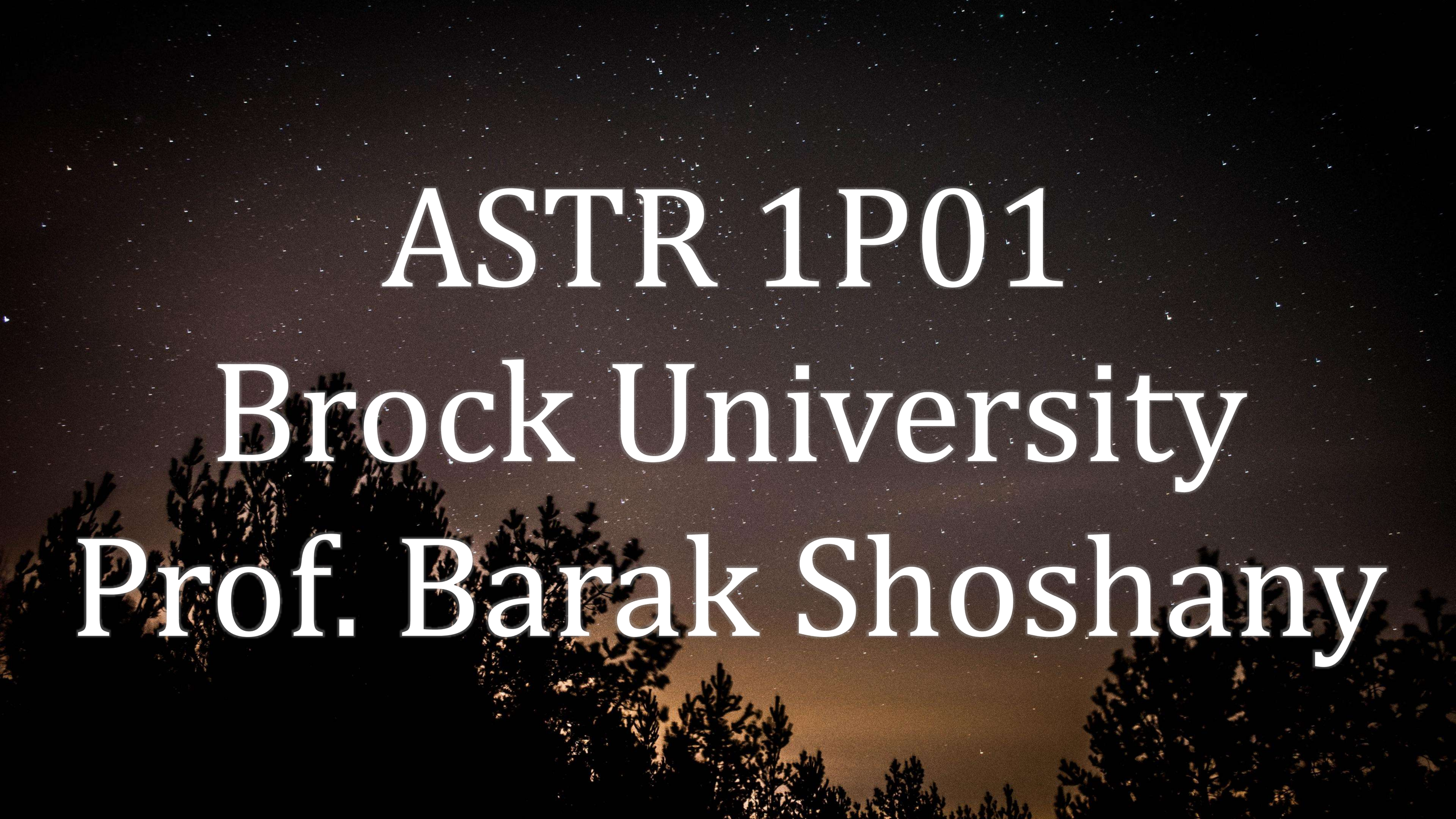
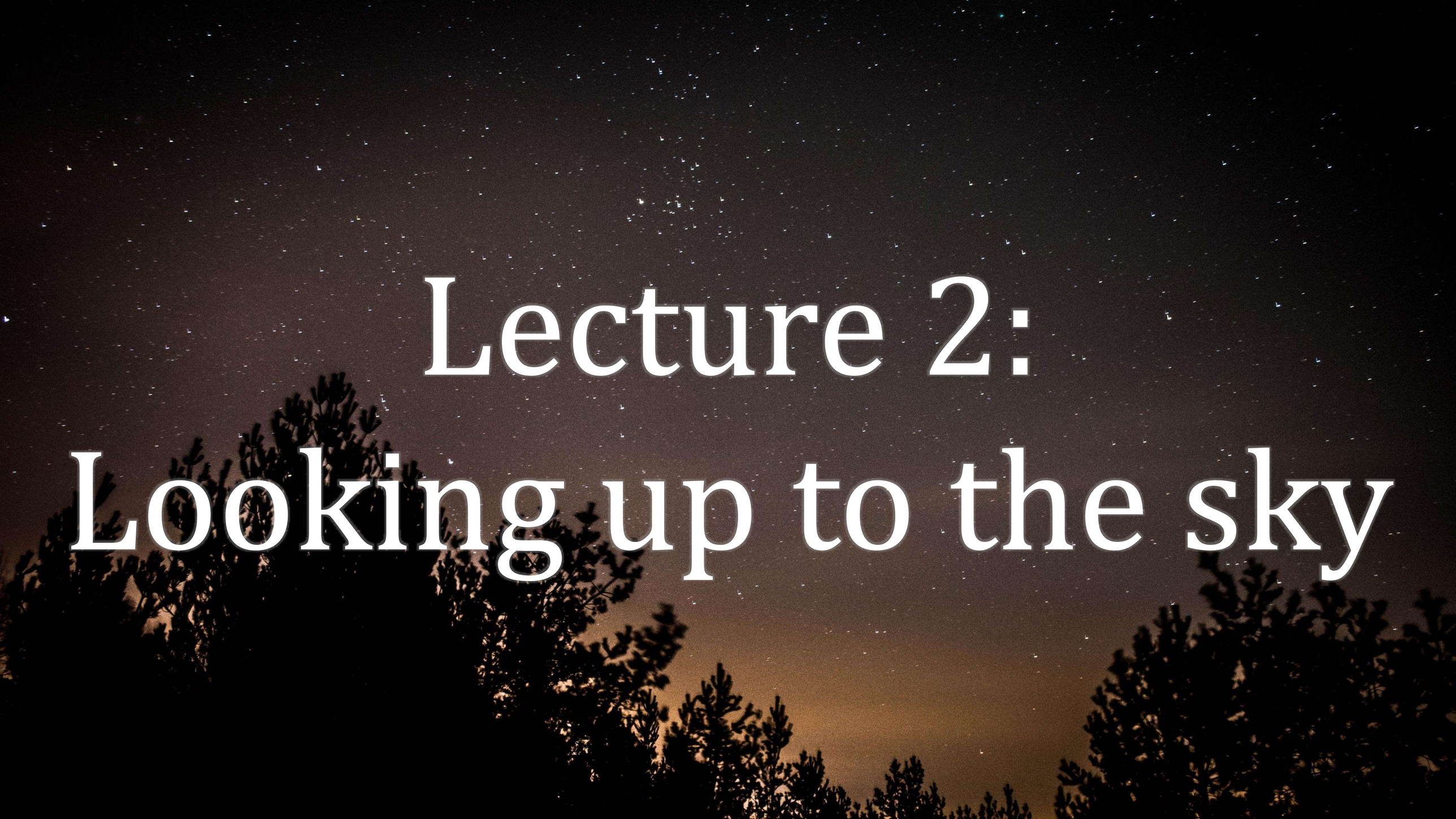

ASTR 1P01
Brock University
Prof. Barak Shoshany

Video

A comparison of the sizes of different celestial bodies.

The video is available at this URL:

