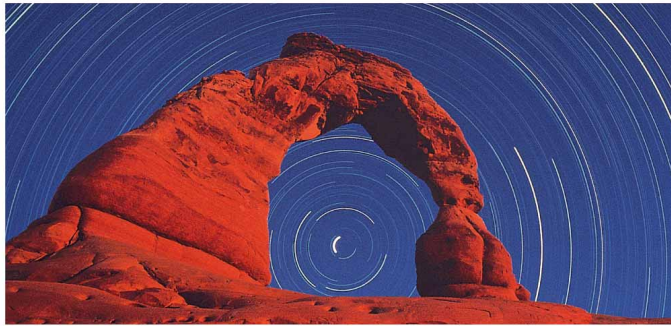


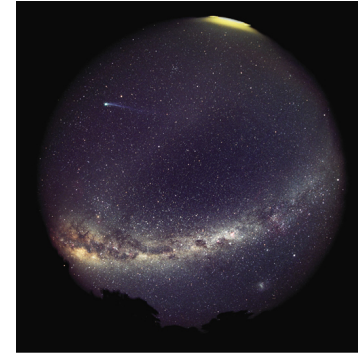
Chapter 2 Discovering the Universe for Yourself



© 2006 Pearson Education Inc, publishing as Addison-Wesley

What does the universe look like from Earth?

With the naked eye,
we can see more
than 2,000 stars as
well as the Milky
Way.

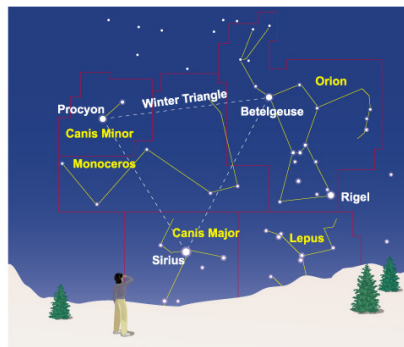


© 2006 Pearson Education Inc, publishing as Addison-Wesley

Constellations

A constellation is a
region of the sky.

88 constellations
fill the entire sky.



Copyright © Addison Wesley

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

The brightest stars in a constellation...

- A. All belong to the same star cluster.
- B. All lie at about the same distance from Earth.
- C. May actually be quite far away from each other.

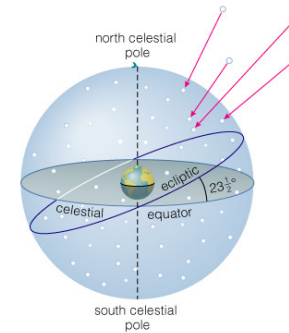
© 2006 Pearson Education Inc, publishing as Addison-Wesley

The brightest stars in a constellation...

- A. All belong to the same star cluster.
- B. All lie at about the same distance from Earth.
- C. May actually be quite far away from each other.**

© 2006 Pearson Education Inc, publishing as Addison-Wesley

The Celestial Sphere



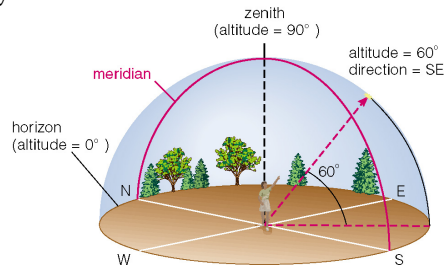
Stars at different distances all appear to lie on the celestial sphere.

