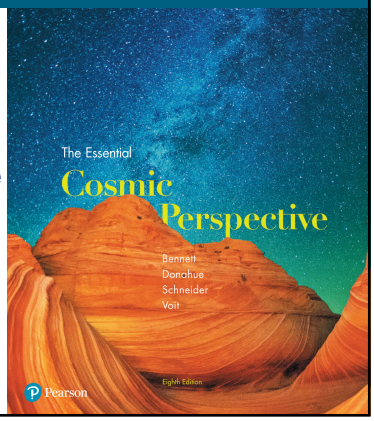
Lecture Outline

Chapter 2: Discovering the Universe for Yourself



1

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?

2

What does the universe look like from Earth?

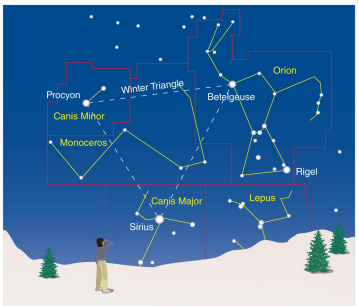
With the naked eye, we can see more than 2000 stars as well as the Milky Way.

3

Constellations

A constellation is a *region* of the sky.

Eighty-eight constellations fill the entire sky.



4

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.

5

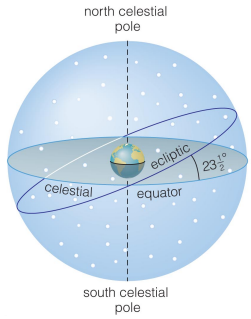
Thought Question

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.

6

The Celestial Sphere

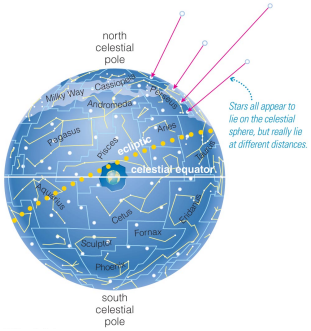


Stars at different distances all appear to lie on the celestial sphere.

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

7

The Celestial Sphere



The 88 official constellations cover the celestial sphere.

8

The Milky Way

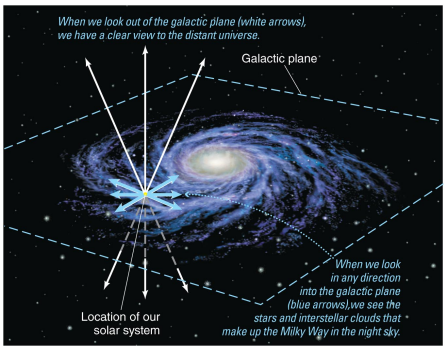
A band of light that makes a circle around the celestial sphere

What is it?

Our view into the plane of our galaxy

9

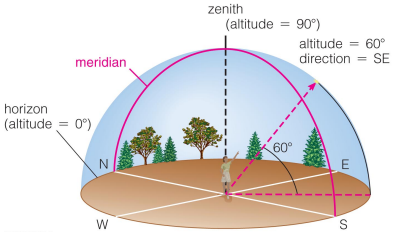
The Milky Way



10

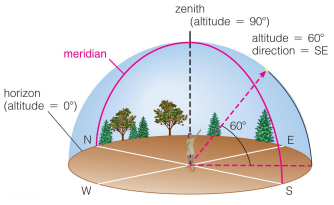
The Local Sky

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



11

The Local Sky



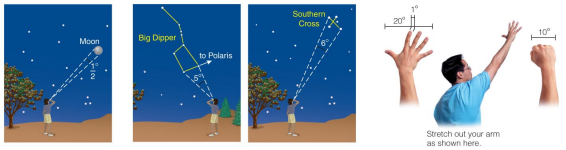
Zenith: The point directly overhead

Horizon: All points 90° away from zenith

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

12

We measure the sky using *angles*.



a The angular sizes of the Sun and the Moon are about ½°.

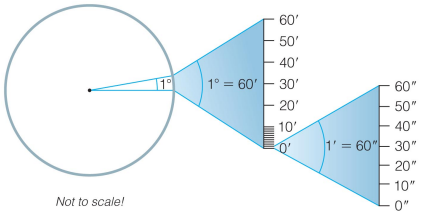
b The angular distance between the "pointer stars" of the Big Dipper is about 5°, and the angular length of the Southern Cross is about 6°.

