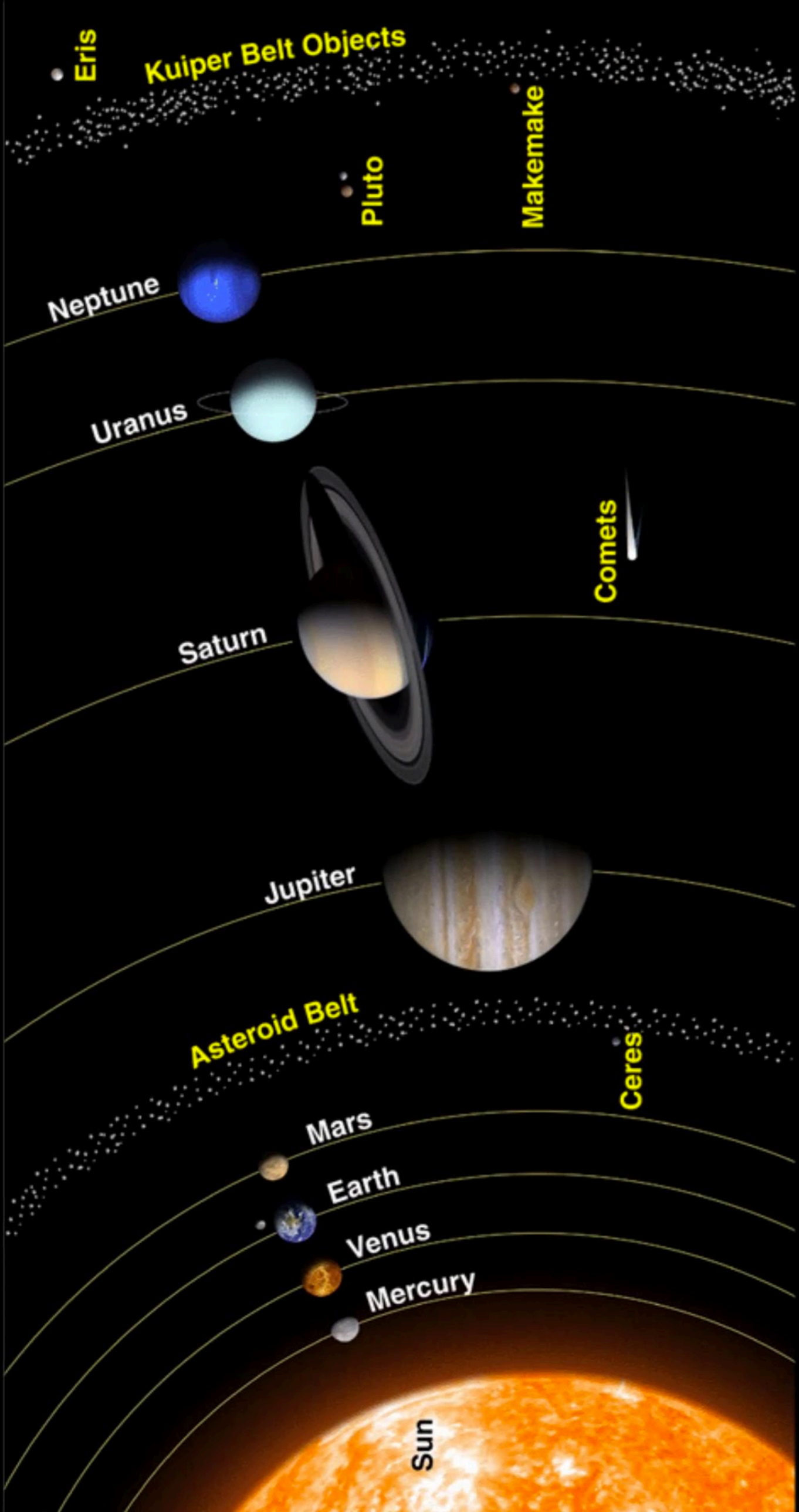
Solar Eclipse

Much like the lunar eclipse, there are regions on Earth with partial eclipse (penumbra) and total eclipse (umbra).

