

**WEEK 2 Outline**  
**Stellar and Galactic ...**

# Astronomy

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# The Naked – Eye Universe

## Constellations and Asterisms

***Constellation:*** a designated region in the sky containing one or more historical star patterns.

***Asterism:*** a recognizable pattern of stars.

**Ex) Orion**

**Ex) Ursa Major**

**Ex) Taurus**

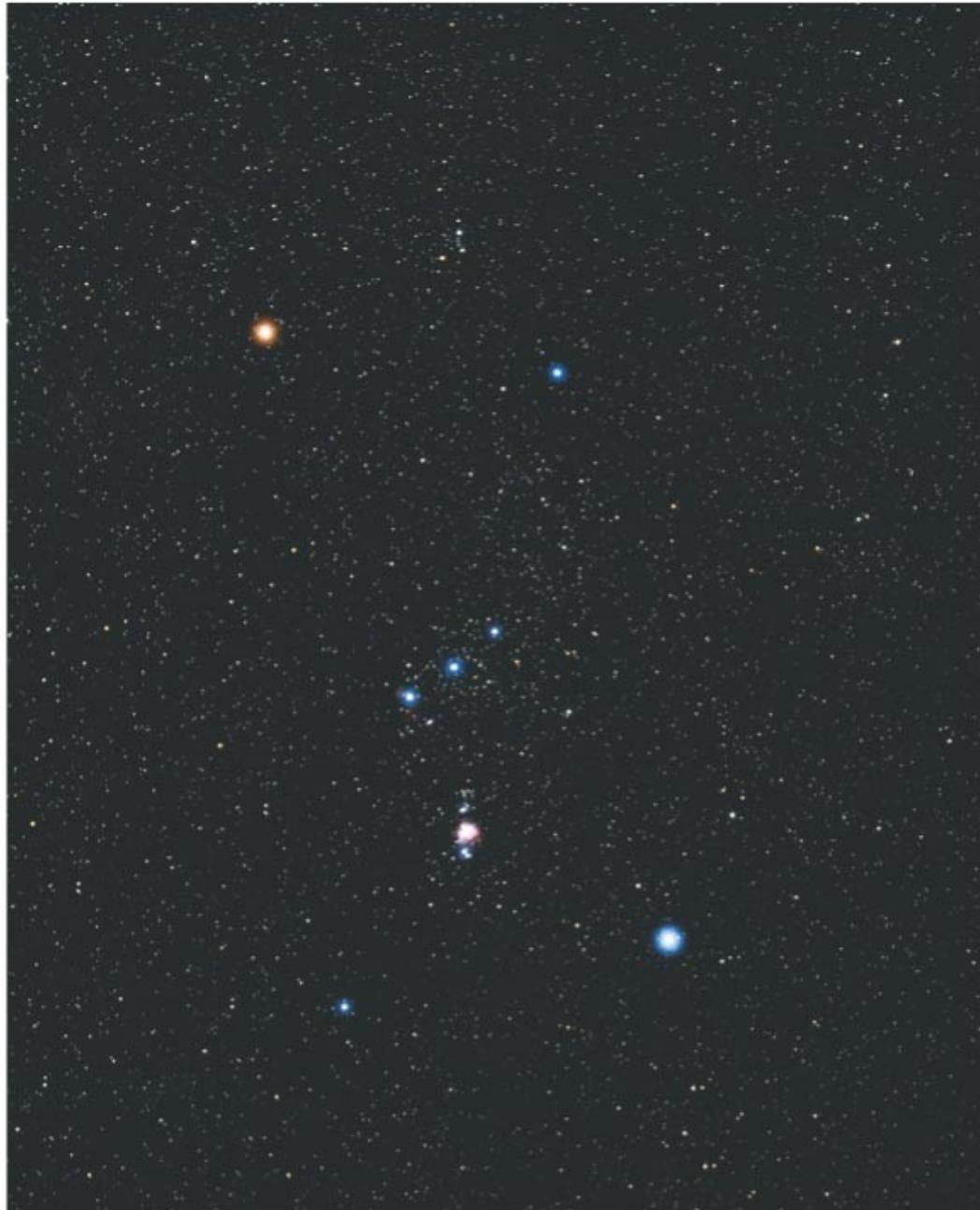
**\* 88 total constellations**

**\* Northern constellations named after Greek Mythological characters**

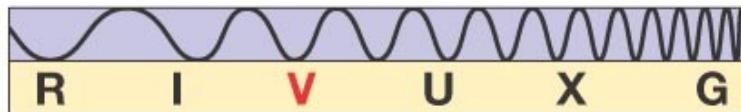
**Example:  
Orion.**

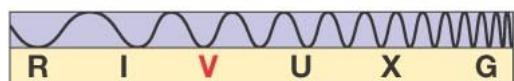
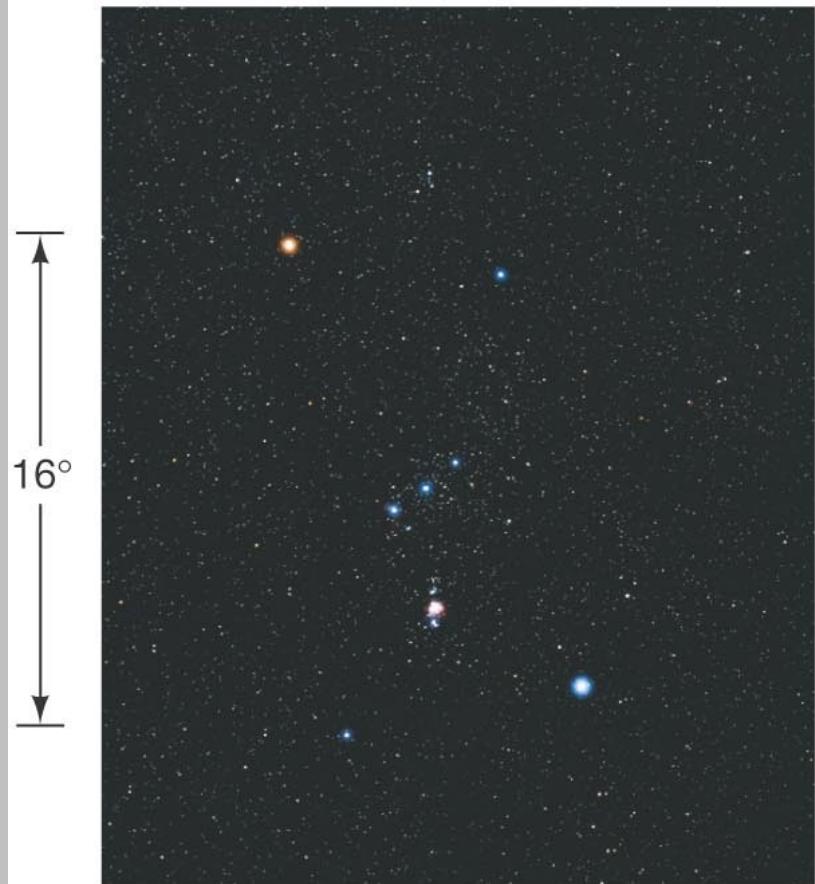
**An easily  
recognized  
constellation!**