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

© 2006 Pearson Education Inc, publishing as Addison-Wesley

The Local Sky

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



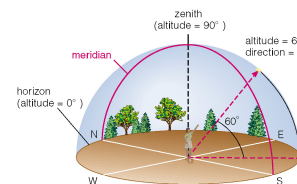
© 2006 Pearson Education Inc, publishing as Addison-Wesley

The Local Sky

Zenith: The point directly overhead

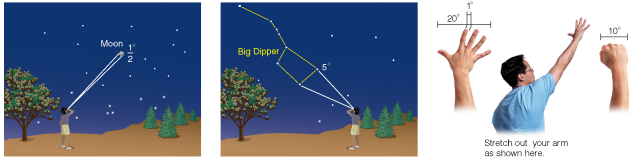
Horizon: All points 90° away from zenith

Meridian: Line passing through zenith and connecting N and S points on horizon



© 2006 Pearson Education Inc, publishing as Addison-Wesley

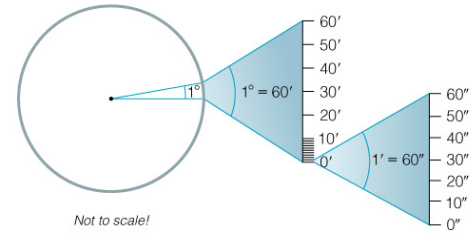
We measure the sky using *angles*



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Angular Measurements

- Full circle = 360°
- $1^\circ = 60'$ (arcminutes)
- $1' = 60''$ (arcseconds)



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

Both the Moon and the Sun are $1/2^\circ$ in “angular” size. How many arcseconds is this?

- A. 30"
- B. 60"
- C. 1800"
- D. 3600"

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

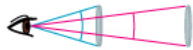
Both the Moon and the Sun are $1/2^\circ$ in “angular” size. How many arcseconds is this?

- A. 30"
- B. 60"
- C. **1800"**
- D. 3600"

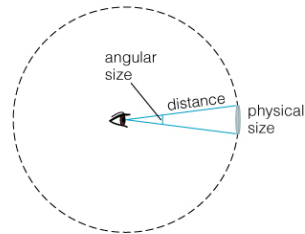
© 2006 Pearson Education Inc, publishing as Addison-Wesley

Angular Size

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

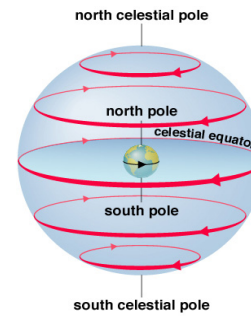


An object's angular size appears smaller if it is farther away



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Why do stars rise and set?



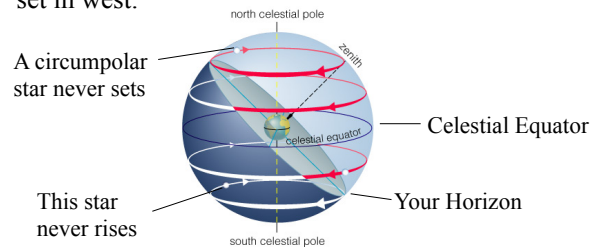
Earth rotates west to east, so stars appear to circle from east to west.

Copyright © Addison Wesley

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Our view from Earth:

- 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.



© 2006 Pearson Education Inc, publishing as Addison-Wesley

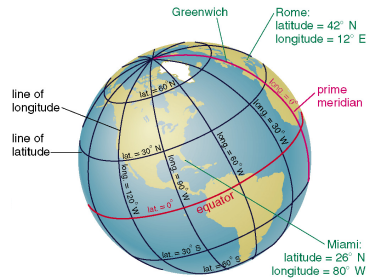
Why do the constellations we see depend on latitude and time of year?

- They depend on latitude because your position on Earth determines which constellations remain below the horizon.
- They depend on time of year because Earth's orbit changes the apparent location of the Sun among the stars.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Review: Coordinates on the Earth

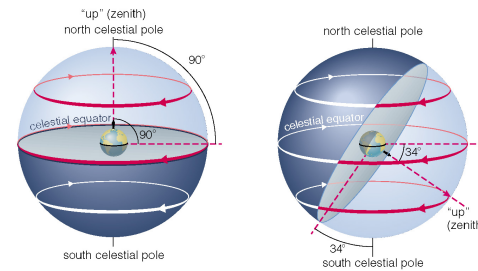
- **Latitude:** position north or south of equator
- **Longitude:** position east or west of prime meridian (runs through Greenwich, England)