https://youtu.be/i93Z7zljQ7I



Lecture 2:
Looking up to the sky

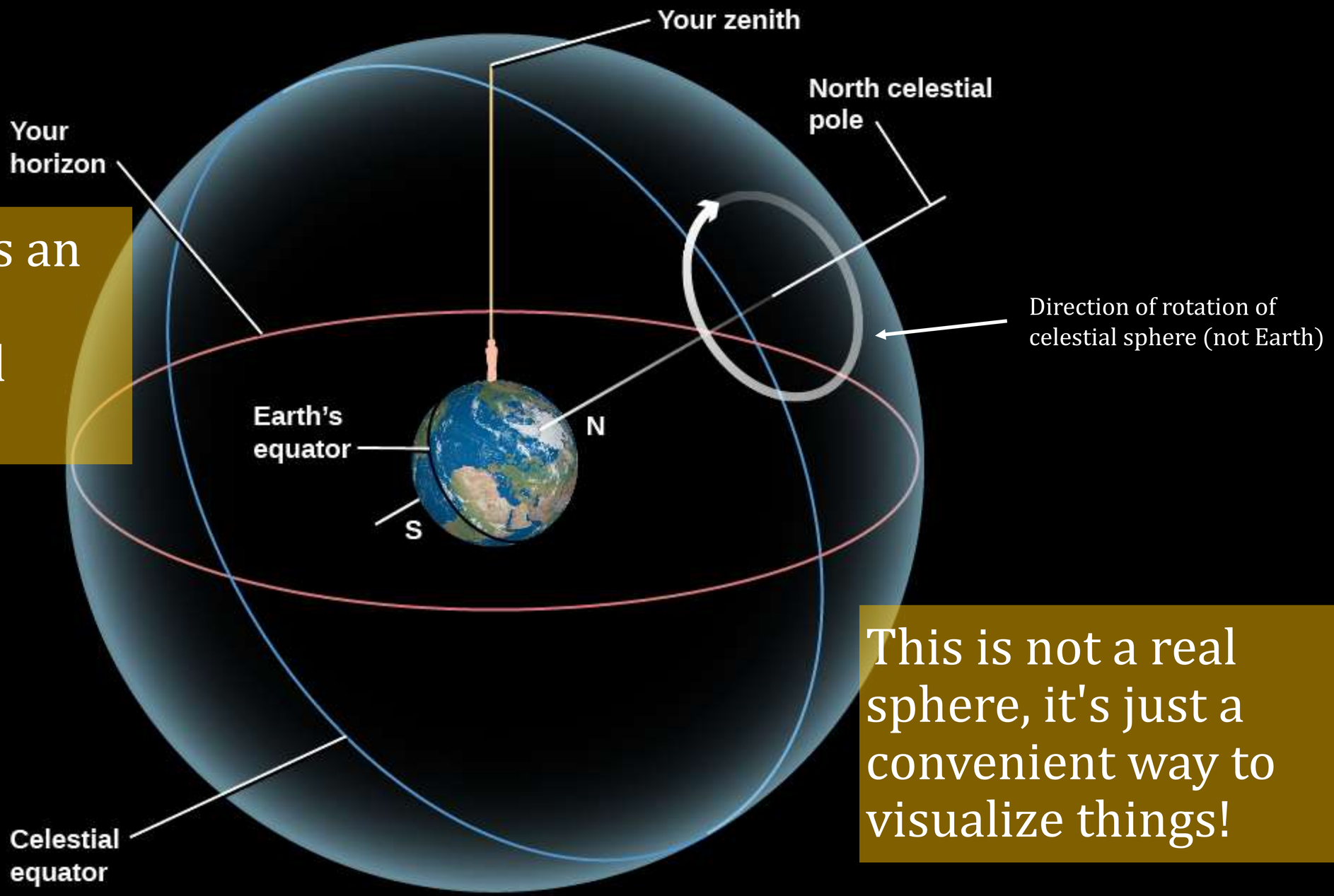
Goals

- Understand how astronomers describe the sky.
- Learn about constellations.
- Discuss the major celestial bodies seen with the naked eye.

Sky Full of Stars
Credits: Davias007

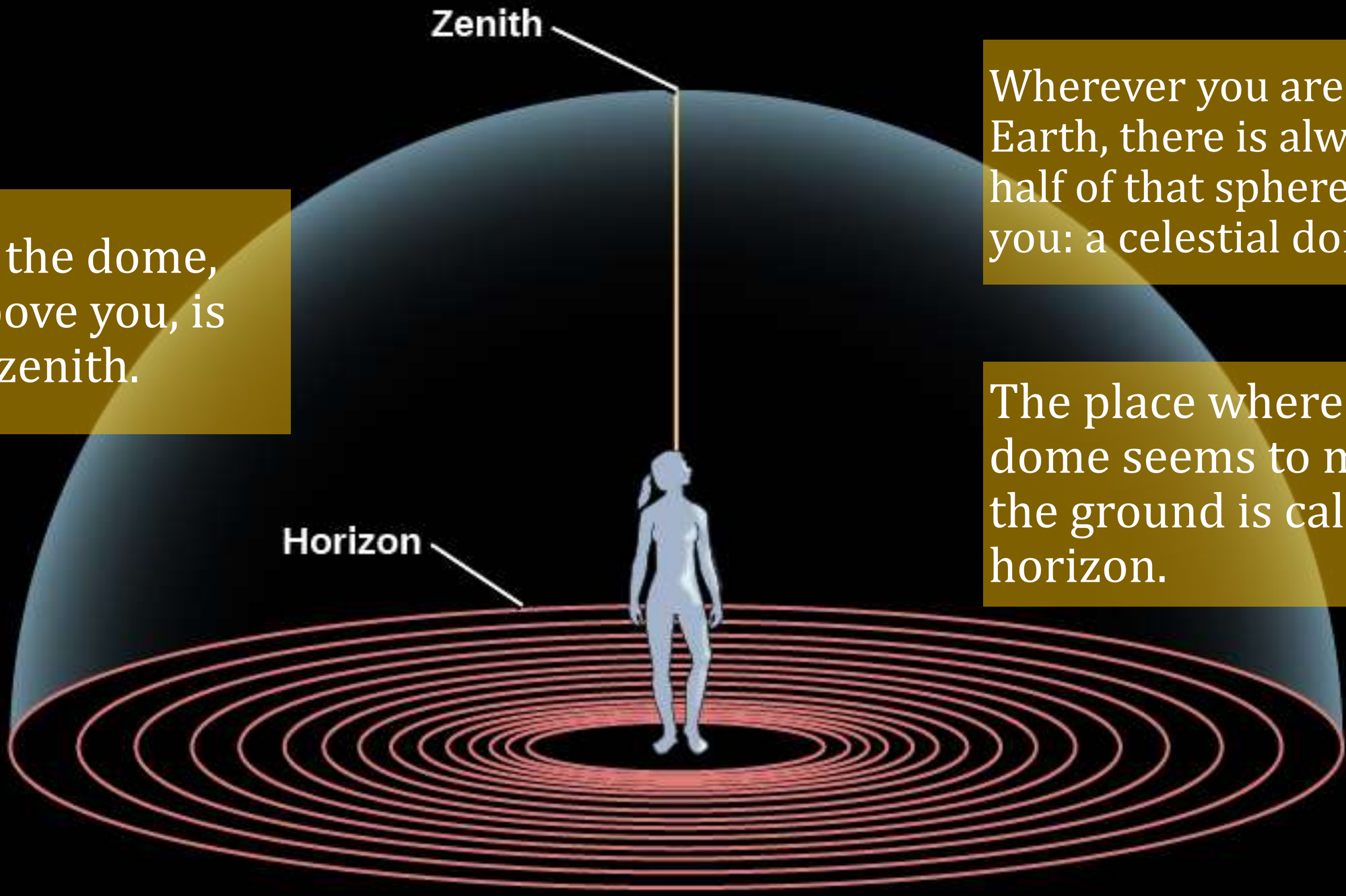
The celestial sphere

Think of the sky as an imaginary sphere, called the celestial sphere.



This is not a real sphere, it's just a convenient way to visualize things!

Circles on the Celestial Sphere
Credits: OpenStax Astronomy



Wherever you are on Earth, there is always half of that sphere above you: a celestial dome.

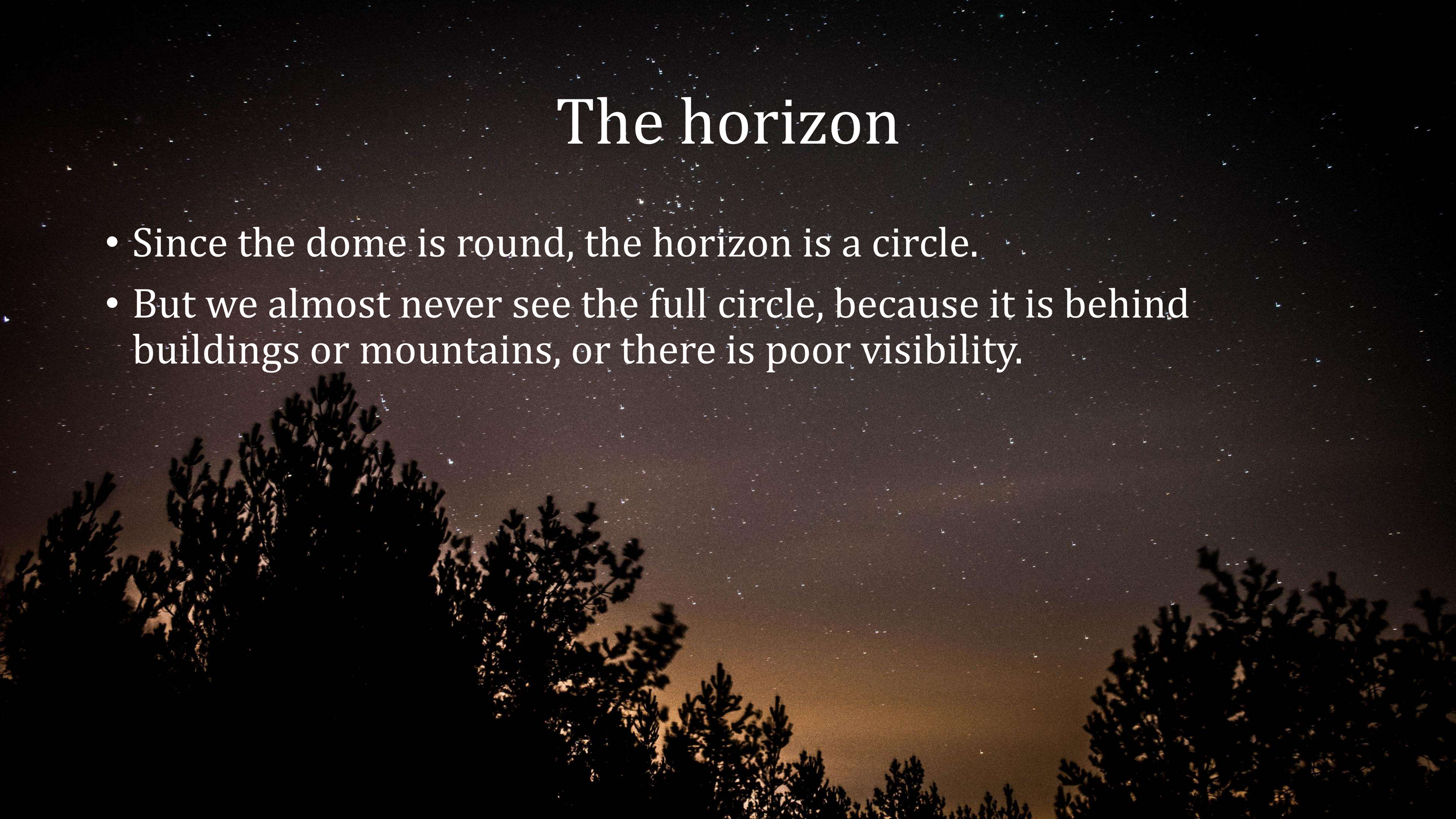
The top of the dome, directly above you, is called the zenith.

The place where the dome seems to meet the ground is called the horizon.