16°

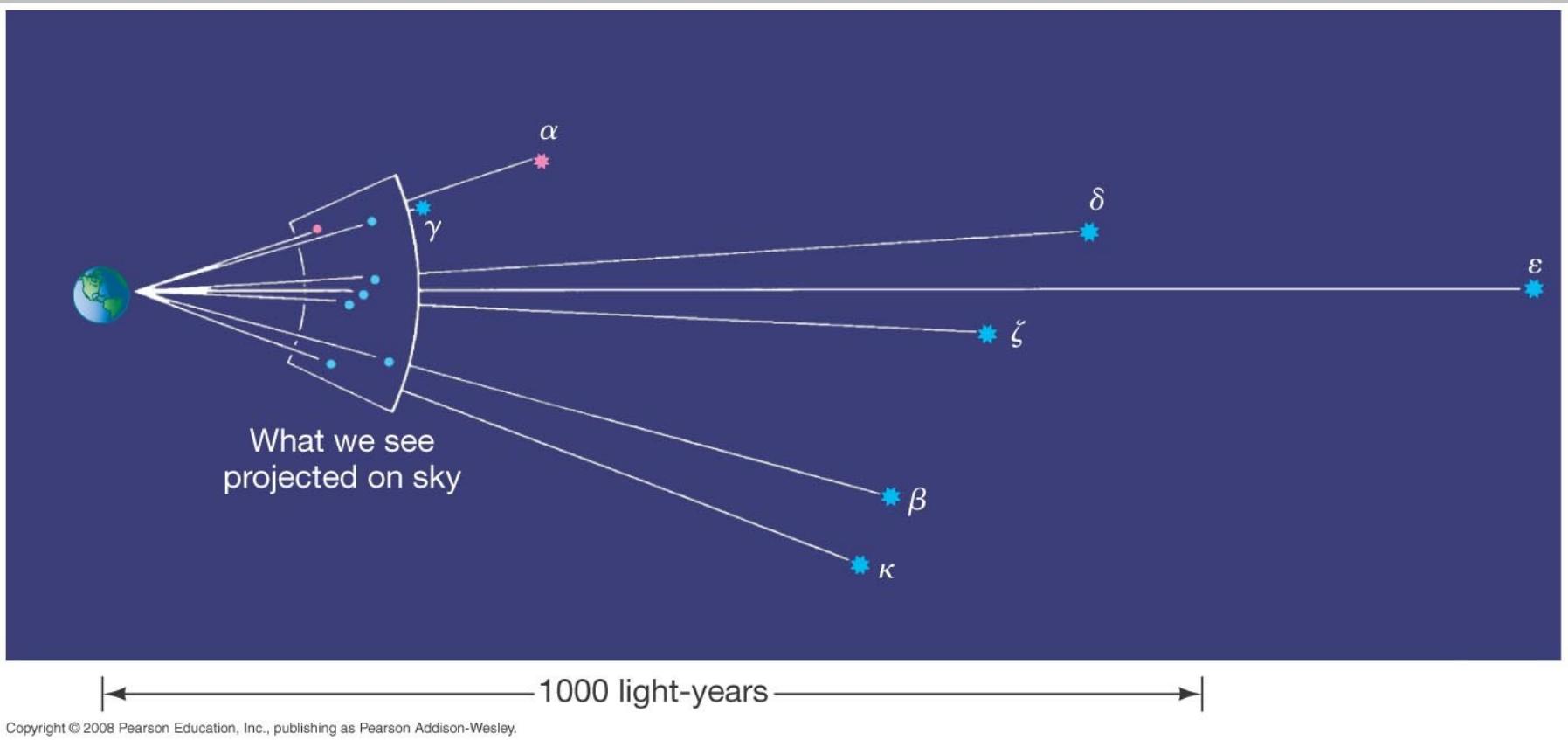


