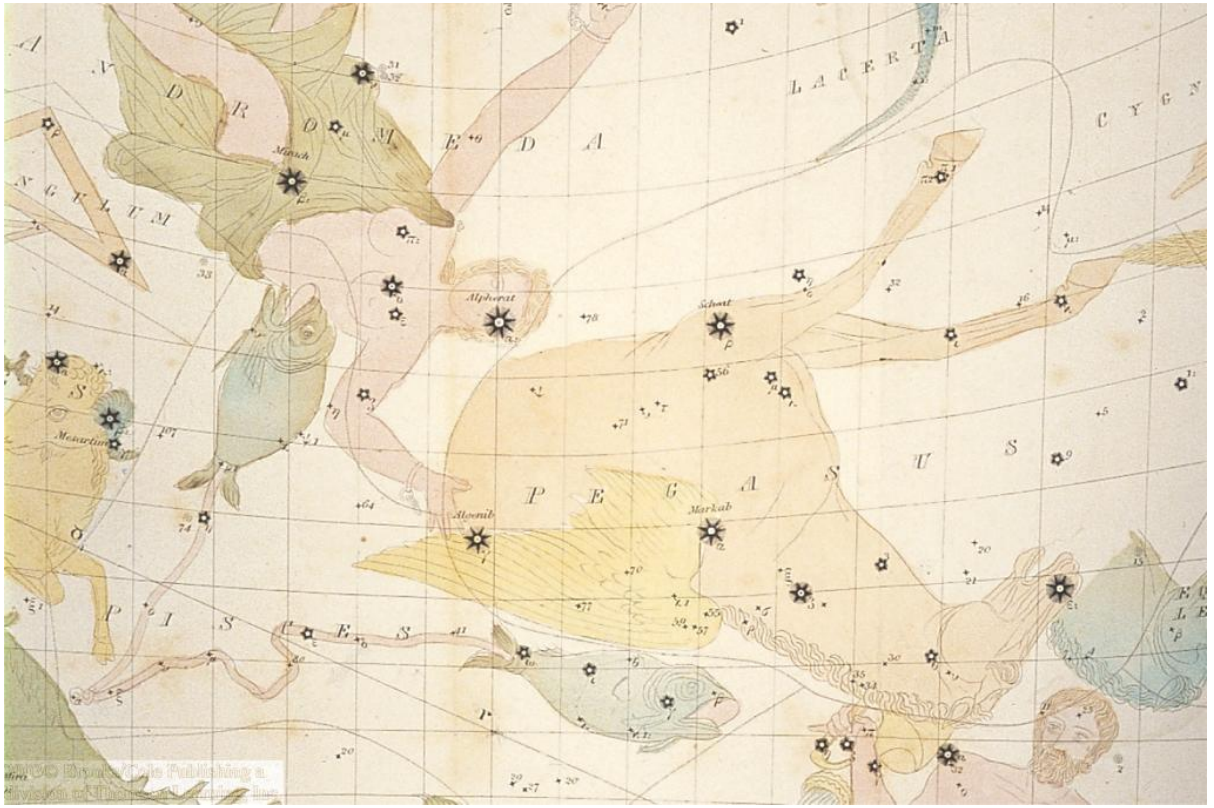
Chapter 2
The Sky

Constellations

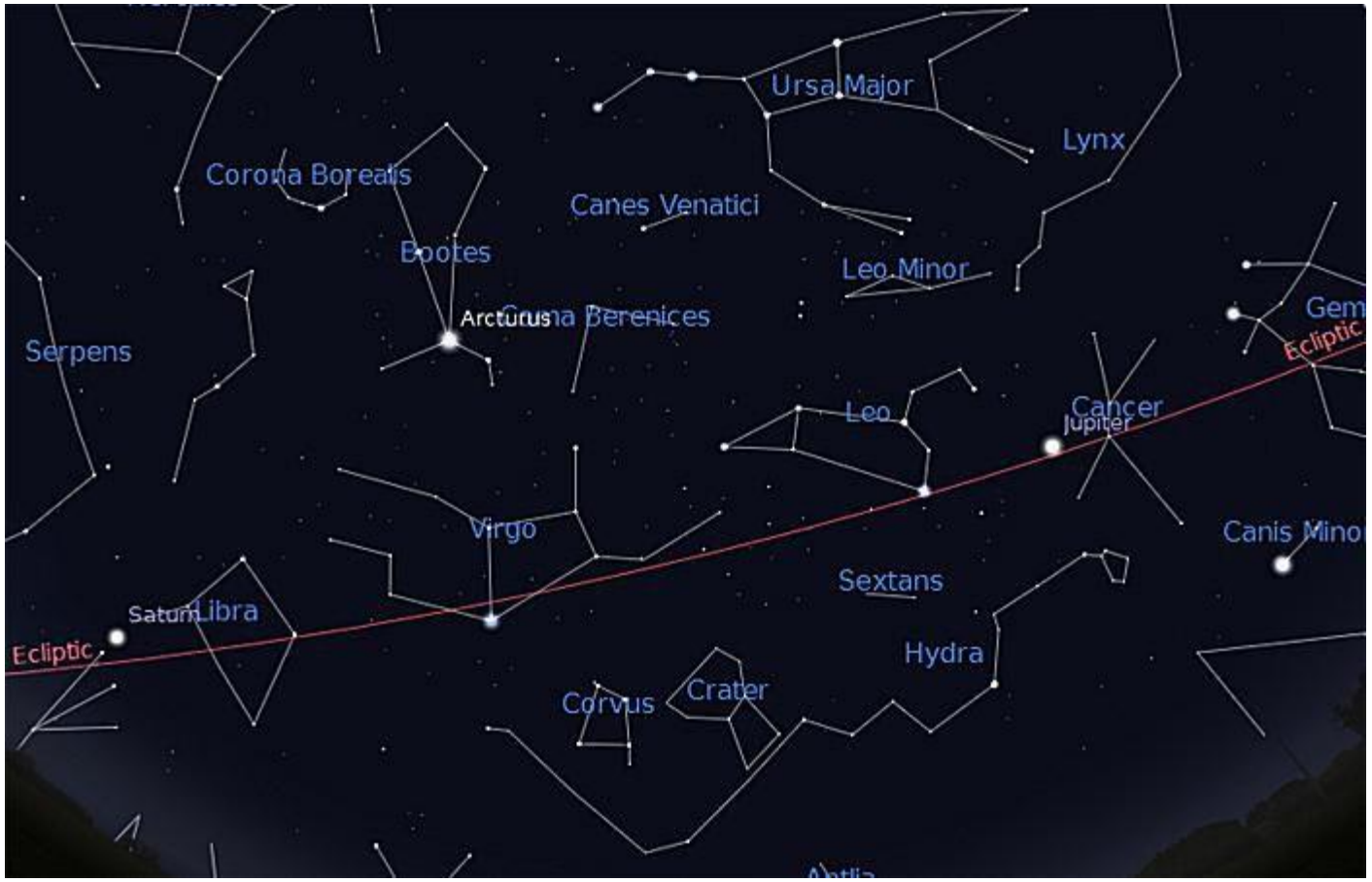


In ancient times, constellations only referred to the brightest stars that appeared to form groups, representing mythological figures.

Constellations

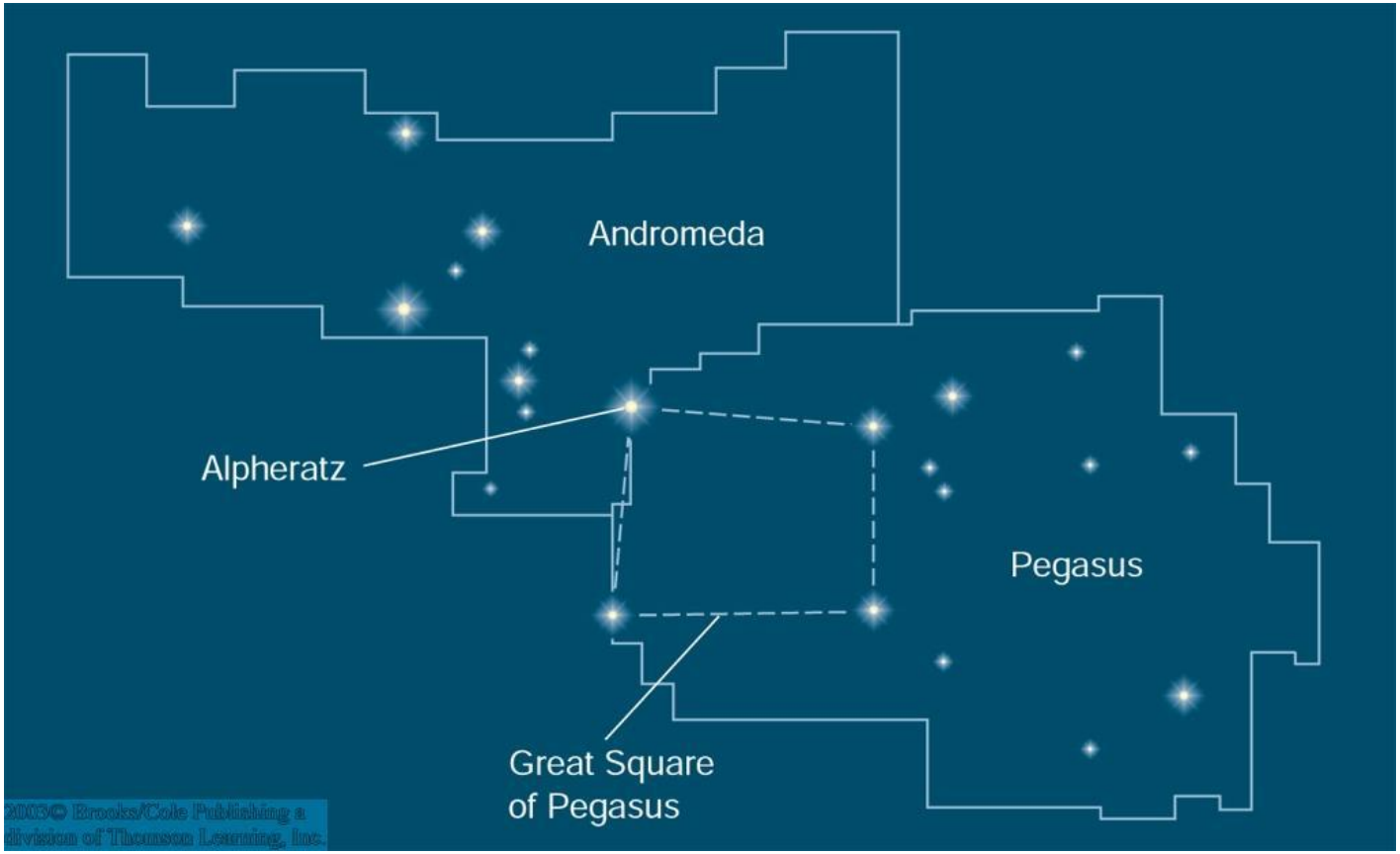
- A constellation is region of the sky
- 88 Constellations fill the entire sky

Ecliptic Constellations



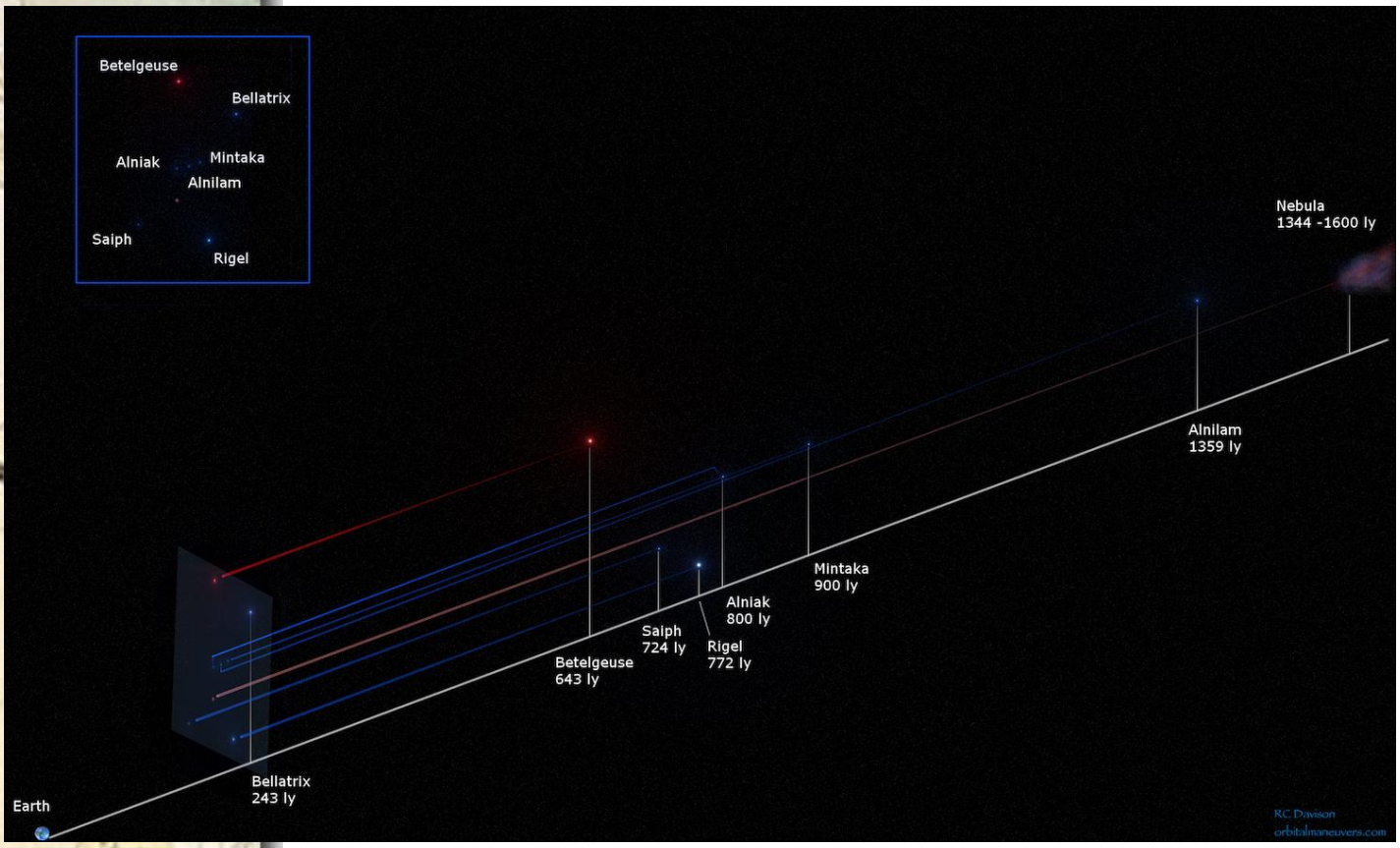
Of the 88 constellations 12 are based on the ecliptic.

Constellations (2)



Today, constellations are well-defined regions on the sky, irrespective of the presence or absence of bright stars in those regions.

Constellations (3)



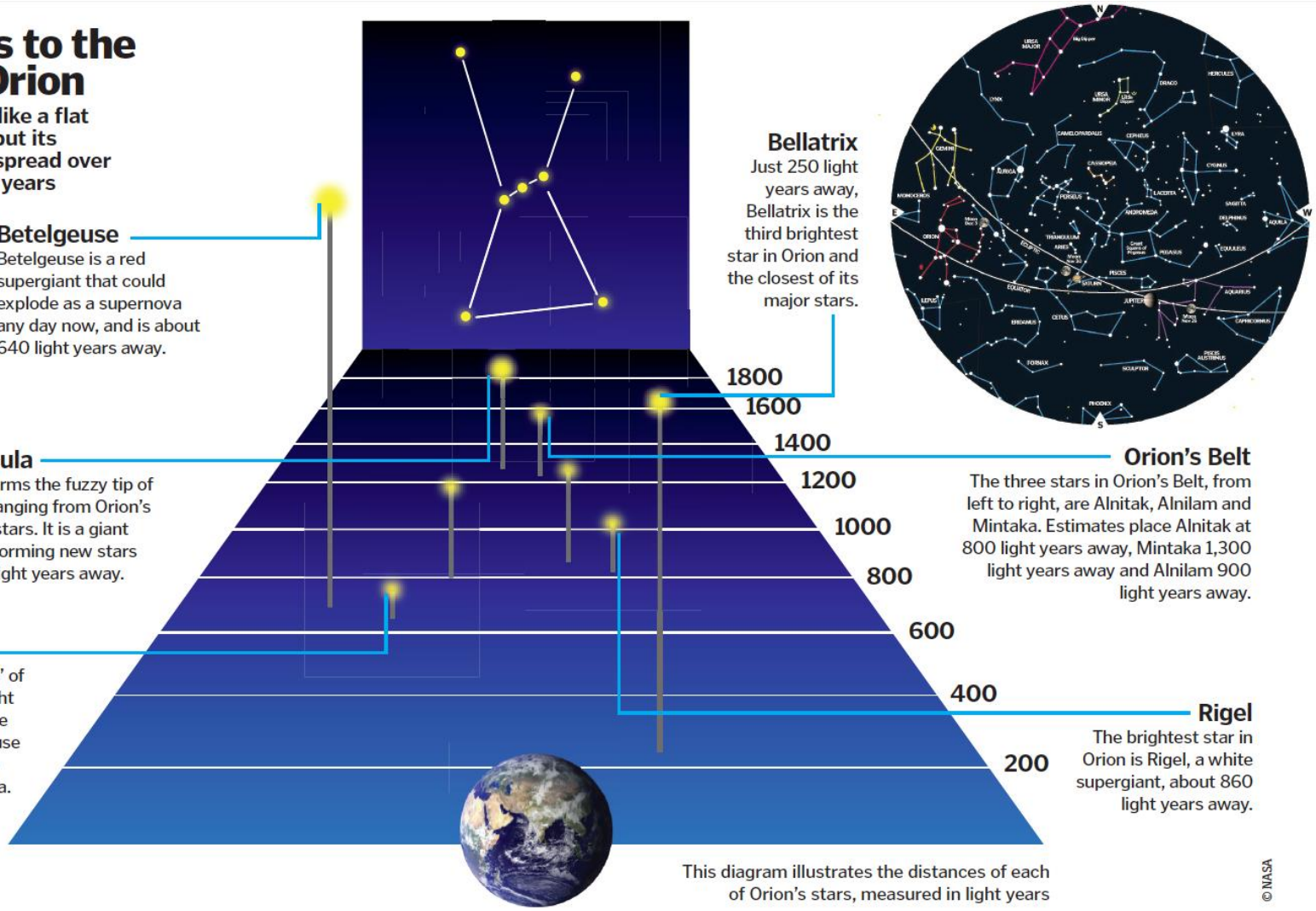
The stars of a constellation only appear to be close to one another

Usually, this is only a *projection effect*.

The stars of a constellation may be located at very different distances from us.

Distances to the stars of Orion

Orion might look like a flat blanket of stars, but its components are spread over hundreds of light years



Betelgeuse
Betelgeuse is a red supergiant that could explode as a supernova any day now, and is about 640 light years away.

Bellatrix
Just 250 light years away, Bellatrix is the third brightest star in Orion and the closest of its major stars.

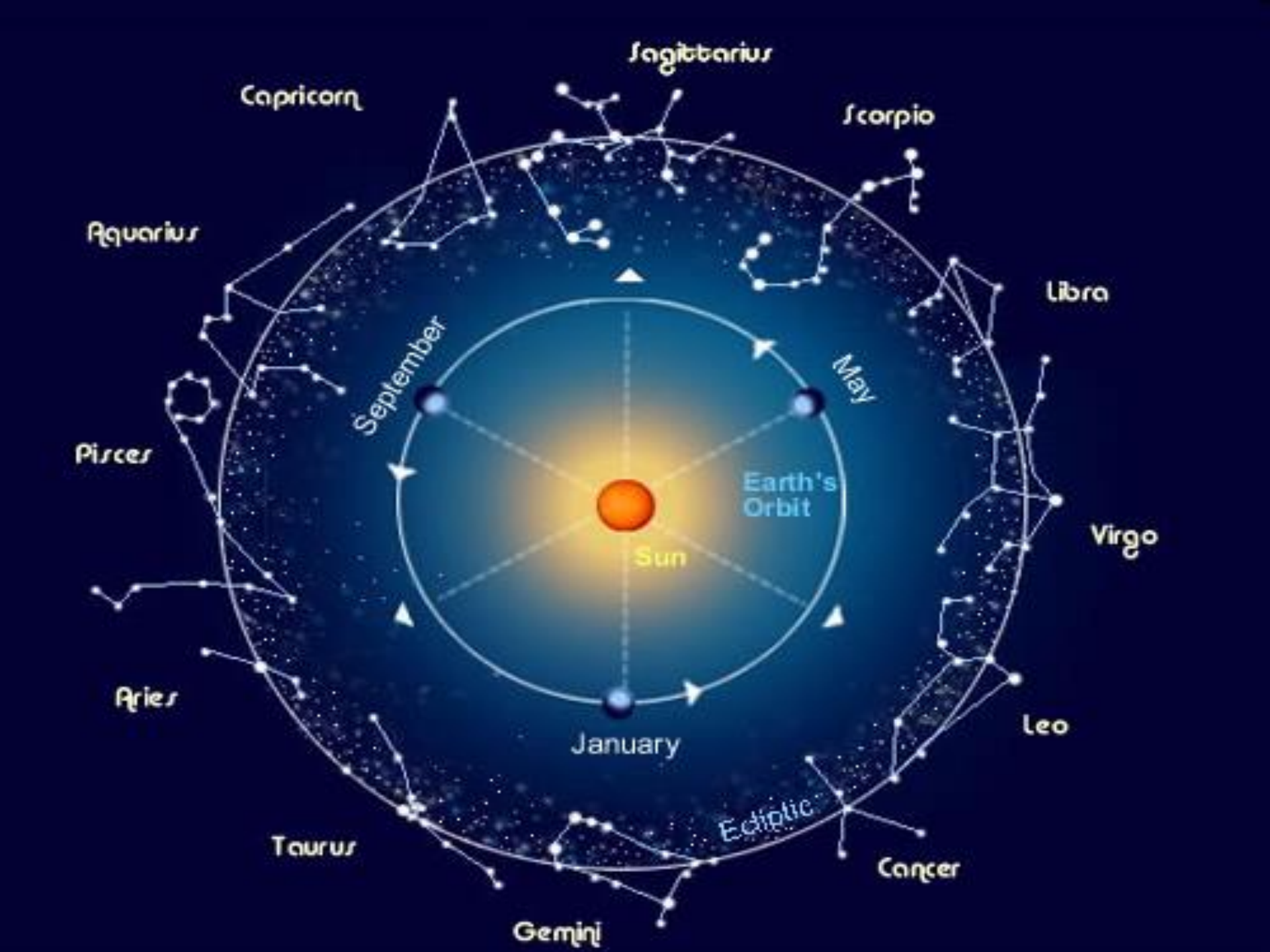
Orion nebula
The nebula forms the fuzzy tip of the 'sword' hanging from Orion's belt of three stars. It is a giant cloud of gas forming new stars and is 1,344 light years away.

