Observing the Sky

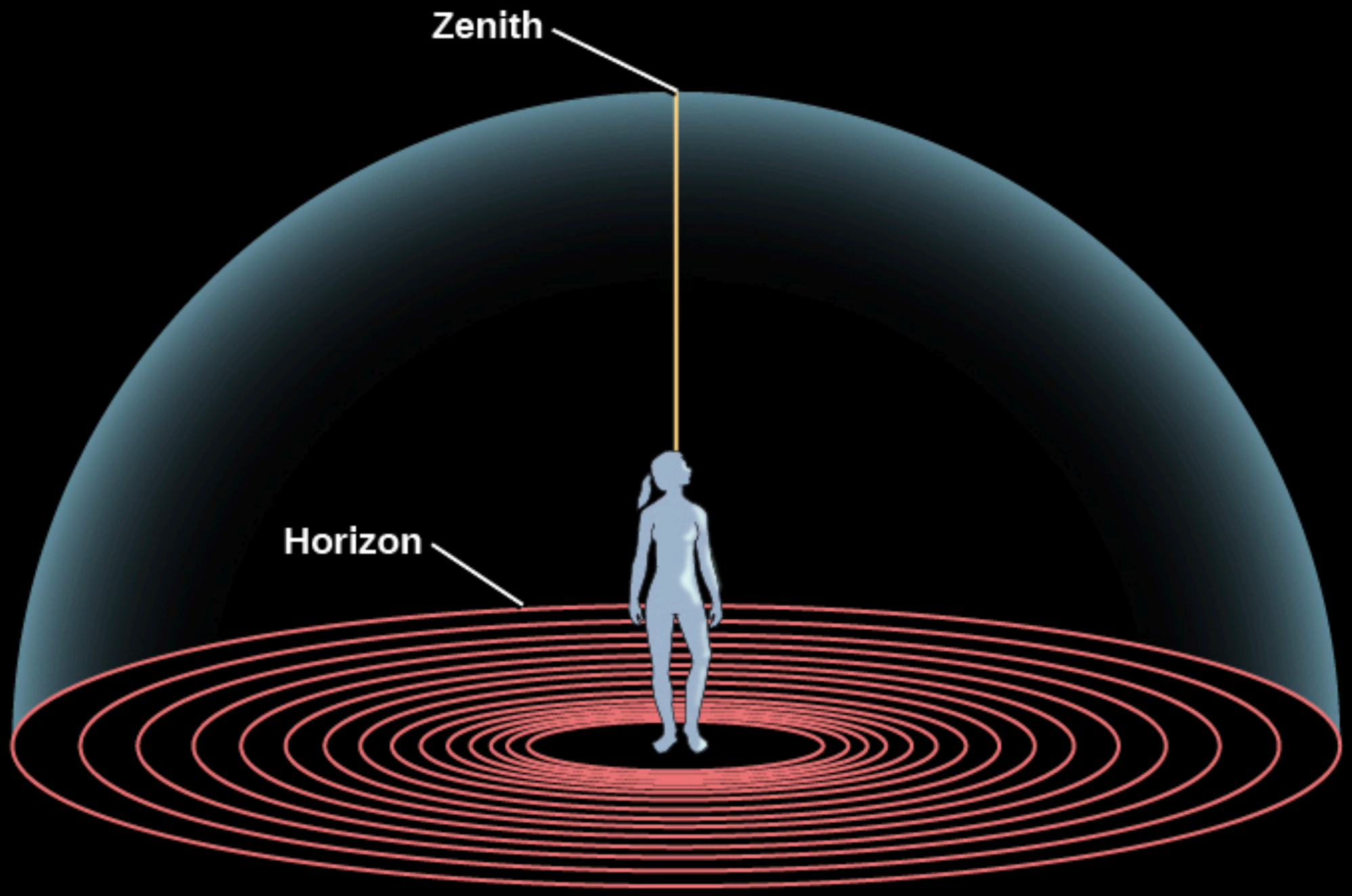
Chapter 2

The Celestial Sphere

- When one looks up at the night sky in a dark location one can see thousands of stars and possibly the Moon. If one watches for hours you may notice that the stars move across the sky, new stars rise in the east and eventually set in the west.

- All the stars move at the same rate and they move at almost the same rate as the Moon and the Sun. You could imagine that all of them are pasted onto a sheet or dome which moves around the Earth.

- This is in fact what many of the Ancient Greeks thought and they called this dome the Celestial Sphere. A sphere because they realized each night the stars came back, so the probably traveled under the Earth too.

