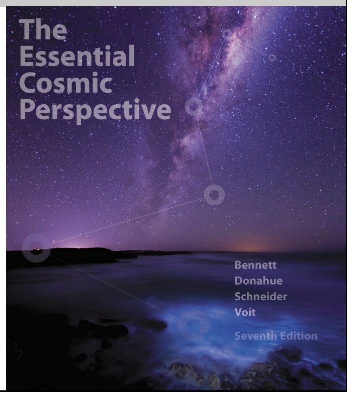
Lecture Outline

Chapter 2: Discovering the Universe for Yourself

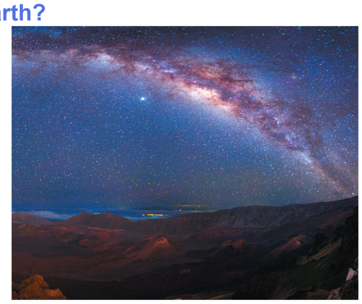


2.1 Patterns in the Night Sky

Our goals for learning:

- What does the universe look like from Earth?
- Why do stars rise and set?
- Why do the constellations we see depend on latitude and time of year?

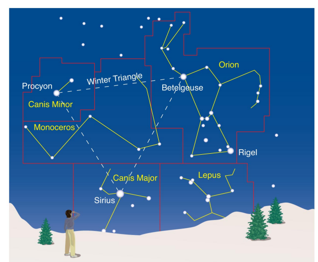
What does the universe look like from Earth?



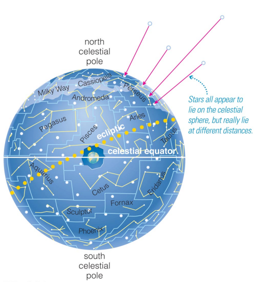
- With the naked eye, we can see more than 2000 stars

Constellations

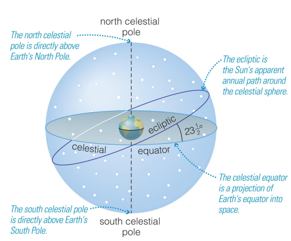
- A constellation is a *region* of the sky.
  - Eighty-eight constellations fill the entire sky.
- An asterism is an easily recognizable group of stars.
  - The big dipper is an asterism



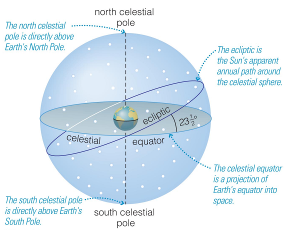
The Celestial Sphere



- Stars at different distances all appear to lie on the celestial sphere.
- The 88 official constellations cover the entire celestial sphere.



- **North celestial pole** is directly above Earth's North Pole.
- **South celestial pole** is directly above Earth's South Pole.
- **Celestial equator** is a projection of Earth's equator onto sky.



- The **ecliptic** is the Sun's apparent path through the celestial sphere.

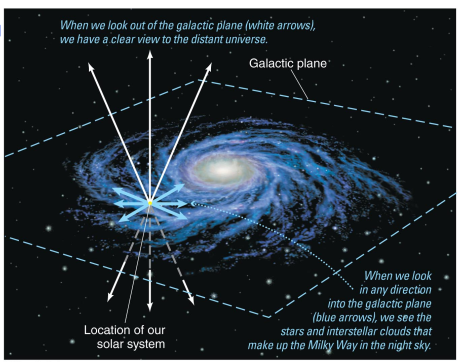
The Milky Way

- A band of light making a circle around the celestial sphere.

What is it?

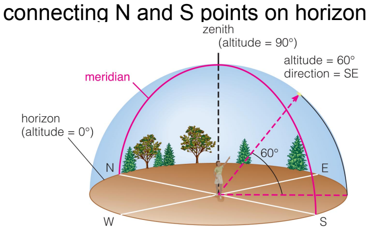
- Our view into the plane of our galaxy.