Orion's Belt
The three stars in Orion's Belt, from left to right, are Alnitak, Alnilam and Mintaka. Estimates place Alnitak at 800 light years away, Mintaka 1,300 light years away and Alnilam 900 light years away.

Saiph
At the lower-left 'knee' of Orion, Saiph is 650 light years away. It is a large star that, like Betelgeuse and Rigel, will one day blow up in a supernova.

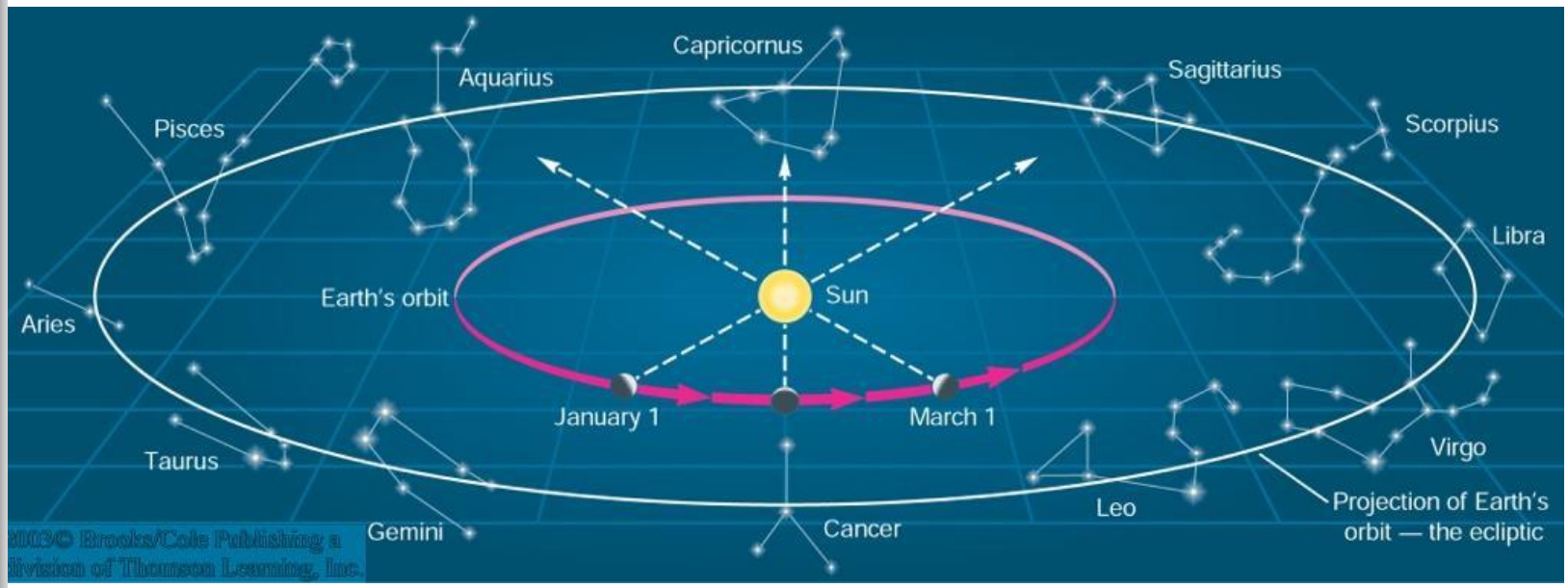
Rigel
The brightest star in Orion is Rigel, a white supergiant, about 860 light years away.

This diagram illustrates the distances of each of Orion's stars, measured in light years


Sagittarius
Capricorn
Scorpio
Aquarius
Libra
September
May
Pisces
Earth's
Orbit
Virgo
Sun
Aries
January
Leo
Ecliptic
Taurus
Cancer
Gemini

The Sun and Its Motions (2)

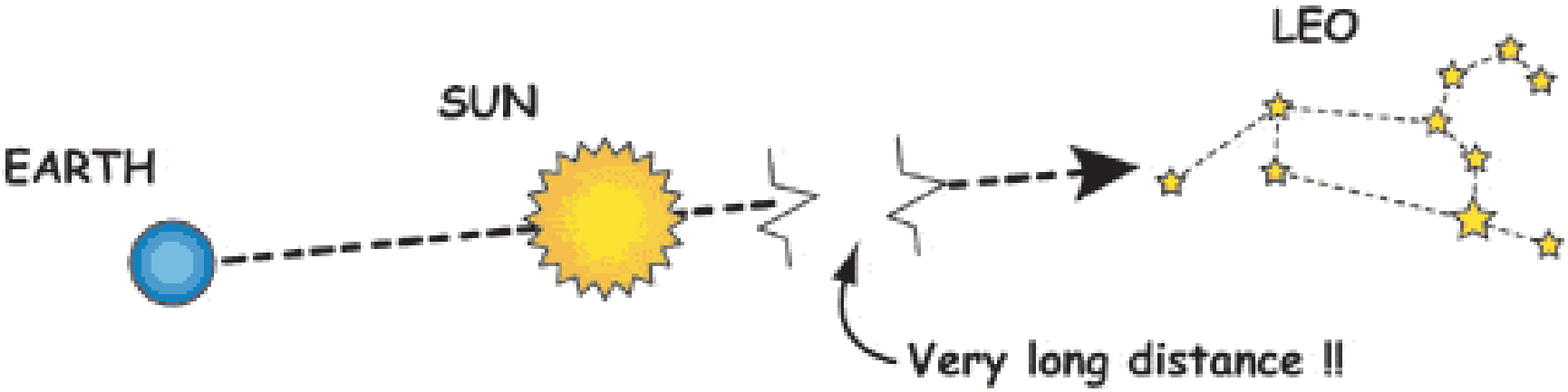
Due to Earth's revolution around the sun, the sun appears to move through the zodiacal constellations.



The Sun's apparent path on the sky is called the **Ecliptic**.

Equivalent: The Ecliptic is the projection of Earth's orbit onto the celestial sphere.

Born under the sign of…



Constellations

- Star Names are most commonly in Arabic
- As Astronomical research was featured heavily in that era.

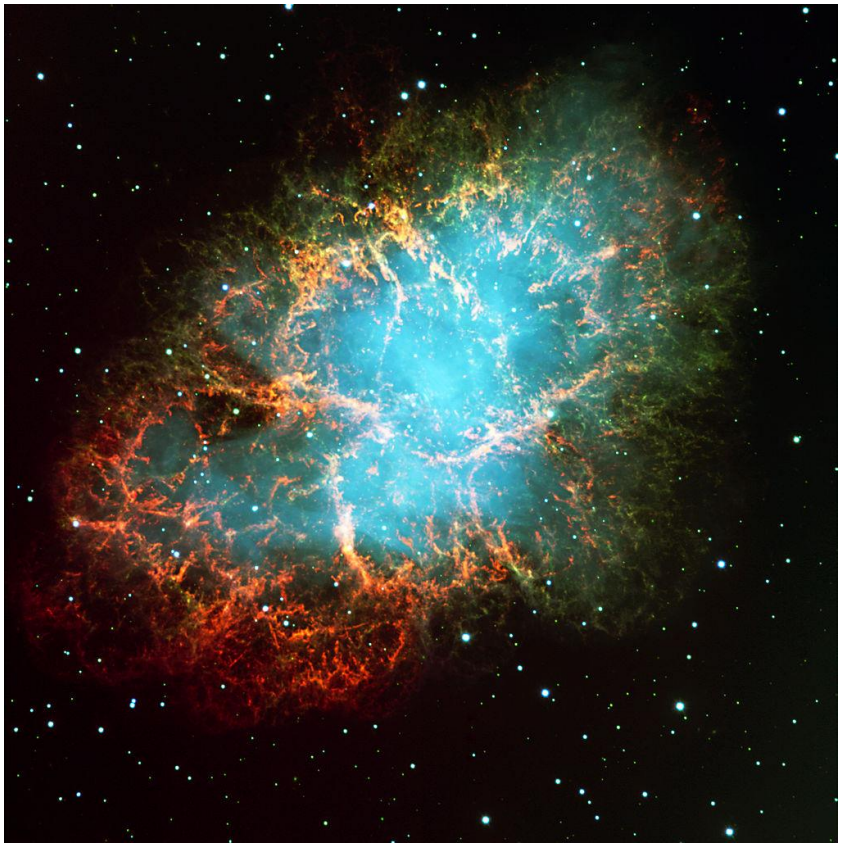
- Aldebaran (bull’s eye)
- Altair (flying eagle)
- Aludra (maiden)
- Alwaid (dragons eye)

Messier Objects

- Charles Messier

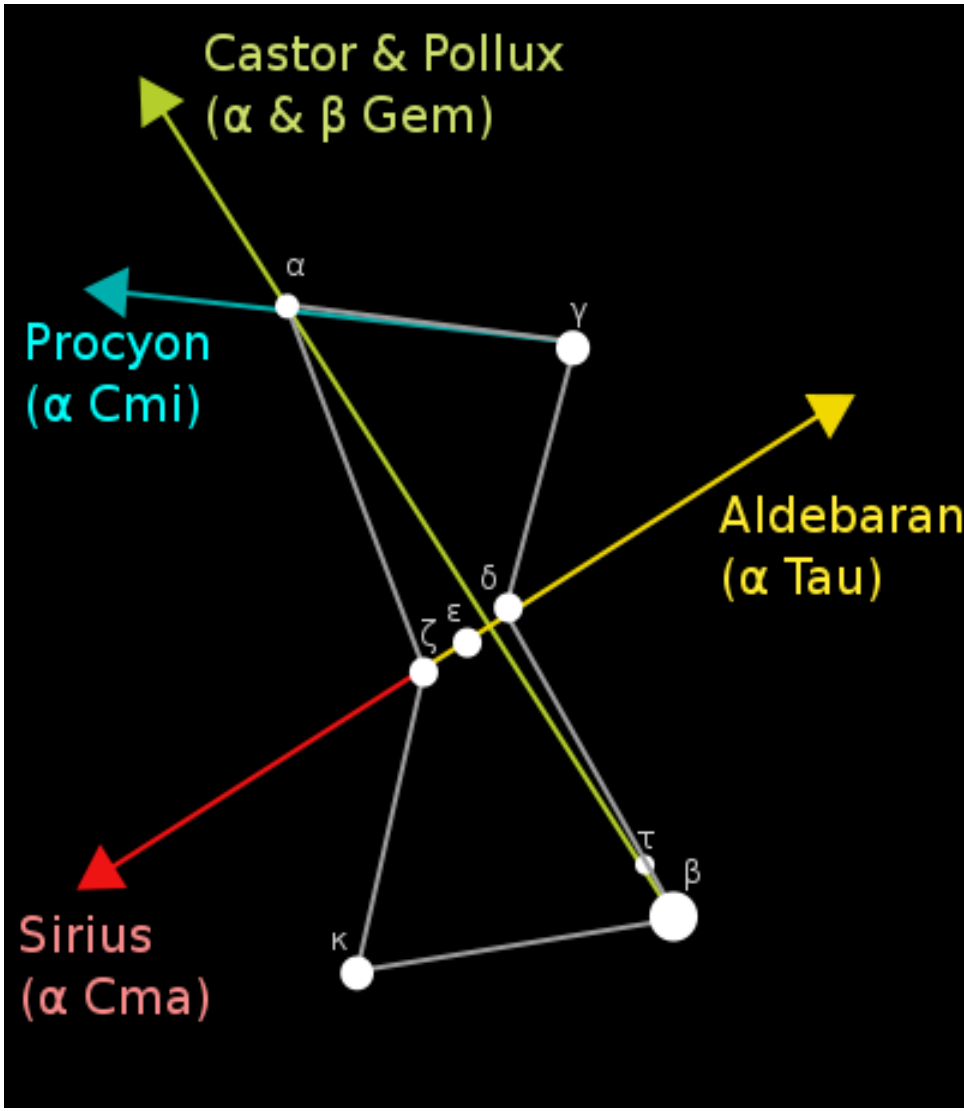
compiled a catalog of objects seen in heavens that were not stars.

Galaxies, Nebulae, Globular and Open Clusters

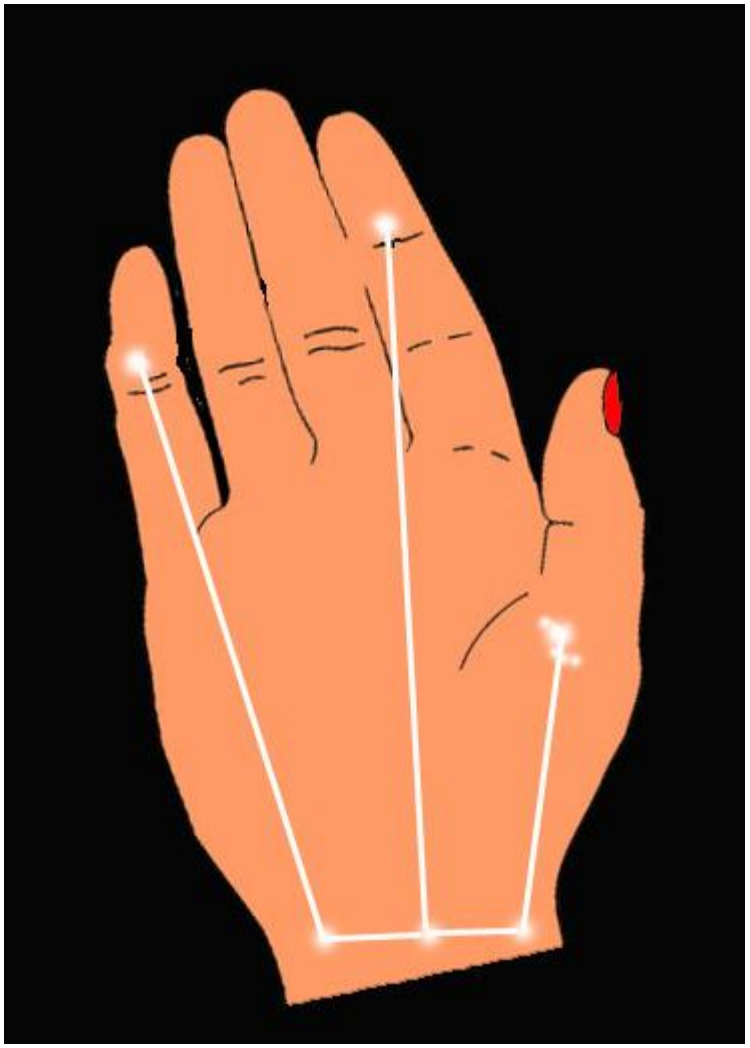


- M1: Crab Neubula
- 1st named by Messier

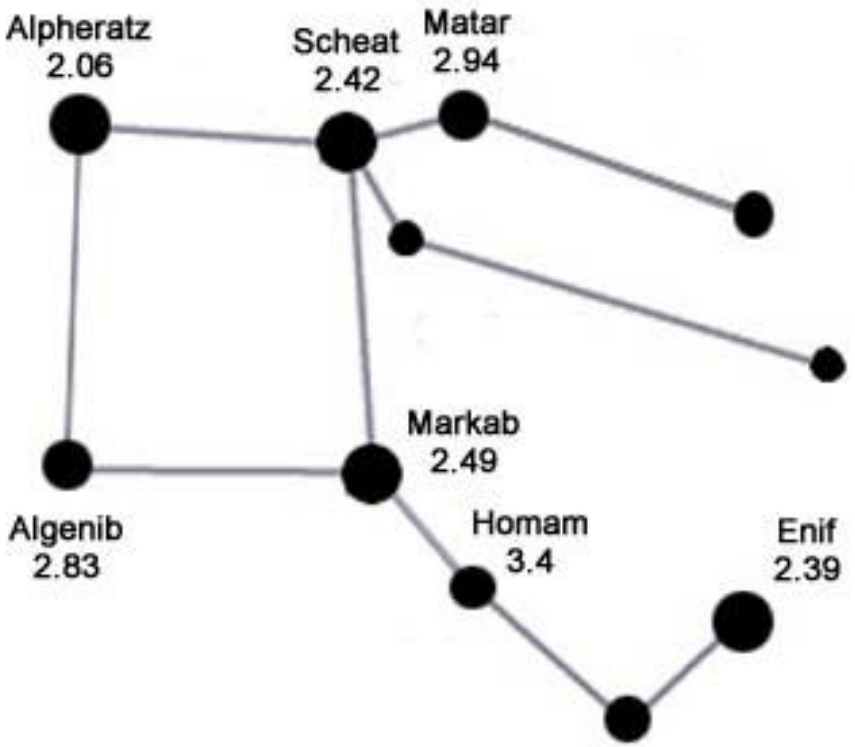
Orion the Hunter



Lakota: The Hand



Front of Card

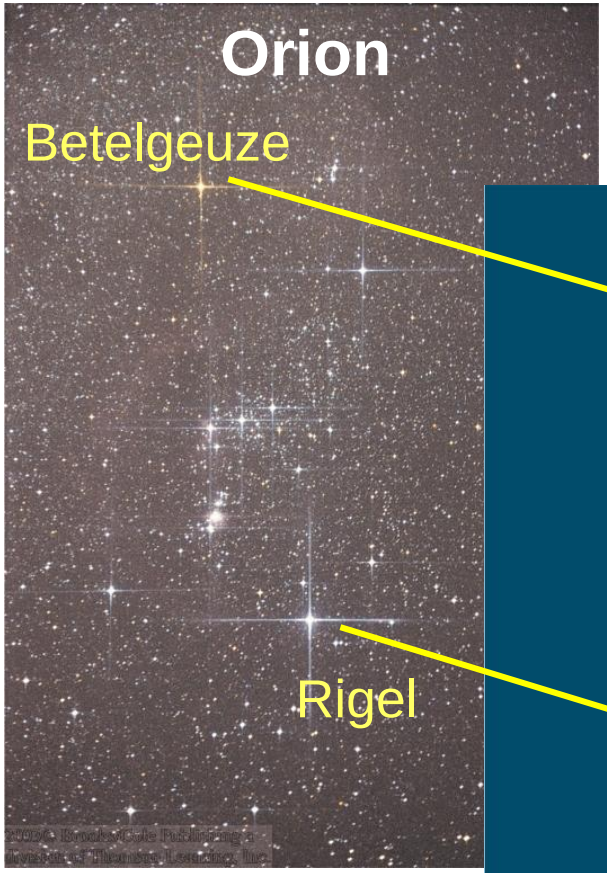


Back of Note Card

- Best Viewing Time October: 9pm
- Brightest Star: Common Name: Markab aka Alpha Peg Class B
- 1 DSO (Deep Sky Object): M15 (Globular Cluster) aka Beehive cluster
- 1 Interesting Fact: Contains the Great Square

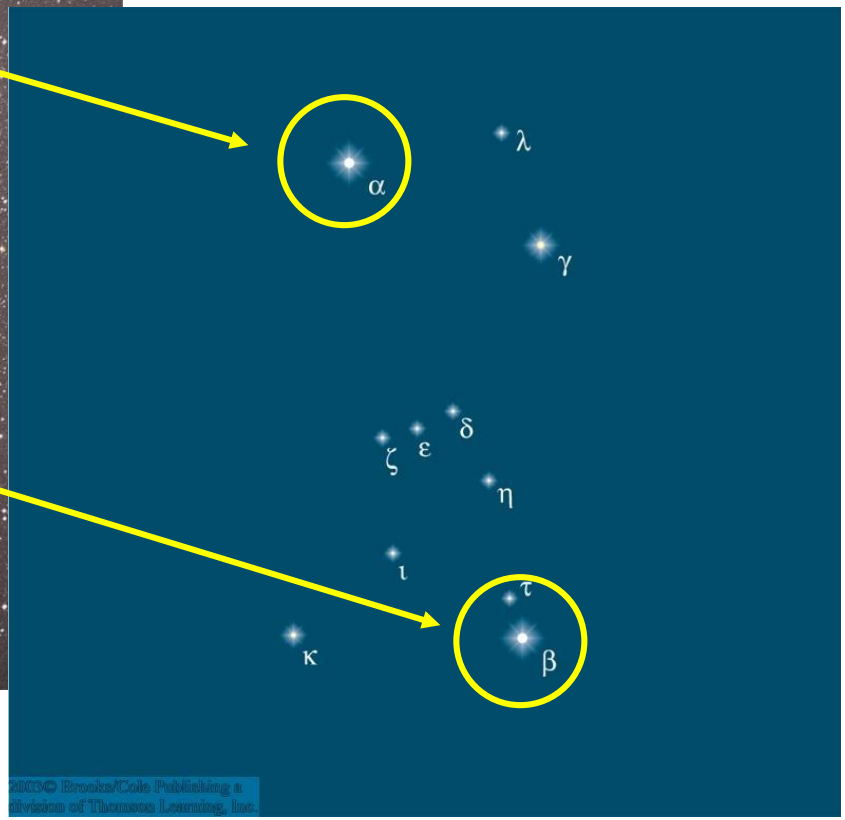
Constellations (4)

Stars are named by a Greek letter (α, β, γ) according to their relative brightness within a given constellation + the possessive form of the name of the constellation:



Betelgeuse = α Orionis

Rigel = β Orionis



The Magnitude Scale

First introduced by Hipparchus (160 - 127 B.C.):

- Brightest stars: ~1st magnitude
- Faintest stars (unaided eye): 6th magnitude

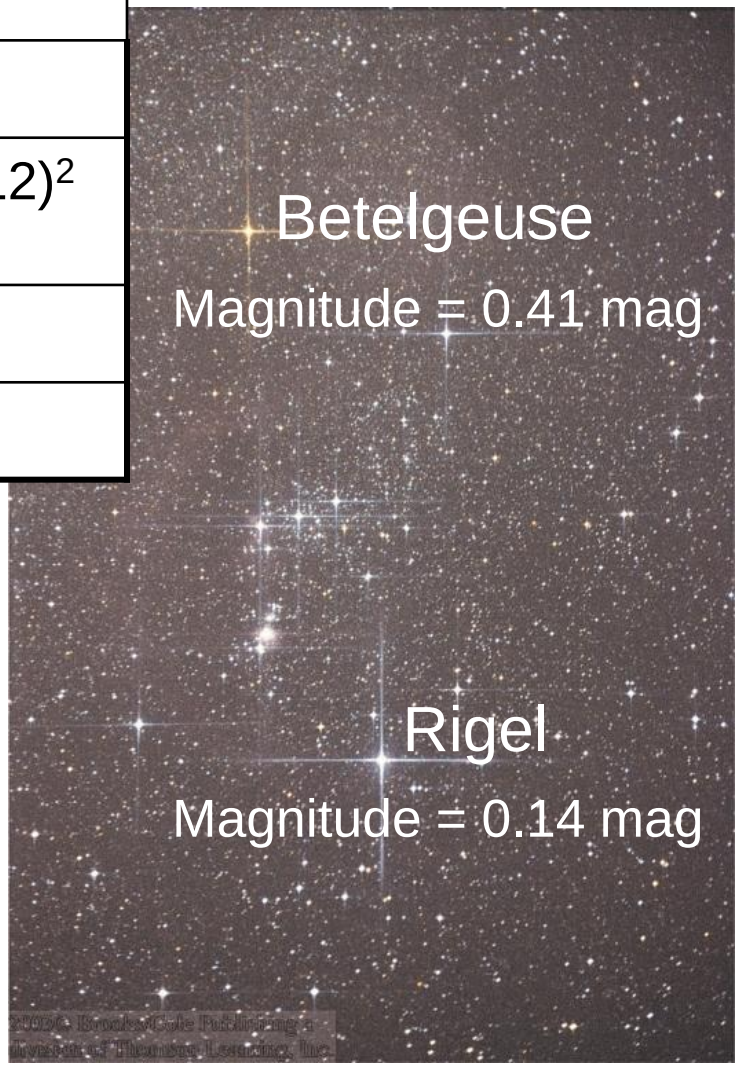
More quantitative:

- 1st mag. stars appear 100 times brighter than 6th mag. stars
- 1 mag. difference gives a factor of 2.512 in apparent brightness (larger magnitude => fainter object!)

