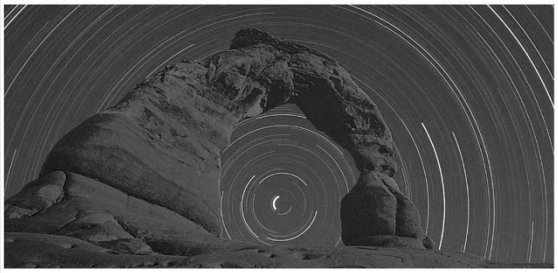
Chapter 2
Discovering the Universe for Yourself



2.1 Patterns in the Night Sky

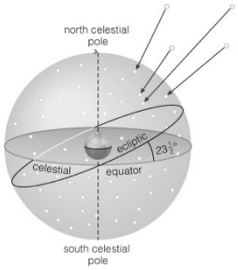
Our goals for learning:

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

Night Sky Map

- See skymaps.com
- Turn map so that direction label on edge of map is turned to the bottom when looking that direction
- Appearance depends on time and location
- About 2000 stars visible to eye arranged in 88 constellations (ancient patterns)

The Celestial Sphere

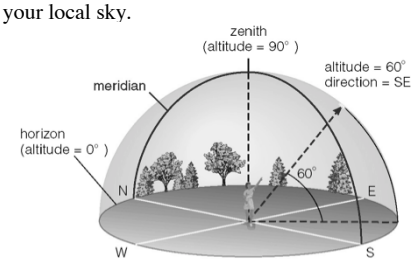


Stars at different distances all appear to lie on the **celestial sphere** (projection of Earth's positions into space).

Ecliptic is Sun's apparent path through the celestial sphere.

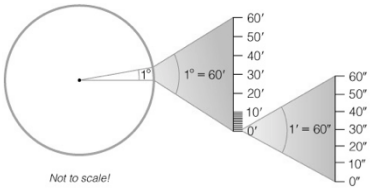
The Local Sky

An object's **altitude** (above horizon) and **azimuth or direction** (along horizon) specifies its location in your local sky.



Sky Angular Measurements

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

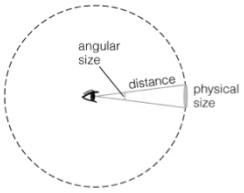


Angular Size

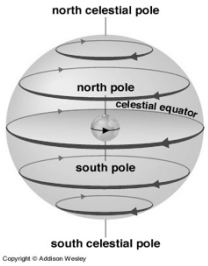
angular size / 360 deg = physical size / circumference

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

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



Why do stars rise and set?



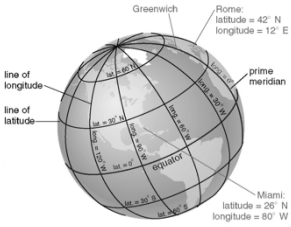
Earth rotates west to east, so stars appear to circle from east to west – **diurnal motion**.

Why do the constellations we see depend on latitude and time of year?

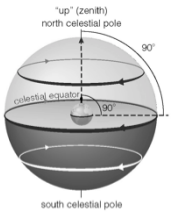
- Latitude: position on Earth determines which constellations remain below the horizon.
- Time of year: Earth's orbit changes the apparent location of the Sun among the stars.

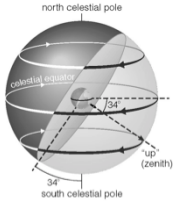
Review: Coordinates on the Earth

- Latitude: position north or south of equator
- Longitude: position east or west of prime meridian (runs through Greenwich, England)



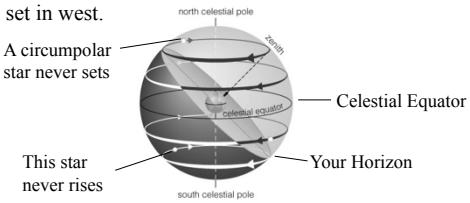
The appearance of the sky varies with latitude





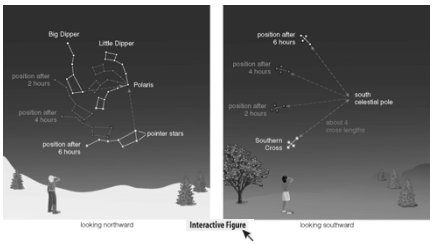
Our view from U.S.A.:

- Stars near the north celestial pole are circumpolar and never set.
- We cannot see stars near the south celestial pole.
- All other stars (and Sun, Moon, planets) rise in east and set in west.