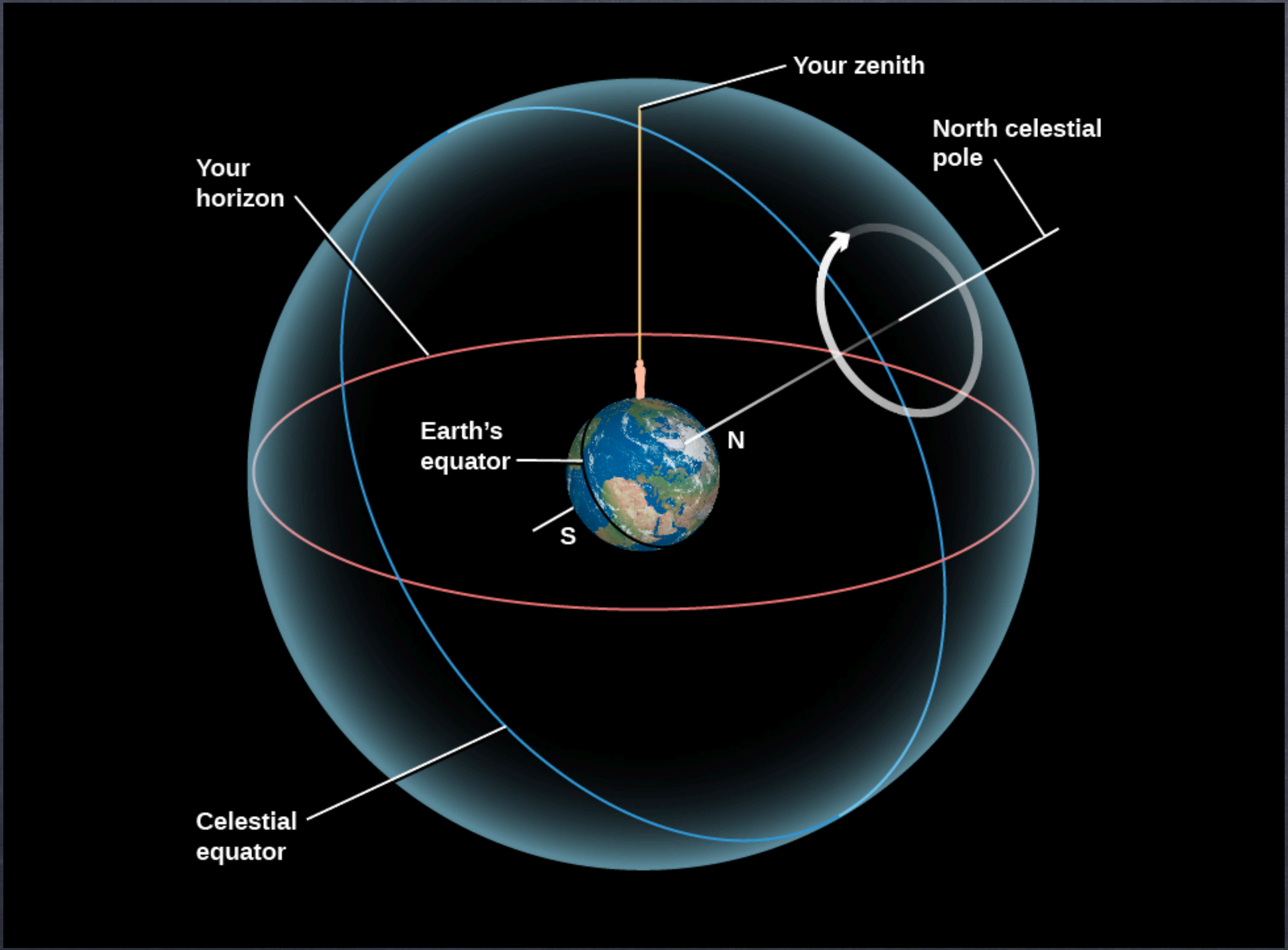

Zenith
Horizon

The Celestial Poles

- Overhead stars do not move directly from East to West, but at an angle. In fact some stars do not rise and set at all, but instead just make circles in the sky.
- The point around which all the stars circle is called the north celestial pole in the northern hemisphere and there is south celestial pole in the southern hemisphere.