The Celestial Dome
Credits: OpenStax Astronomy

The horizon

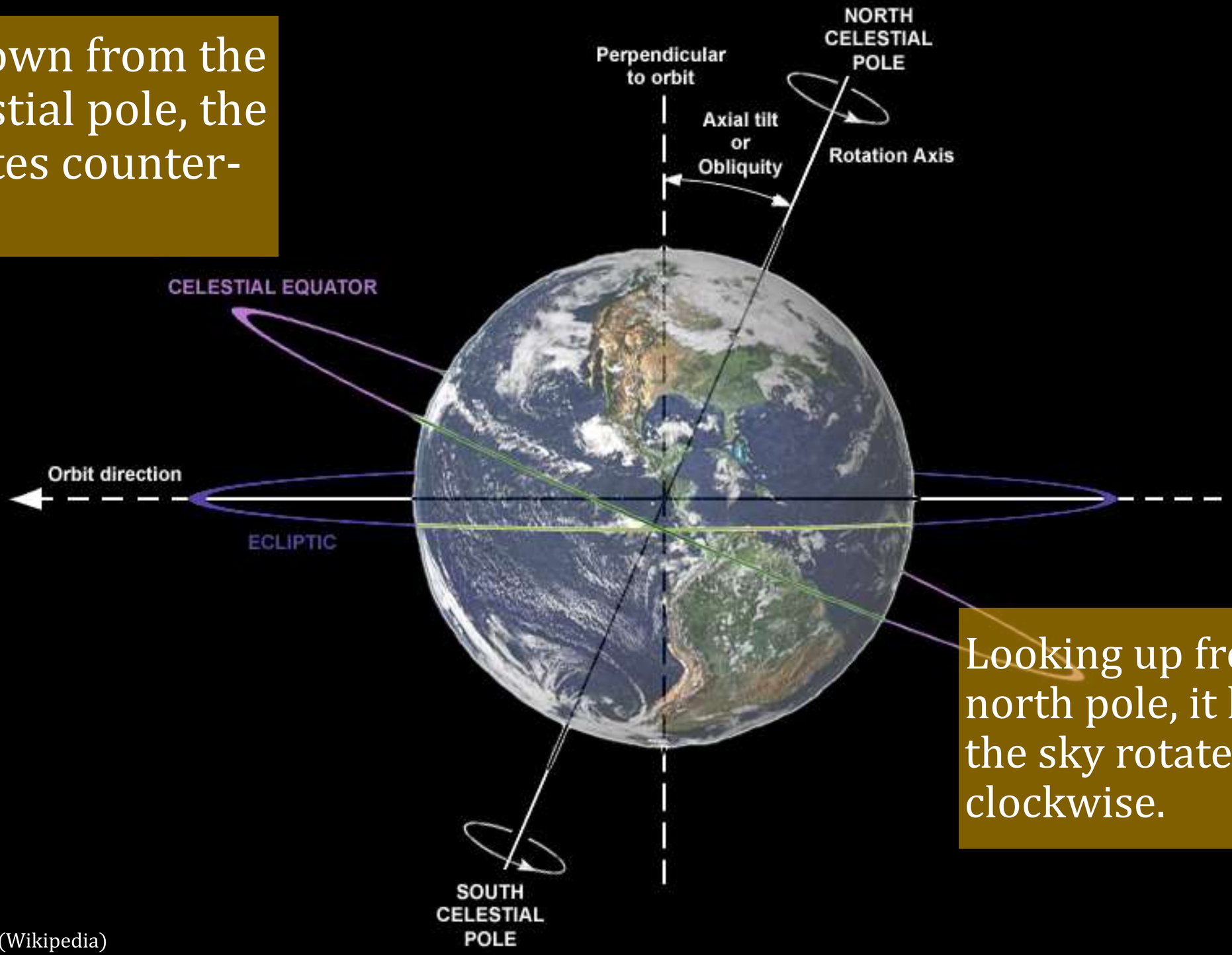
- Since the dome is round, the horizon is a circle.
- But we almost never see the full circle, because it is behind buildings or mountains, or there is poor visibility.



The celestial poles

- Imagine a line going through the Earth, connecting the north and south poles.
- This is the axis of rotation of the Earth.
- If we extend this line until it meets the celestial sphere, the points of intersection are called the north celestial pole and the south celestial pole.

Looking down from the north celestial pole, the Earth rotates counter-clockwise.



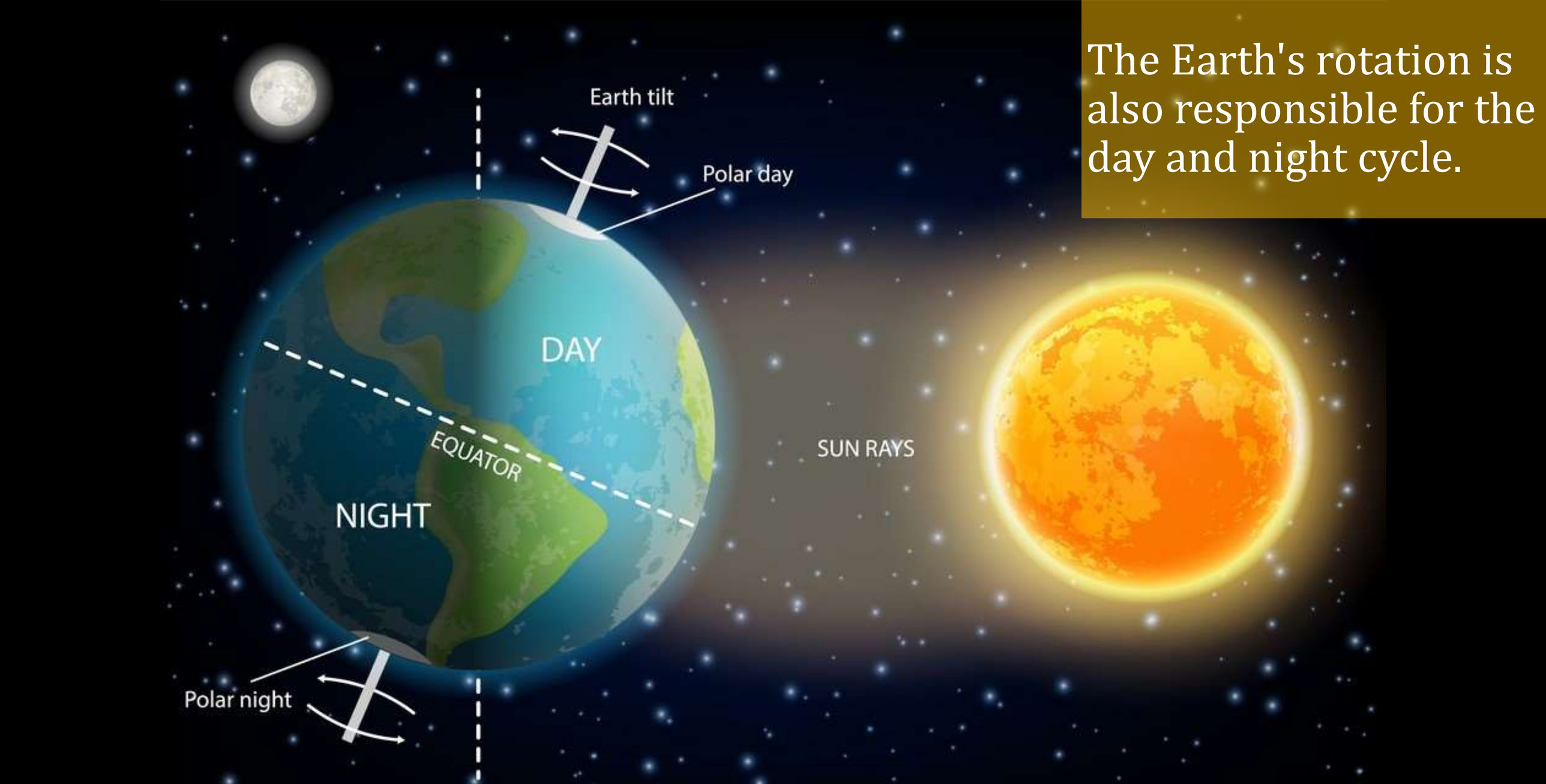
Looking up from Earth's north pole, it looks like the sky rotates counter-clockwise.

The Celestial Poles
Credits: Dna-webmaster (Wikipedia)