Altitude of the celestial pole = your latitude

see *SkyGazer* simulator



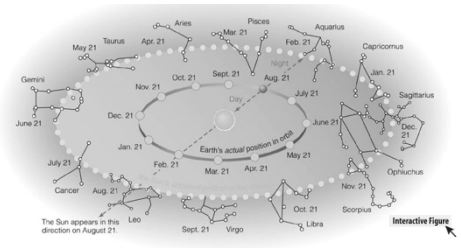
2.2 The Reason for Seasons

Our goals for learning:

- How does our view of the Sun and stars change as Earth orbits the Sun?
- What causes the seasons?
- How do we mark the progression of the seasons?

Our sky view varies as Earth orbits the Sun

- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic (against constellations of the zodiac).
- At midnight, the stars on our meridian are opposite the Sun in the sky.



Thought Question

TRUE OR FALSE? Earth is closer to the Sun in summer and farther from the Sun in winter.

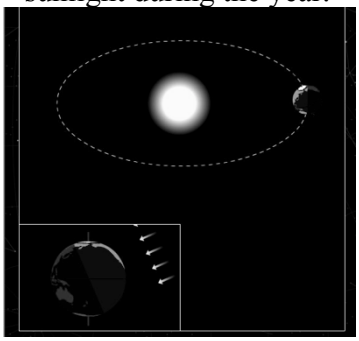
Hint: When it is summer in the U.S., it is winter in Australia.

Thought Question

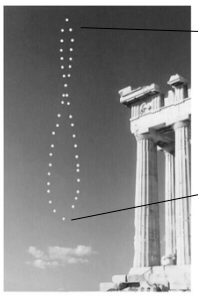
TRUE OR **FALSE!** Earth is closer to the Sun in summer and farther from the Sun in winter.

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

Axis tilt changes directness of sunlight during the year.



Sun's altitude also changes with seasons



Sun's position at noon in summer: higher altitude means more direct sunlight and more daylight hours.

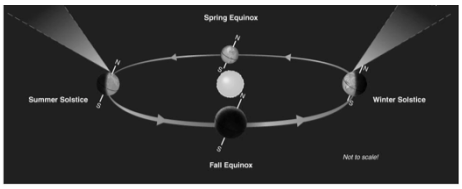
Sun's position at noon in winter: lower altitude means less direct sunlight and fewer daylight hours.

Axis Tilt: The Real Reason for Seasons

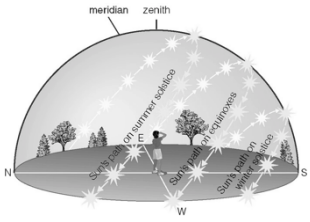
- Earth's axis points in the same direction year round, so its orientation *relative to the Sun* changes as Earth orbits the Sun.
- Summer occurs in your hemisphere when sunlight hits it more directly; winter occurs when the sunlight is less direct.

How do we mark the progression of the seasons?

- Four special points (north):
  summer solstice (June 21)
  winter solstice (Dec. 21)
  spring (vernal) equinox (Mar. 21)
  fall (autumnal) equinox (Sept. 21)



Sun's path at solstices and equinoxes

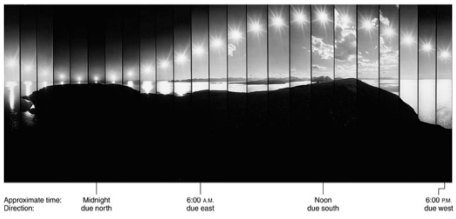


Summer solstice: Highest path, rise and set at most extreme north points (warmest later because atmospheric heating lags).