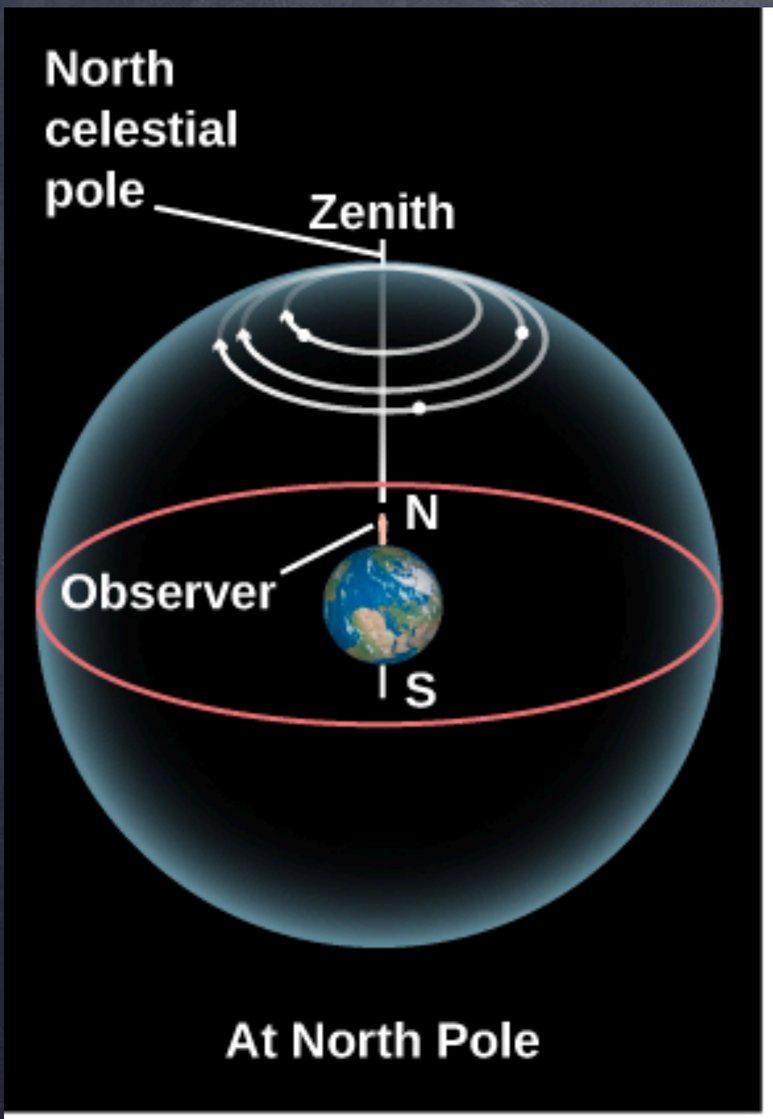
Rotation of the Earth

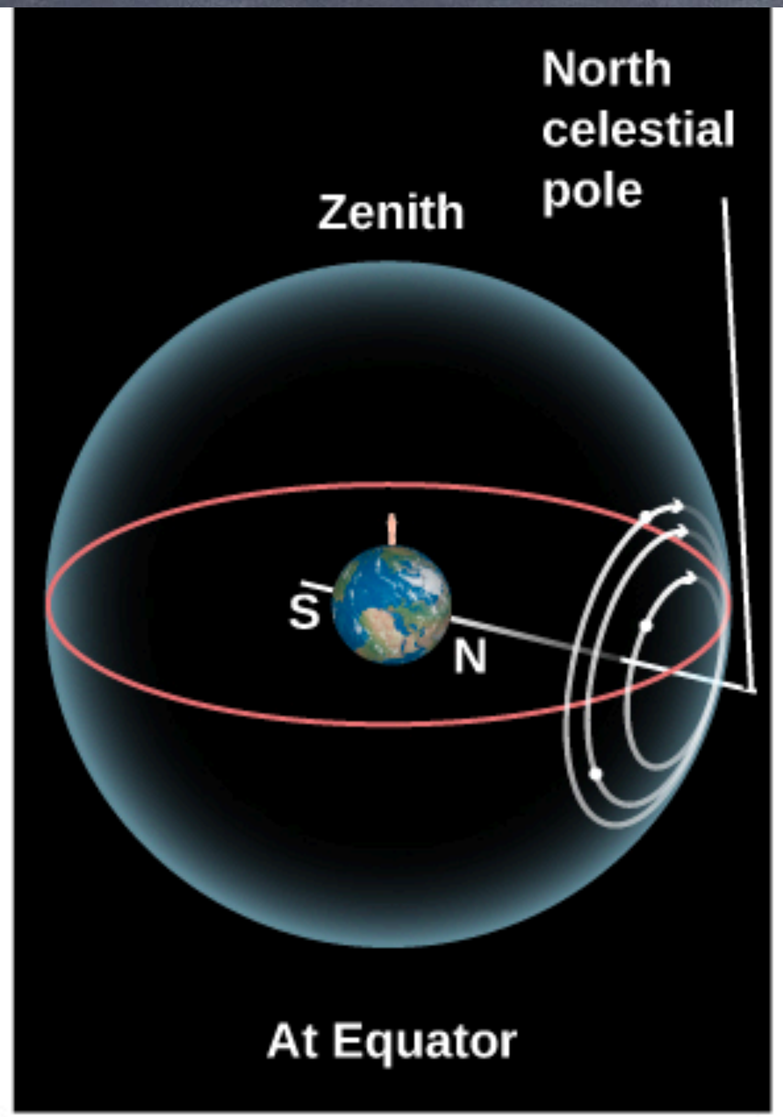
- In fact there is no celestial sphere, the stars appear to move because of the rotation of the Earth.
- The celestial poles simply correspond to the Earth's axis of rotation.
- The night sky appears to move only because it is us who are in fact moving.

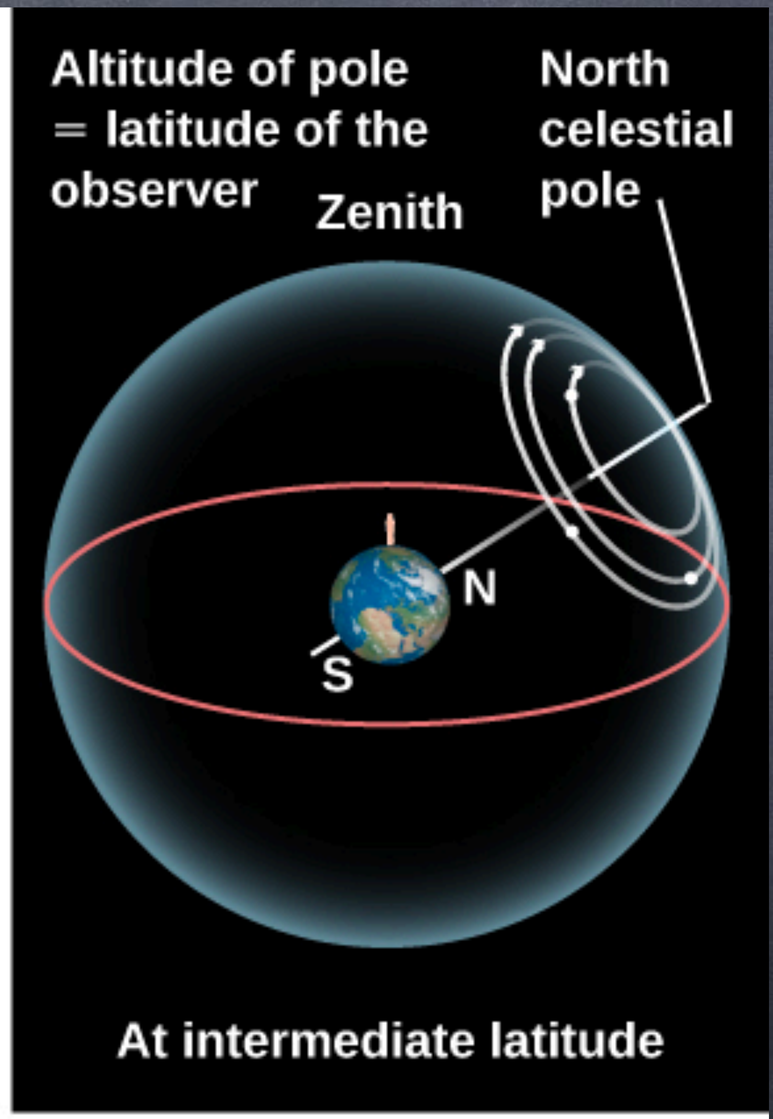

Your zenith
North celestial pole
Your horizon
Earth's equator
N
S
Celestial equator

- If you stand at the north pole, then the stars do not rise and set, they simply make circles in the sky, with the ones directly overhead making the smallest circles and the ones near the horizon circling the entire sky.
- If you stand on the equator, then all the stars rise and set. Stars that rise far apart from one another will all still all set at the same time.
- For most of us who live between these two points we get a mixture of these two extremes. We can see a celestial pole and the stars appear to rotate around it, but many stars also drop below the horizon so they appear to rise and set.

There happens to currently be a star that is very near the north celestial pole, so it appears like the stars rotate around it. But it just happens to be there and in the past there have been times where there is no star at that point.