Th

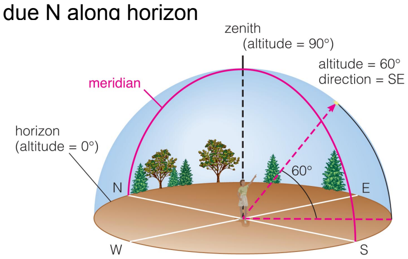


The Local Sky

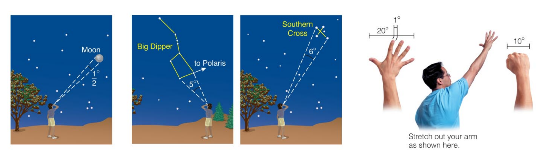
- **Zenith:** the point directly overhead
- **Horizon:** all points 90° away from zenith
- **Meridian:** line passing through zenith and connecting N and S points on horizon



- **altitude** is position above horizon
- **direction** (azimuth) degrees clockwise from due N along horizon



Angular Sizes and Distances



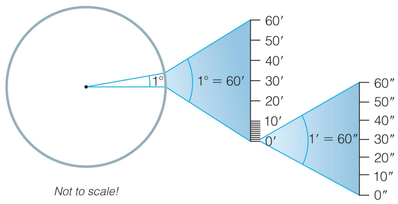
a The angular sizes of the Sun and the Moon are about 1/2°.

b The angular distance between the "pointer stars" of the Big Dipper is about 5°, and the angular length of the Southern Cross is about 6°.

c You can estimate angular sizes or distances with your outstretched hand.

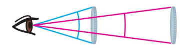
Angular Measurements

- Full circle = 360°
- 1° = 60′ (arcminutes)
- 1′ = 60″ (arcseconds)

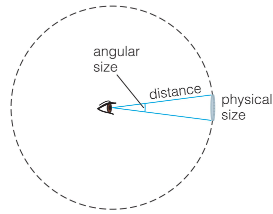


Angular Size

$$\text{angular size} = \text{physical size} \times \frac{360 \text{ degrees}}{2\pi \times \text{distance}}$$

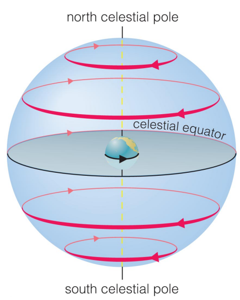


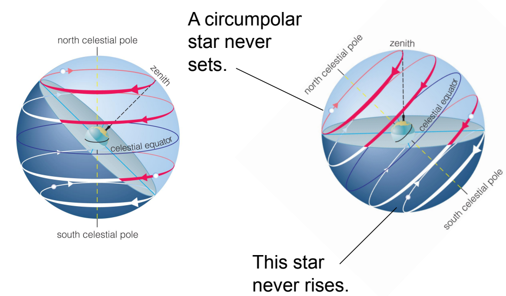
An object's angular size appears smaller if it is farther away.



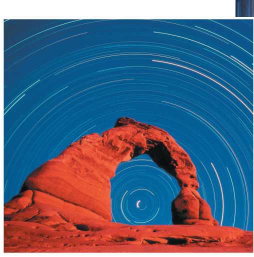
Why do stars rise and set?

- Earth rotates from west to east, so stars appear to circle from east to west.





- Stars near the celestial pole are **circumpolar** and never set.

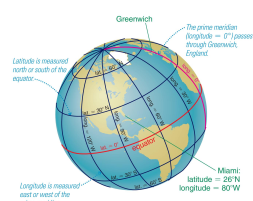


- Here in Long Beach we cannot see stars near the south celestial pole.

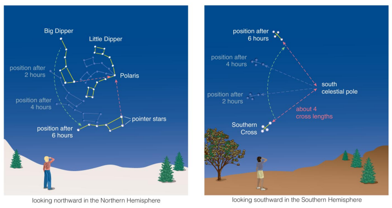
What do the constellations we see depend on?

- **1) Latitude**
  - your position on Earth determines which constellations remain below the horizon.