The Magnitude Scale (Example)

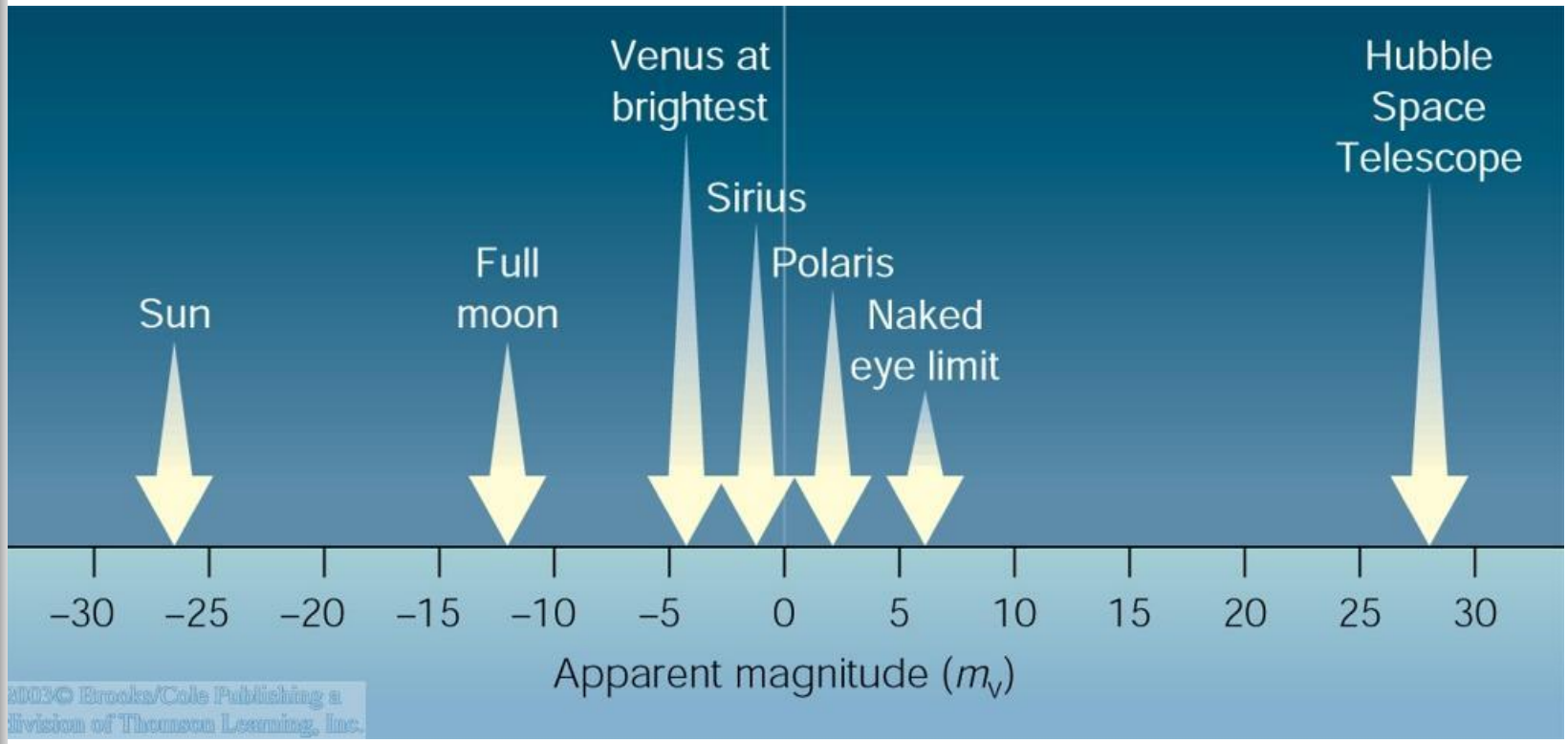
Magn. Diff.	Intensity Ratio
1	2.512
2	$2.512*2.512 = (2.512)^2 = 6.31$
…	…
5	$(2.512)^5 = 100$

For a magnitude difference of 0.41 – 0.14 = 0.27, we find an intensity ratio of $(2.512)^{0.27} = 1.28$.



The Magnitude Scale (2)

The magnitude scale system can be extended towards negative numbers (very bright) and numbers > 6 (faint objects):



Sirius (brightest star in the sky): $m_v = -1.42$

Full moon: $m_v = -12.5$

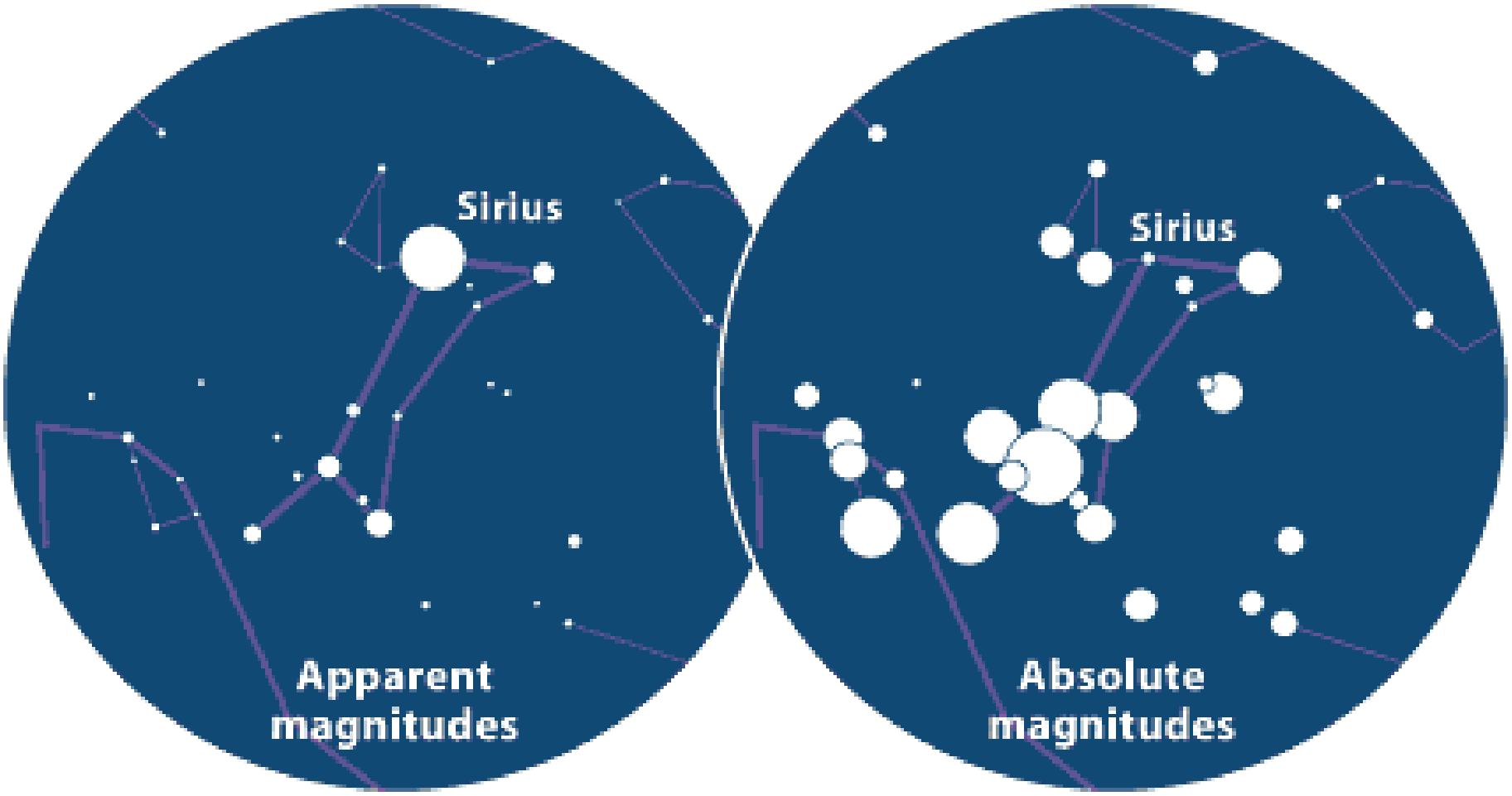
Sun: $m_v = -26.5$

Apparent vs Absolute Magnitude

- Apparent:
- How bright a star appears from Earth

- Absolute:
- How bright a star would appear if it were at a distance of 10pc from Earth

Canis Majoris



Distance Modulus

(a useful quantity for determining distances)

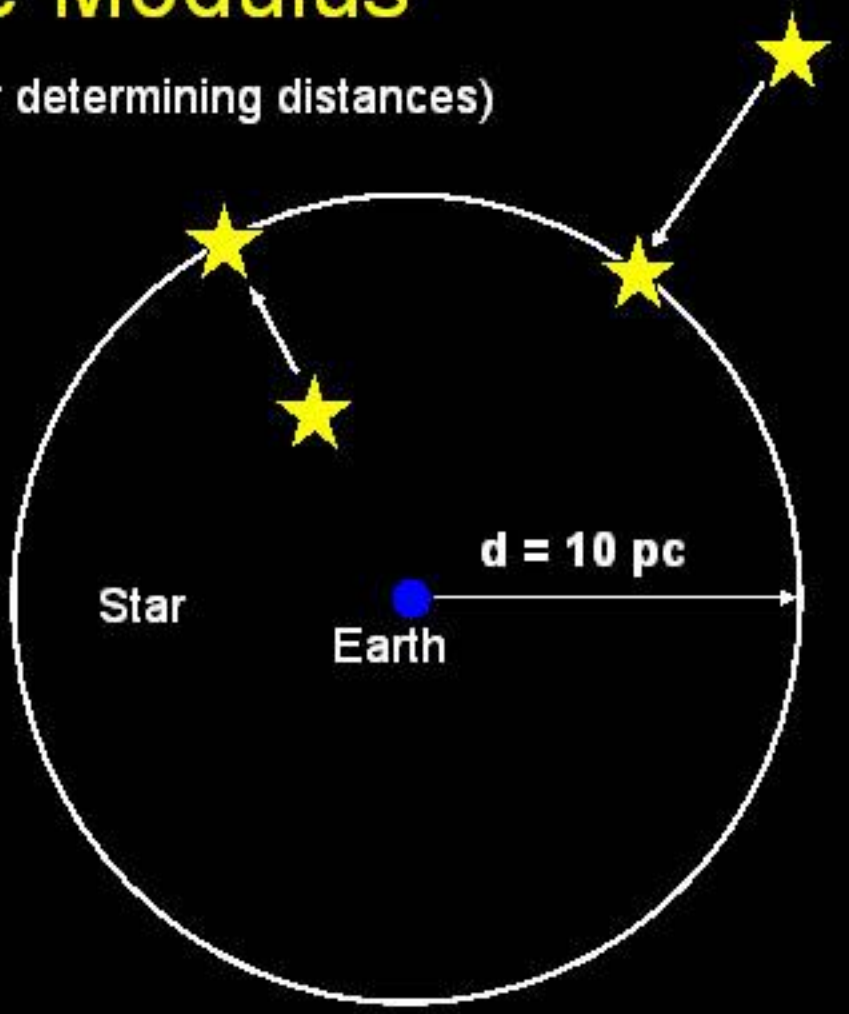
The distance modulus is the difference between apparent magnitude m and absolute magnitude M for an object.

$$m - M = -5 + 5\log_{10} d$$

m < M $\rightarrow$ d < 10 pc

m >M $\rightarrow$ d > 10 pc

$$d = (10\,pc) \times 10^{\frac{m-M}{5}}$$



Rule: A distance modulus of 5 corresponds to a distance of 100 pc

Rewriting Exponential Expressions as Logarithmic Expressions

- Base $^{\text{exponent}}$ = result
- Log_{base} result = exponent
- Discuss writing the following exponential equations as logarithmic equations
- $2^3 = 8$
- $10^4 = 10{,}000$

Absolute Magnitude (M)

Knowing the apparent magnitude (m) and the distance in pc (d) of a star its absolute magnitude (M) can be found using the following equation:

$$m - M = 5\log\left(\frac{d}{10}\right)$$

Example: Find the absolute magnitude of the Sun.

The apparent magnitude is -26.7

The distance of the Sun from the Earth is 1 AU = 4.9×10^{-6} pc

Answer = +4.8

Practice

- β Crucis (or Mimosa) has an apparent magnitude of 1.25 and is 108 parsecs distant. *What is its absolute magnitude?*

Practice 2

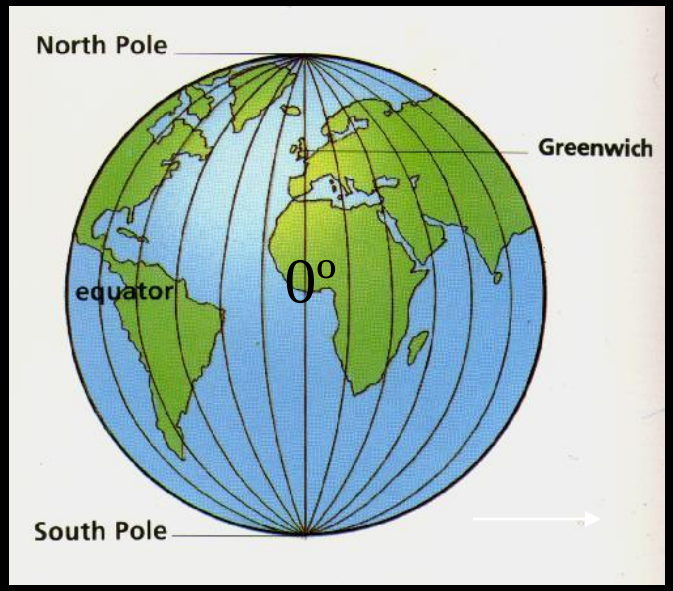
- Betelgeuse has an apparent magnitude of 0.45 and an absolute magnitude of -5.14. *How far away is it?*

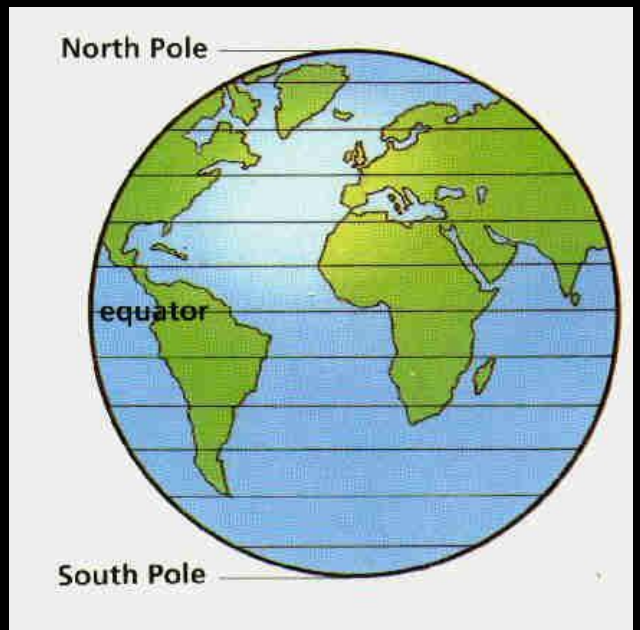
Example Problem

- A star has an apparent magnitude of 4.0 and an absolute magnitude of -3.0. What is the distance to the star?

How do we locate a spot on the earth?

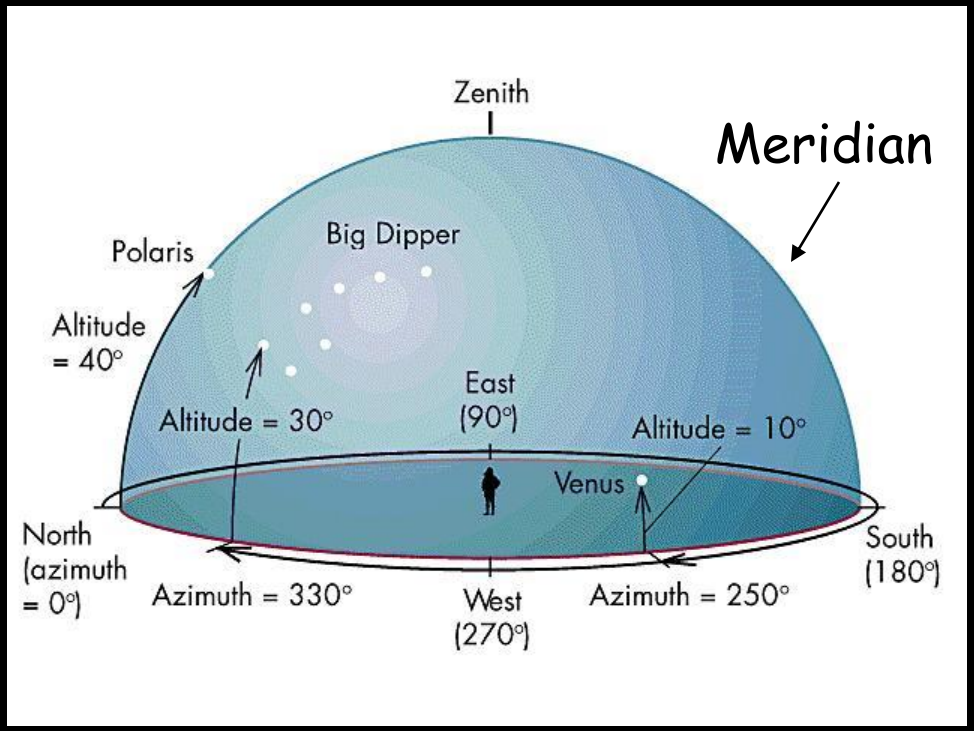
- Maps, mapquest, Google Map, GPS
- If we ignore how high it is above the sea
- To describe a spot on the surface of the earth, we use a set of numbers (degrees), called Coordinates
  - Longitude
  - Latitude





The horizon coordinate system

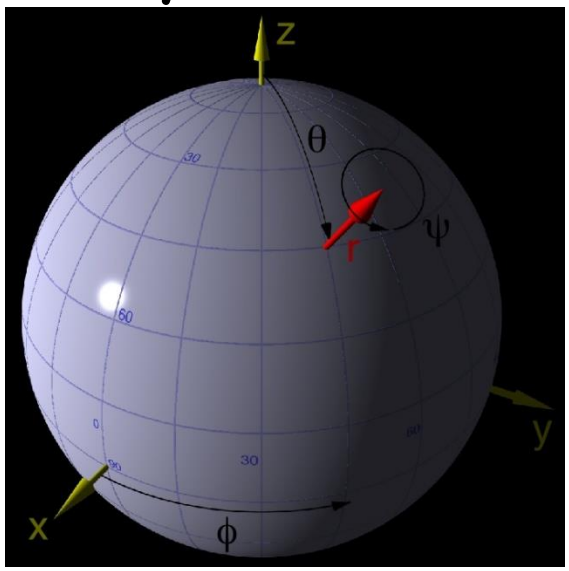
- Altitude
  - Angle above the horizon
  - 0° - 90°
  - The altitude of the north celestial pole equals the observer's latitude on the earth
- Azimuth
  - Angle measured eastward along the horizon, starting from the north
  - 0° - 360°
- Zenith
  - The extended vertical line intersects with the celestial sphere directly above
- Meridian
  - The great circle passing through the celestial poles and the zenith