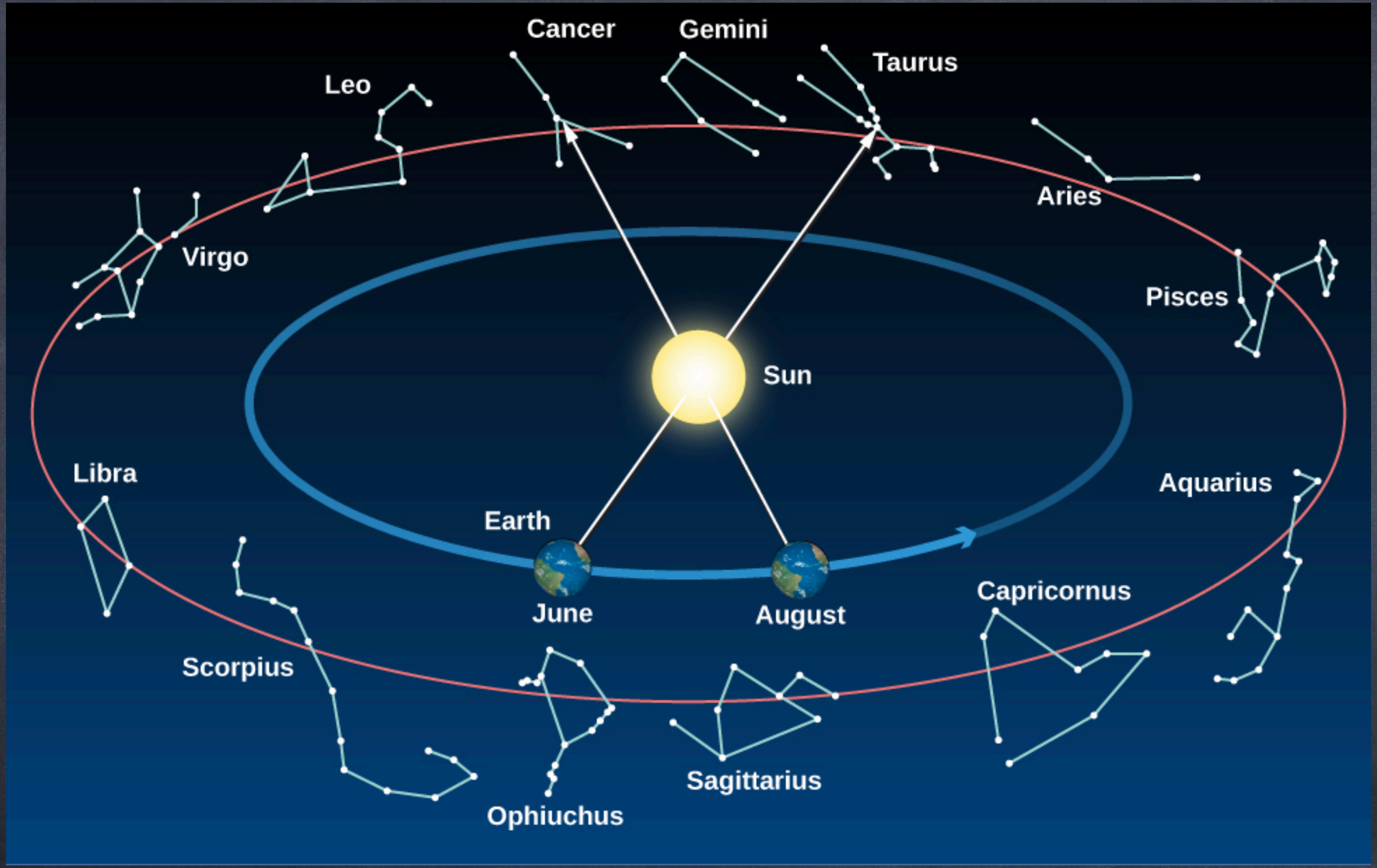






Motion of the Sun

- On any given day the Sun and the Moon behave just like the stars rising in the East and setting in the West.
- The Sun will slightly change its apparent position compared to the stars. Slowly, but over a full year it will move its location completing a circle through the stars.
- The Moon also changes it apparent position completeling a circle in a month.
- The path that the Sun takes in the sky is called the ecliptic. Of course the Sun isn't really moving compared to the stars, its apparent motion is caused by the motion of the Earth around the Sun.


Cancer
Gemini
Taurus
Leo
Aries
Virgo
Pisces
Sun
Libra
Aquarius
Earth
June
August
Capricornus
Scorpius
Sagittarius
Ophiuchus