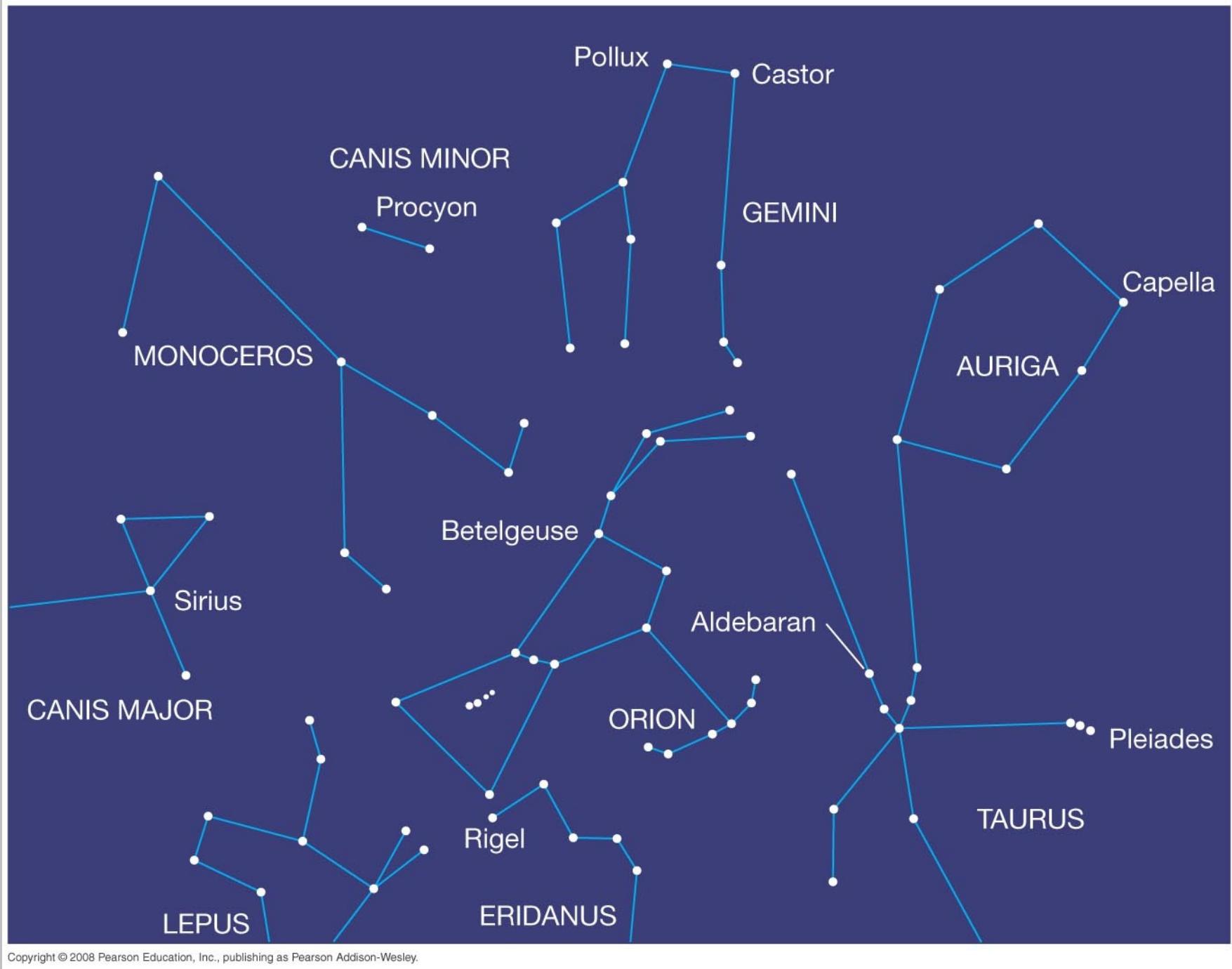
(a)