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

13

Angular Measurements

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



14

Thought Question

The angular size of your finger at arm's length is about 1°. How many arcseconds is this?

A. 60 arcseconds
B. 600 arcseconds
C. 60 x 60 = 3600 arcseconds

15

Thought Question

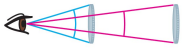
The angular size of your finger at arm's length is about 1°. How many arcseconds is this?

A. 60 arcseconds
B. 600 arcseconds
C. 60 x 60 = 3600 arcseconds

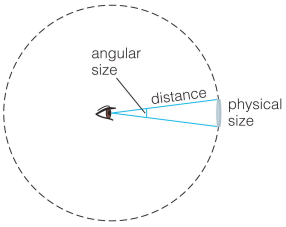
16

Angular Size

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

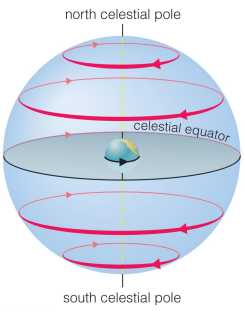


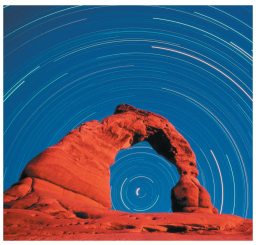
An object's angular size appears smaller if it is farther away.



17

Why do stars rise and set?



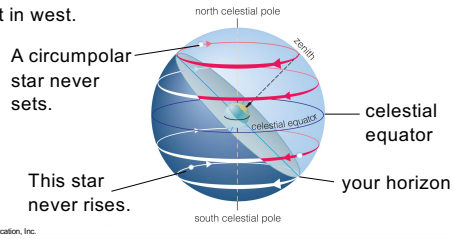


Earth rotates west to east, so stars appear to circle from east to west.

18

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.

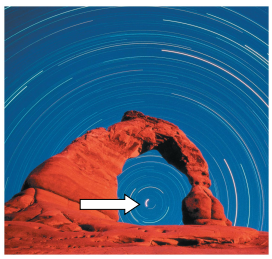


19

Thought Question

What is the arrow pointing to?

A. the zenith
B. the north celestial pole
C. the celestial equator

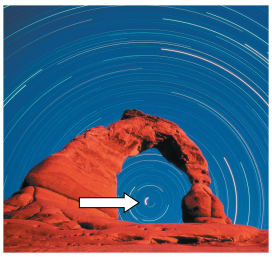


20

Thought Question

What is the arrow pointing to?

A. the zenith
B. the north celestial pole
C. the celestial equator



21

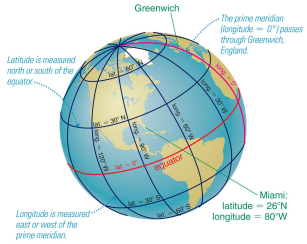
Why do the constellations we see depend on latitude and time of year?

- 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.

22

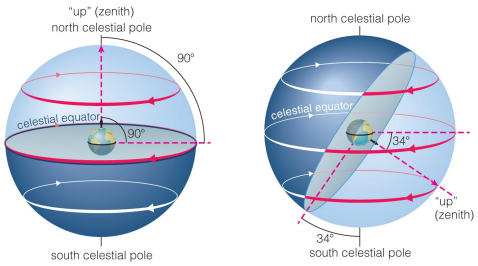
Review: Coordinates on the Earth

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



23

The sky varies with latitude but not longitude.

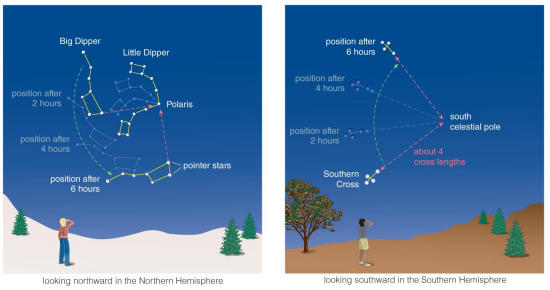


a The local sky at the North Pole (latitude 90°N).

b The local sky at latitude 34°S.

24

Altitude of the celestial pole = your latitude



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.