- **Latitude:** position north or south of equator
- **Longitude:** position east or west of meridian



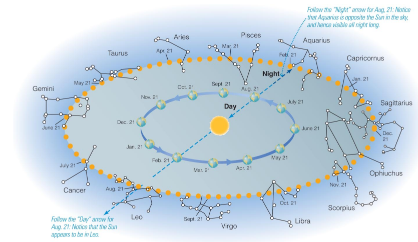
- Altitude of the celestial pole = your latitude
- The north star Polaris is due north at a height equal to your longitude above the horizon
- Your latitude at LBC is 34°thus Polaris is 34° above the horizon



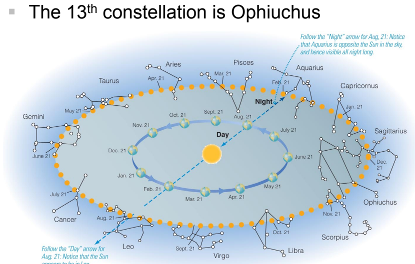
a The pointer stars of the Big Dipper point to the North Star, Polaris, which lies within 1° of the north celestial pole. The sky appears to turn counterclockwise around the north celestial pole.

b The Southern Cross points to the south celestial pole, which is not marked by any bright star. The sky appears to turn clockwise around the south celestial pole.

- **2) Time of year**
  - The sky varies as Earth orbits the Sun.

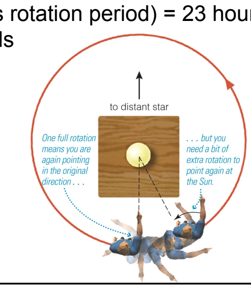


- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.
- The constellations along the ecliptic make up the **zodiac**
  - The 13th constellation is Ophiuchus



How Long Will it take a Star to make a full circuit through the night sky?

- Solar day = 24 hours
- Sidereal day (Earth's rotation period) = 23 hours, 56 minutes 4 seconds



2.2 The Reason for Seasons

Our goals for learning:

- What causes the seasons?
- How does the orientation of Earth's axis change with time?

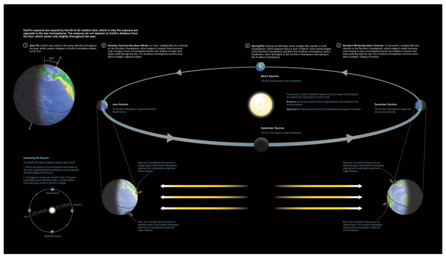
Thought Question

In what session is the Earth closer to the Sun?

Hint: When it is summer in America, it is winter in Australia.

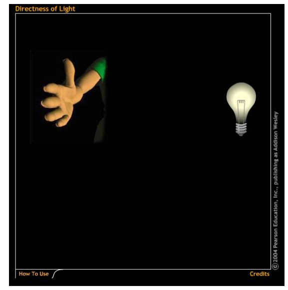
- Seasons are opposite in the N and S hemispheres, so distance cannot be the reason for sessions.
- The real reason for seasons involves Earth's axis tilt.

➢What causes the seasons?



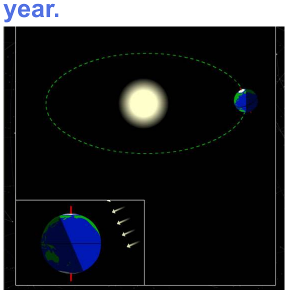
❑Seasons depend on how Earth's axis tilt of 23 ½ degrees affects the directness of sunlight.

Direct light causes more heating.



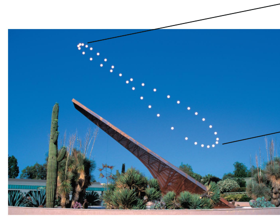
PLAY Directness of Light

Axis tilt changes directness of sunlight during the year.



PLAY Why Does the Flux of Sunlight Vary

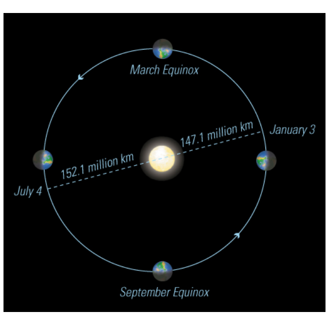
Sun's altitude also changes with seasons.



❑Sun's position at noon in summer: Higher altitude means more direct sunlight.

❑Sun's position at noon in winter: Lower altitude means less direct sunlight.

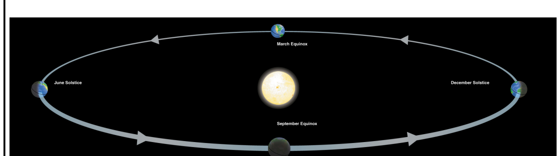
Why *doesn't* distance matter?