Winter solstice: Lowest path, rise and set at most extreme south points.

Equinoxes: Sun rises due east and sets due west.

Seasonal changes are more extreme at high latitudes



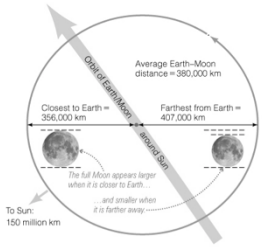
Path of the Sun on the summer solstice at the Arctic Circle

2.3 The Moon, Our Constant Companion

Our goals for learning:

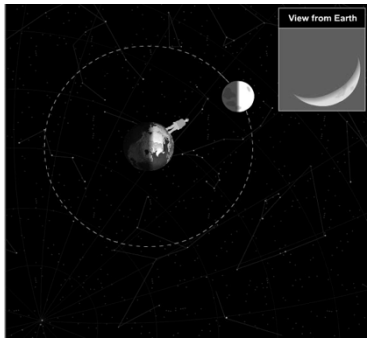
- Why do we see phases of the Moon?
- What causes eclipses?

Why do we see phases of the Moon?

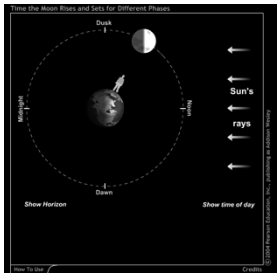


- Lunar phases are a consequence of the Moon's orbit around Earth

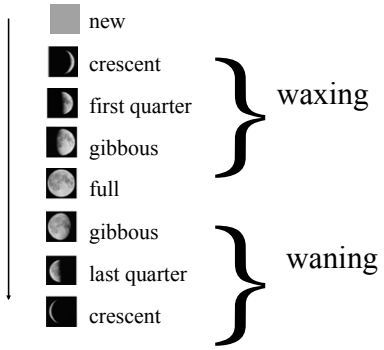
Phases of the Moon



Moon Rise/Set by Phase



Phases of the Moon: 29.5-day cycle



Thought Question

It's 9 am. 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

Thought Question

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

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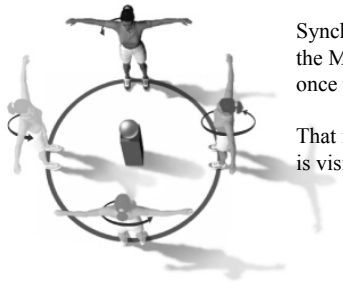
We see only one side of Moon

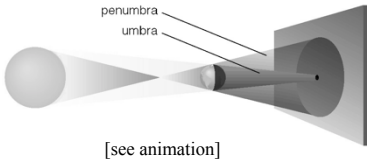


Synchronous rotation: the Moon rotates exactly once with each orbit.

That is why only one side is visible from Earth.

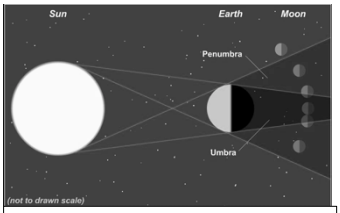
What causes eclipses?

- The Earth and Moon cast shadows.
- Moon enters Earth's shadow: lunar eclipse.
- Moon casts shadow on Earth: solar eclipse.
- **Eclipses tutorial on masteringastronomy.com.**



[see animation]

Lunar Eclipse

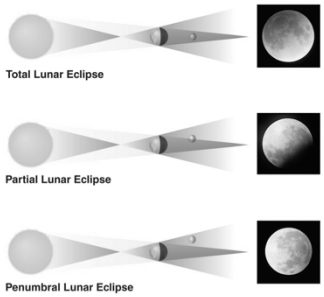


Moon may appear reddish in totality (sunlight refracted by Earth's atmosphere).