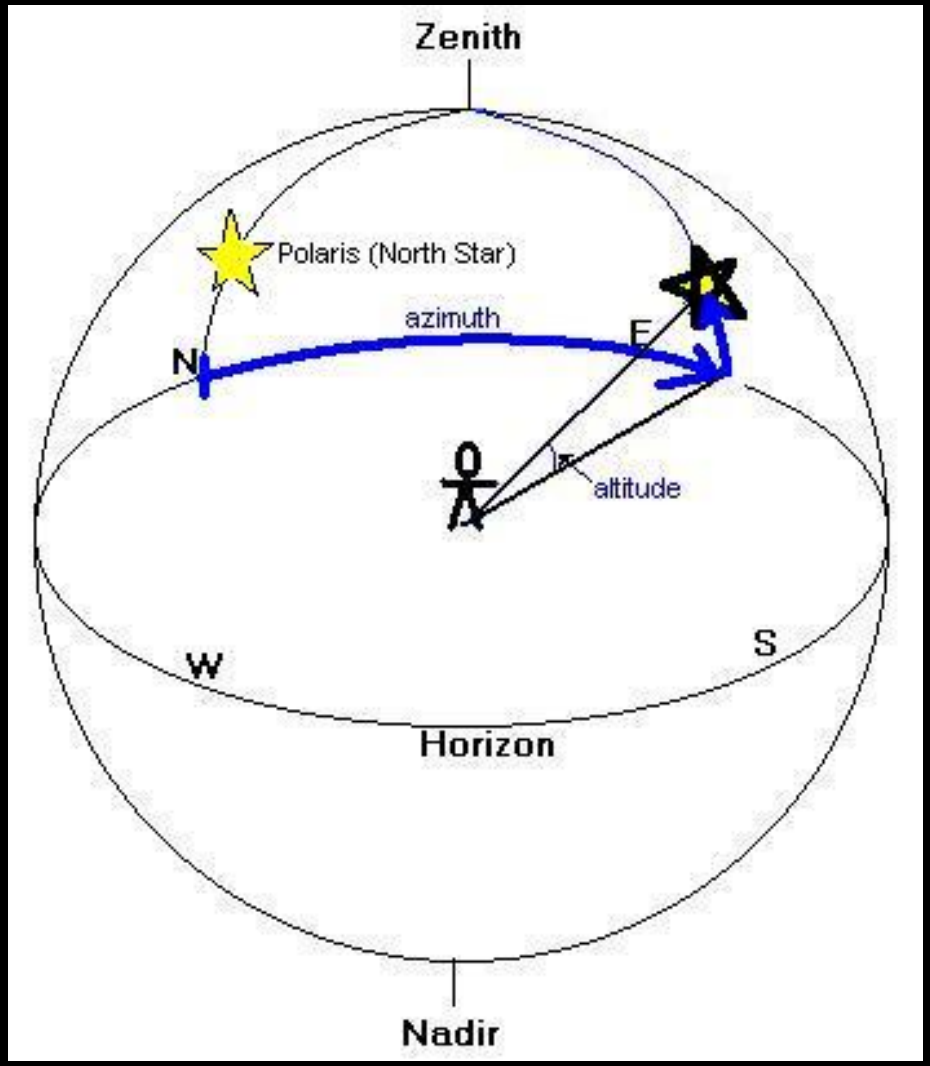
- Horizon
  - The great circle whose pole is the zenith

Pros and Cons of the horizon system

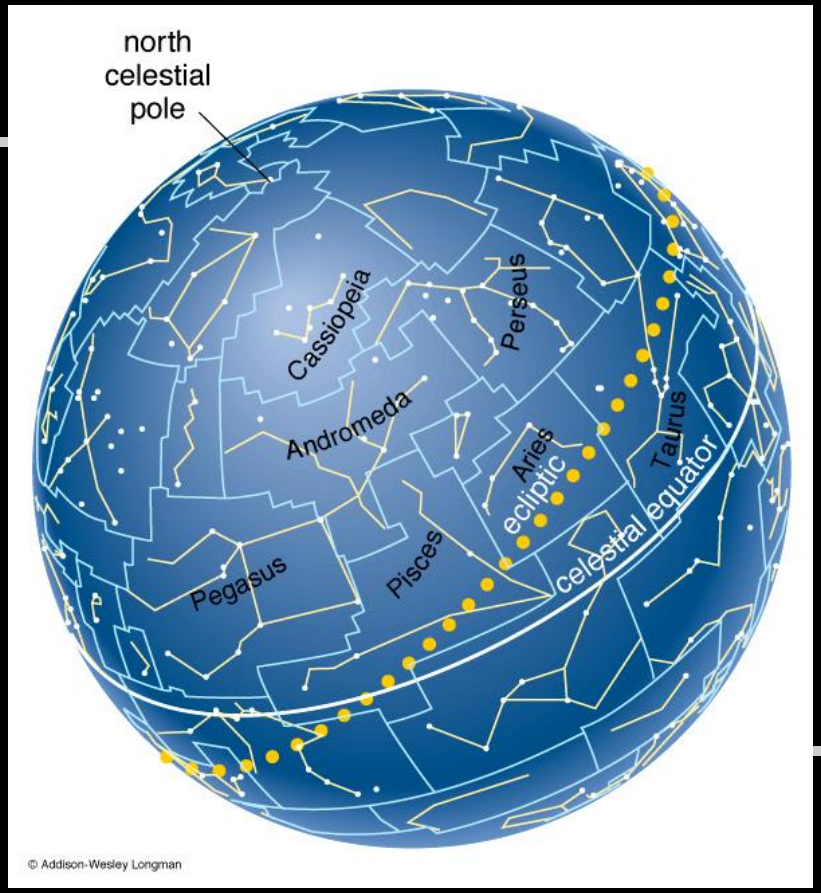
- Pros
  - Easy to tell and understand
- Cons
  - At different position on the earth, the same object has different coordinates
  - At different time, the same object has different coordinates



The Coordinates of an object Change in the horizon system!


Zenith
Polaris (North Star)
azimuth
N
E
altitude
W
S
Horizon
Nadir

The Celestial Sphere



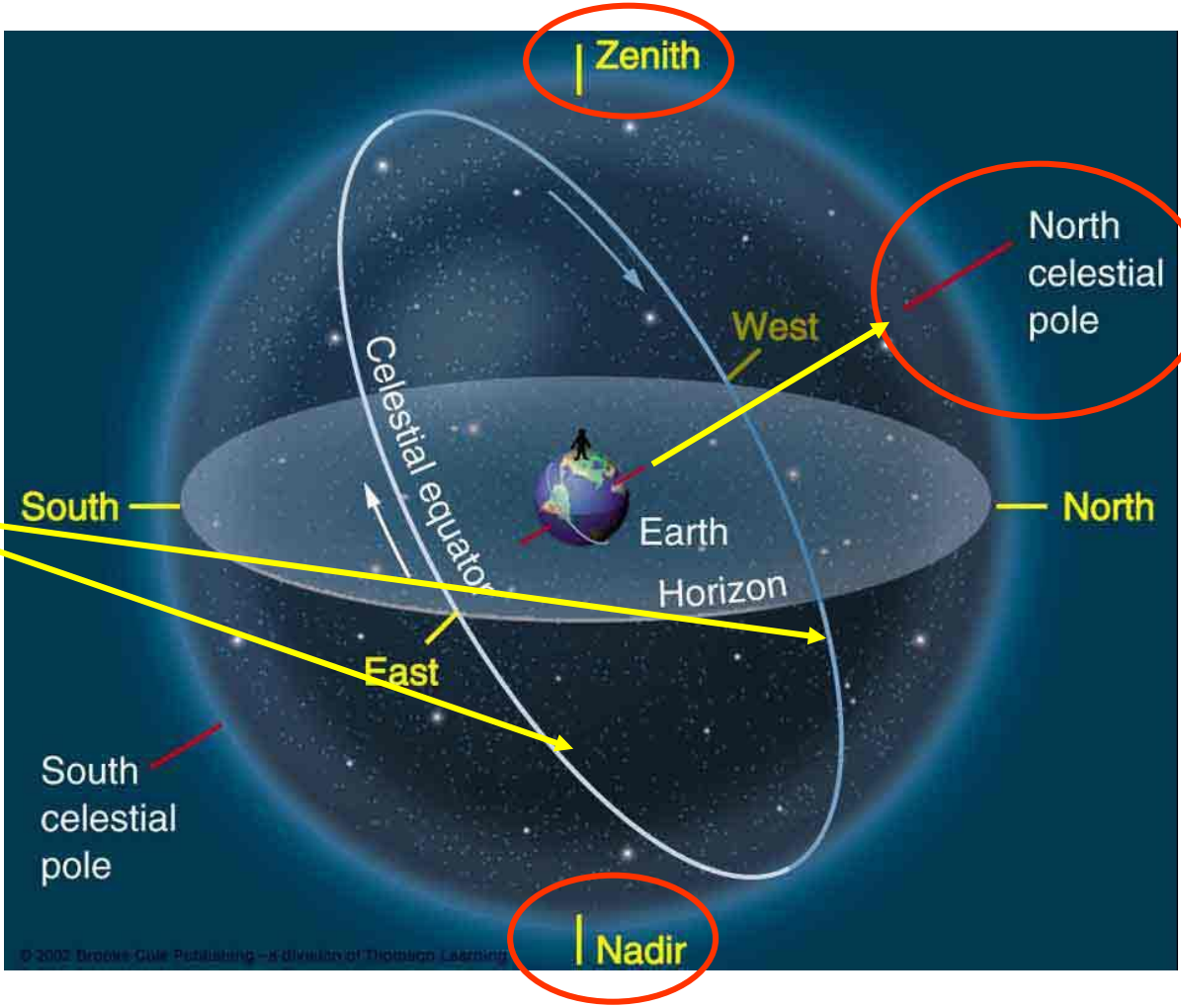
The Celestial Sphere

Zenith = Point on the celestial sphere directly overhead

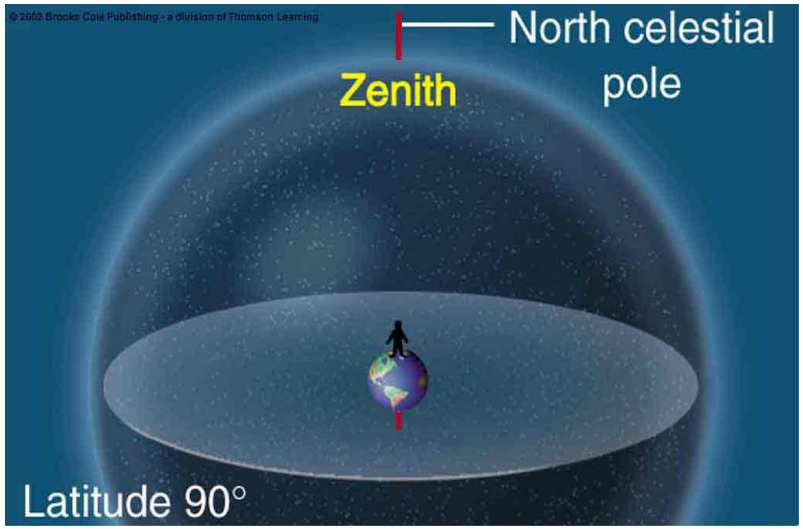
Nadir = Point on the c.s. directly underneath (not visible!)

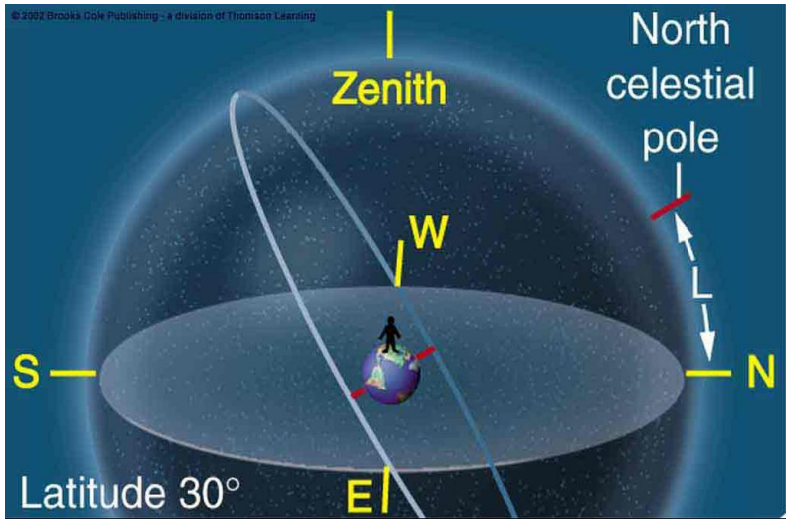
Celestial equator = projection of Earth's equator onto the c. s.

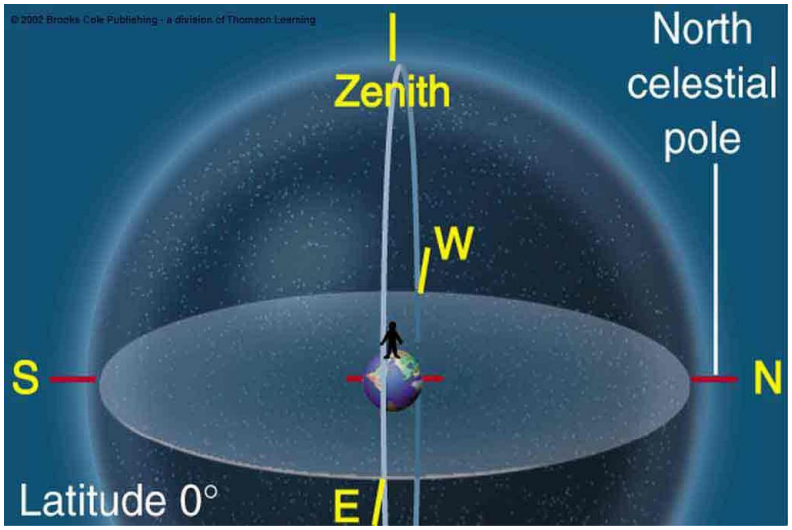
North celestial pole = projection of Earth's north pole onto the c. s.

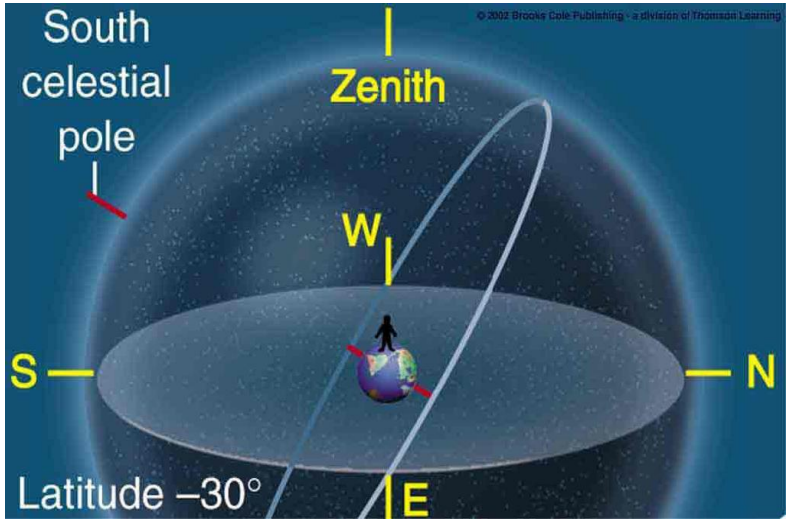


The Celestial Sphere (3)



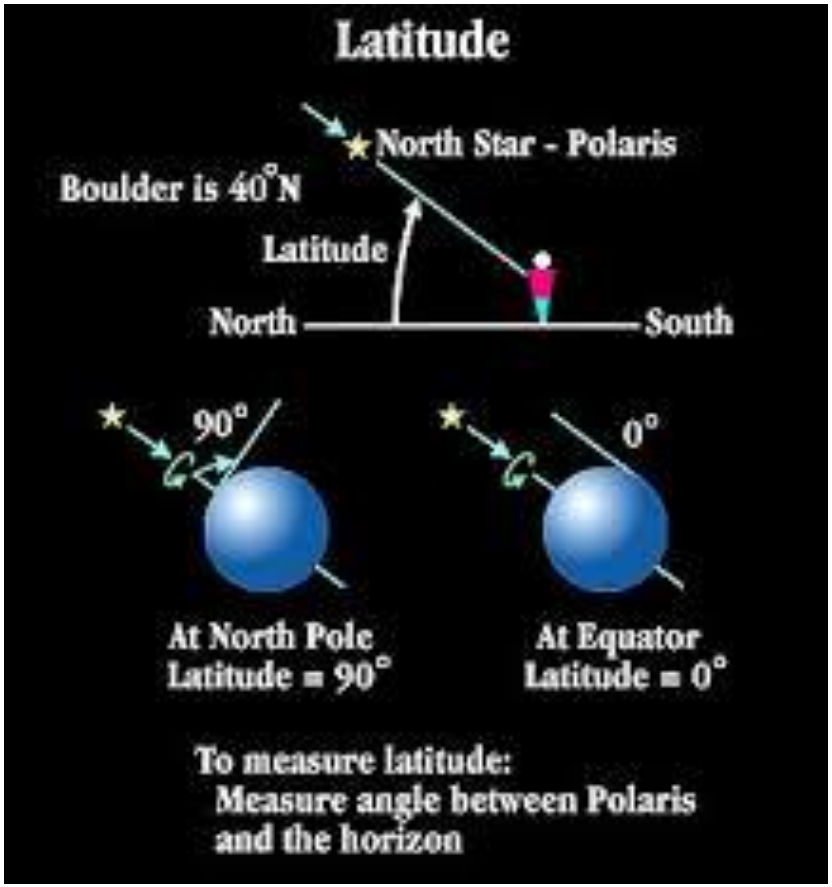






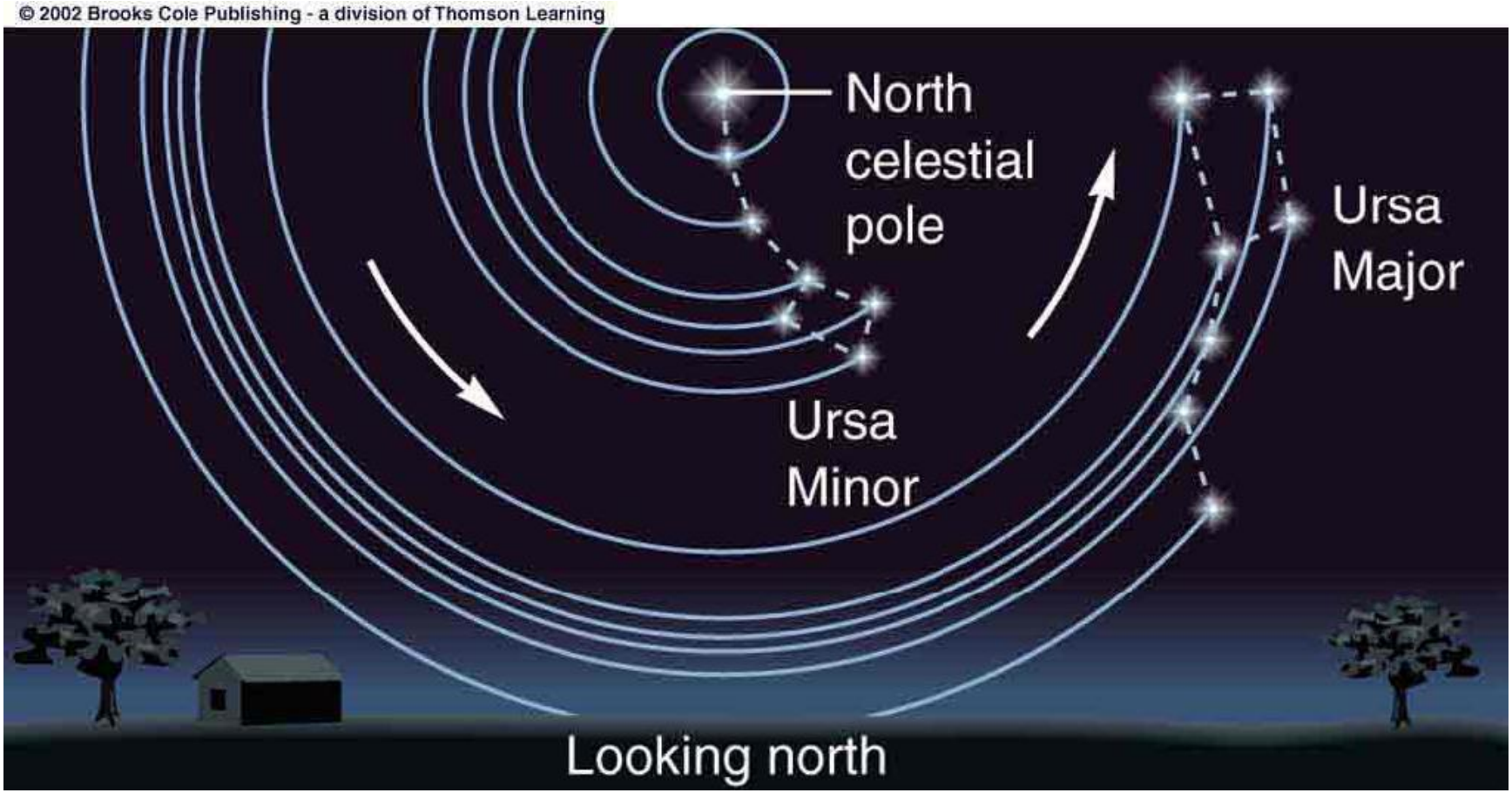
This Means

- At Northern Latitudes
- The angle which Polaris is above the horizon is actually your latitude