The rotation of the Earth

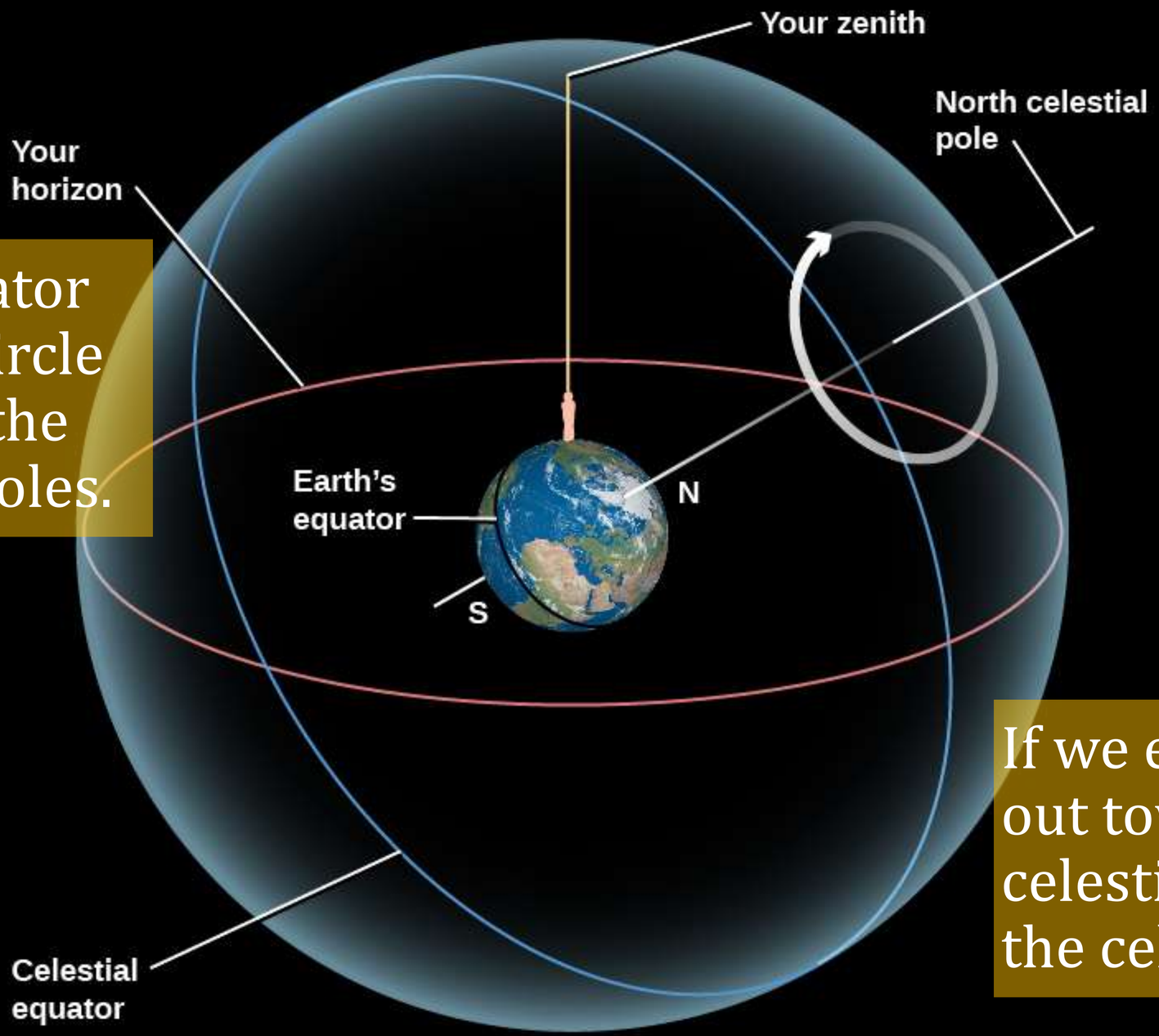
- The Earth completes a full rotation approximately every 24 hours.
- This rotation is responsible for the rising and setting of the Sun, Moon, and stars.
- All of them rise in the east and set in the west.
- That means the Earth rotates in the opposite direction - from west to east.

The Earth's rotation is also responsible for the day and night cycle.



The Day and Night Cycle
Credits: Found online, author unknown

On Earth, the equator is the imaginary circle halfway between the north and south poles.



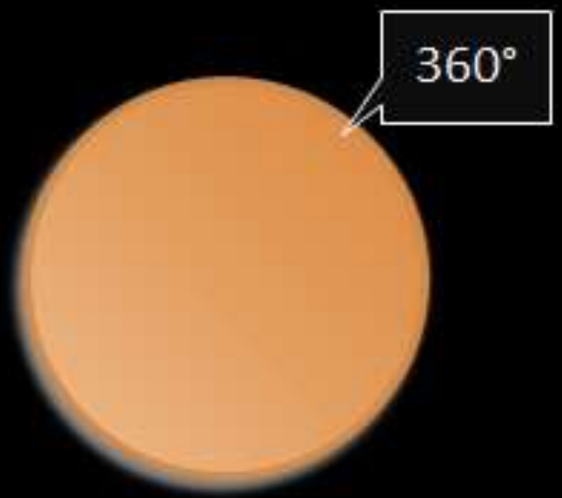
If we extend this circle out towards the celestial sphere, we get the celestial equator.

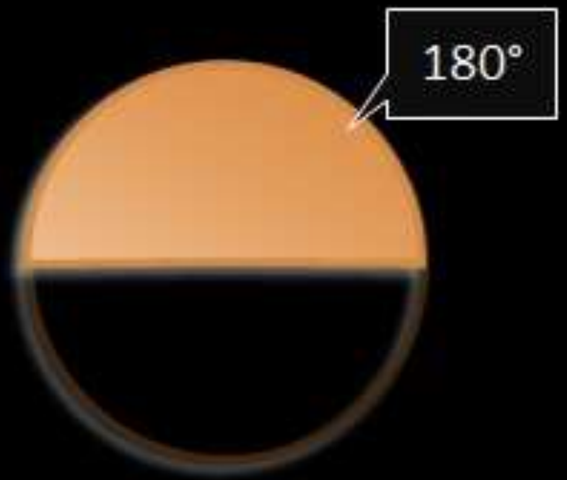
Circles on the Celestial Sphere
Credits: OpenStax Astronomy

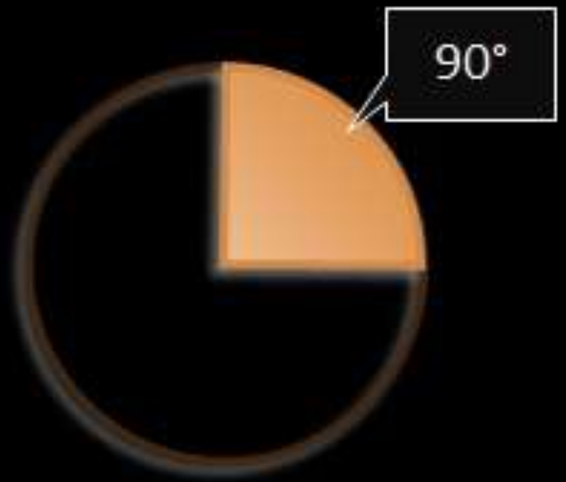

Latitude & longitude

Angles

- There are 360° in a circle.
- Half a circle is 180°. For example: the celestial dome.
- A quarter of a circle is 90°. For example: between pole and equator.







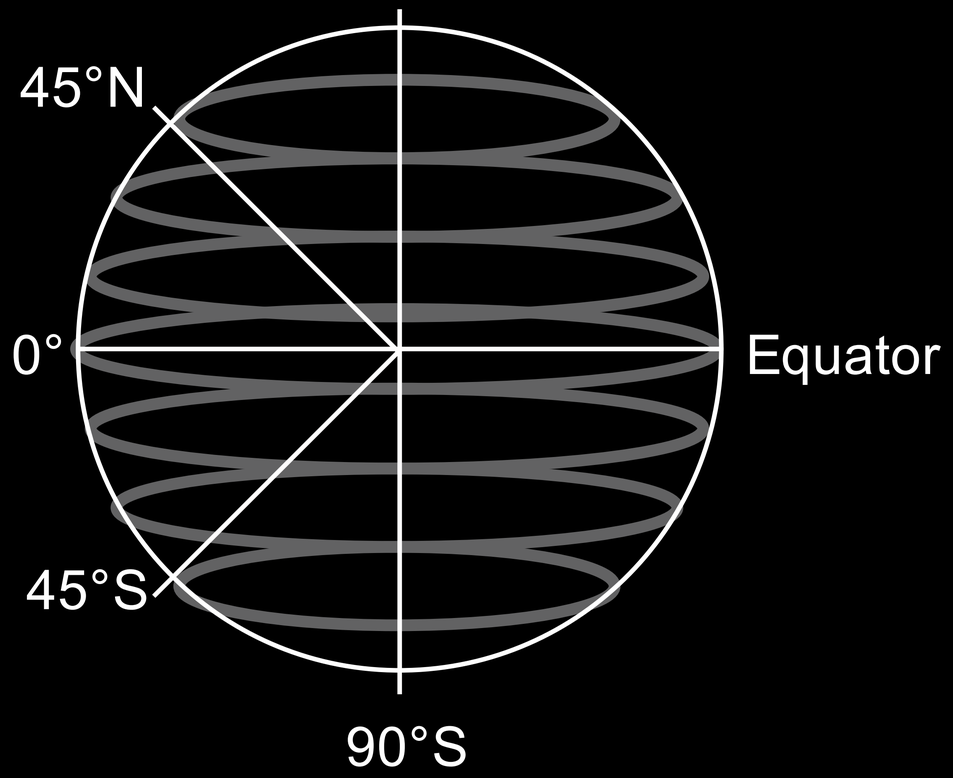
Latitude and longitude

- The latitude of a point on Earth's surface is the angle it makes with the equator, either to the north or to the south.
- The latitude of the equator itself is 0°.
- The latitude of the north pole is 90° N.
- The latitude of the south pole is 90° S.

Latitude and longitude

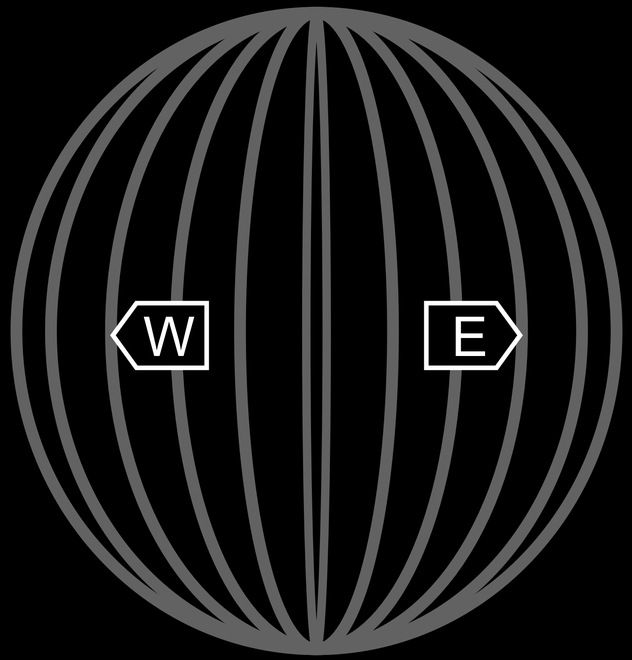
- The longitude of a point on Earth's surface is the angle it makes with the prime meridian, which is a line stretching from pole to pole and passing through the Royal Observatory in Greenwich, England.
- The prime meridian itself has a longitude of 0°.
- There's nothing special about the Royal Observatory, it was only chosen for historical reasons.

Latitude (North/South)



Latitude varies from 0° at the equator to 90° North and South at the poles

Longitude (West/East)



Longitude varies from 0° at Greenwich to 180° East and West

Latitude and Longitude
Credits: Found on Wikipedia, author unknown

Latitude and longitude

- To remember the difference between latitude and longitude, notice that if you switch the first two letters of "latitude", you get "altitude", which is another word for "height".
- Maps of the Earth always have north on top, so the latitude tells you the “height” along this map.