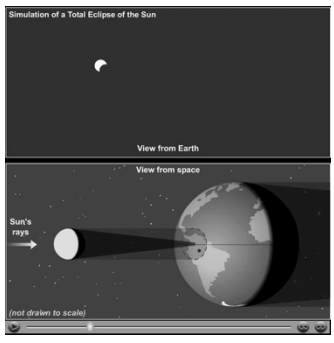
Penumbral stage is very subtle!
[see animation]

When can eclipses occur?

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

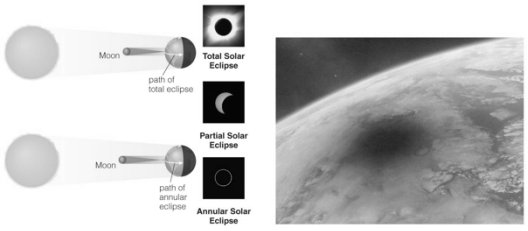


Solar Eclipse



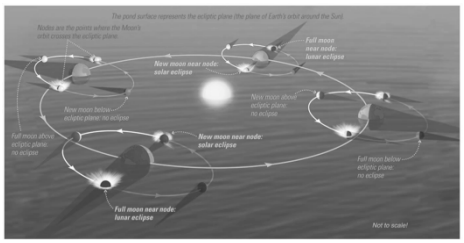
When can eclipses occur?

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



Why don't we have an eclipse at every new and full moon?

- The Moon's orbit is tilted 5° to ecliptic plane.
- So we have about two **eclipse seasons** each year, with a lunar eclipse at new moon and solar eclipse at full moon.

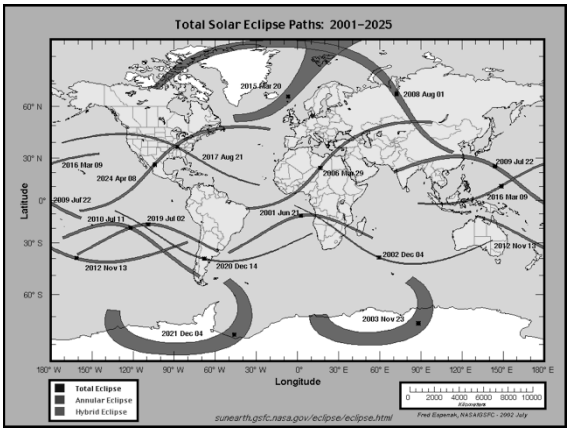


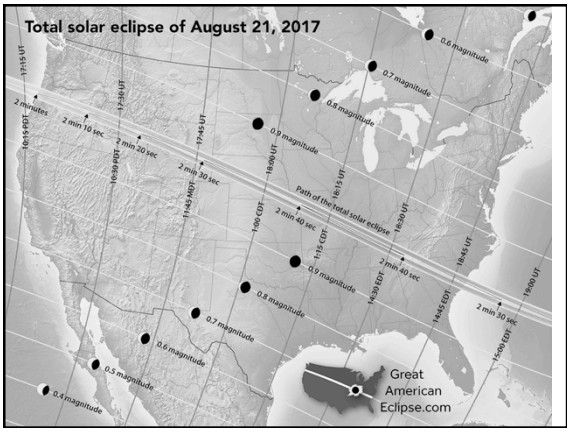
Summary:
Two conditions must be met to have an eclipse

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





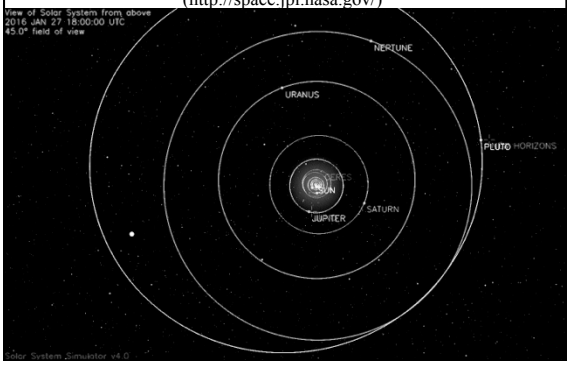
While you are watching a total lunar eclipse on Earth, an astronaut is standing on the near side of the Moon, facing Earth. What would the astronaut see?