Atlanta:
Longitude = 84° 24' W
Latitude = 33° 45' N

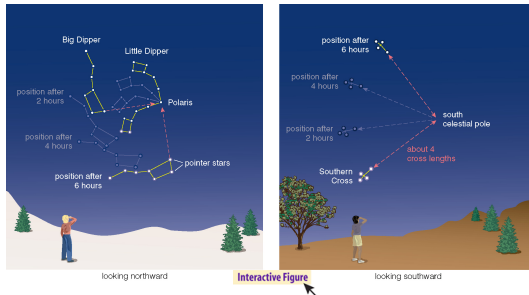
© 2006 Pearson Education Inc, publishing as Addison-Wesley

The sky varies with latitude but not longitude.



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Altitude of the celestial pole = your latitude



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

How far above the horizon is Polaris as seen from Atlanta?

- It is on the horizon.
- It is 33 degrees above the horizon.
- It is 57 degrees above the horizon.
- It is overhead.
- It varies between 33 and 57 degrees.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

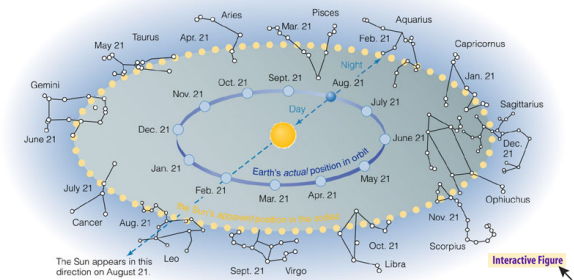
How far above the horizon is Polaris as seen from Atlanta?

- A. It is on the horizon.
- B. It is 33 degrees above the horizon.**
- C. It is 57 degrees above the horizon.
- D. It is overhead.
- E. It varies between 33 and 57 degrees.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

The sky varies as Earth orbits the Sun

- As the Earth orbits the Sun, the Sun appears to move **eastward** along the ecliptic.
- At midnight, the stars on our meridian are opposite the Sun in the sky.



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

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

© 2006 Pearson Education Inc, publishing as Addison-Wesley

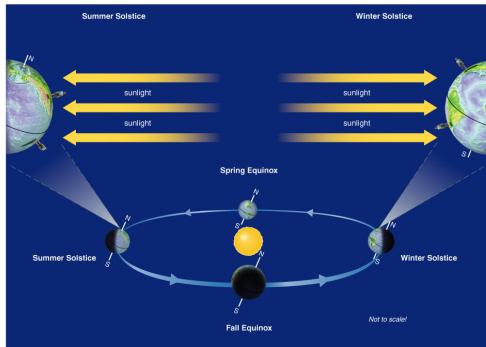
Thought Question

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 for the seasons.
- The real reason involves Earth's axis tilt.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

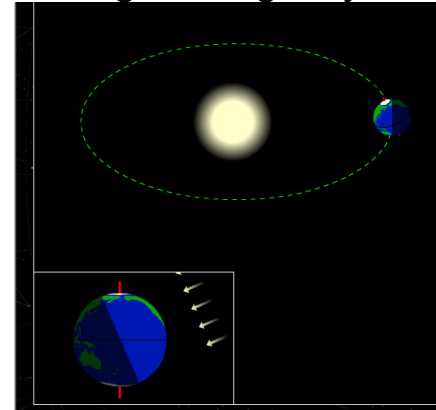
What causes the seasons?



Seasons depend on how Earth's axis affects the directness of sunlight

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Axis tilt changes directness of sunlight during the year.