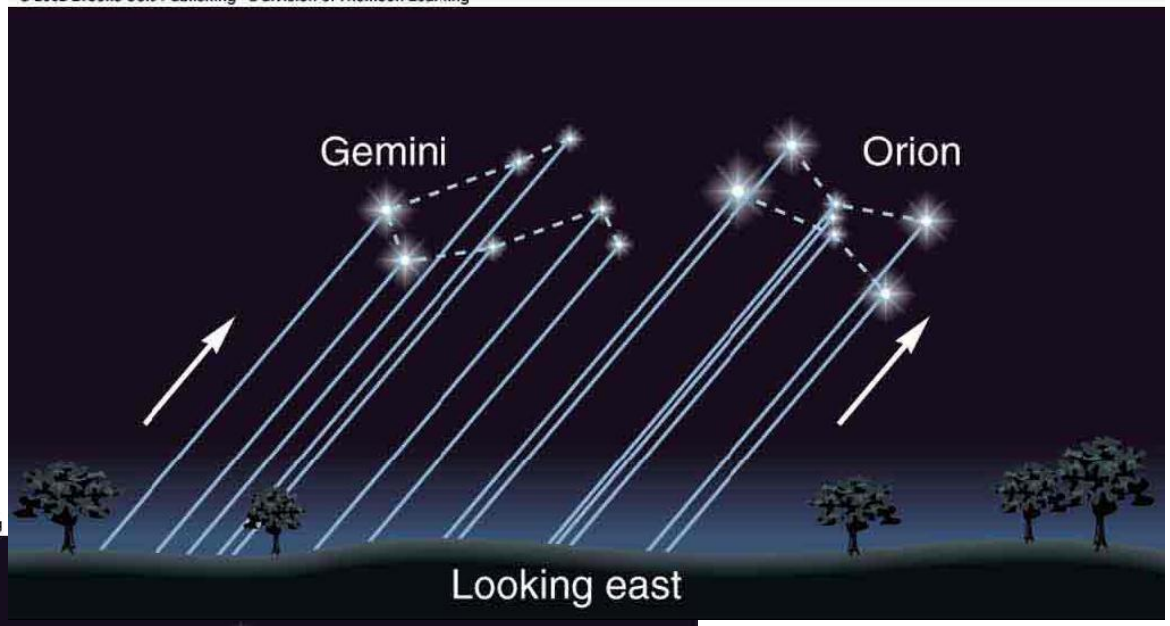


Apparent Motion of The Celestial Sphere

Motion is Counter clockwise when Viewing North



Apparent Motion of The Celestial Sphere (2)



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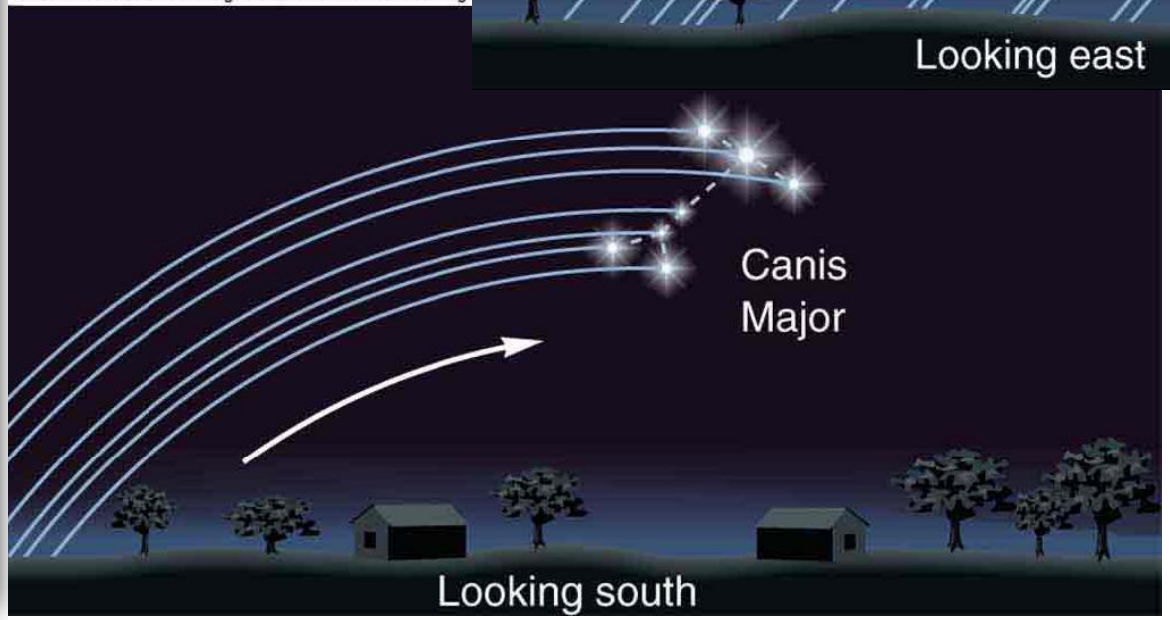
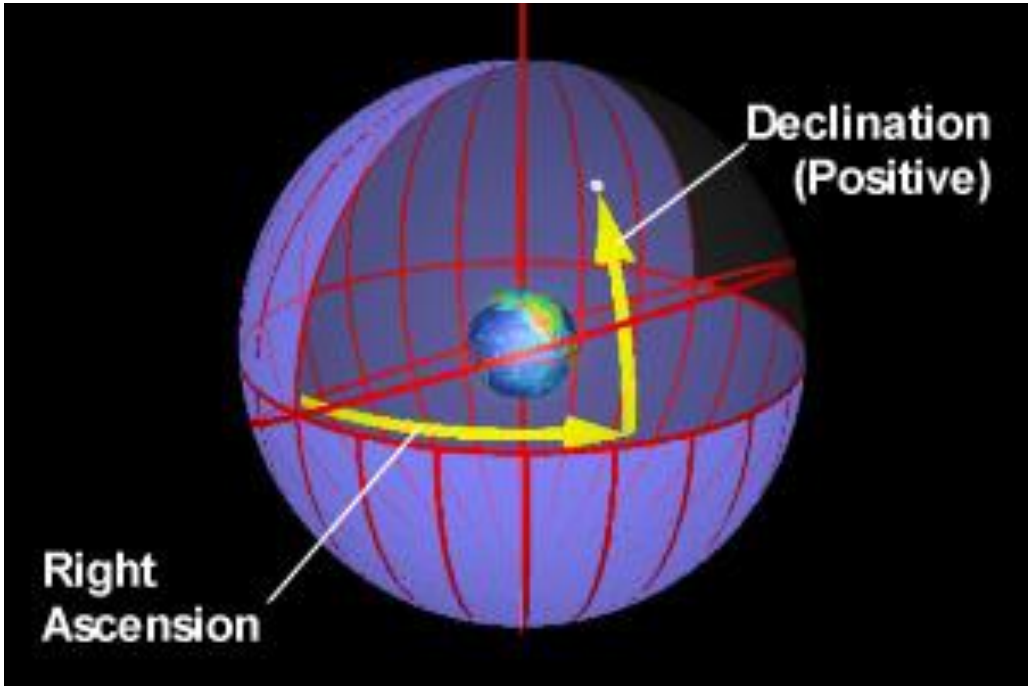


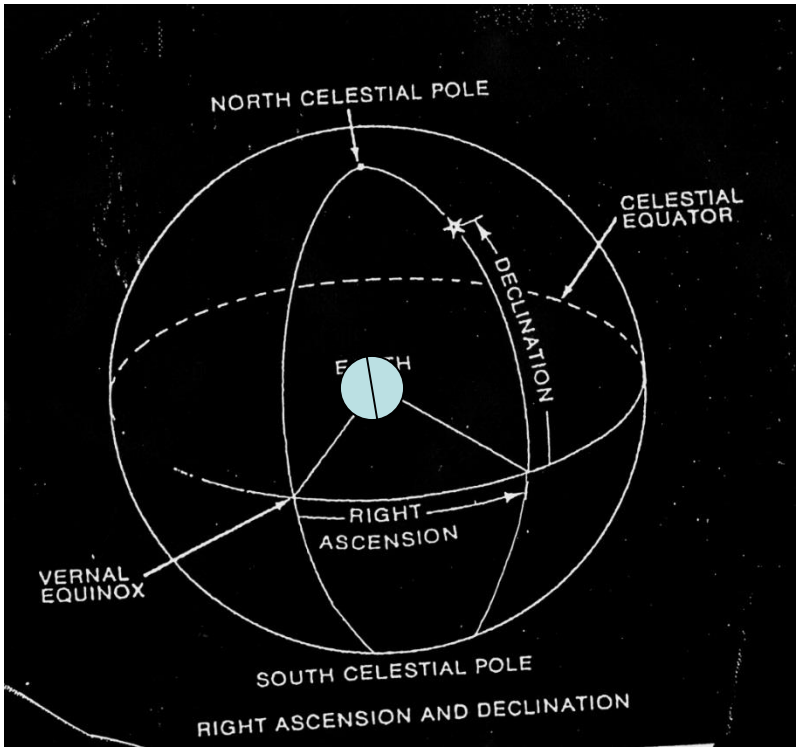
Equatorial Coordinate System

- A system in which the coordinates of an object does not change
- Like the longitude and latitude on the earth, we have Right Ascension and Declination in the Equatorial system
- The equatorial coordinate system rotates with stars and galaxies

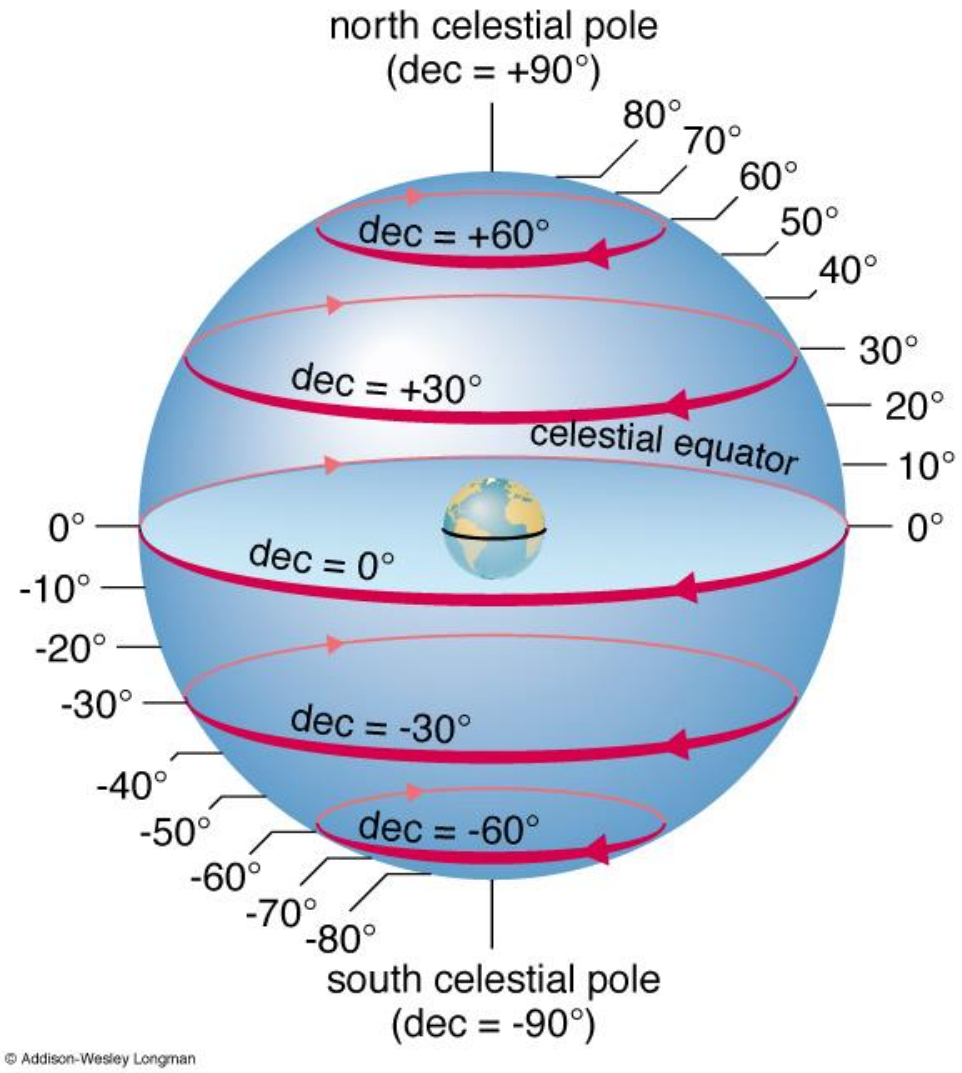


Equatorial Coordinate System

- Declination (DEC)
  - A set of imaginary lines parallel to the Celestial Equator
  - 0 ° at the celestial equator, increases from south to north
  - negative in the southern hemisphere
  - Dec of the north celestial pole is 90 °
  - Dec of the south celestial pole is -90 °

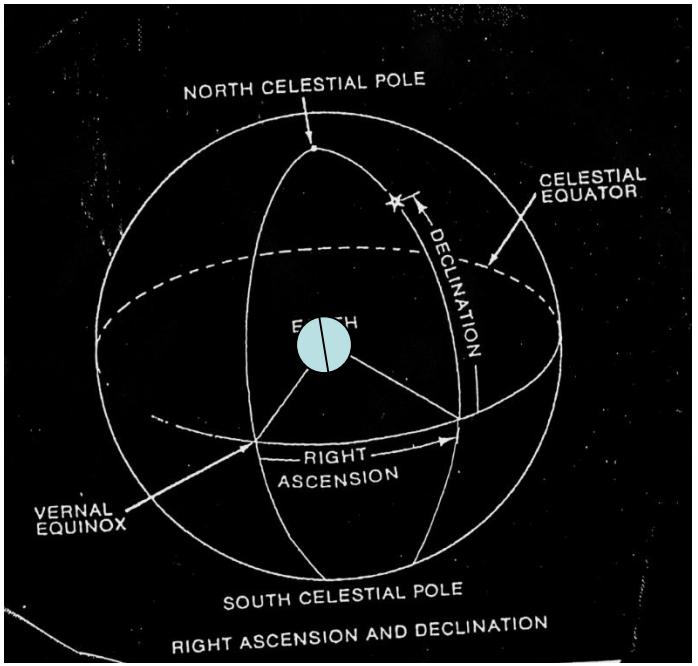


-90 °



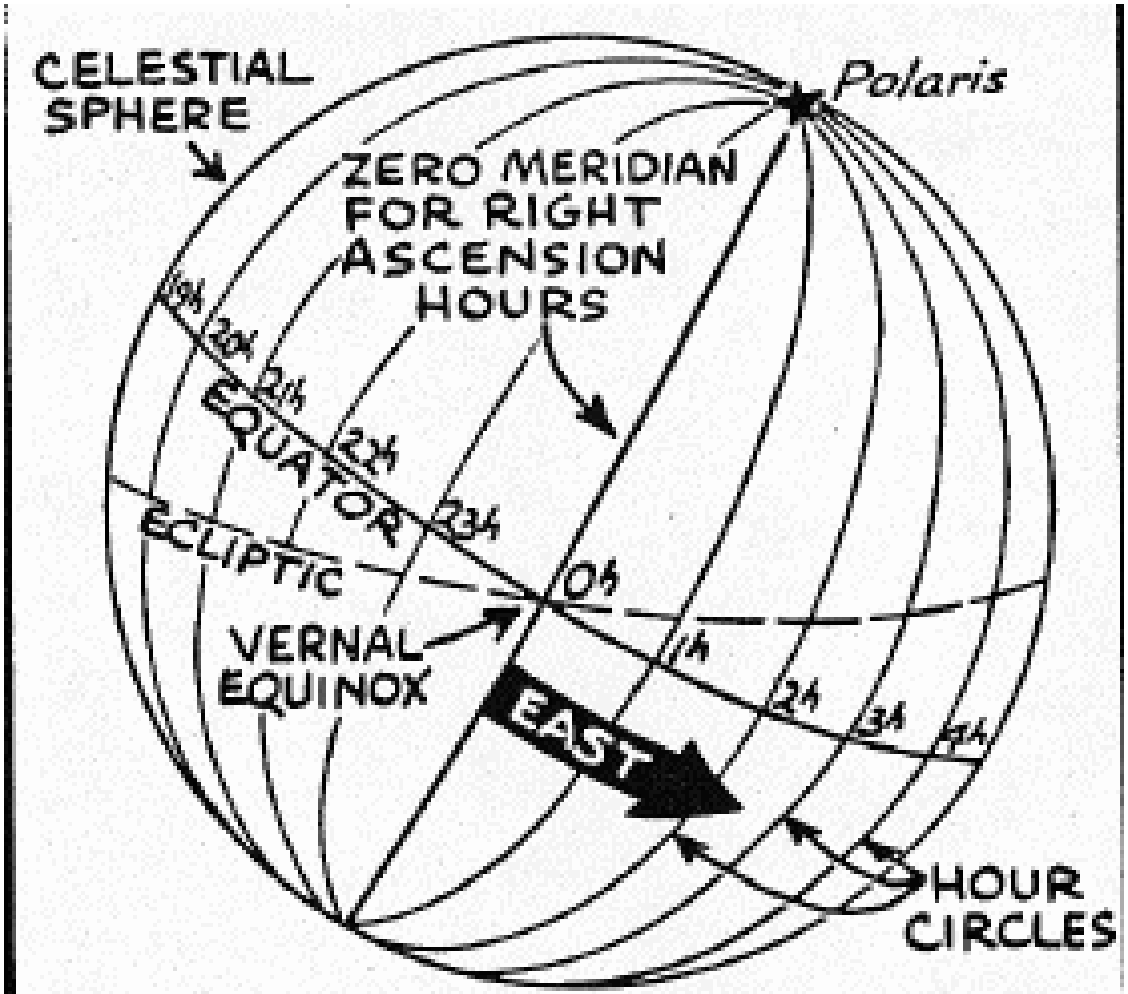
Equatorial Coordinate System

- Right Ascension (RA)
  - imaginary lines that connect the celestial poles
  - The origin of the longitude of the earth is the Greenwich Observatory
  - The origin of the RA is Vernal Equinox



-90 ◦

What is Vernal Equinox?

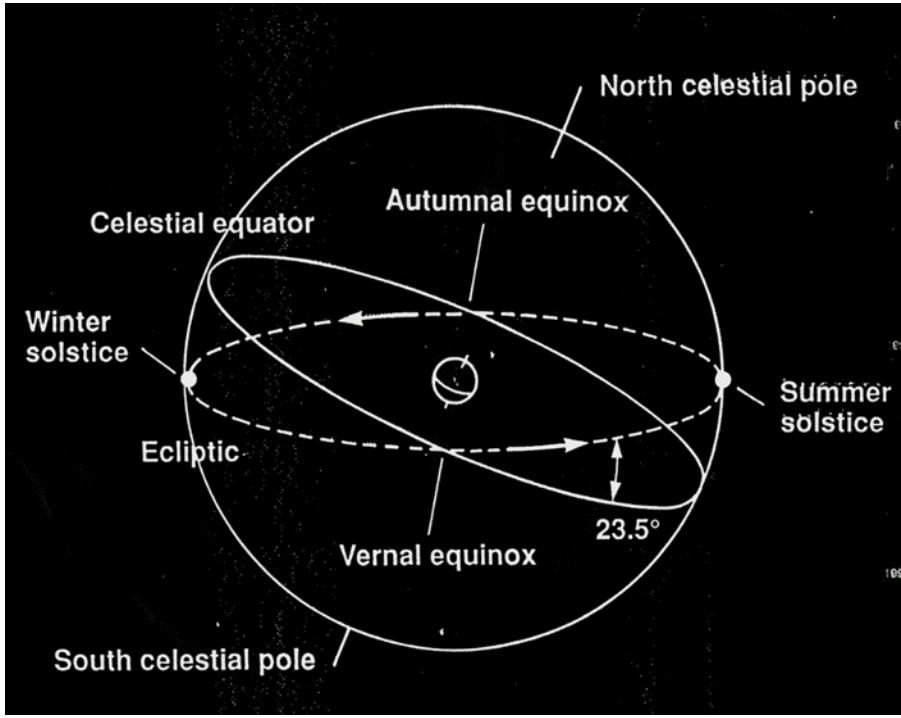


R.A. HOUR CIRCLES

RIGHT ASCENSION HOURS ARE SET OFF FROM THE VERNAL EQUINOX, *EASTWARD*. 1 HR. EQUALS 15°

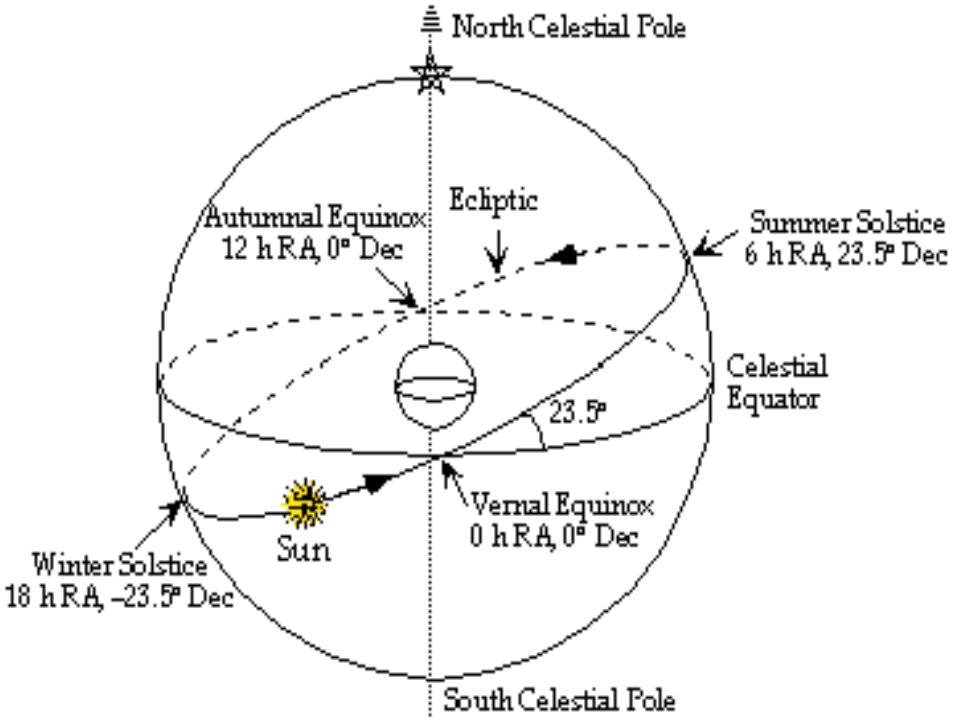
The equatorial system

- Ecliptic
  - The earth revolves annually around the Sun
  - The Sun appears to moves from west to east on the celestial sphere
  - The path of the sun is called ecliptic