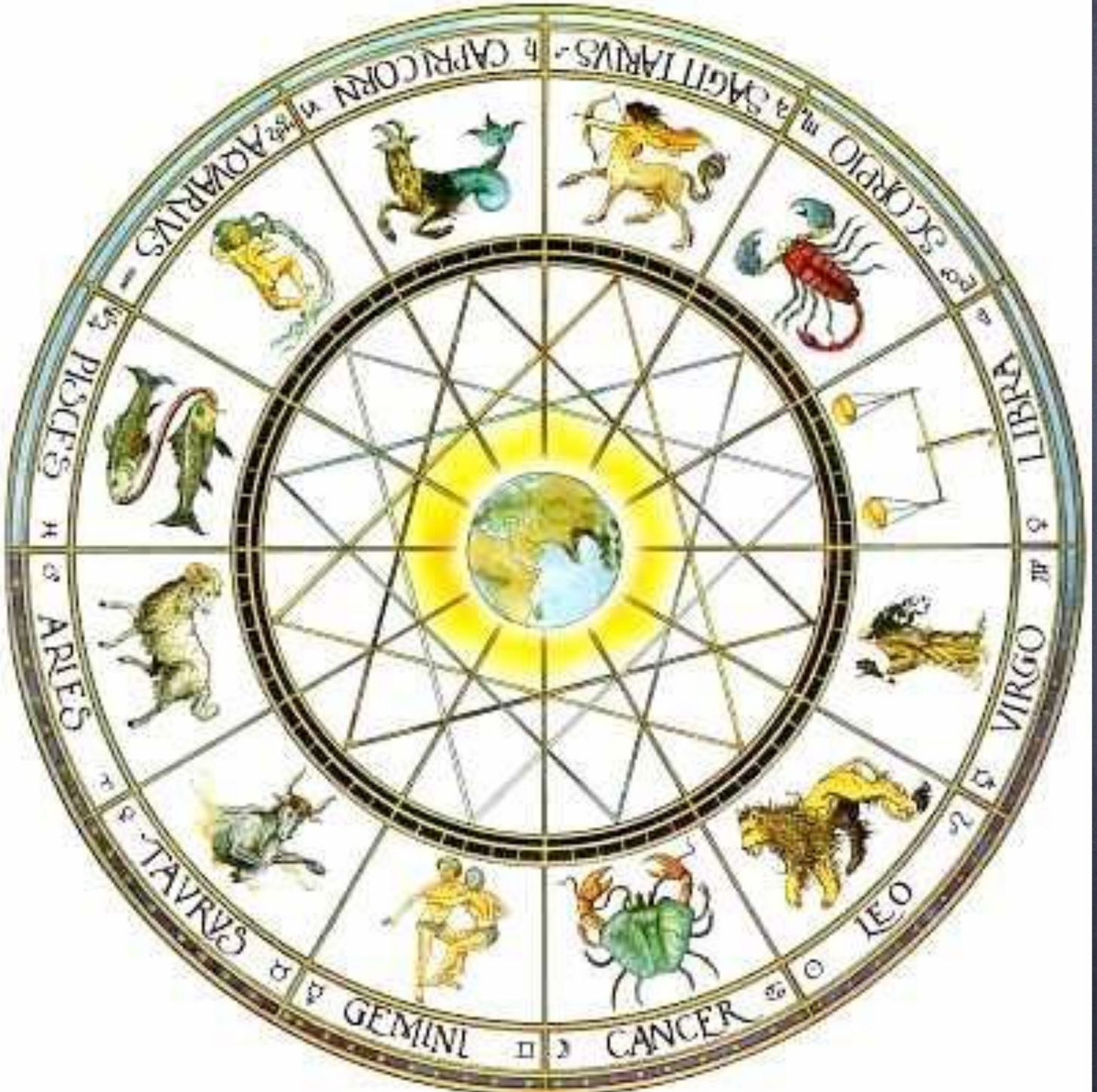
The Zodiac

- As the Sun moves to different apparent positions in the night sky it has different constellations behind it. These 12 constellations are called the zodiac.
- These constellations are there all the time, just like all constellations, but because of the Sun's apparent motion they can be used like a clock.
- Note that when the Sun is at the location of one of the zodiacal constellations is the one time you certainly won't be able to find that constellation, because it is only up during the day.

Constellations

- Constellations are patterns that cultures have seen in the stars over time. The differ by culture and don't signify anything about the car, just about people's imaginations.
- You should think of constellations like seeing images in clouds, if you have a lot of time and imagination it helps.

The constellations that make up the zodiac.



Wandering Stars

- While all of the stars are in fixed locations compared to the rest of the stars, there are actually five stars as seen by the naked eye that appear to move.
- These are the planets, Mercury, Venus, Mars, Jupiter and Saturn (Uranus can just barely be seen if pointed out and Neptune can not be seen by eye).
- To the ancients there are 7 objects that wander unlike stars, the five planets above, the Sun and the Moon.
- All of these objects are found very close to the ecliptic the circle the Sun makes in the sky.

Angular Velocity

- When we usually think about speed or velocity we think about the distance an object moves in a given time.

$$\text{velocity} = \frac{\text{distance}}{\text{time}}$$

- But when looking at the sky we are considering the angle an object moves

$$\text{angular velocity} = \frac{\text{angle}}{\text{time}}$$

Angular Velocity

- Let's look at some examples. A star moving overhead would appear to make a full circle in 24hours, so

$$\text{angular velocity} = 360^\circ/24\text{hr} = 15^\circ/\text{hr}$$

- The Moon makes a full circle in 29.5days so

$$\text{angular velocity} = 360^\circ/29.5\text{d} = 12.2^\circ/\text{day}$$

- The Sun makes a full circle in 365.25 days so

$$\text{angular velocity} = 360^\circ/365.25\text{d} = 0.98^\circ/\text{day}$$

Ancient Astronomy

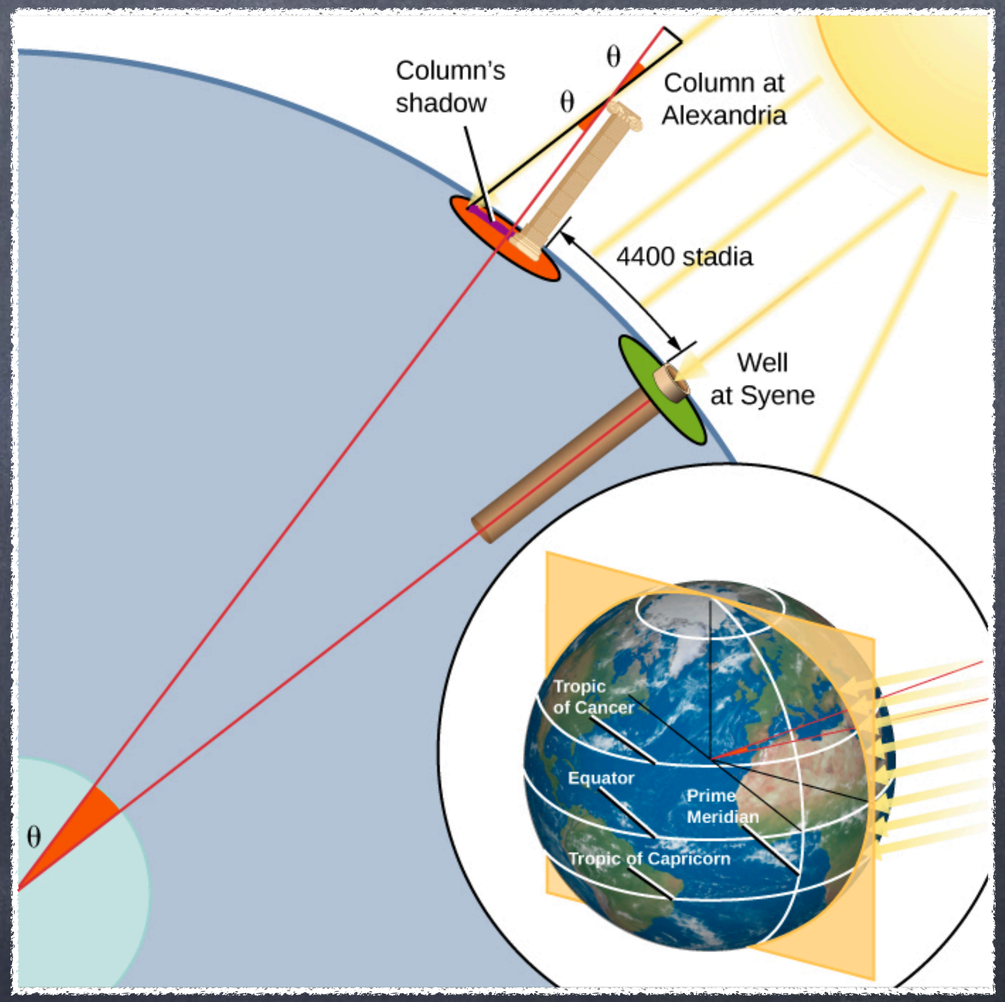
- All ancient cultures studied astronomy. Many of them built structures to mark the passage of the Sun around the ecliptic.
- Stonehenge (England)
- Medicine Wheel (Wyoming)
- Mayan Temples (Mexico and Central America)
- Chinese observations - include a supernova in 1054 A.D.
- Islamic observations during the dark ages.