© 2006 Pearson Education Inc, publishing as Addison-Wesley

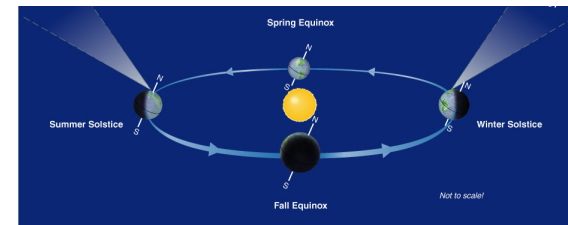
Summary: The Real Reason for Seasons

- Earth's axis points in the same direction (to Polaris) all 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.
- **AXIS TILT** is the key to the seasons; without it, we would not have seasons on Earth.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

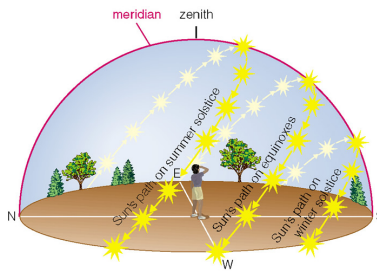
How do we mark the progression of the seasons?

- We define four special points:
 - summer solstice
 - winter solstice
 - spring (vernal) equinox
 - fall (autumnal) equinox



© 2006 Pearson Education Inc, publishing as Addison-Wesley

We can recognize solstices and equinoxes by Sun's path across sky:



Summer solstice: Highest path, rise and set at most extreme north of due east.

Winter solstice: Lowest path, rise and set at most extreme south of due east.

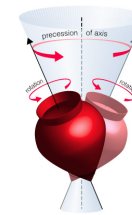
Equinoxes: Sun rises precisely due east and sets precisely due west.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

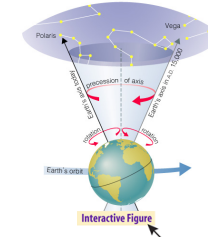
How does the orientation of Earth's axis change with time?

• Although the axis seems fixed on human time scales, it actually precesses over about 26,000 years.

- Polaris won't always be the North Star.
- Positions of equinoxes shift around orbit; e.g., spring equinox, once in *Aries*, is now in *Pisces*!



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



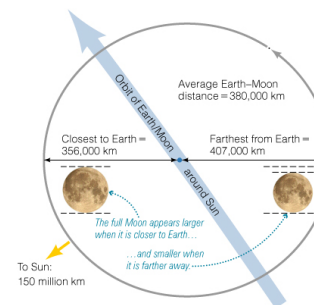
© 2006 Pearson Education Inc, publishing as Addison-Wesley

The 3 major motions of the Earth are therefore:

1. **Rotation** of the Earth on its axis.
2. **Revolution** of the Earth in its orbit around the Sun.
3. **Precession** of the Earth around an axis perpendicular to its orbit

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Why do we see phases of the Moon?

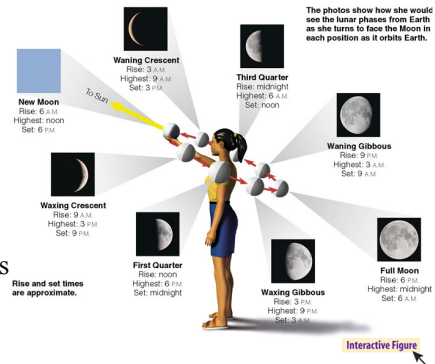


- Lunar phases are a consequence of the Moon's 27.3-day orbit around Earth
- The Moon moves **eastward** (counterclockwise as seen from above the North Pole) relative to the stars.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

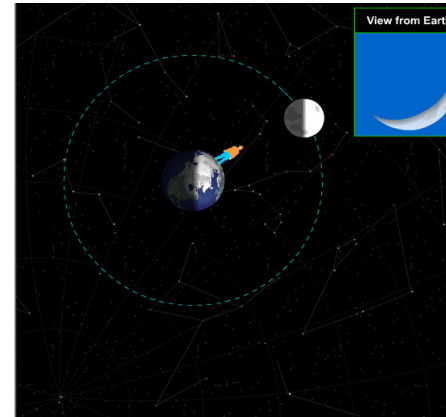
Phases of Moon

- Half of Moon is illuminated by Sun and half is dark
- We see a changing combination of the bright and dark faces as Moon orbits