At latitude 90° N, the north celestial pole is at your zenith, and the celestial equator is at your horizon.

The stars don't rise or set, they just circle around the pole.

You can only see half of the sky, and always the same stars.

Star Circles at the North Pole
Credits: OpenStax Astronomy

In this photo, very long exposure was used, to capture the paths of the stars in the sky.

The center of these circles is the south celestial pole.

Because the Earth rotates around the pole, the pole itself doesn't change its position in the sky.

Star Circles at the South Pole
Credits: ESO/Iztok Bončina

At latitude 0°, the celestial equator passes through your zenith, and the celestial poles are on your horizon.

(Or at least, you would see them if the Sun wasn't in the way during daytime.)

Over a 24-hour period, you will see all the stars in the sky rising in the east and setting in the west.

Star Circles at the Equator
Credits: OpenStax Astronomy

In Niagara Falls, 43° N, the north celestial pole will be 43° above the northern horizon.

The south celestial pole will be 43° below the southern horizon, so it will never be visible.

Stars within 43° of the north pole can never set. They are always above the horizon, and circle around the north celestial pole.

This part of the sky is called the north circumpolar zone.

Star Circles at the Equator
Credits: OpenStax Astronomy


Asterisms

Patterns in the sky

- On a perfect night, with no clouds or artificial light, it is possible to see about 3,000 stars with the naked eye.
- The positions of these stars are random, but humans love to find patterns in things, so ancient cultures gave names to specific geometric patterns that were particularly noticeable.
- These patterns of stars are called asterisms.
  - Note: they are NOT called constellations! We'll define constellations later.
- Identifying these patterns is a bit like solving a celestial connect-the-dots puzzle.

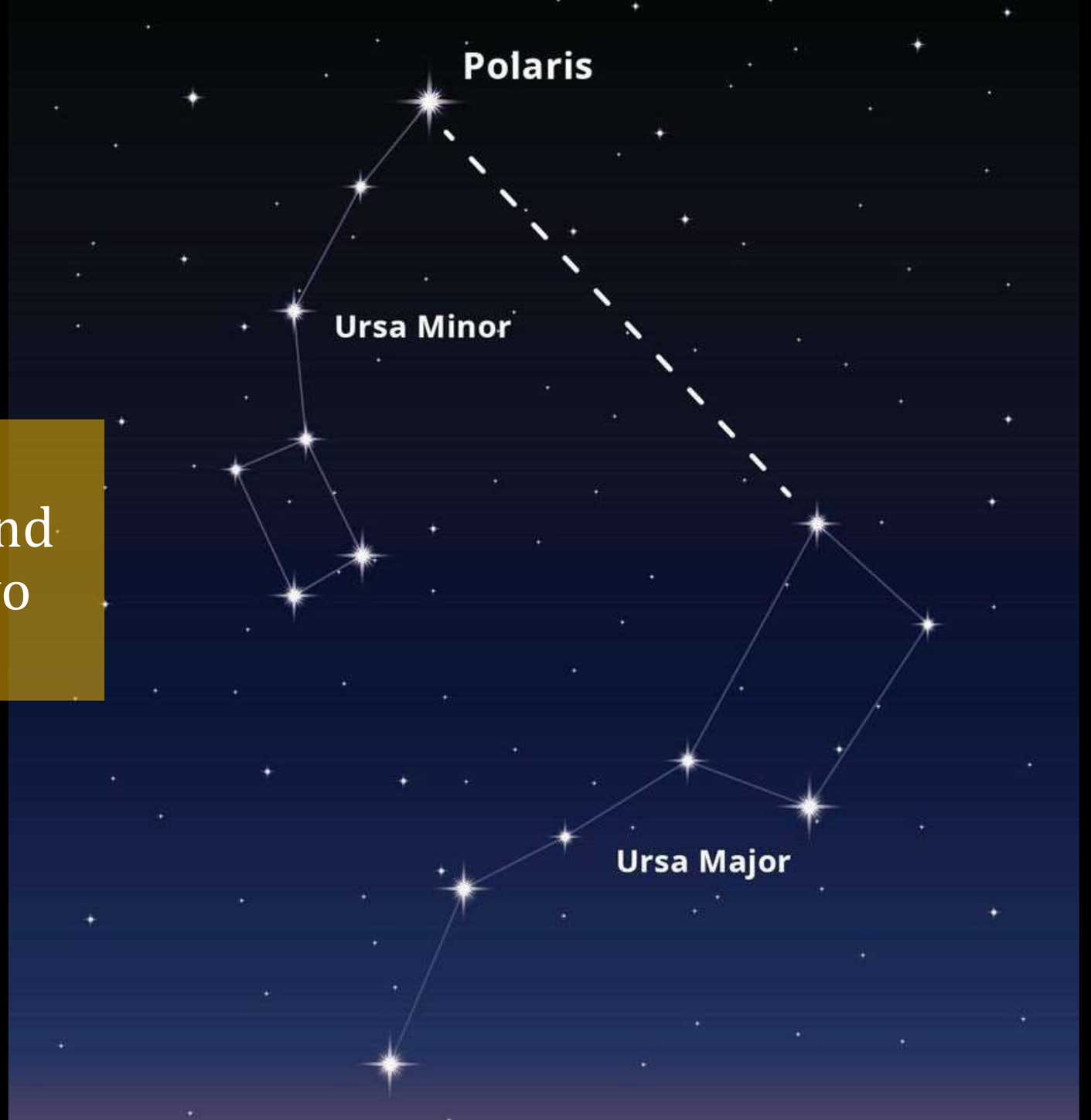
Patterns in the sky

- Historically, these patterns were helpful in navigation, because before we had GPS, they allowed people to orient themselves at night.
- Here are some examples of asterisms you may already be familiar with, or perhaps you saw but didn't know they had names.

The Big Dipper consists of 7 bright stars that look a bit like a bowl with a handle.

The Big Dipper
Credits: Found online, author unknown

The Little Dipper
Credits: Found online, author unknown



This diagram illustrates how to find Polaris using the two Dippers.

How to Find Polaris
Credits: Found online, author unknown


Constellations

Regions in the sky

- In modern times, astronomers divide the celestial sphere into 88 regions, called constellations.
- These regions cover the entire sphere, so any point in the sky is located in exactly one of the constellations.
- Each constellation contains one or more prominent asterisms, and they get their names from various animals, objects, and mythological characters or creatures.

Historical origins

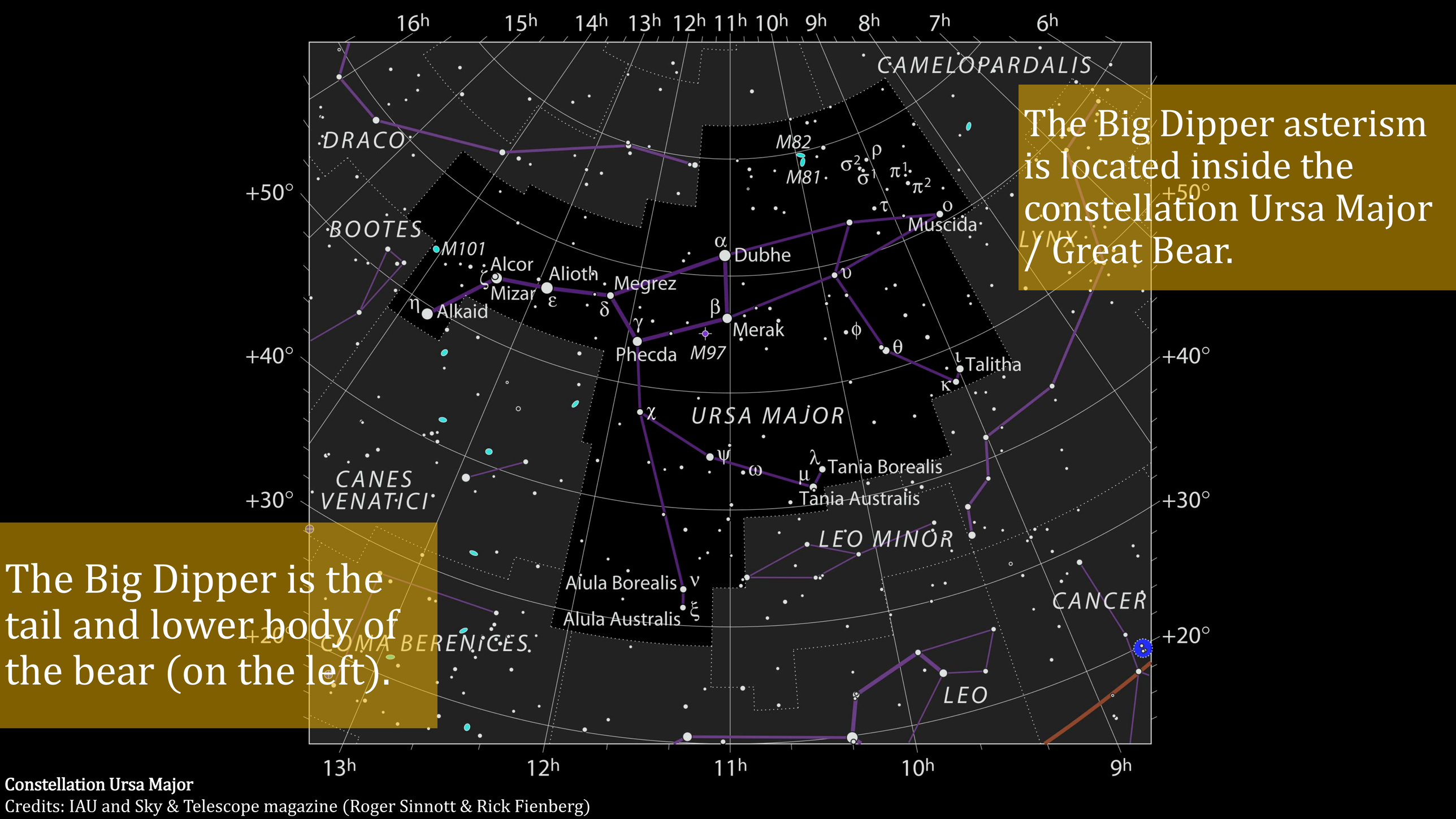
- Many of these constellations originated as early as 5,000 years ago in ancient Mesopotamia.
- This is the historical region where Iraq is located today.
- The civilizations of that area include the Sumerians and the Babylonians.
- The ancient Greeks adopted the Babylonian constellations around 400 BC.
- The ancient astronomer Ptolemy described 48 of the 88 modern constellations in his influential book Almagest around the year 150.