Ancient Greece and Rome

- The Ancient Greeks and Romans made a number of impressive astronomical discoveries.
  - That the Earth was round and measured its size
  - They understood the phases of the Moon
  - Proposed Earth went around the Sun
  - Discovered precession of the Earth's pole
  - Explained the motion of the planets

Eratosthenes and Measuring the Circumfrance of the Earth

- In 200BC, Eratosthenes measured the size of the Earth.
- He did this is a clever way, he found the day when the Sun was directly over head at one spot.
- Then on the same day he measured a columns shadow a far distance away.
- He reasoned that the Sun was not directly over the column because the Earth was curved and thus determined how much it curved over 4400 stadia.

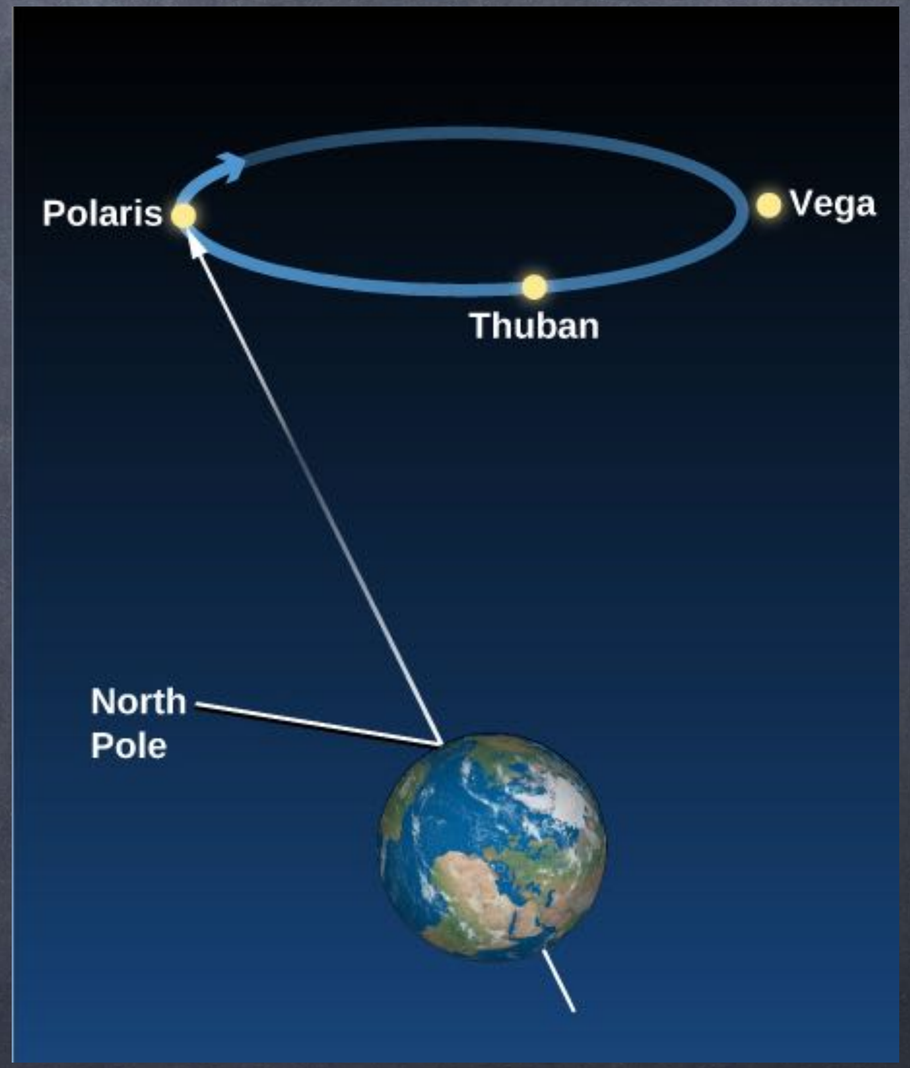


Aristarchus and the Sun Centered Solar System

- Aristarchus suggested the Sun might be the center of the solar system around 310BC. However, this idea was rejected for some very good reasons.
- If you look at a distant object from one location and then move and look at it again the apparent location will have shifted. A phenomena called parallax.
- However, observing the stars no parallax was observed as during the year, so they concluded the Earth was not moving.
- It turns out the theory was absolutely correct, but that the stars are so far away it took the invention of telescopes to measure their parallax.