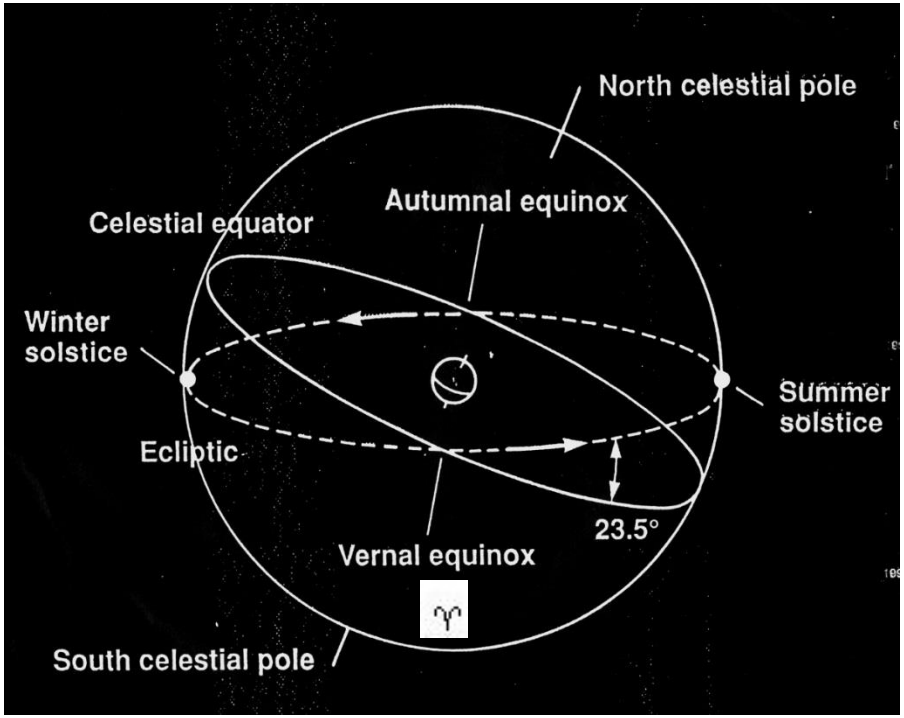
The equatorial system

- The earth's axis is titled – line through the celestial poles is NOT perpendicular to the plane of ecliptic
- 23.5 degree angle between the celestial equator and the ecliptic
- The ecliptic and the celestial equator intersect at vernal equinox and autumnal equinox

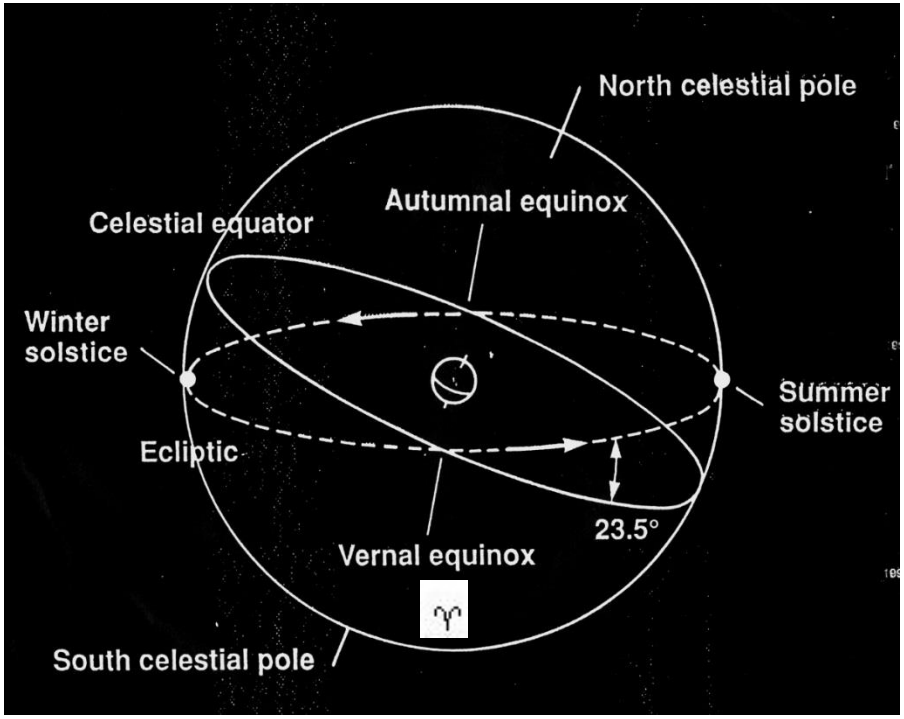


The equatorial system

- RA
  - 360 degrees
  - Historically, use HOURS:MINS:SECS as unit – 24 hours
  - Starts from Vernal equinox (0 h)
  - increases from west to east
  - Stars w/ larger RA rise later



Andromeda:
RA: $00^h\ 42^m\ 44.3^s$
DEC: $+41^\circ\ 16'\ 9''$



Vernal Equinox: RA: 0h DEC: 0°

Summer Solstice: RA: 6h DEC: 23.5°

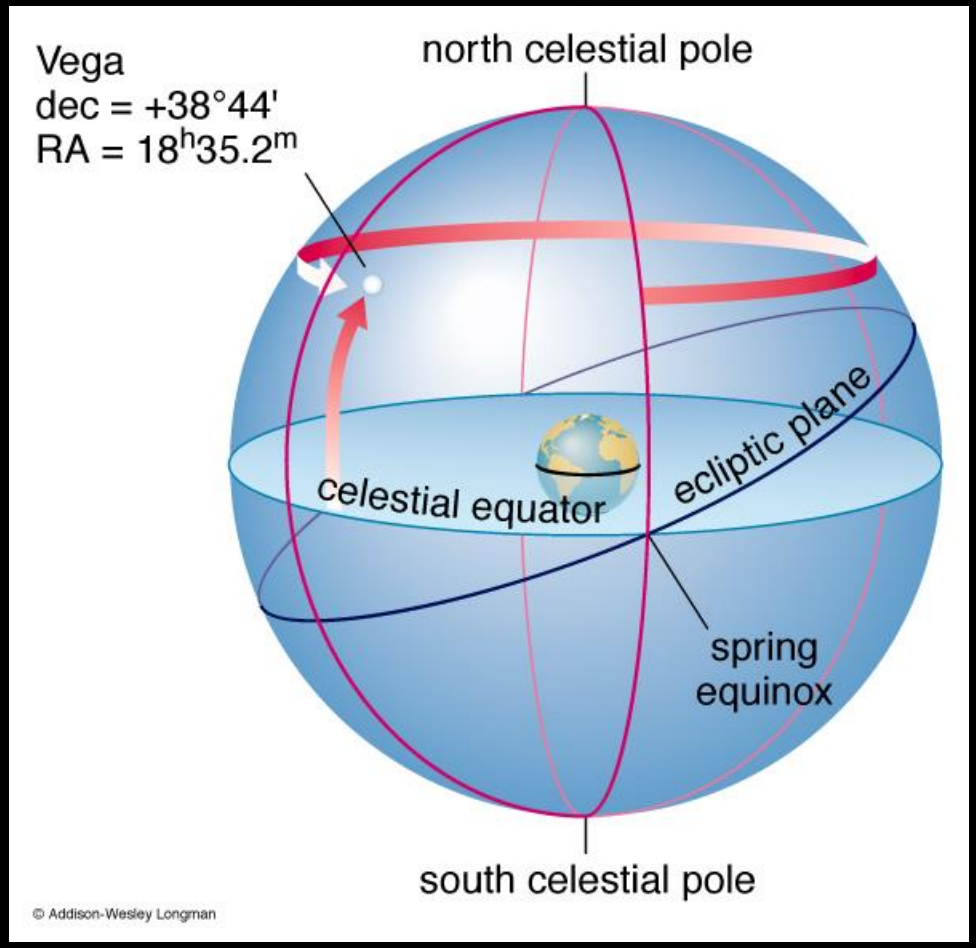
Autumnal Equinox: RA: 12h DEC: 0°

Winter Solstice: RA: 18h DEC: -23.5°

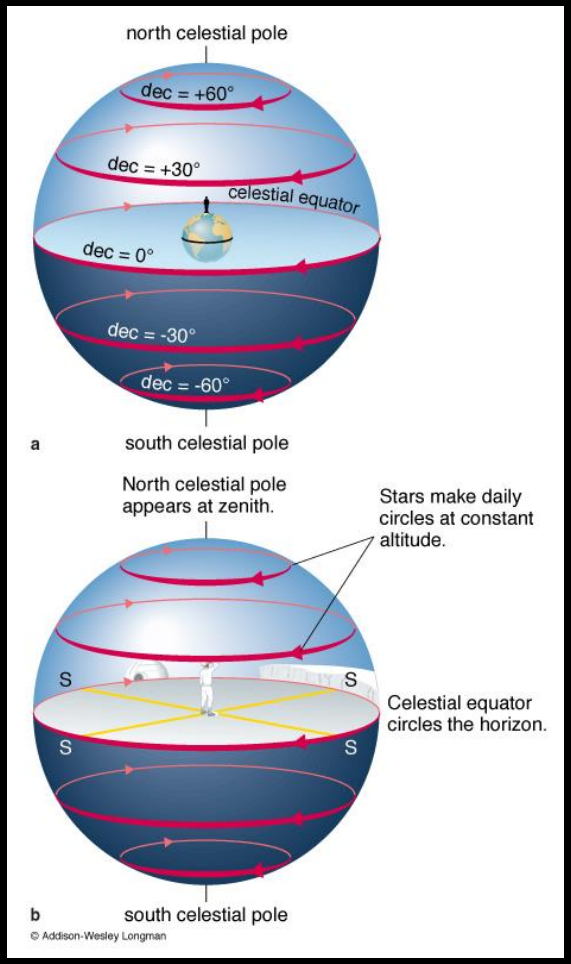
Questions

- How many hours of RA does the sun move through/month?
- How many degrees of declination does the sun seem to move /month?
- What is the approximate RA and DEC of sunrise presently?

Celestial Coordinates

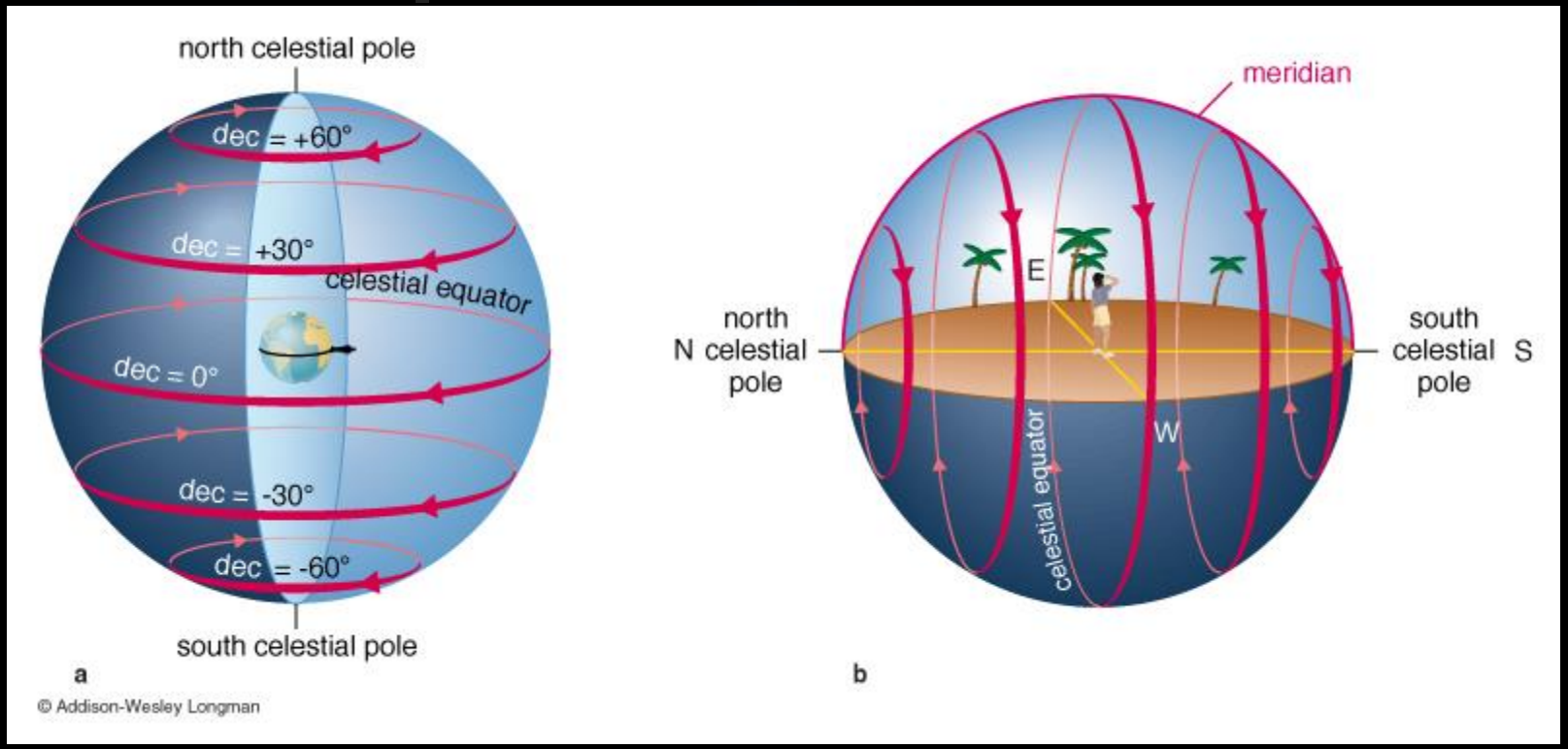


The Sky at the North Pole

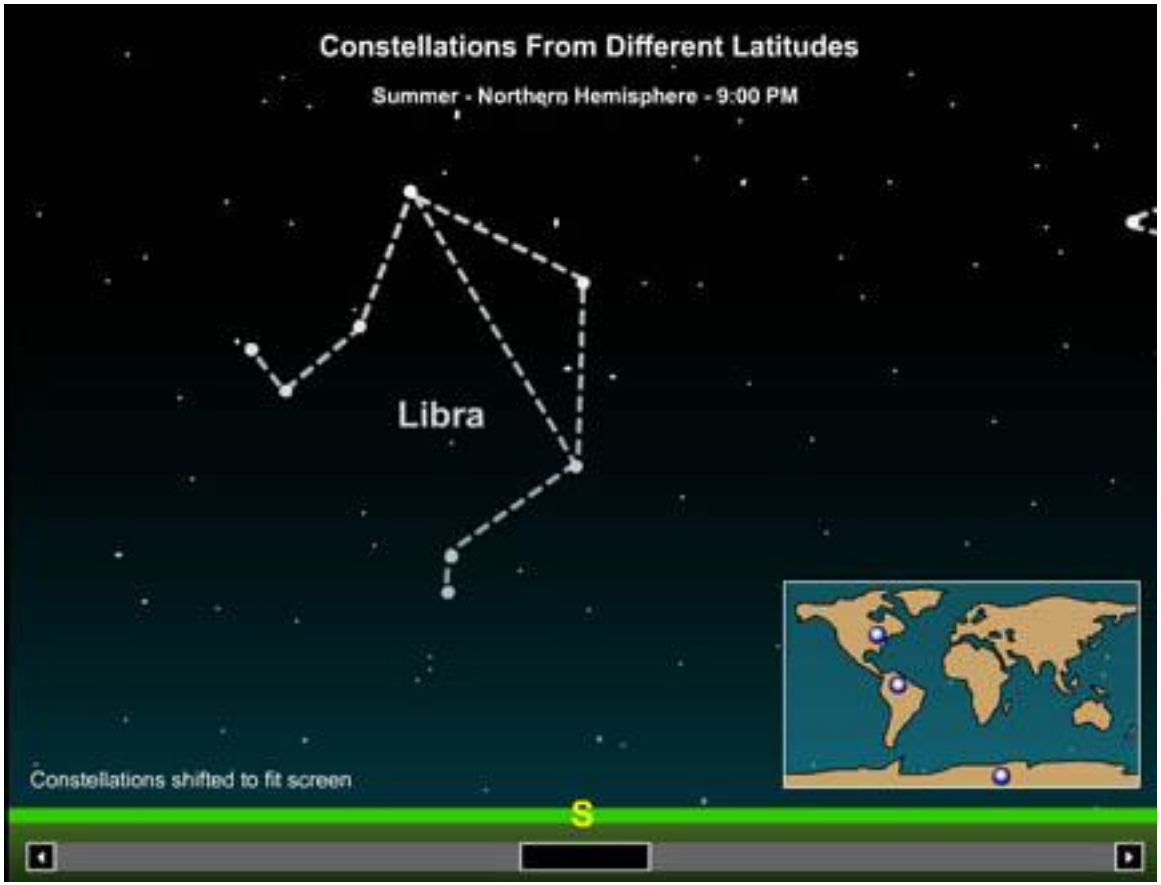


- At the North Pole, the North Celestial Pole is at the zenith
- Stars never rise or set
- Planets, Moon, and Sun do rise and set…Why?

Stars Rise and Set at the Equator



Constellations from Different Latitudes

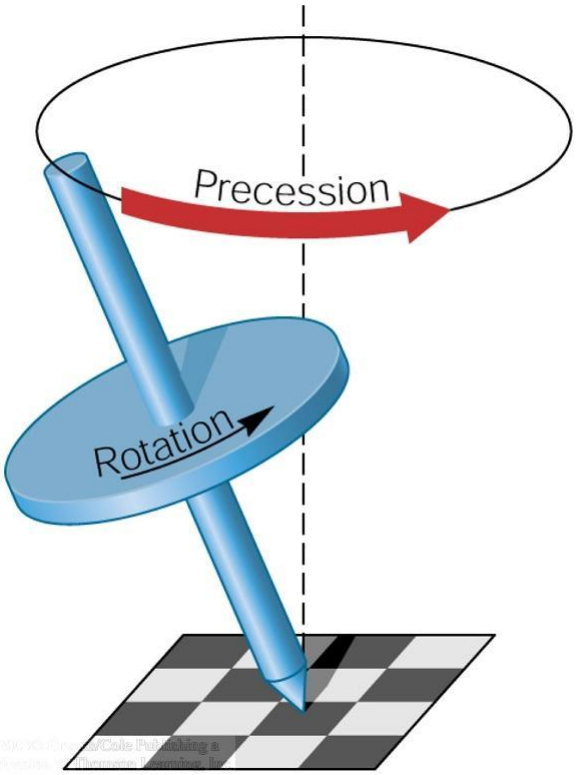


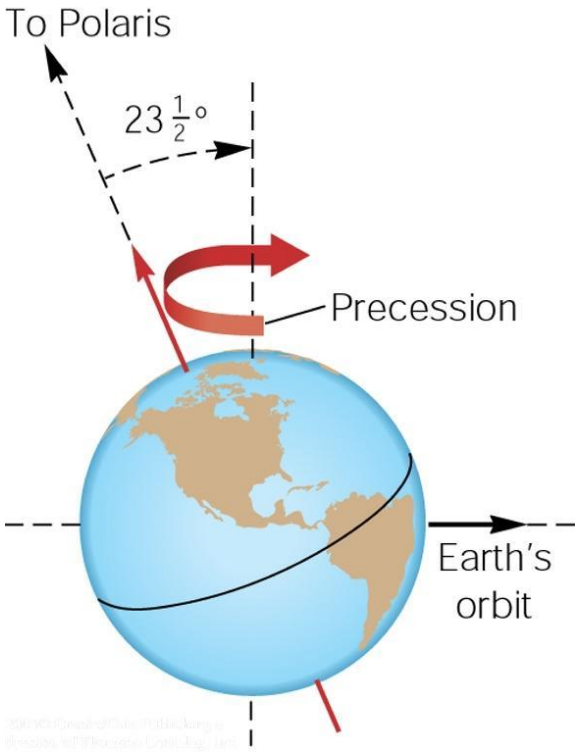
PLAY ANIMATION

(SLIDESHOW MODE ONLY)

Precession (1)

At left, gravity is pulling on a slanted top. => Wobbling around the vertical.





The Sun's gravity is doing the same to Earth.

The resulting "wobbling" of Earth's axis of rotation around the vertical w.r.t. the Ecliptic takes about 26,000 years and is called **precession**.