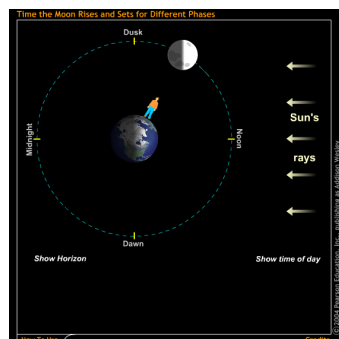
© 2006 Pearson Education Inc, publishing as Addison-Wesley

Phases of the Moon



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Moon Rise/Set by Phase



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

What time of day does the first quarter moon rise?

- Sunrise
- Noon
- Sunset
- Midnight

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

What time of day does the first quarter moon rise?

- A. Sunrise
- B. Noon**
- C. Sunset
- D. Midnight

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

At the time that we see a New Moon on the Earth, what would an astronaut on the Moon see?

- A. New Earth
- B. Full Earth
- C. First quarter Earth
- D. Crescent Earth
- E. Gibbous Earth

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

At the time that we see a New Moon on the Earth, what would an astronaut on the Moon see?

- A. New Earth
- B. Full Earth**
- C. First quarter Earth
- D. Crescent Earth
- E. Gibbous Earth

© 2006 Pearson Education Inc, publishing as Addison-Wesley

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

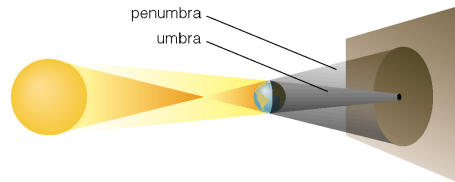
So, is the dark side of the Moon also the far side?

No, each side of the Moon goes through equal periods of day and night.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

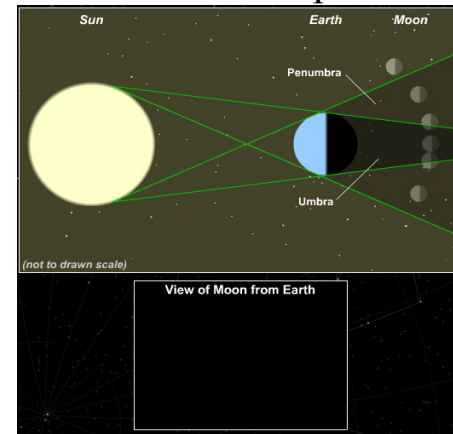
What causes eclipses?

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



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Lunar Eclipse



© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

What is the Moon's phase just before a lunar eclipse?

- A. new
- B. first quarter
- C. full
- D. third quarter
- E. It can be any phase.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Thought Question

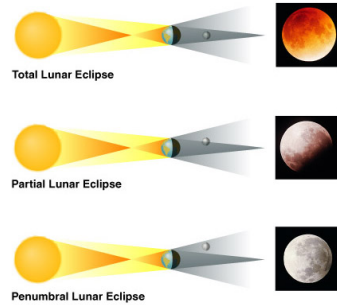
What is the Moon's phase just before a lunar eclipse?

- A. new
- B. first quarter
- C. **full**
- D. third quarter
- E. It can be any phase.

© 2006 Pearson Education Inc, publishing as Addison-Wesley

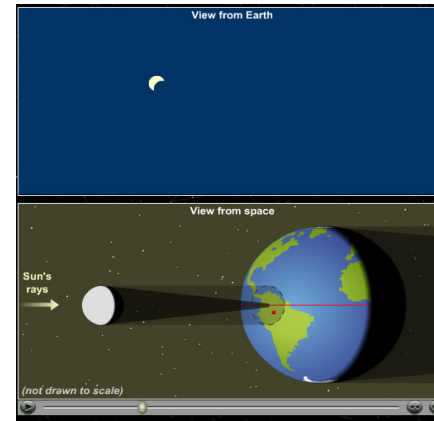
When can eclipses occur?