Historical origins

- The Greeks could not see the entire sky, since they never saw any stars from the south circumpolar zone.
- When European explorers began traveling to the southern hemisphere, in the 15th century, they gradually added new constellations that can only be seen in the southern sky.
- The modern list of 88 constellations along with their boundaries, which cover the entire celestial sphere, was adopted by the International Astronomical Union in 1928.

Asterism vs. constellation

- “Constellation" means a region in the sky.
- “Asterism” means a specific pattern of stars.
- However, each constellation has one or more defining patterns within its region, sometimes referred to colloquially as "the constellation".
- The International Astronomical Union only defined the regions of each constellations, they didn't define how to connect the stars.



The Big Dipper asterism is located inside the constellation Ursa Major / Great Bear.

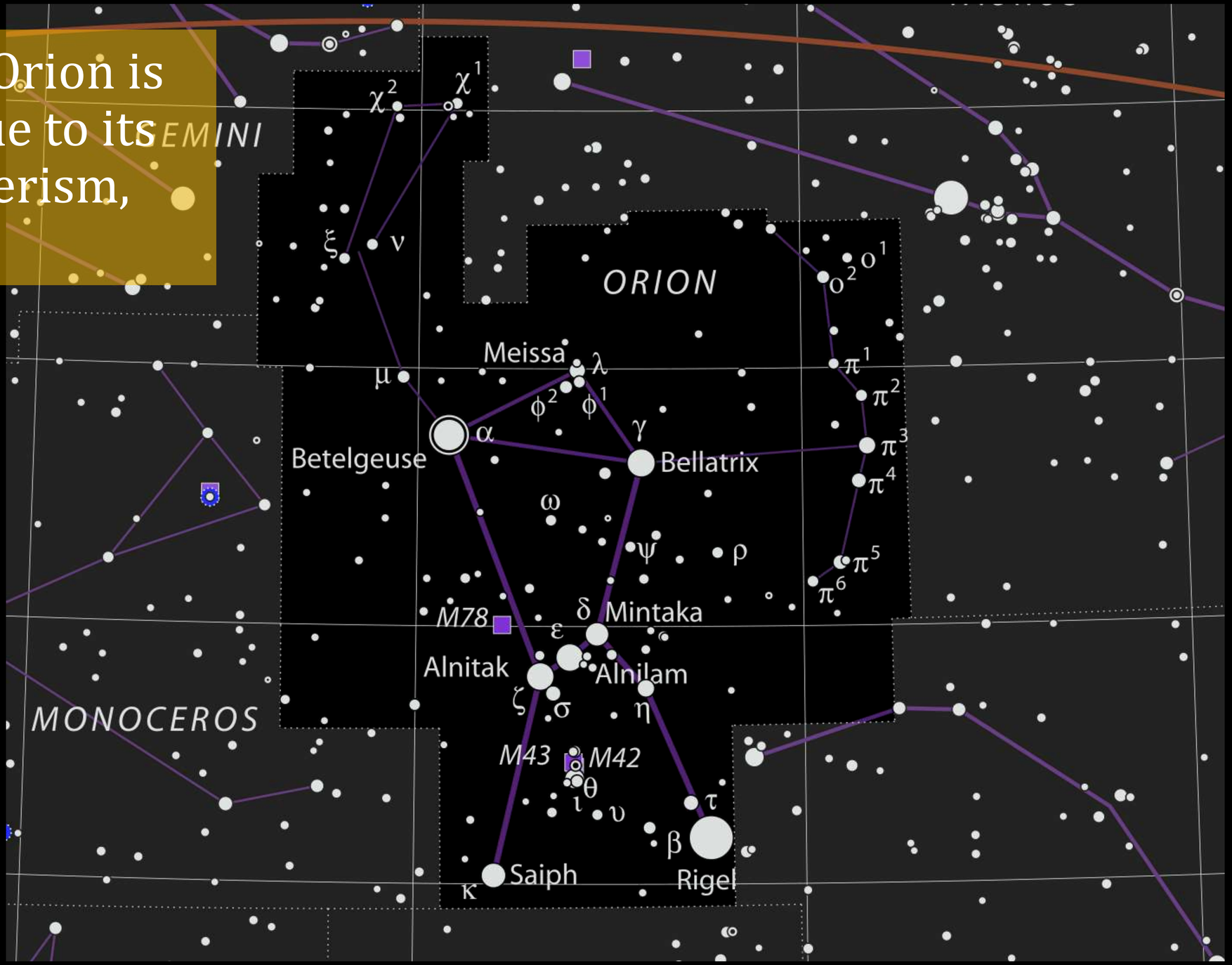
The Big Dipper is the tail and lower body of the bear (on the left).

Constellation Ursa Major

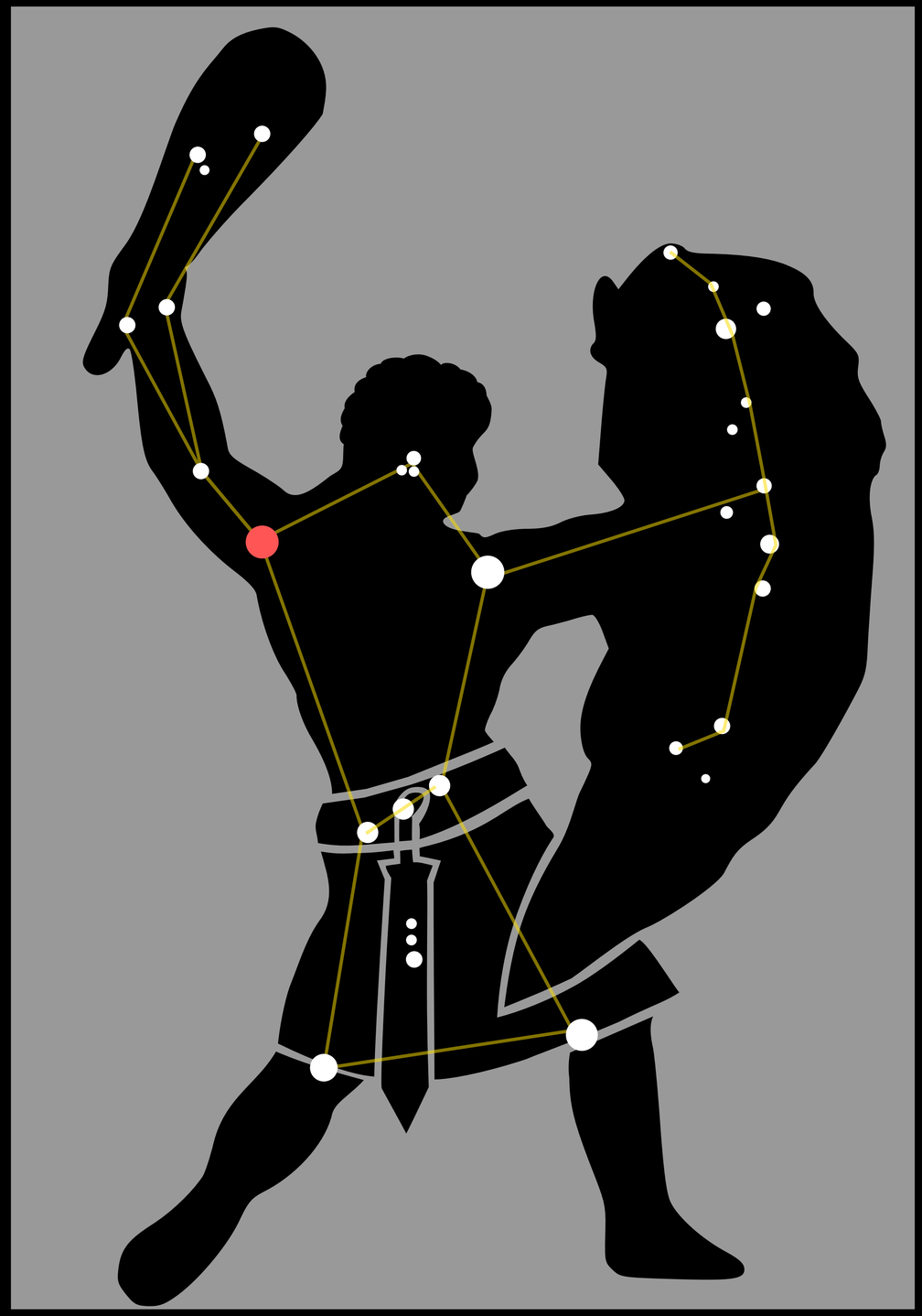
Credits: IAU and Sky & Telescope magazine (Roger Sinnott & Rick Fienberg)