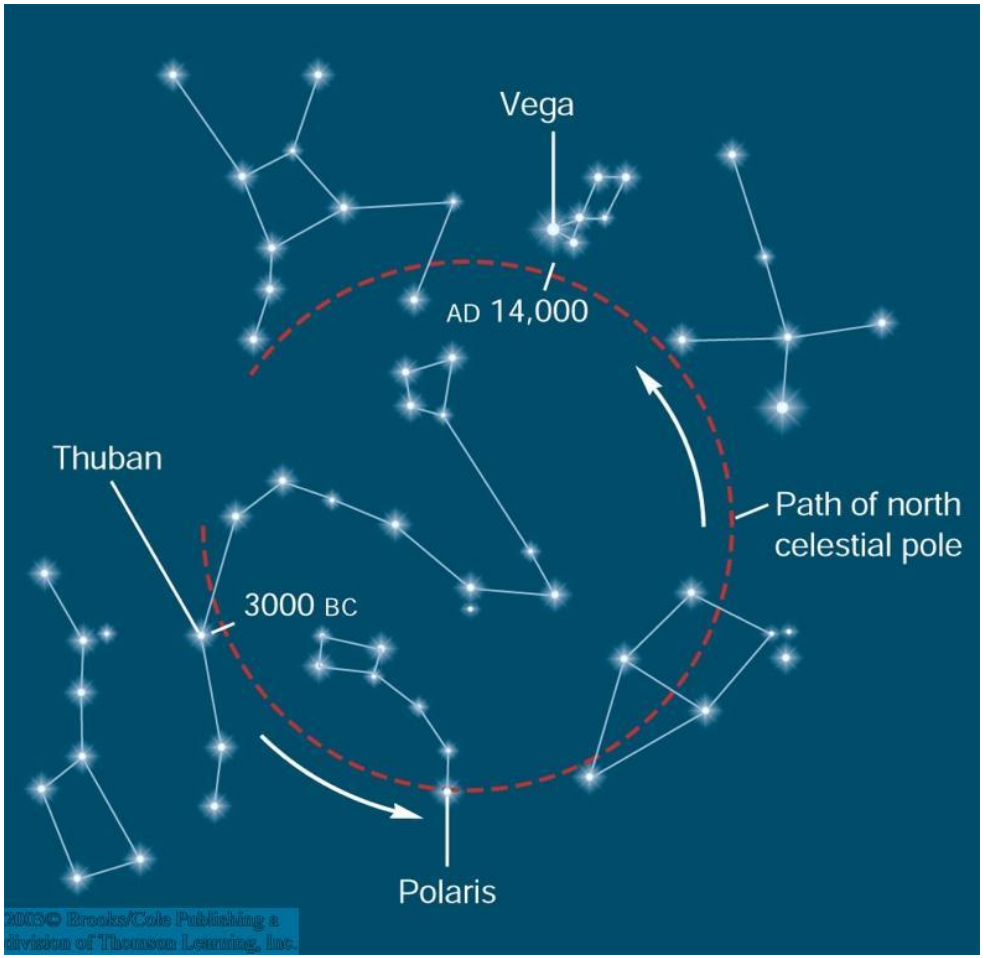
Precession (2)

As a result of precession, the celestial north pole follows a circular pattern on the sky, once every 26,000 years.

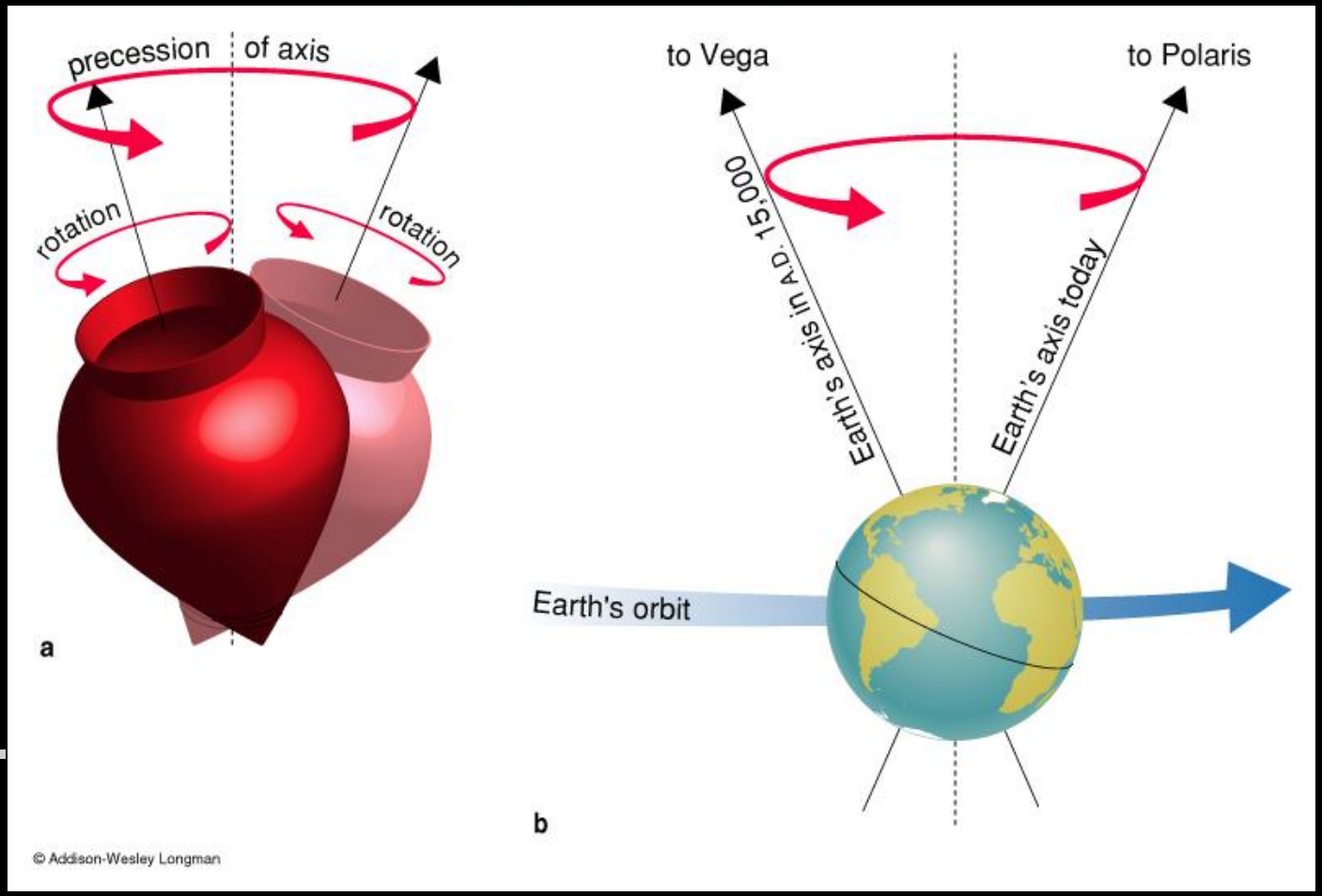
It will be closest to Polaris ~ A.D. 2100.

There is nothing peculiar about Polaris at all (neither particularly bright nor nearby etc.)

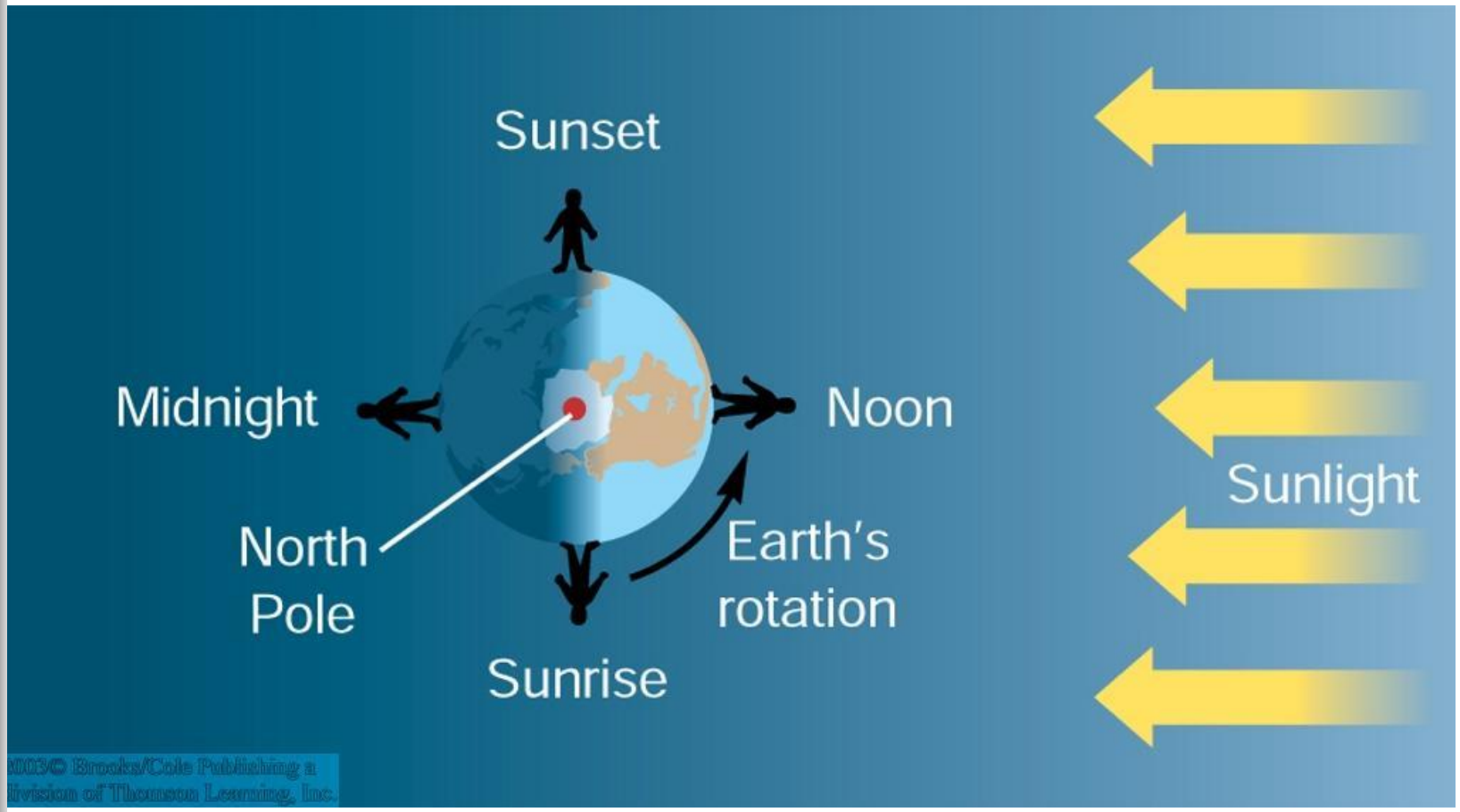
~ 12,000 years from now, it will be close to Vega in the constellation Lyra.



Precession of the Earth's Axis

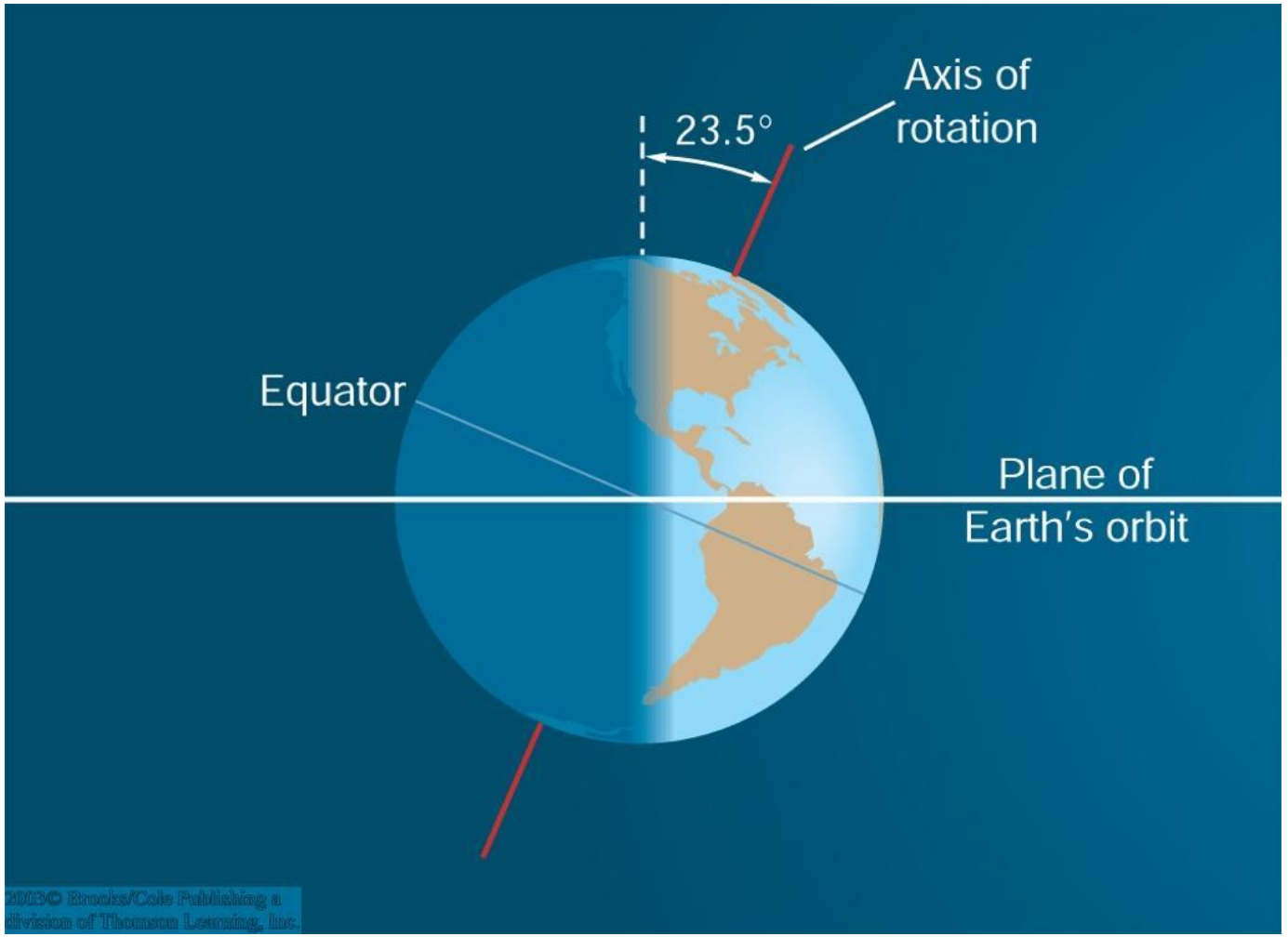


The Sun and Its Motions



Earth's rotation is causing the day/night cycle.

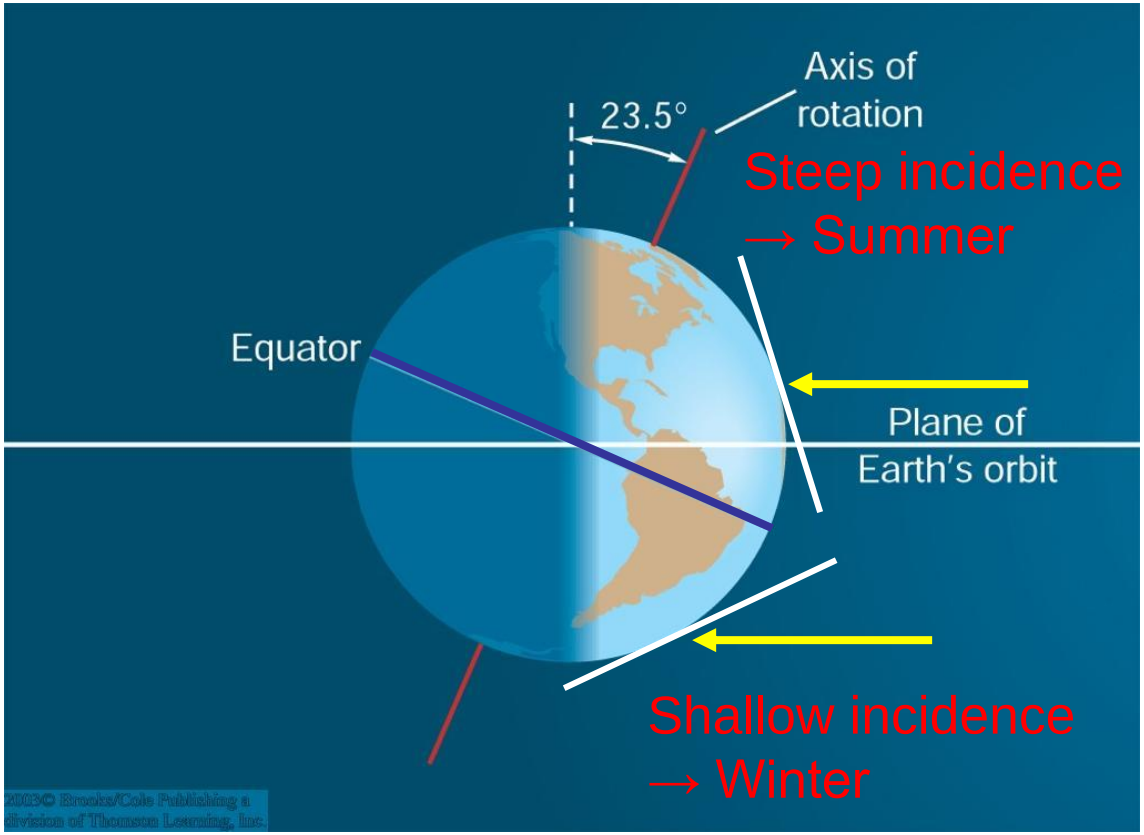
The Seasons



Earth's axis of rotation is inclined vs. the normal to its orbital plane by 23.5°, which causes the **seasons**.

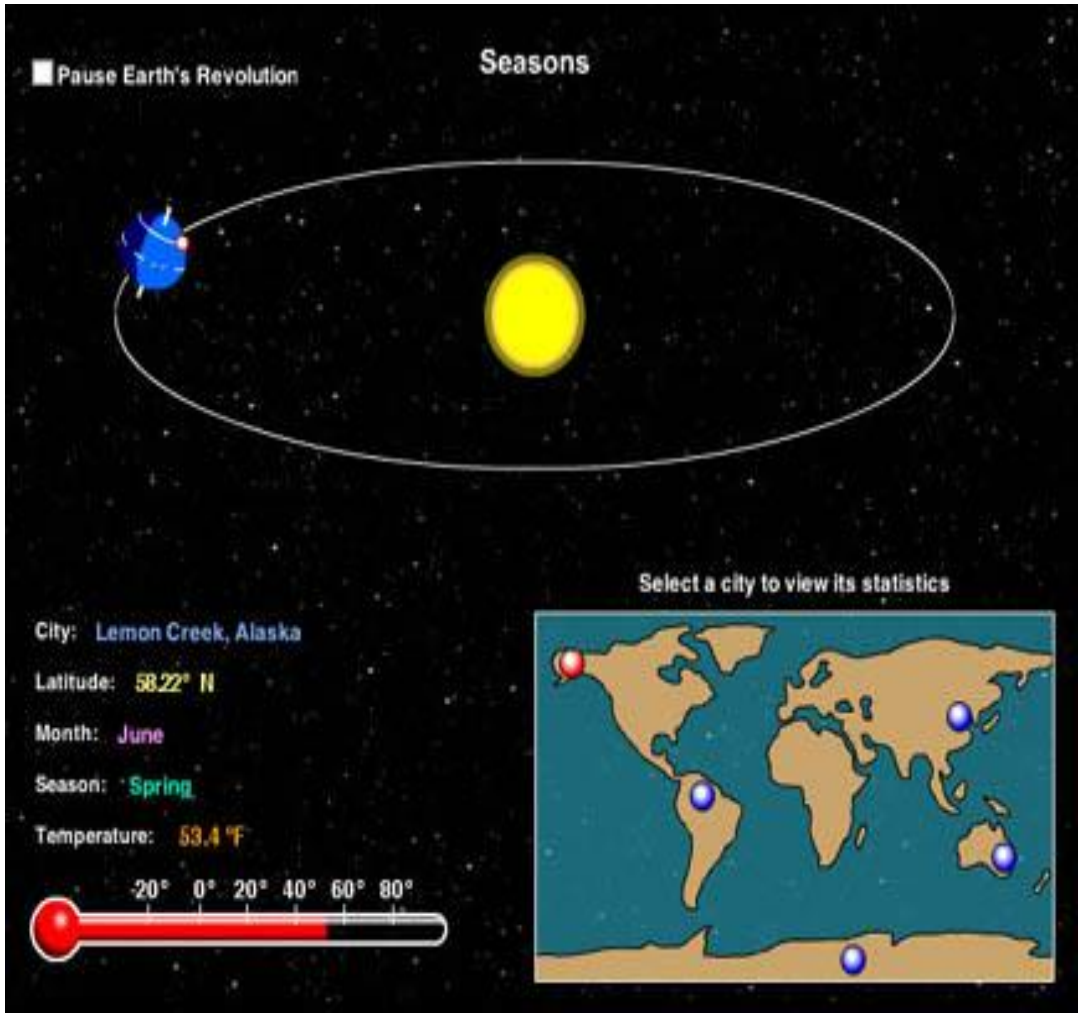
The Seasons (2)

The Seasons are only caused by a varying angle of incidence of the sun's rays.



They are **not** related to Earth's distance from the sun. In fact, Earth is slightly closer to the sun in (northern-hemisphere) winter than in summer.