❑Variation of Earth–Sun distance is small only about 3%;

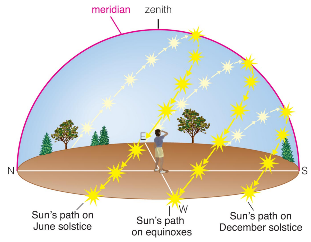
First day of sessions

❑We define four special points:
- summer (June 21) solstice
- winter (December 21) solstice
- spring (March 21) equinox
- fall (September 21) equinox

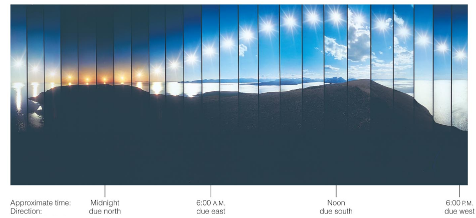


Solstices and equinoxes

- Summer (June) solstice: highest path; rise and set at most extreme north of due east
- Winter (December) solstice: lowest path; rise and set at most extreme south of due east
- Equinoxes: Sun rises precisely due east and sets precisely due west.



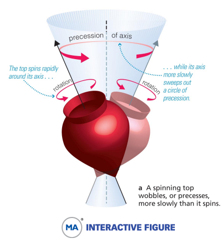
Seasons Around the World



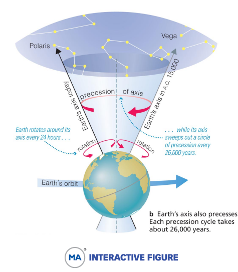
- Season changes are more extreme at higher latitudes
  - Vermont has longer summer days than Florida
- Arctic Circle (latitude 66 ½)
  - During summer solstice the sun remains above the horizon
- At the North and South pole during summer and winter
  - the sun never sets or rises for 6 months at a time

➢How does the orientation of Earth's axis change with time?

- Earth's axis precesses like the axis of a spinning top.



- Earth's precession cycle takes about 26,000 years.
  - Polaris won't always be the North Star.
  - Precession does not change axis tilt (23 ½ degrees)

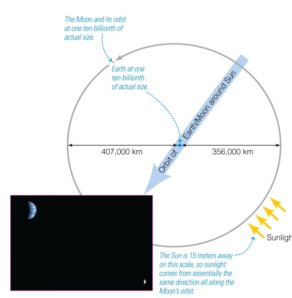


2.3 The Moon, Our Constant Companion

Our goals for learning:

- ➢ Why do we see phases of the Moon?
- ➢ What causes eclipses?

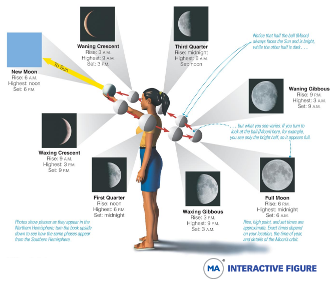
➢Why do we see phases of the Moon?



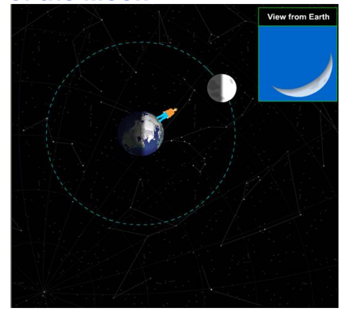
- Lunar phases are a consequence of the Moon's orbit around Earth
- The Moon does not shine. It reflects sun light.
- The orbital period is about 27 1/3 days

Understanding Phases

- Half of the Moon is illuminated by the Sun and half is dark.
- During it's orbit we see different portions illuminated



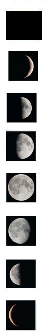
Phases of the Moon



PLAY Phases of the Moon

Phases of the Moon: 29.5-day cycle

"Think Moonth"



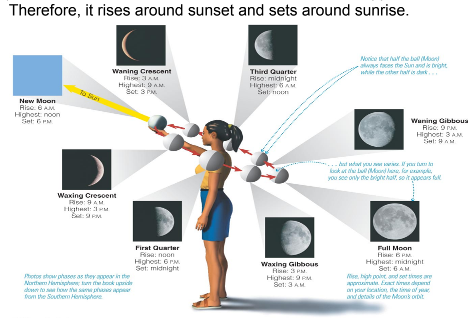
- new
- crescent
- first quarter
- gibbous
- full
- gibbous
- last quarter
- crescent

waxing (crescent, first quarter, gibbous)
- Right side is illuminated
- Moon visible in afternoon/evening
- Gets "fuller" and rises later each day

waning (gibbous, last quarter, crescent)
- Left side is illuminated
- Moon visible in late night/morning
- Gets "less" and sets later each day

The Moon's phase also affects rise and set times

Ex) a full moon occurs when the sun and moon are at opposites. Therefore, it rises around sunset and sets around sunrise.