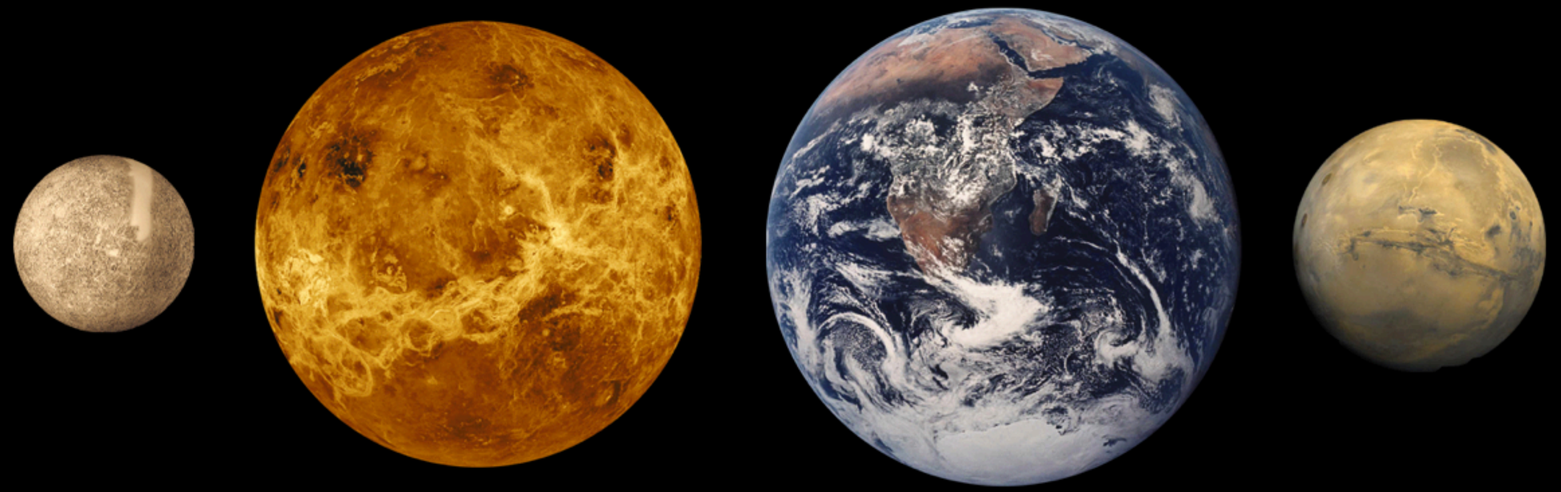
If you have an opportunity, it is well worth the effort to experience the umbral total eclipse.



The Layout of the Solar System


Eris
Kuiper Belt Objects
Pluto
Makemake
Neptune
Uranus
Comets
Saturn
Jupiter
Asteroid Belt
Ceres
Mars
Earth
Venus
Mercury
Sun

Inner Solar System



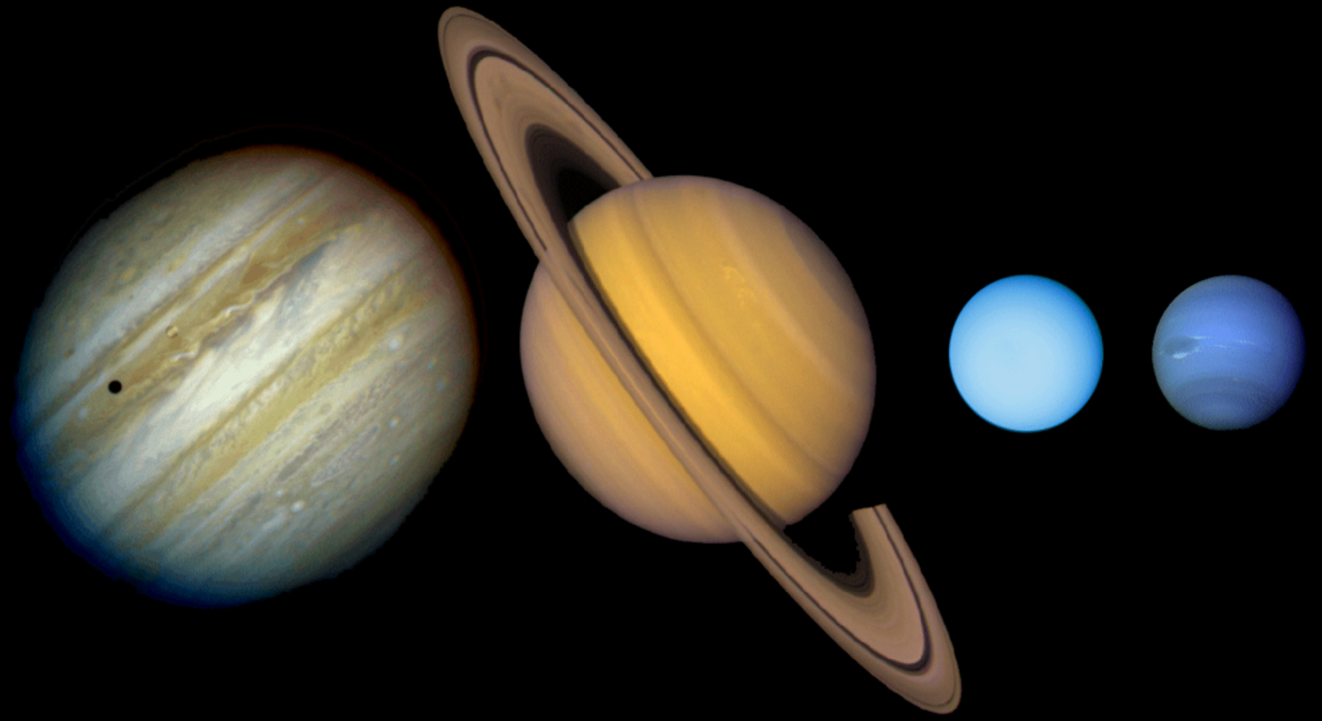
The inner four planets are Mercury, Venus, Earth and Mars.