MA INTERACTIVE FIGURE

25

Thought Question

The North Star (Polaris) is 50° above your horizon, due north. Where are you?

A. You are on the equator.
B. You are at the North Pole.
C. You are at latitude 50°N.
D. You are at longitude 50°E.
E. You are at latitude 50°N and longitude 50°E.

26

Thought Question

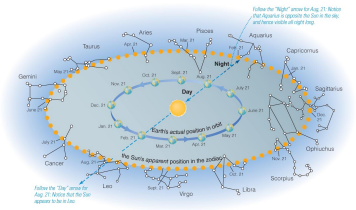
The North Star (Polaris) is 50° above your horizon, due north. Where are you?

A. You are on the equator.
B. You are at the North Pole.
C. You are at latitude 50°N.
D. You are at longitude 50°E.
E. You are at latitude 50°N and longitude 50°E.

27

The sky varies as Earth orbits the Sun

- As 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.



28

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?

29

Thought Question

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

30

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 United States, it is winter in Australia.)

31

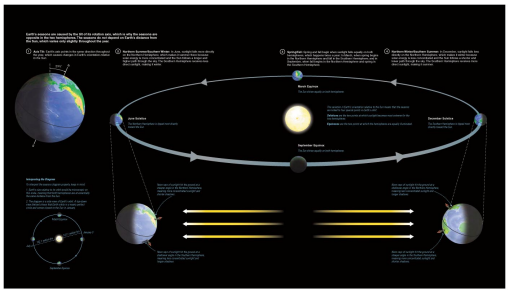
Thought Question

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 real reason for seasons involves Earth's axis tilt.

32

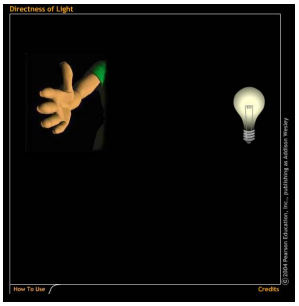
What causes the seasons?



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

33

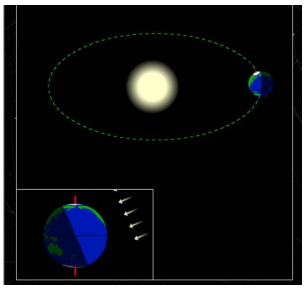
Direct light causes more heating.



PLAY Directness of Light

34

Axis tilt changes directness of sunlight during the year.



PLAY Why Does the Flux of Sunlight Vary?

35

Sun's altitude also changes with seasons.

Sun's position at a certain time in the morning in summer: higher altitude means more direct sunlight.

Sun's position at the same time in winter: lower altitude means less direct sunlight.

36

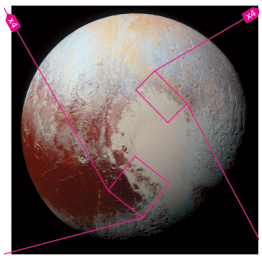
Summary: The Real Reason for Seasons

- 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.

37

Why doesn't distance matter?

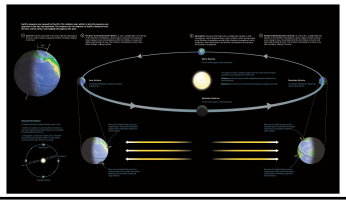
- Variation of Earth–Sun distance is small—about 3%; this small variation is overwhelmed by the effects of axis tilt!
- For objects with greater variation in their Earth–Sun distance, it can play a large role in seasons – Mars and Pluto are examples.



38

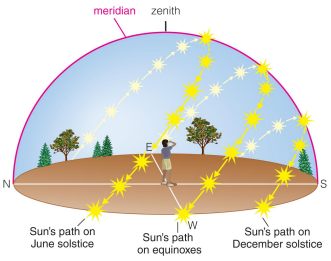
How do we mark the progression of the seasons?

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



39

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



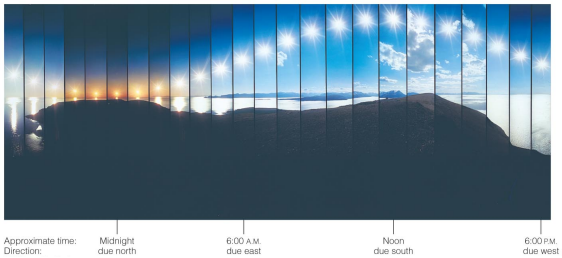
Summer solstice: Highest path, rise and set at most extreme north of due east

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.