2.4 The Ancient Mystery of the Planets

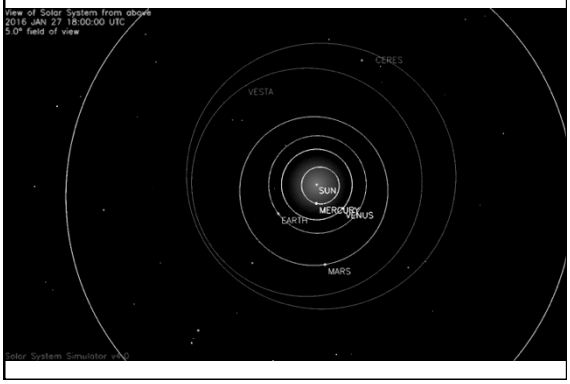
Our goals for learning:

- What was once so mysterious about planetary motion in our sky?
- Why did the ancient Greeks reject the real explanation for planetary motion?

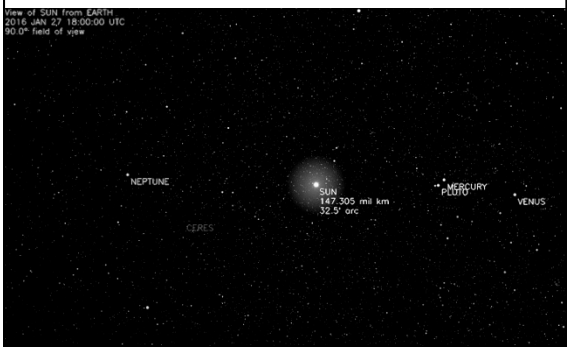
Planets have same counter-clockwise direction of motion when Solar system viewed from above (http://space.jpl.nasa.gov/)



View closer to the center.



From our viewpoint within plane of Solar System, planets are seen along band near the ecliptic.

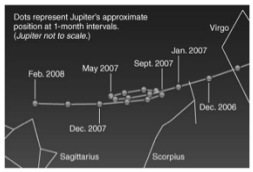


Planets Known in Ancient Times

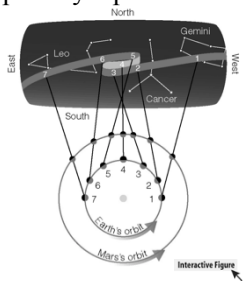
- Mercury
  - difficult to see; always close to Sun in sky
- Venus
  - very bright when visible; morning or evening "star"
- Mars
  - noticeably red
- Jupiter
  - very bright
- Saturn
  - moderately bright

Mysterious planetary motion?

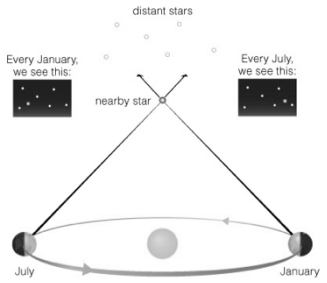
- Planets usually move slightly *eastward* from night to night relative to the stars.
- But outer planets may go *westward* relative to the stars for a few weeks: **apparent retrograde motion**



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



Ancient Greeks considered but rejected the real explanation: no parallax observed



The lack of observable parallax could mean:

1. Stars are so far away that stellar parallax is too small to notice with the naked eye.
2. Earth does not orbit Sun; it is the center of the universe and stationary.
   With rare exceptions (Aristarchus), the Greeks rejected the correct explanation (1) because they did not think the stars could be *that* far away.

Set the stage for a long controversy about Earth-centered and Sun-centered theories.

Next time:

- Chapter 3: Science of Astronomy
  please read pages 56 – 76 in text.