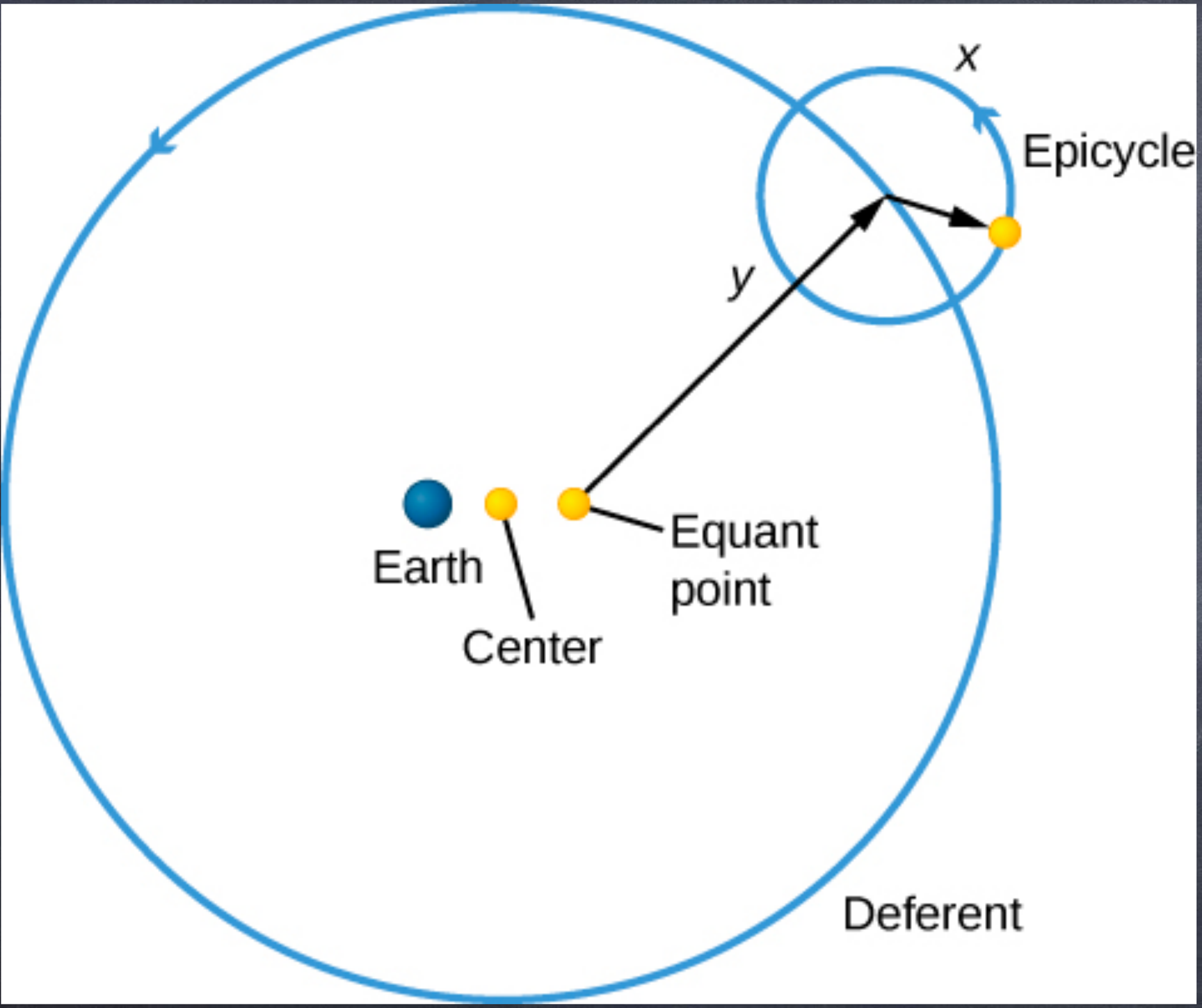
Hipparchus and Precession

- By comparing the positions of stars at his time with 150 years earlier, Hipparchus discovered that the north star had moved.
- This is due to the Earth being a little wobbly like a top, so the spin axis doesn't stay always pointing in the same direction.
- Over time it will point towards different stars before making it back to Polaris.

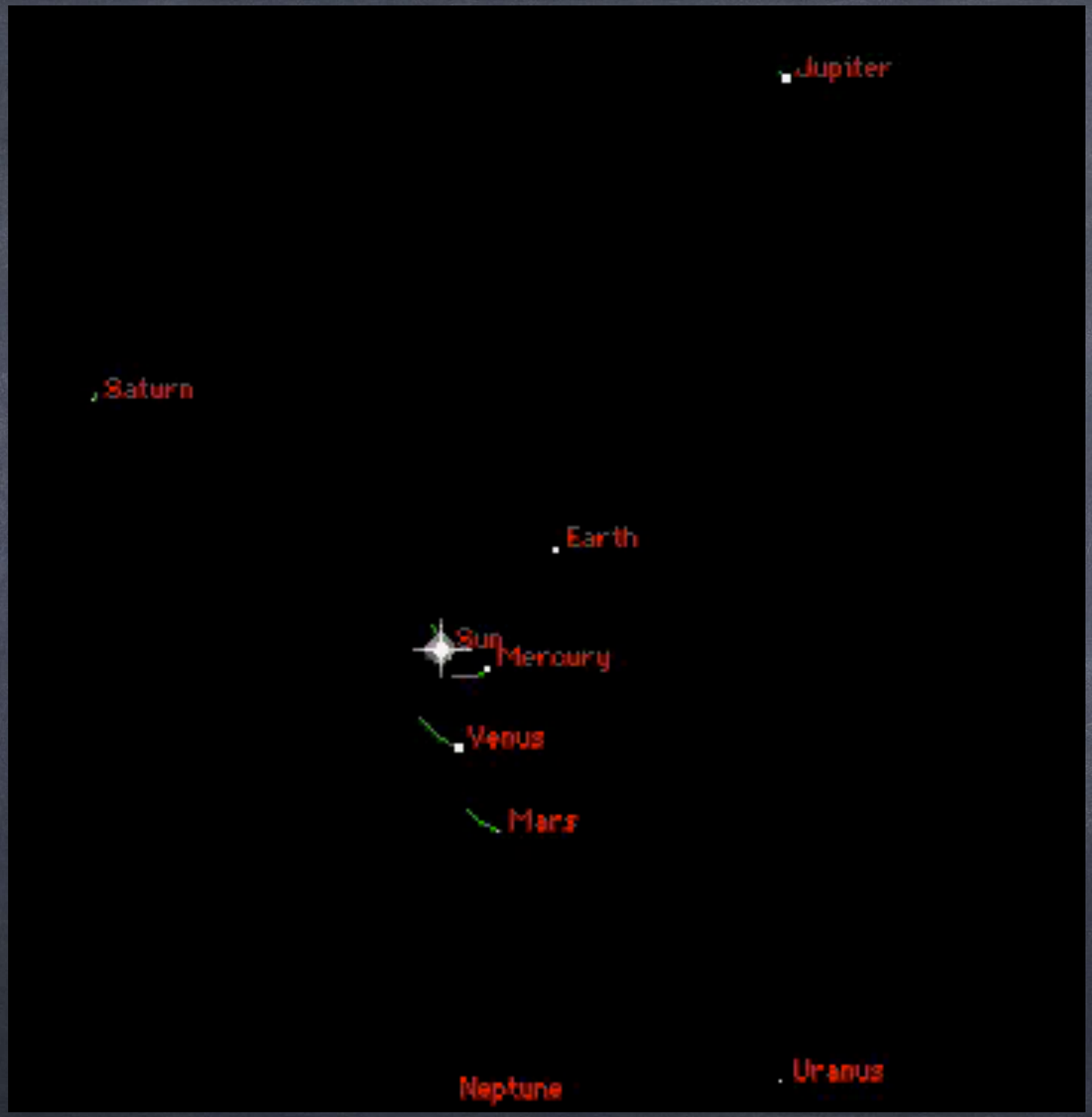


Ptolemy's Model of the Solar System

- Ptolemy created a model of the Solar System in 140AD that was used for about 1400 years.
- In this model the planets motion was described by being a circle whose center was going around in a circle. This was called an epicycle.
- This model successfully predicted the positions of the planets and explained why they sometimes moved in a retrograde orbit. But it was very complex.