40

Seasonal changes are more extreme at high latitudes.

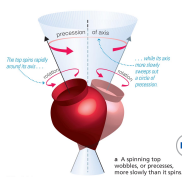


Path of the Sun on the summer solstice at the Arctic Circle

41

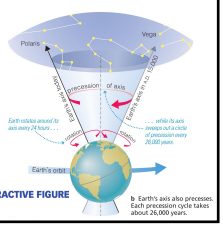
How does the orientation of Earth's axis change with time?

- 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; for example, the spring equinox, once in *Aries*, is now in *Pisces*!



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

MA INTERACTIVE FIGURE



MA INTERACTIVE FIGURE

42

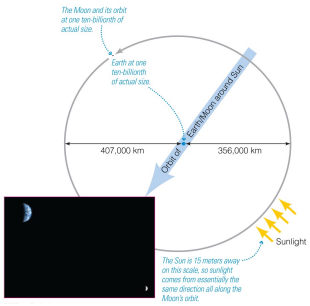
2.3 The Moon, Our Constant Companion

Our goals for learning:

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

43

Why do we see phases of the Moon?

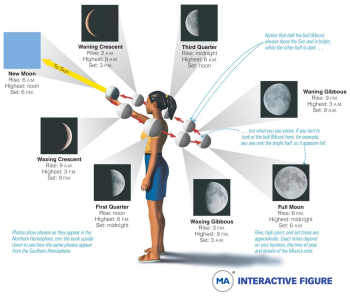


- Lunar phases are a consequence of the Moon's 27.3-day orbit around Earth.

44

Phases of the Moon

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



INTERACTIVE FIGURE

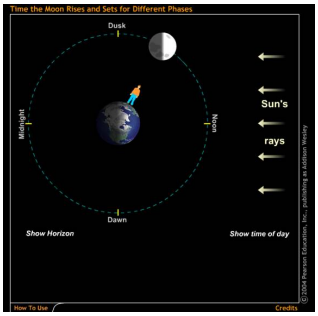
45

Phases of the Moon

PLAY Phases of the Moon

46

Moon Rise/Set by Phase



PLAY Time the Moon Rises and Sets for Different Phases

47

Phases of the Moon: 29.5-day cycle

- new
- crescent
- first quarter
- gibbous

waxing
- Moon visible in afternoon/evening
- Gets "fuller" and rises later each day

- full
- gibbous
- last quarter
- crescent

waning
- Moon visible in late night/morning
- Gets "less" and sets later each day

48

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

49

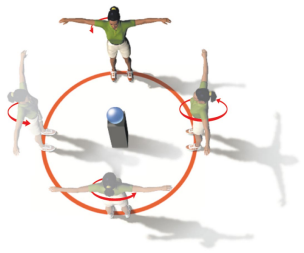
Thought Question

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

50

We see only one side of the Moon.



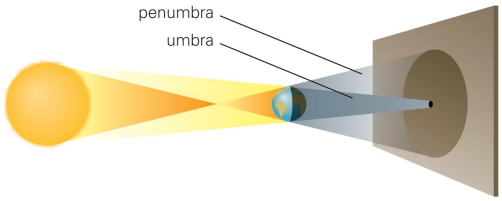
b You will face the model at all times only if you rotate exactly once during each orbit.

- Synchronous rotation: The Moon rotates exactly once with each orbit.
- This is why only one side is visible from Earth.

51

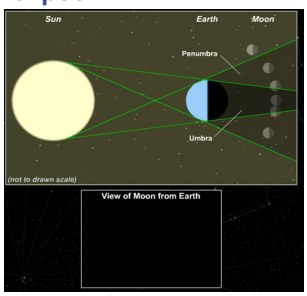
What causes eclipses?

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



52

Lunar Eclipse

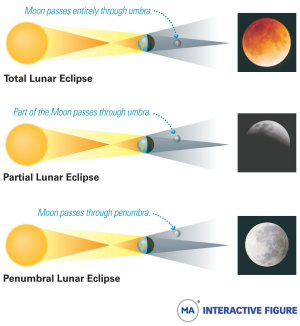


PLAY Lunar Eclipse

53

When Lunar can eclipses occur?