Ursa Major
Credits: Found online, author unknown

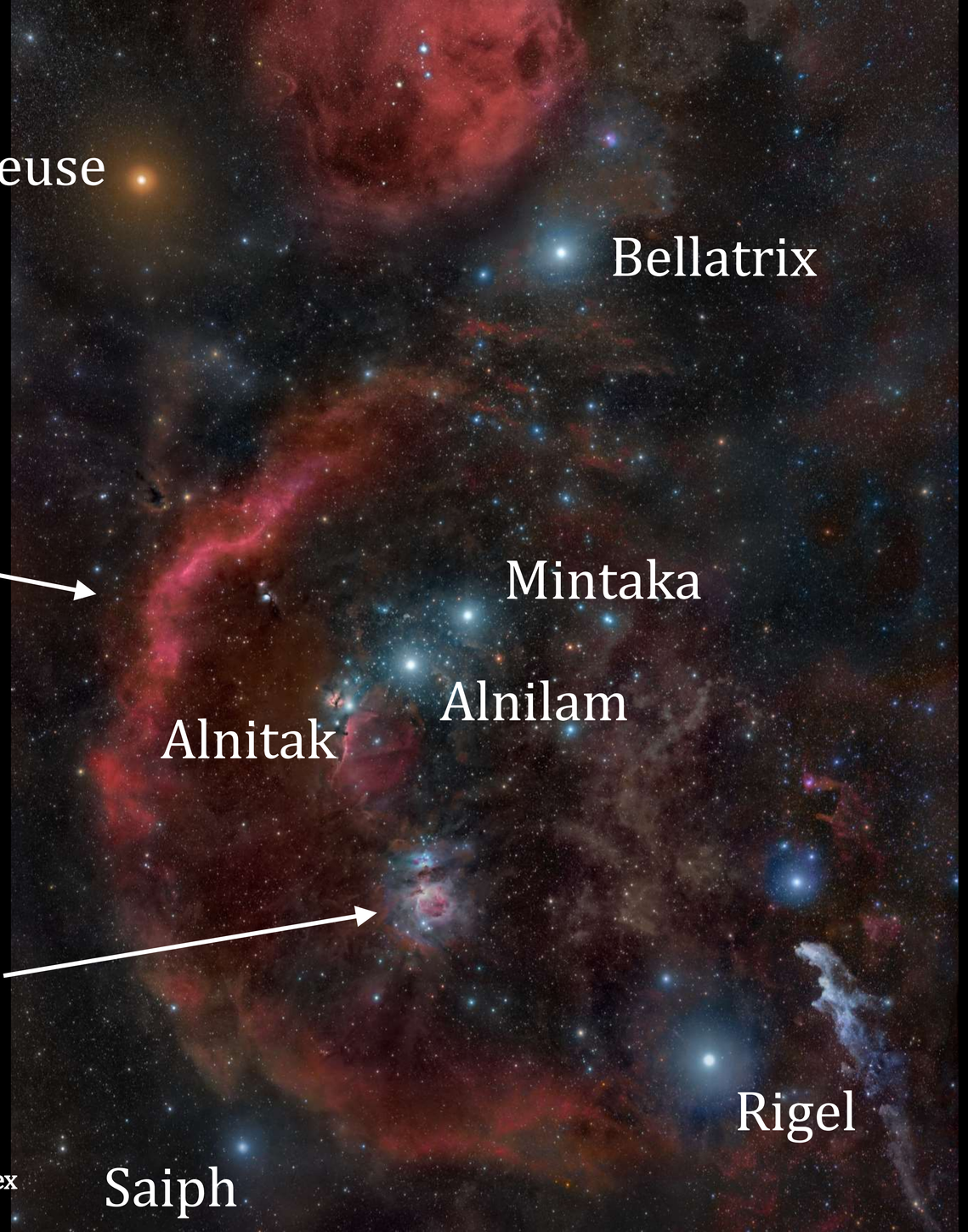
Constellation Orion is easy to find due to its distinctive asterism, Orion’s belt.



Constellation Orion
Credits: IAU and Sky & Telescope magazine (Roger Sinnott & Rick Fienberg)



Orion Constellation Art
Credits: Sanu N (Wikipedia)



The Orion Constellation & Orion Molecular Cloud Complex
Credits: Rogelio Bernal Andreo

Computer simulation

Let us explore some constellations and asterisms using Stellarium.

It is available at this URL:

https://stellarium.org/

The stars in 3 dimensions

- The sky looks like a 2-dimensional sphere, the celestial sphere, with the stars located on the sphere itself.
- Some ancient civilizations thought that this was an actual sphere rotating around the Earth.
- In reality, it's the Earth that's rotating.
- More importantly, the stars are not located on a 2-dimensional sphere, they are distributed in 3 dimensions all over the galaxy.

The stars in 3 dimensions

- Our sky, with its specific patterns of stars like Orion or the Big Dipper, is unique to us.
- Aliens on a distant planet, many light-years away, will see a completely different sky with different patterns of stars.
- They will see the same 3-dimensional distribution of stars from a different location in the galaxy.

The stars in 3 dimensions

- Stars that seem to be close together in our 2D sky might be very far apart in the actual 3D space.
- If two stars happen to both be in the same direction as seen from Earth, they will appear close together in the sky, even if in reality they are many light-years away from each other.

Orion’s Belt
Credits: Digitized Sky Survey, ESA/ESO/NASA FITS Liberator

Video

Let us see how Orion looks like from different places in the galaxy.

The video is available at this URL:

https://youtu.be/lD-5ZOipE48

The movement of the stars

- The stars are not fixed in place. Each star has its own independent motion in 3D. Different stars move in different speeds and directions.
- Over tens of thousands of years, the patterns that we recognize now in the sky may not exist anymore.
- For example, one star in a constellation may move north while another one moves east.
- Prehistoric humans who lived hundreds of thousands of years ago saw a different sky!

Video

Let us see how Orion looks like from Earth at different points in time.

The video is available at this URL:

https://youtu.be/sNqVRzjTSFg

The Pleiades
Credits: NASA, ESA, AURA/Caltech, Palomar Observatory

Observing constellations

- Next time you're far away from the city lights at night, take a look at the sky and try to find all the constellations that I mentioned today!
- The course website has links to apps that you can install on your phone for free and will show you the location of the constellations when you point your phone towards the sky.

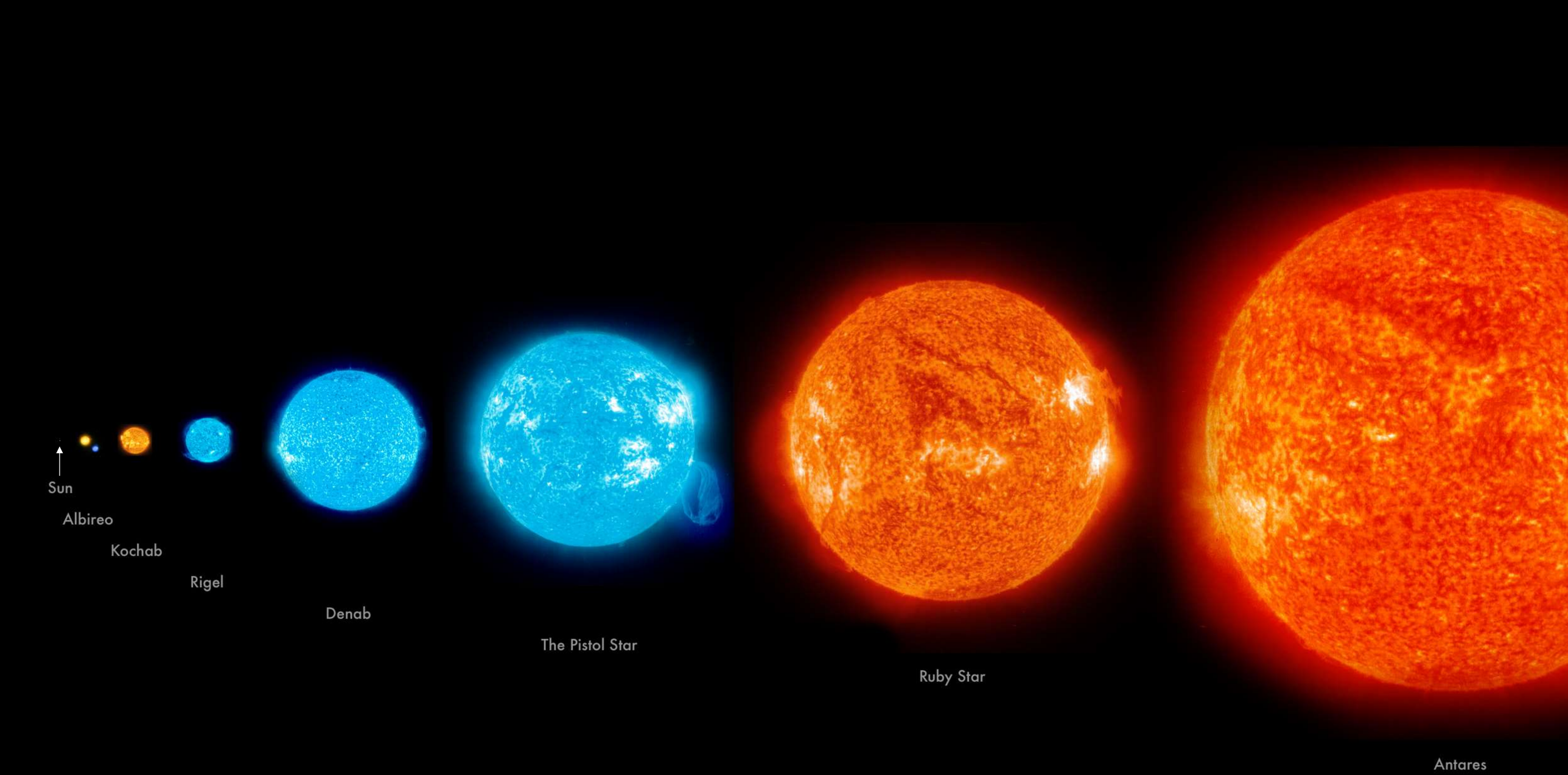

The ecliptic

The Sun

- There is one particular star that is the closest to Earth by far. This star is called the Sun.
- While the other stars are many light-years away, the Sun is only about 8.3 light-minutes away.
- We call that distance an astronomical unit (denoted by AU), and it is equal to around 150 million km.

The Sun

- Since the Sun is so much closer to us than the other stars, it also appears much larger and brighter.
- This doesn't mean it's actually larger or brighter than the other stars.
- Since those stars are so far away, we only see them as tiny dots in the sky.
- But if we put one of these stars in real size next to the Sun, the other star could turn out to be much larger and/or brighter.