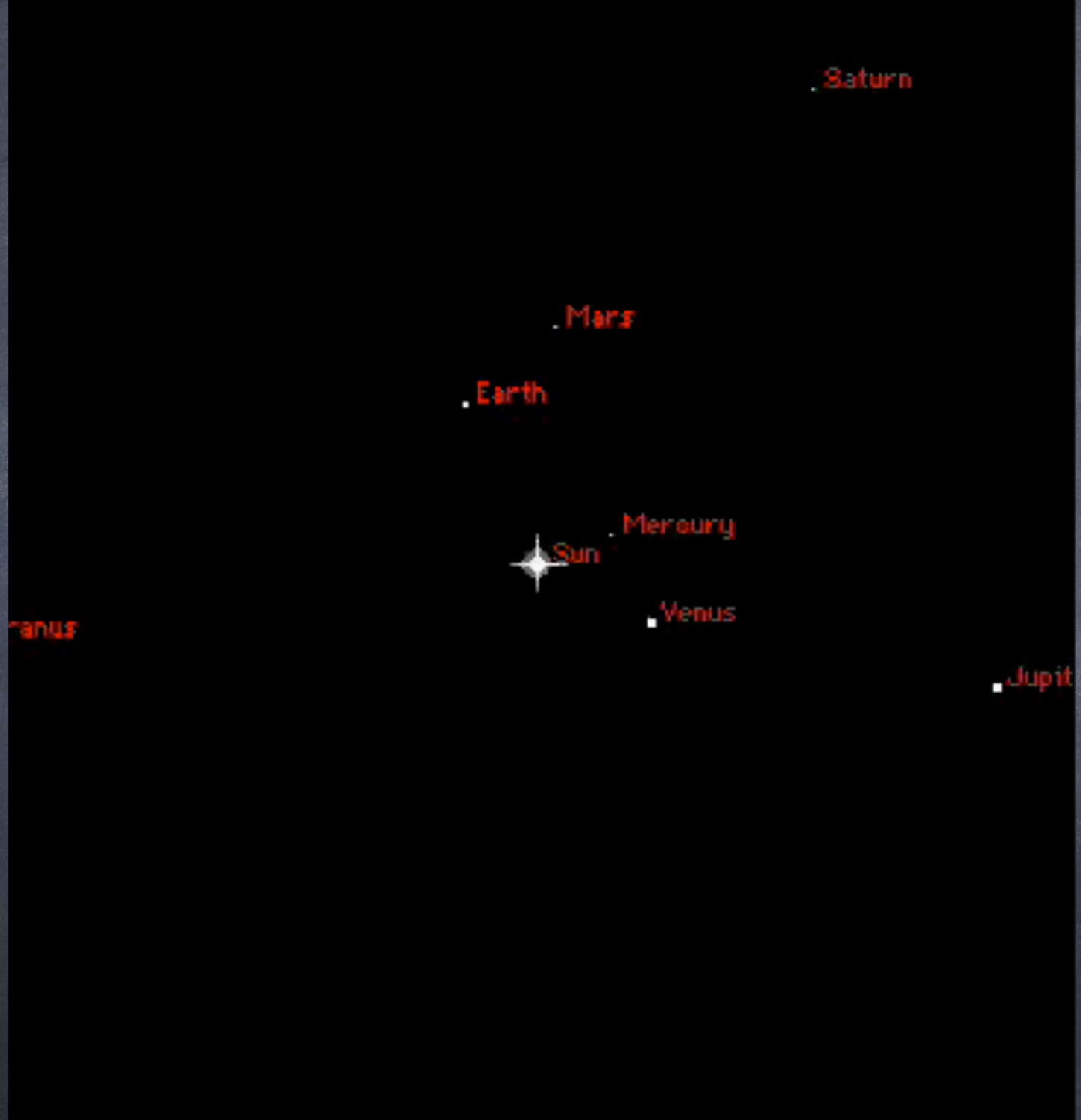


A planet moves in a circle around a point that itself moves in a circle around a point that is close to, but not exactly the Earth.


Jupiter
Saturn
Earth
Sun
Mercury
Venus
Mars
Uranus
Neptune

Copernicus

- Nothing much happened in Europe in regards to astronomy from Ptolemy until the Renaissance.
- In 1543, Copernicus published his rediscovery that one could assume that the Sun was the center of the Solar System and the planets all revolved around the sun.
- He argued that this made a simpler more beautiful model of the Solar System.


Saturn
Mars
Earth
Mercury
Sun
Venus
anus
Jupit

Galileo

- The Italian scientist Galileo marks the beginning of modern science and modern astronomy. He is often regarded as the father of modern astronomy.
- Galileo began the process of using the scientific method in Western Europe. He used observations to formulate theories and conceived of experiments to test these ideas.
- For astronomy he most importantly took the telescope (invented in Holland) and pointed it up in the sky, seeing many things that no person had every seen before.
- He also developed many of the important ideas in mechanics like inertia and that all objects fall at the same rate.

https://apod.nasa.gov/apod/ap111101.html

Galileo

- Galileo made a number of observations using the telescope that demonstrated that Copernicus's Sun centered model of the Solar System was correct.
  - He observed craters on the Moon and sunspots on the Sun that showed that the celestial objects were not perfect.
  - He observed 4 moons of Jupiter showing that not everything orbits the Earth (or Sun).
  - Most importantly he observed that Venus goes through phases like the Moon. By studying the phases this demonstrated that Venus revolved around the Sun.