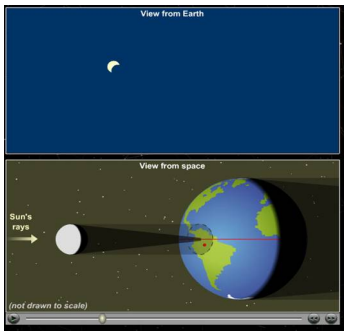
- **Lunar eclipses** can occur only at *full moon*.
- Lunar eclipses can be **penumbral**, **partial**, or **total**.



MA INTERACTIVE FIGURE

54

Solar Eclipse



PLAY Evolution of a Total Solar Eclipse

55

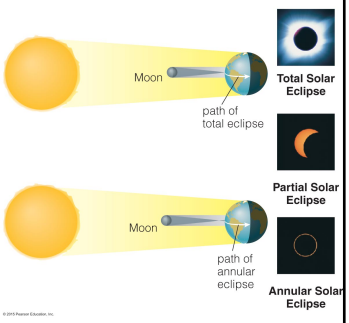
Total Solar Eclipse

Here we see a multiple-exposure image of a total solar eclipse in Zambia

56

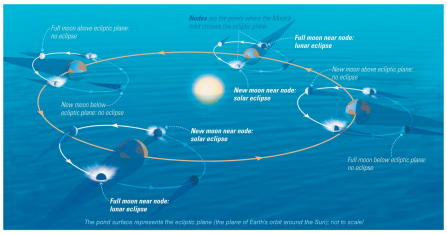
When can Solar eclipses occur?

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



57

- 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.



58

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).

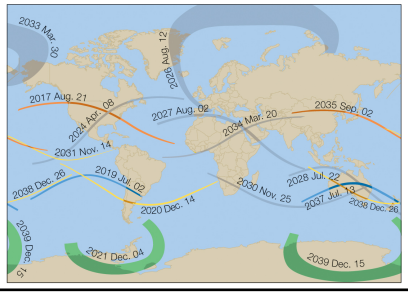
   AND

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

59

Predicting Eclipses

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



60

2.4 The Ancient Mystery of the Planets

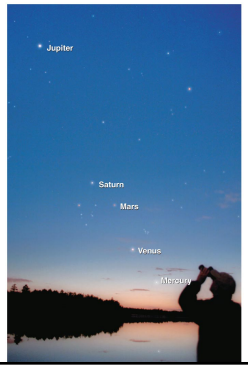
Our goals for learning:

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

61

Planets Known in Ancient Times

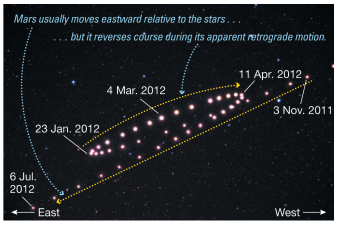
- Mercury (bottom)
  - Difficult to see; always close to Sun in sky
- Venus (above Mercury)
  - Very bright when visible; morning or evening "star"
- Mars (middle)
  - Noticeably red
- Jupiter (top)
  - Very bright
- Saturn (above Mars)
  - Moderately bright



62

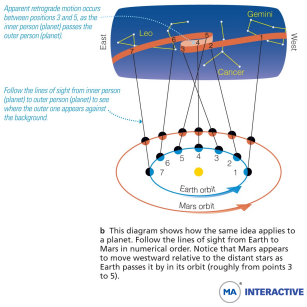
Why was planetary motion so hard to explain?

- 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.**



63

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



b This diagram shows how the same idea applies 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 as Earth passes it by in its orbit (roughly from points 3 to 5).

MA INTERACTIVE FIGURE

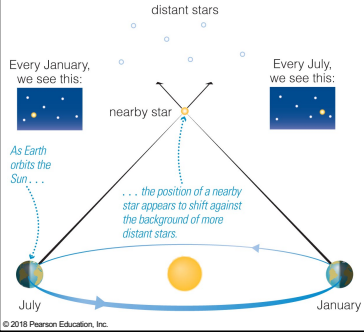
64

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.*

65

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



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

66

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.

67