They are called the Terrestrial Planets - they are primarily rocky objects with small atmospheres.

Rock refers to solid matter made up of a mixture of metals and non-metals.

In contrast, ices are solid matter made up of materials that would be liquid or gaseous at room temperature.

Outer Solar System



The four outer planets are
Jupiter, Saturn, Uranus,
and Neptune.

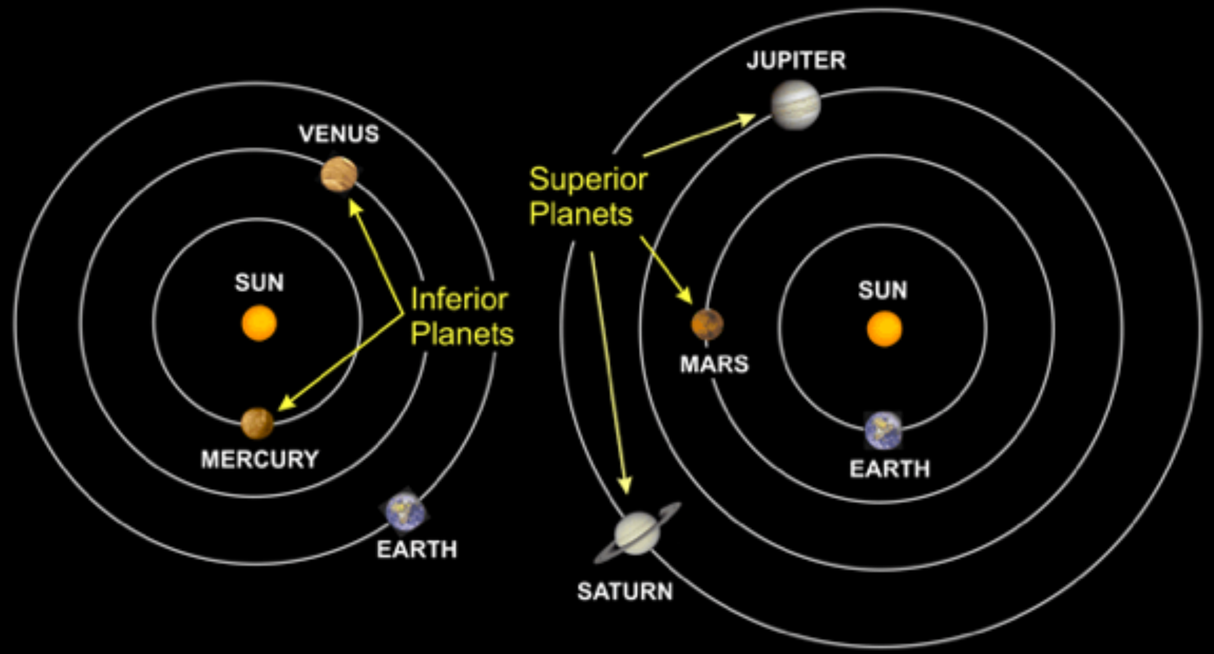
They are called the Jovian Planets,
and are commonly thought of as “gas giants” due to their thick atmosphere.

However, as we will see “gas” may not be the best way to refer to them -
especially Uranus and Neptune, which are more ice than gas!

Hierarchy of Planets

Inferior Planets - orbit is closer to the Sun than Earth's orbit.

Rarely move far from the Sun; can never be visible in midnight sky



Superior Planets - orbit is further from Sun than Earth's orbit.

Planetary Alignments

Conjunction - when the planets are close to the axis between Earth and the Sun

Opposition - when superior planets are opposite Earth in line with the Sun