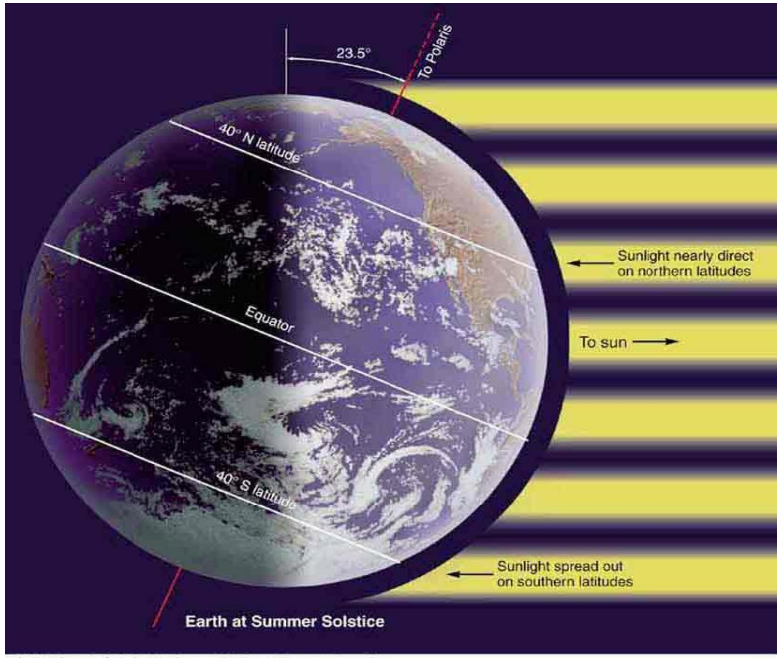
Seasons



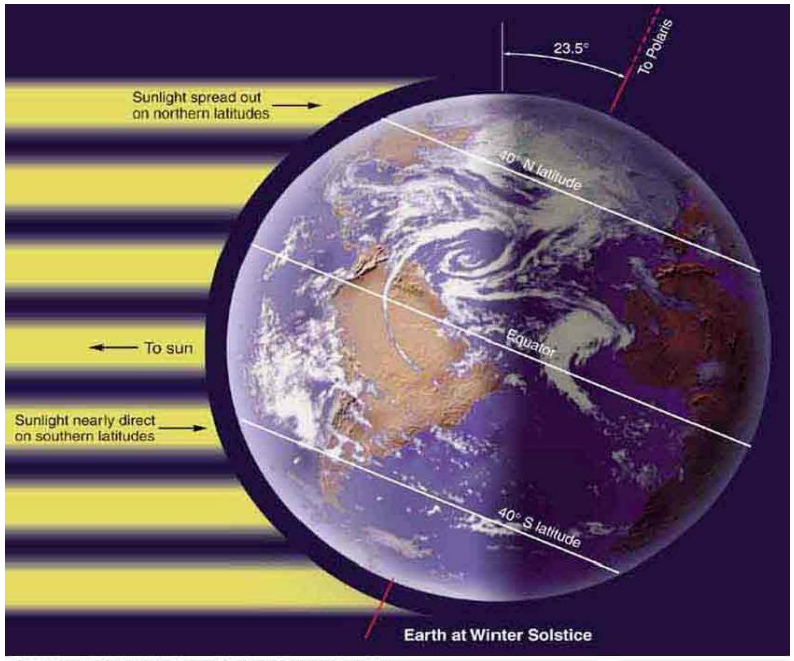
PLAY ANIMATION

(SLIDESHOW MODE ONLY)

The Seasons (3)



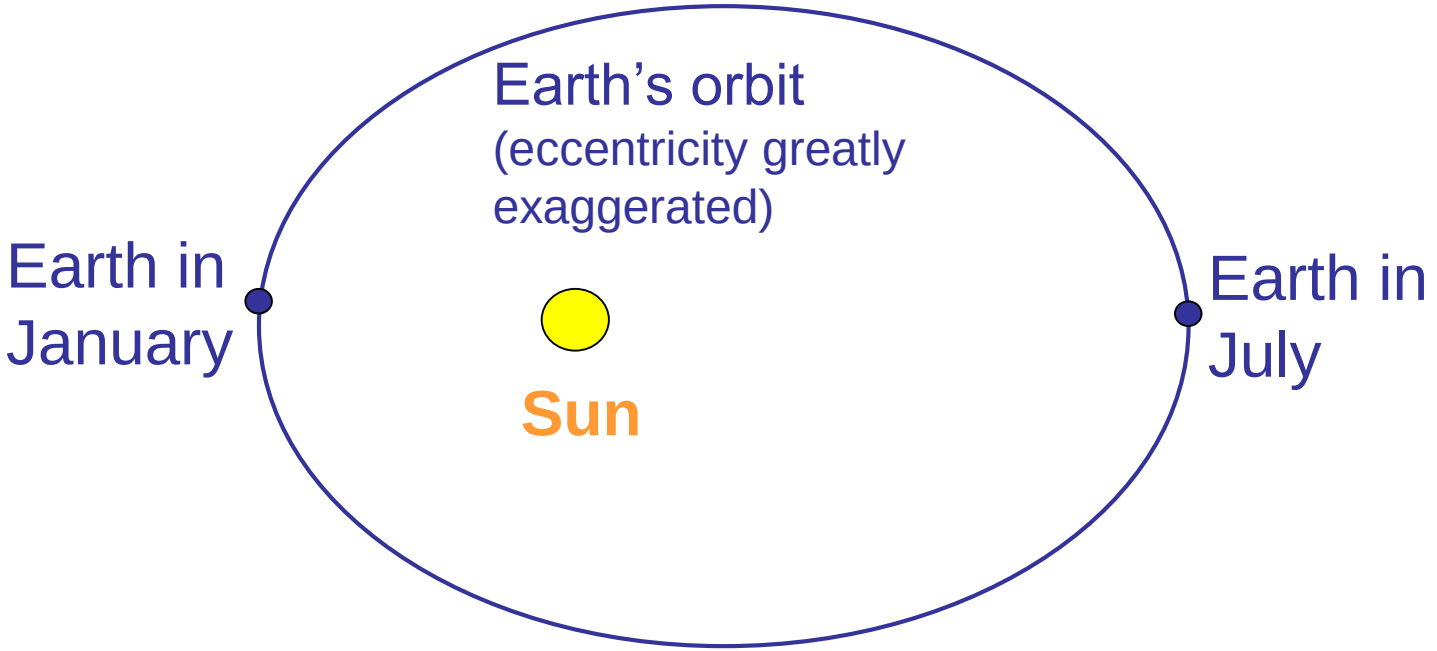
Northern summer = southern winter



Northern winter = southern summer

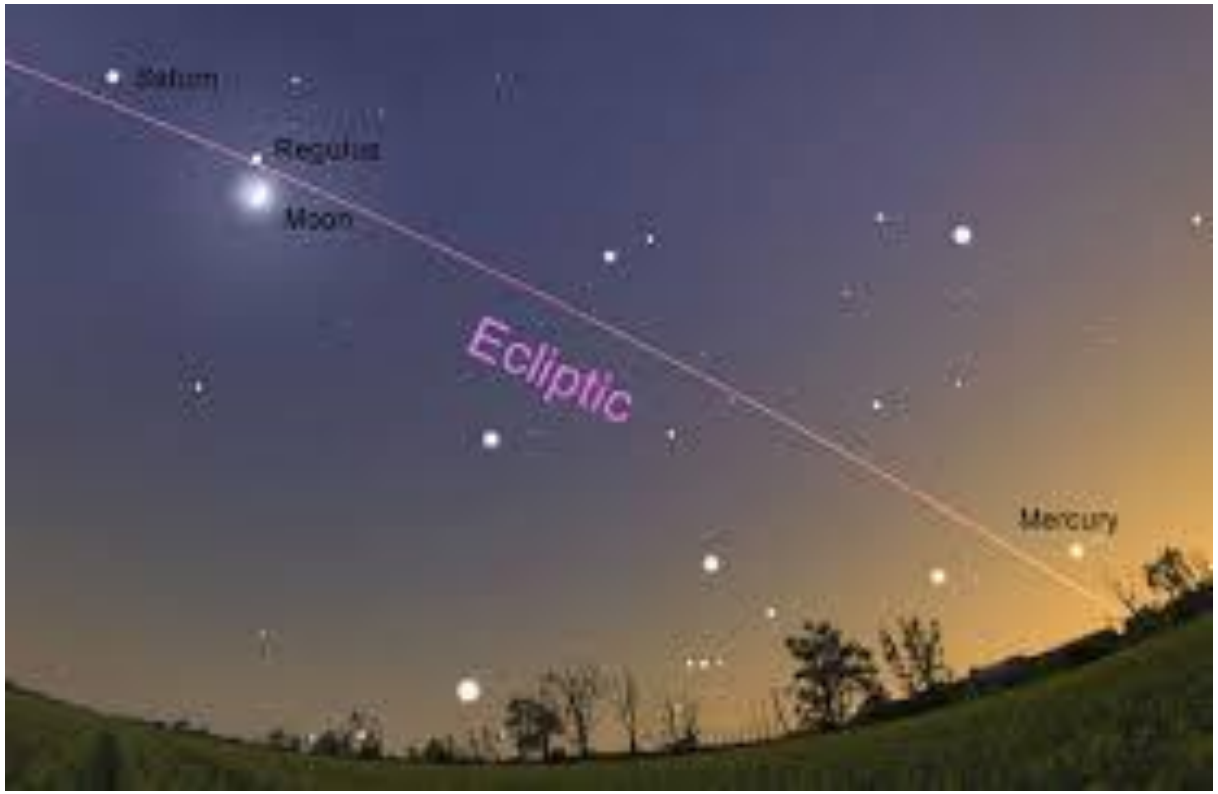
The Seasons (4)

Earth's distance from the sun has only a very minor influence on seasonal temperature variations.



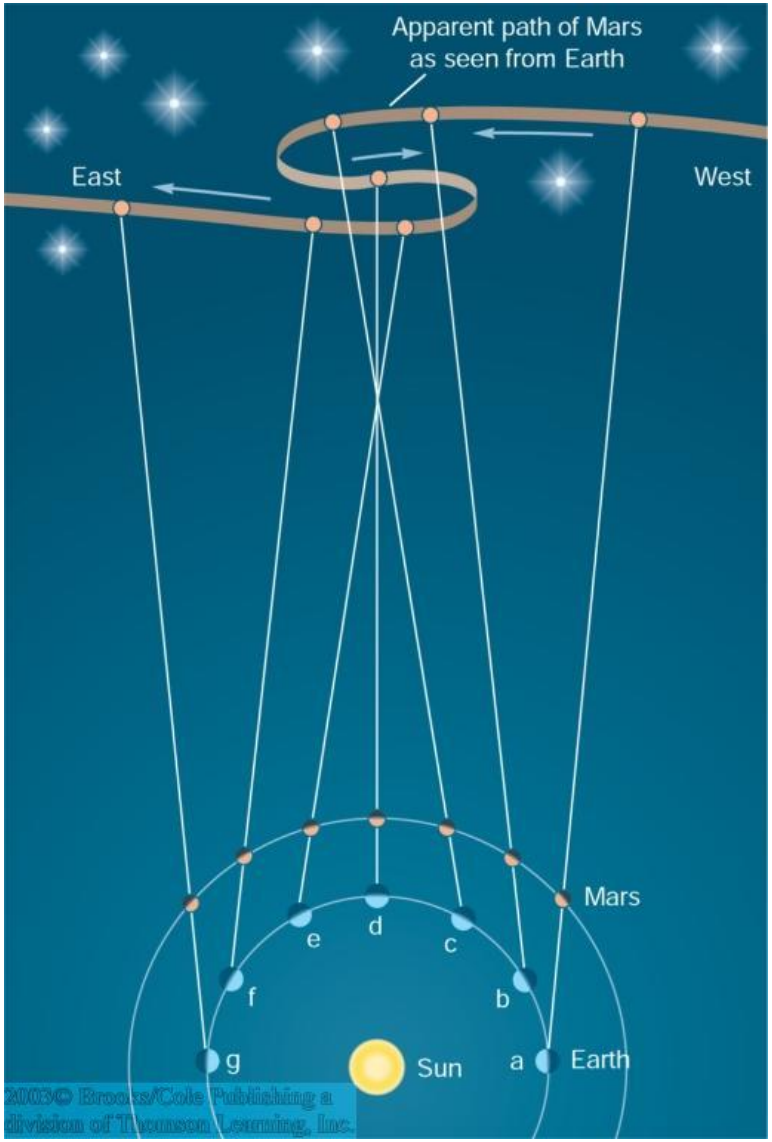
Planetary Motion

- The planets are orbiting the sun almost exactly in the plane of the ecliptic

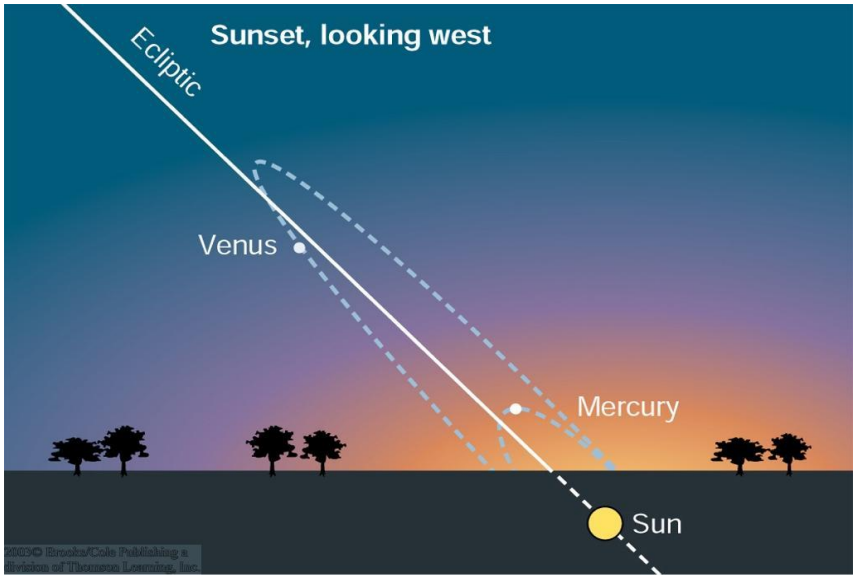


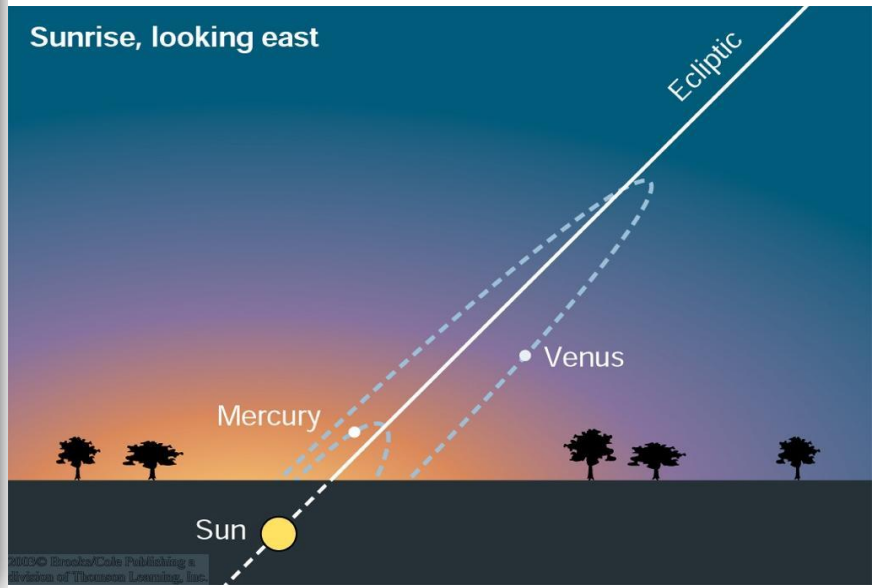
Planetary Motion

- All **outer planets** (Mars, Jupiter, Saturn, Uranus, Neptune and Pluto) generally appear to move eastward along the Ecliptic.
- The **inner planets** Mercury and Venus can never be seen at large angular distance from the sun and appear only as *morning* or *evening stars*.



The Motion of the Planets (3)





Mercury appears at most ~28° from the sun.

It can occasionally be seen shortly after sunset in the west or before sunrise in the east.

Venus appears at most ~46° from the sun.

It can occasionally be seen for at most a few hours after sunset in the west or before sunrise in the east.

Astronomical Influences on Earth's Climate

Factors affecting Earth's climate:

- Eccentricity of Earth's orbit around the Sun (varies over period of ~ 100,000 years)
- Precession (Period of ~ 26,000 years)
- Inclination of Earth's axis versus orbital plane

Milankovitch Hypothesis: Changes in all three of these aspects are responsible for long-term global climate changes (ice ages).

There is a Big Range of Stellar Luminosities Out there!

Star	Luminosity (in units of solar Luminosity)
Sun	1
Proxima Centauri	0.0006
Rigel (Orion)	70,000
Deneb (Cygnus)	170,000

New Terms

constellation
asterism
magnitude scale
apparent visual magnitude (m_v)
celestial sphere
horizon
zenith
nadir
north celestial pole
south celestial pole
celestial equator
north point
south point
east point
west point
angular distance
minute of arc
second of arc
angular diameter
circumpolar constellation
scientific model
precession
rotation
revolution
ecliptic
vernal equinox
summer solstice
autumnal equinox
winter solstice
perihelion
aphelion
evening star
morning star
zodiac
horoscope
Milankovitch hypothesis

Discussion Questions

1. Have you thought of the sky as a ceiling? as a dome overhead? as a sphere around Earth? as a limitless void?

2. How would the seasons be different if Earth were inclined 90° instead of 23.5°? 0° instead of 23.5°?

Quiz Questions

1. The remaining 48 ancient constellations that we still recognize today are located

a. along the ecliptic.
b. along the celestial equator.
c. near the south celestial pole.
d. at mid and northern celestial latitudes.
e. uniformly around the celestial sphere.

Quiz Questions

2. Which statement below most accurately describes modern constellations?

a. They are 88 well defined regions on the celestial sphere.
b. They are 88 connect-the-dot mythological sky figures.
c. They are 13 connect-the-dot mythological sky figures along the ecliptic.
d. They are 13 well defined sky regions along the ecliptic.
e. They are 88 groups of stars with members of each constellation physically close together in space.

Quiz Questions

3. What is the most likely Greek letter name of the second brightest star in the constellation Lyra?

a. alpha Lyrae.
b. beta Lyrae.
c. gamma Lyrae.
d. delta Lyrae.
e. epsilon Lyrae.

Quiz Questions

4. The apparent visual magnitudes of four stars are listed below. Of these four stars which one appears dimmest in the sky?

a. - 0.5
b. +2.8
c. -1.2
d. +0.7
e. It cannot be determined from the given information.

Quiz Questions

5. Which pair of apparent visual magnitudes listed below indicates that we receive about 16 times as much visible light from star W than from star X?

a. m_v star W = 16, and m_v star X = 1
b. m_v star W = 1, and m_v star X = 16
c. m_v star W = 1, and m_v star X = 6
d. m_v star W = 5, and m_v star X = 2
e. m_v star W = 2, and m_v star X = 5

Quiz Questions

6. The apparent visual magnitude of star A is 2 and the apparent visual magnitude of star B is 1. Based on this information which statement below must be true?

a. Star A emits more light than star B.
b. Star B emits more light than star A.
c. Star A is closer than star B.
d. Star B is closer than star A.
e. Light output and distance cannot be determined from a star's apparent visual magnitude alone.

Quiz Questions

7. If the apparent visual magnitude of the Sun is -26.5 and that of the full moon is -12.5, what is the light intensity ratio of sunlight to moonlight received at Earth on the day of the full moon?

a. 40
b. 100
c. 4000
d. 10,000
e. 400,000

Quiz Questions

8. When you observe a star on the celestial equator for a period of a few hours, you notice that it

a. moves from north to south relative to the horizon.
b. moves from south to north relative to the horizon.
c. moves from east to west relative to the horizon.
d. moves from west to east relative to the horizon.
e. does not move relative to the horizon.

Quiz Questions

9. What is responsible for the motion described in the previous question?

a. All celestial objects orbit around Earth.
b. Earth's rotation on its axis.
c. Earth's revolution around the Sun.
d. The Sun's motion around the center of the galaxy.
e. The motion of Earth's tectonic plates.

Quiz Questions

10. At what location on Earth is an observer who has the south celestial pole directly overhead?

a. At Earth's equator (0 degrees latitude).
b. At Earth's North Pole (90 degrees North latitude).
c. At Earth's South Pole (90 degrees South latitude).
d. At 45 degrees North latitude.
e. At 45 degrees South latitude.

Quiz Questions

11. At what location on Earth is an observer who has the celestial equator passing through a point directly overhead?

a. At Earth's equator (0 degrees latitude).
b. At Earth's North Pole (90 degrees North latitude).
c. At Earth's South Pole (90 degrees South latitude).
d. At 45 degrees North latitude.
e. At 45 degrees South latitude.

Quiz Questions

12. If the tilt of Earth's axis were to change from 23.5 degrees to 0 degrees what celestial circles would coincide for all observers?

a. The celestial equator and the horizon.
b. The horizon and the ecliptic.
c. The celestial equator and the ecliptic.
d. The horizon and the celestial equator.
e. The horizon, the ecliptic, and the celestial equator.

Quiz Questions

13. Why does the rotational axis of Earth precess?

a. The Sun and Moon pull on Earth's equatorial bulge.
b. The Earth's spin rate is decreasing.
c. The Earth's spin rate is increasing.
d. The shrinking of the Antarctic ice sheet, brought on by global warming.
e. The Sun's magnetic field interacts with Earth's magnetic field.

Quiz Questions

14. The precession of Earth's rotational axis causes the location of the

a. north celestial pole and south celestial pole to change.
b. vernal equinox and autumnal equinox to change.
c. summer solstice and winter solstice to change.
d. Both a and b above.
e. All of the above.

Quiz Questions

15. If you could see the Sun and stars during the daytime for several weeks you would notice that the Sun

a. never moves relative to the stars.
b. moves slowly westward relative to the stars.
c. moves slowly eastward relative to the stars.
d. sometimes moves westward and at other times eastward relative to the stars.
e. rises in the west and sets in the east.

Quiz Questions

16. Why does the Sun move relative to the stars as described in the previous question?

a. It is due to Earth rotating on its axis.
b. It is due to Earth revolving around the Sun.
c. It is due to the Sun rotating on its axis.
d. It is due to the Sun revolving around the center of our galaxy.
e. The Sun does not move relative to the stars.

Quiz Questions

17. Why is amount of solar heating less on a clear day in January at northern latitudes than on a clear day in July?

a. The Sun is above the horizon for less than 12 hours in January in the north.
b. Earth is farther from the Sun in January and closer in July.
c. At low Sun angles, the received sunlight is spread over a larger surface area.
d. Both a and b above.
e. Both a and c above.

Quiz Questions

18. When it is autumn in Asia, what season is it in Antarctica?

a. Autumn.
b. Winter.
c. Spring.
d. Summer.
e. Antarctica does not have seasons.

Quiz Questions

19. The five naked-eye planets and three telescopic planets that wander among the stars in the sky are always near the

a. horizon.
b. celestial equator.
c. ecliptic.
d. Moon.
e. Sun.

Quiz Questions

20. The Milankovitch hypothesis proposes that the ice ages on Earth are due to long-term changes in the amount of seasonal solar heating brought about by

a. changes in the shape of Earth's orbit.
b. precession of Earth's rotational axis.
c. changes in the tilt angle of Earth's rotational axis.
d. Both a and c above.
e. All of the above.

Answers

1. d
2. a
3. b
4. b
5. e
6. e
7. e
8. c
9. b
10. c
11. a
12. c
13. a
14. e
15. c
16. b
17. e
18. c
19. c
20. e