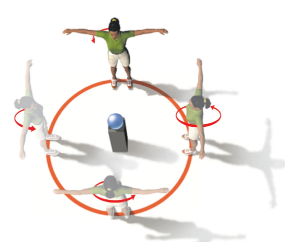


Thought Question

It's 9 A.M. You look up in the sky and see a moon with half its face bright and half dark. What phase is it?

A. first quarter
B. waxing gibbous
C. third quarter
D. half moon

The Moon's Synchronous Rotation



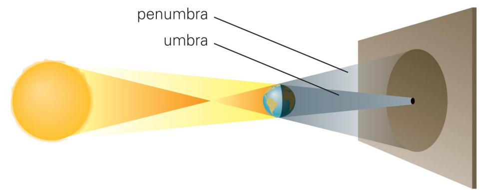
b You will face the model at all times only if you rotate exactly once during each orbit.

- The Moon rotates exactly once with each orbit.
- The same side is always visible from Earth.

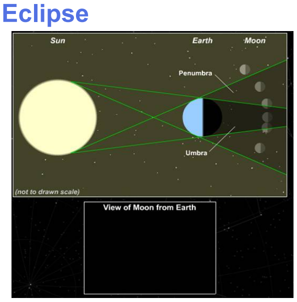
Is There a Dark Side of the moon?

➢What causes eclipses?

- The Earth and Moon cast shadows.
- When either passes through the other's shadow, we have an **eclipse**.



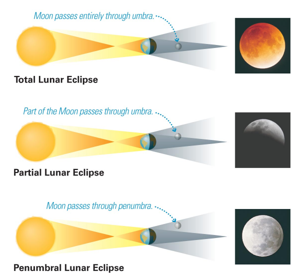
Lunar Eclipse



PLAY Lunar Eclipse

Lunar Eclipses

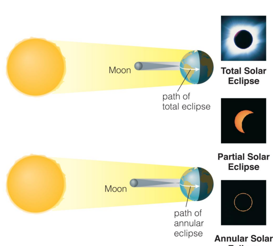
- **Lunar eclipses** can occur only at *full moon*.
- Lunar eclipses can be **penumbral**, **partial**, or **total**.



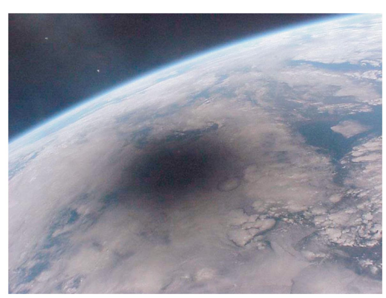
MA INTERACTIVE FIGURE

Solar Eclipses

- **Solar eclipses** can occur only at *new moon*.
- Solar eclipses can be **partial**, **total**, or **annular**.

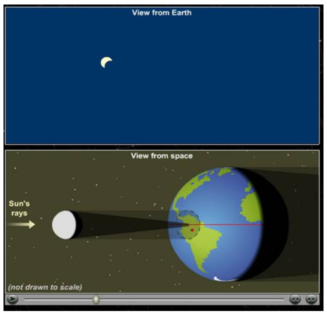


a The three types of solar eclipse. The diagrams show the Moon's shadow falling on Earth; note the dark central umbra surrounded by the much lighter penumbra.



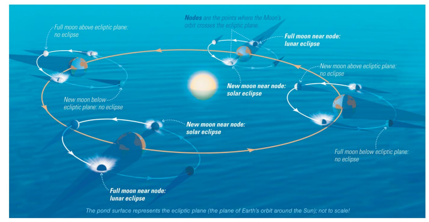
b This photo from Earth orbit shows the Moon's shadow (umbra) on Earth during a total solar eclipse. Notice that only a small region of Earth experiences totality at any one time.