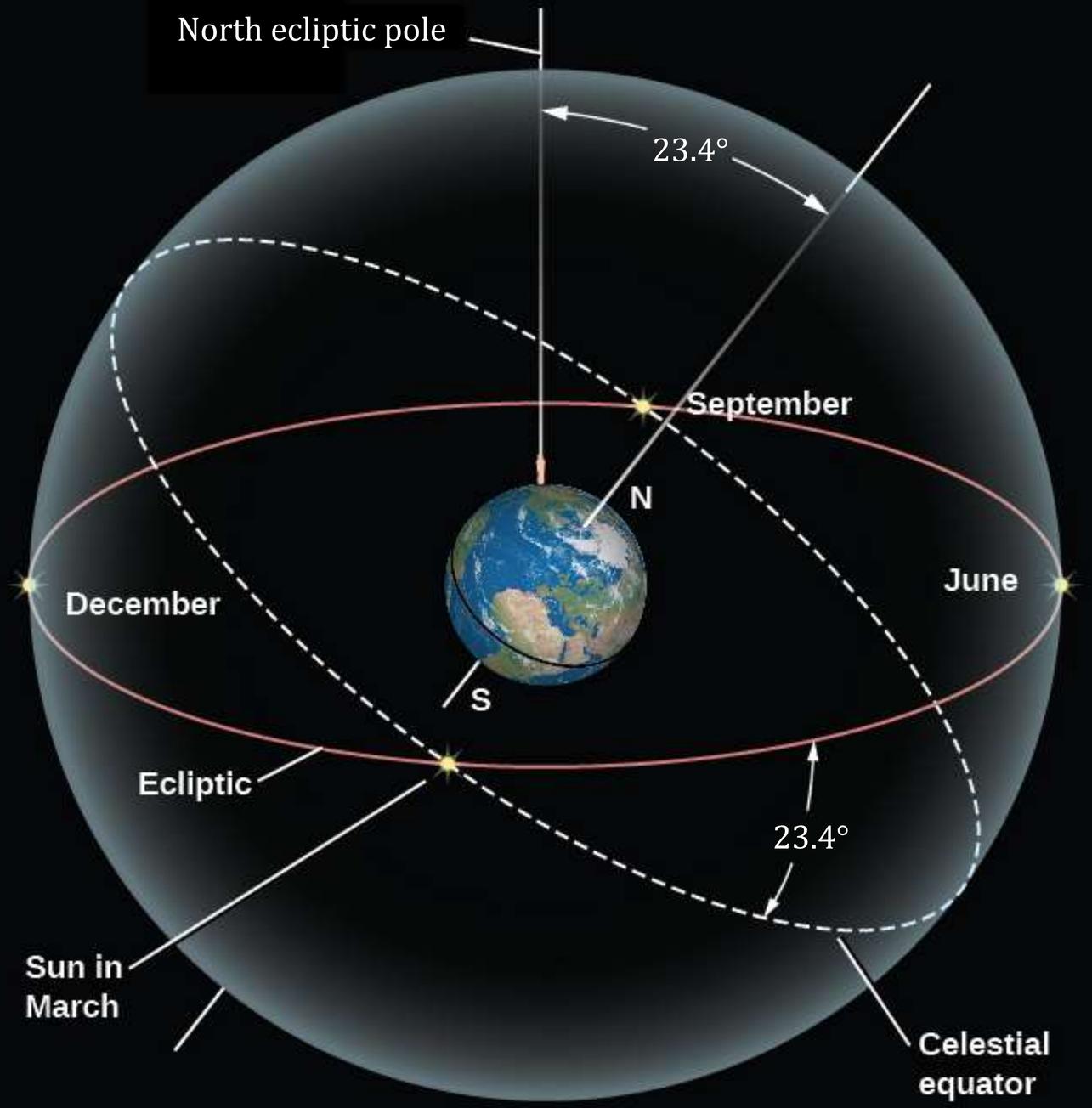
The Sun as 1 Pixel Compared to Other Stars
Credits: Found online, author unknown

The Sun

- The Sun is so bright that you can get serious eye damage just by looking directly at it for a few seconds!
- During daytime, when the Sun is in the sky, we cannot see any other stars in the sky, because they're just not bright enough compared to the immense brightness of the Sun.
- This is why we can only see the stars during the night, or during a solar eclipse.
- The Sun is also bright enough to turn the color of the sky from black to blue; we'll learn how that works later.

The Earth’s rotation

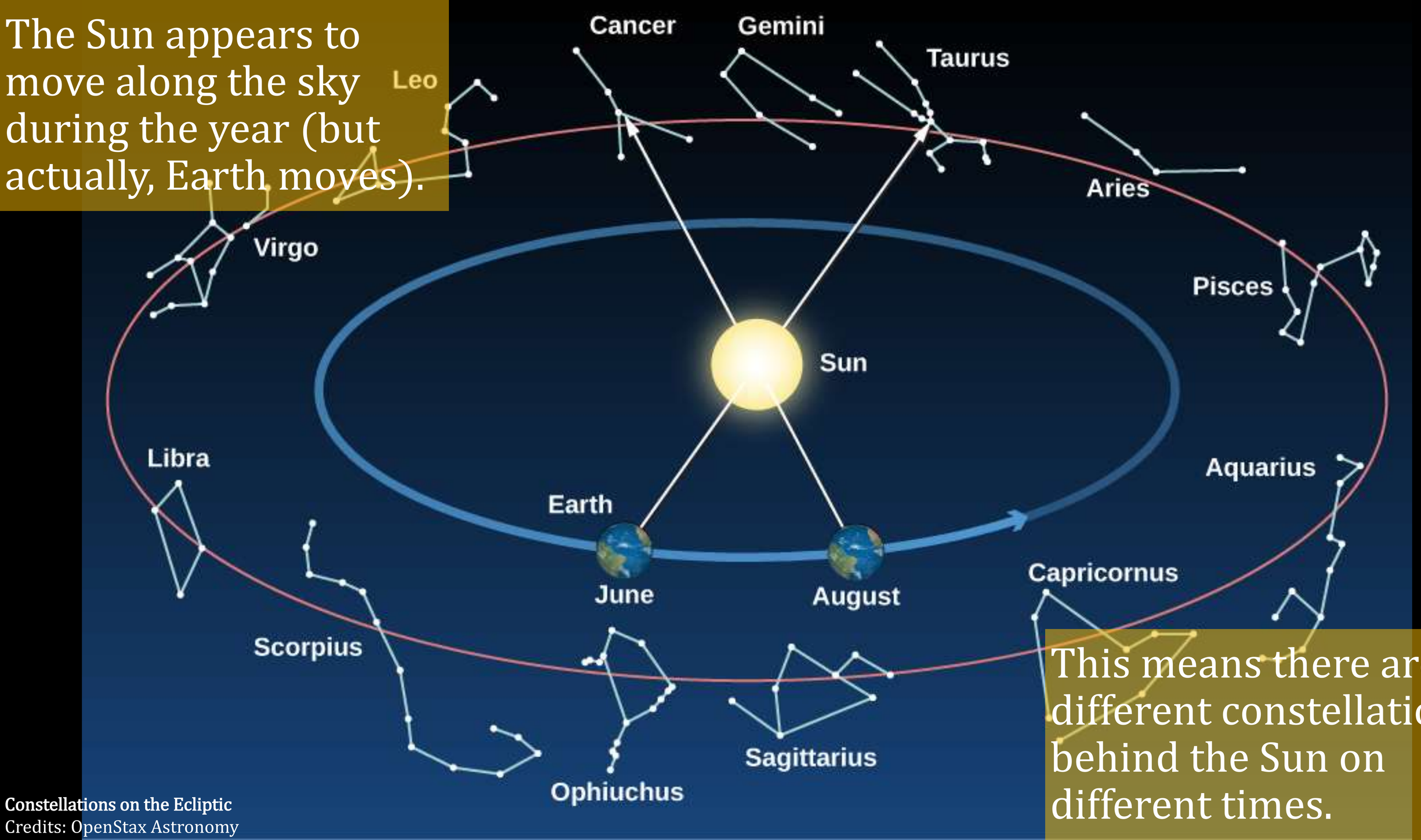
- The Earth rotates:
  1. Around its own axis,
  2. Around the Sun.
- A day is the period during which the Earth completes one rotation around its axis, around 24 hours.
- A year is the time it takes the Earth to complete a full revolution around the Sun, around 365 days.



The Celestial Tilt
Credits: Modification of illustration from OpenStax Astronomy

- The plane of Earth's rotation around the Sun is the ecliptic.
- The line perpendicular to the ecliptic intersects the celestial sphere at the ecliptic poles.
- The plane of Earth's rotation around its axis intersects the celestial sphere at the celestial equator.
- The two planes of rotation differ by an axial tilt of 23.4°.
- The two intersections of the ecliptic and the celestial equator are called equinoxes.
- The Sun is at the equinoxes around March 20 and September 23.

The Sun appears to move along the sky during the year (but actually, Earth moves).



Constellations on the Ecliptic
Credits: OpenStax Astronomy

This means there are different constellations behind the Sun on different times.

The Sun’s path in the sky

- In total, there are 13 constellations on the ecliptic.
- The Sun appears to move in a circle eastward, and comes back to its original spot after exactly a year.
- There are 360° in a circle, and around 365 days in a year, so the Sun appears to move ~1° per day.

Other celestial bodies in the sky

- With the naked eye, we can see 5 planets:
  - Mercury
  - Venus
  - Mars
  - Jupiter
  - Saturn
- The Sun, the Moon, and these 5 planets were known in ancient Greece as the “7 classical planets”.
- The word "planet" means "wanderer" in ancient Greek. These 7 objects seem to wander around the sky, while the stars stay in place.
- However, in modern terminology, the word "planet" only applies to large objects that orbit the Sun.

Other celestial bodies in the sky

- The Sun follows the ecliptic on the celestial sphere.
- The paths of the Moon and the planets are close to the ecliptic, but not exactly on it.
- The orbits of the planets around the Sun, and of the Moon around Earth, all lie on their own planes, but these planes turn out to be very close to the ecliptic plane.

Other celestial bodies in the sky

- The Sun, Moon, and planets are always within 8-9° north or south of the ecliptic.
- This “belt” is called the zodiac.
- “Zodiac" means “circle of animals”. Many of the 13 constellations on the zodiac are named after animals.

Conclusions

- This lecture focused on things that can be seen with the naked eye: stars, asterisms, and constellations.
- We also learned about many imaginary points and lines in the sky, such as the zenith, celestial poles, ecliptic, equinoxes, and so on.

- Reading: OpenStax astronomy, section 2.1.
- Exercises: Practice questions are available in the textbook and on the course website.