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



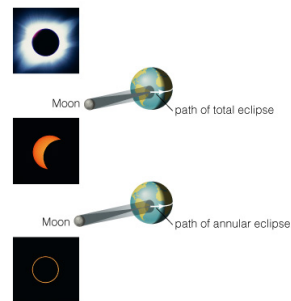
© 2006 Pearson Education Inc, publishing as Addison-Wesley

Solar Eclipse



When can eclipses occur?

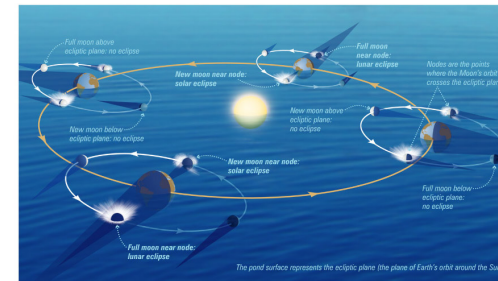
- **Solar eclipses** can occur only at *new moon*.
- Solar eclipses can be **partial, total, or annular**.



© 2006 Pearson Education Inc, publishing as Addison-Wesley

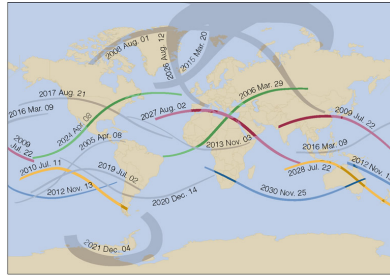
Why don't we have an eclipse at every new and full moon?

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



Predicting Eclipses

- Solar eclipse type (e.g., partial, total) and location vary.



© 2005 Pearson Education, Inc., publishing as Addison-Wesley

© 2006 Pearson Education Inc., publishing as Addison-Wesley

Total Solar Eclipse of 1999 August 11



©1999 by F. Espenak

© 2006 Pearson Education Inc., publishing as Addison-Wesley



Copyright 2001 Fred Espenak

© 2006 Pearson Education Inc., publishing as Addison-Wesley

Planets Known in Ancient Times

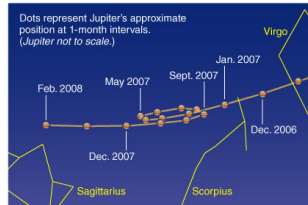
- **Mercury**
 - difficult to see; always close to Sun in sky
- **Venus**
 - very bright when visible; morning or evening “star”
- **Mars**
 - noticeably red
- **Jupiter**
 - very bright
- **Saturn**
 - moderately bright



© 2006 Pearson Education Inc., publishing as Addison-Wesley

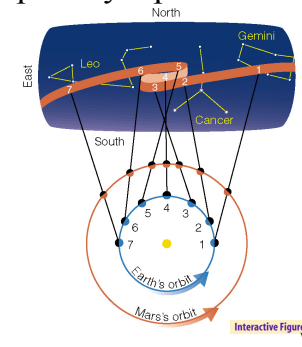
What was once so mysterious about planetary motion in our sky?

- 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**



© 2006 Pearson Education Inc, publishing as Addison-Wesley

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



Interactive Figure

© 2006 Pearson Education Inc, publishing as Addison-Wesley

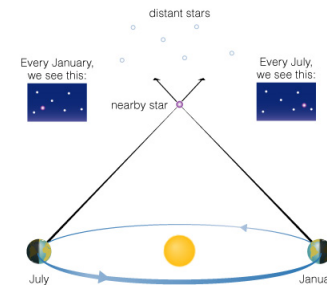
Explaining Apparent Retrograde Motion

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

© 2006 Pearson Education Inc, publishing as Addison-Wesley

Why did the ancient Greeks reject the heliocentric explanation for planetary motion?

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



© 2006 Pearson Education Inc, publishing as Addison-Wesley

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 Sun; it is the center of the universe

Most Greeks rejected the correct explanation (1) because they did not think the stars could be *that* far away