Solar Eclipse



PLAY Evolution of a Total Solar Eclipse

- Why don't we have an eclipse at every new and full moon?
  - The Moon's orbit is tilted 5° to the ecliptic plane.
  - So we have about two **eclipse seasons** each year, with a lunar eclipse at new moon and solar eclipse at full moon.



Summary: Two conditions must be met to have an eclipse

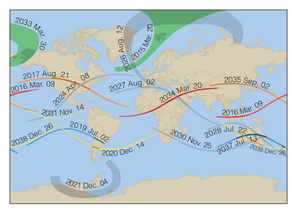
1. It must be a full moon (for a lunar eclipse) or a new moon (for a solar eclipse).

   AND

2. The Moon must be at or near one of the two points in its orbit where it crosses the ecliptic plane (its nodes).

Predicting Eclipses

- Eclipses recur with the 18-year, 11 1/3-day **saros cycle**, but type (e.g., partial, total) and location may vary.



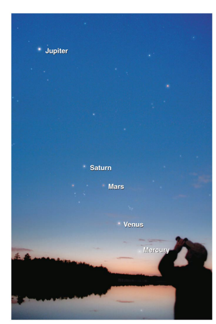
2.4 The Ancient Mystery of the Planets

Our goals for learning:

- Why was planetary motion so hard to explain?
- Why did the ancient Greeks reject the real explanation for planetary motion?

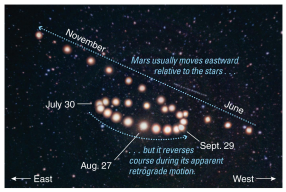
Planets Known in Ancient Times

- Mercury (bottom)
  - Difficult to see; always close to Sun in sky
- Venus (above Mercury)
  - Very bright when visible; morning or evening "star"
- Mars (middle)
  - Noticeably red
- Jupiter (top)
  - Very bright
- Saturn (above Mars)
  - Moderately bright

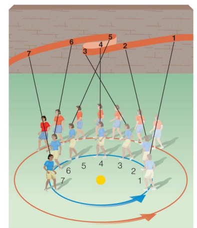


➢Why was planetary motion so hard to explain?

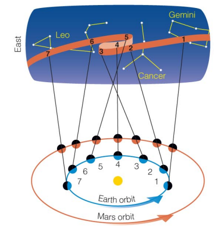
- Planets usually move slightly *eastward* from night to night relative to the stars.
- But sometimes they go *westward* relative to the stars for a few weeks: **apparent retrograde motion.**



We see apparent retrograde motion when we pass by a planet in its orbit.



a The retrograde motion demonstration: Watch how your friend (in red) usually appears to move forward against the background of the building in the distance but appears to move backward as you (in blue) catch up to and pass her in your "orbit."

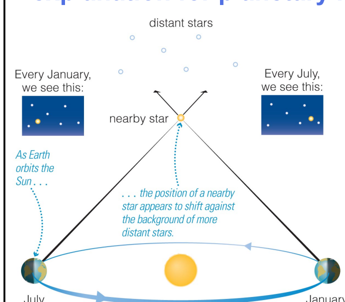


b This diagram shows the same idea applied to a planet. Follow the lines of sight from Earth to Mars in numerical order. Notice that Mars appears to move westward relative to the distant stars (from points 3 to 5) as Earth passes it by in its orbit.

Explaining Apparent Retrograde Motion

- Easy *for us* to explain: this occurs when we "lap" another planet (or when Mercury or Venus laps us).
- But it is very difficult to explain if you think that Earth is the center of the universe!
- *In fact, ancients considered but rejected the correct explanation.*

➢Why did the ancient Greeks reject the real explanation for planetary motion?



- Their inability to observe **stellar parallax** was a major factor.

The Greeks knew that the lack of observable parallax could mean one of two things:

1. Stars are so far away that stellar parallax is too small to notice with the naked eye.
2. Earth does not orbit the Sun; it is the center of the universe.

With rare exceptions, such as Aristarchus, the Greeks rejected the correct explanation (1) because they did not think the stars could be *that* far away.

Thus the stage was set for the long, historical showdown between Earth-centered and Sun-centered systems.