(b)

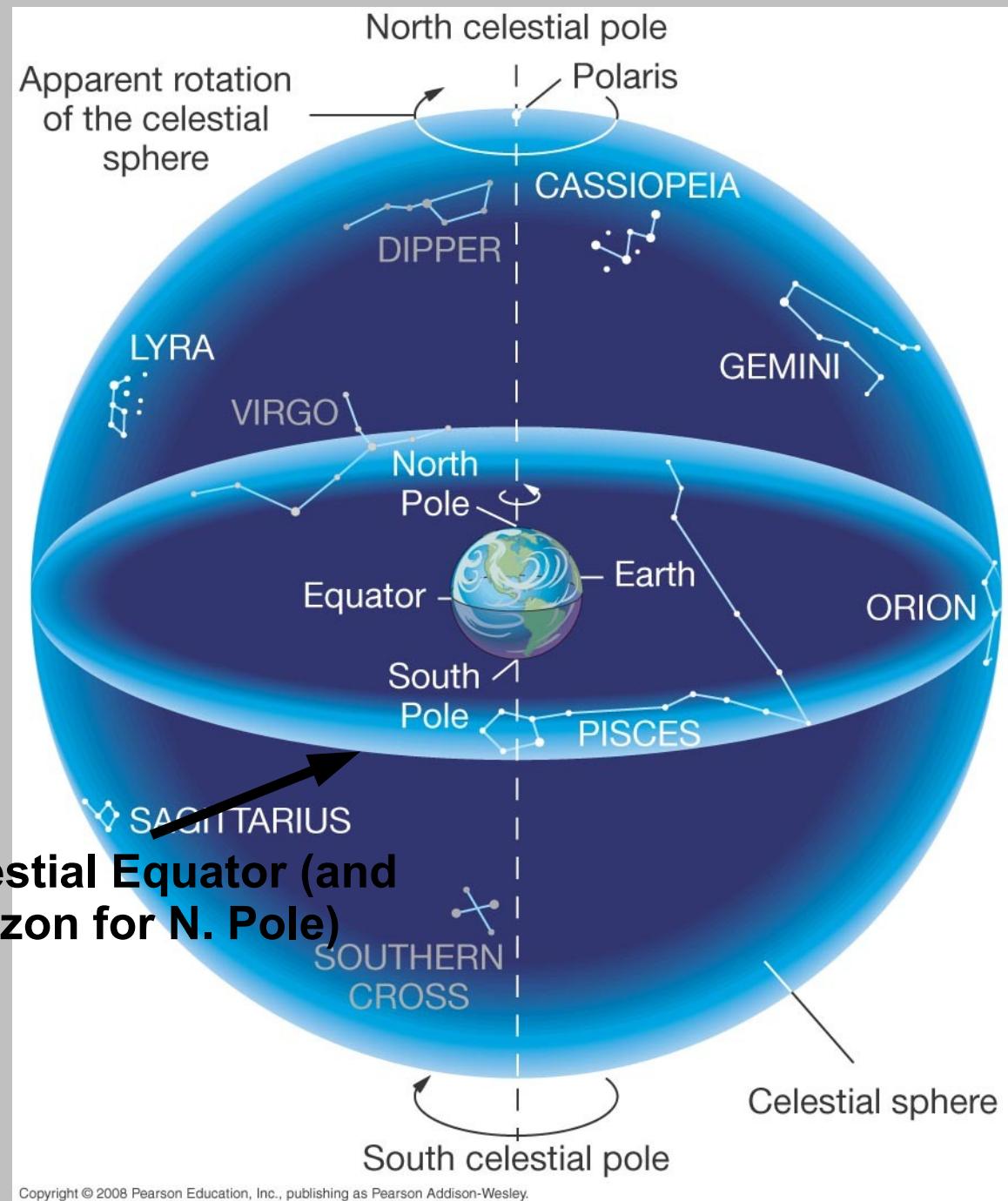




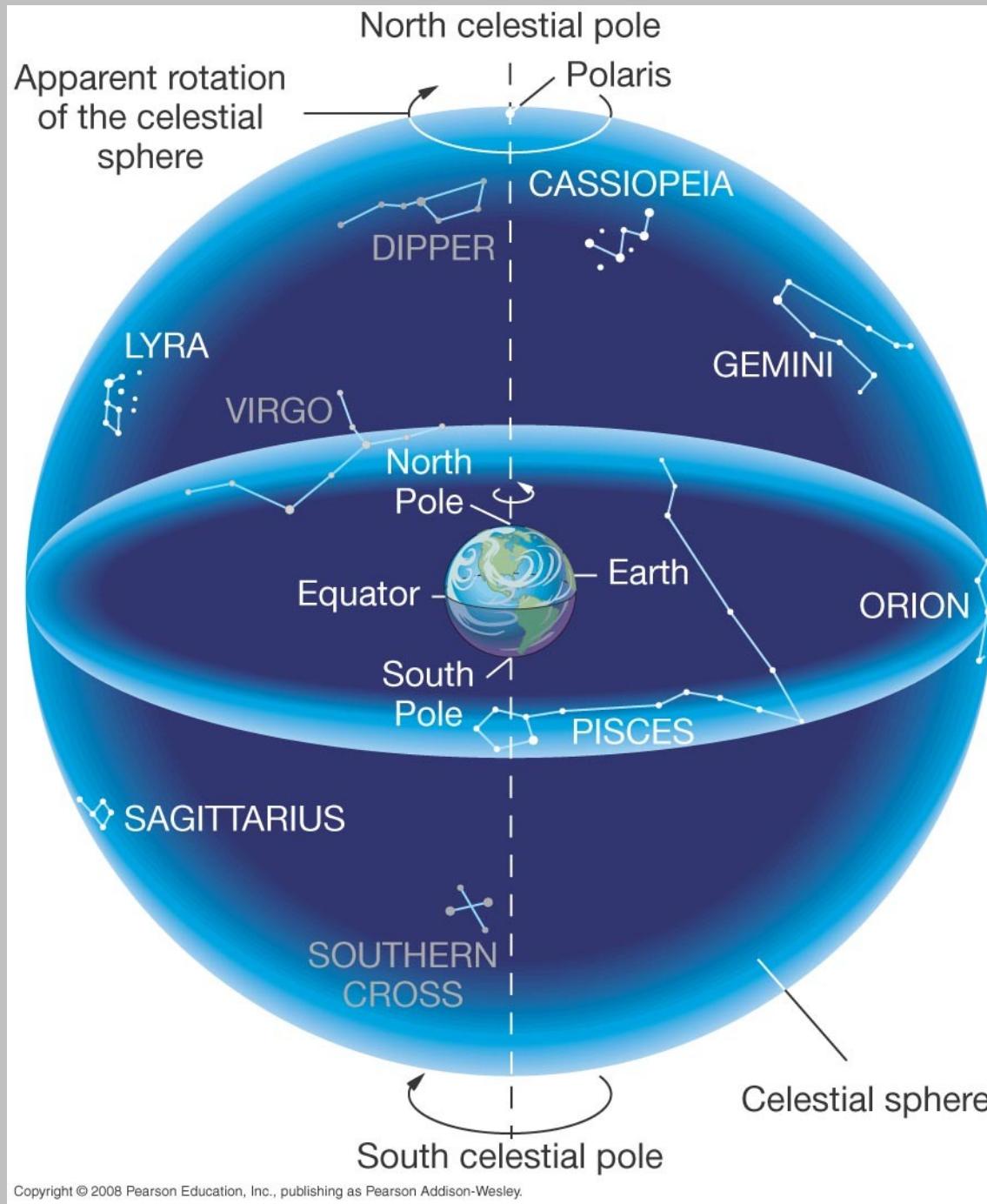
Try a planetarium program like “Stellarium” or “Skychart III” or “Celestia” to see the sky in motion.

# The Celestial Sphere

- a conceptual model of the sky.
- geocentric (wrong)
- all stars at same distance (wrong)
- a distortion-free sky map
- reproduces daily rising and setting motions for any latitude on Earth
- Cel. Sphere is infinitely bigger than the Earth.



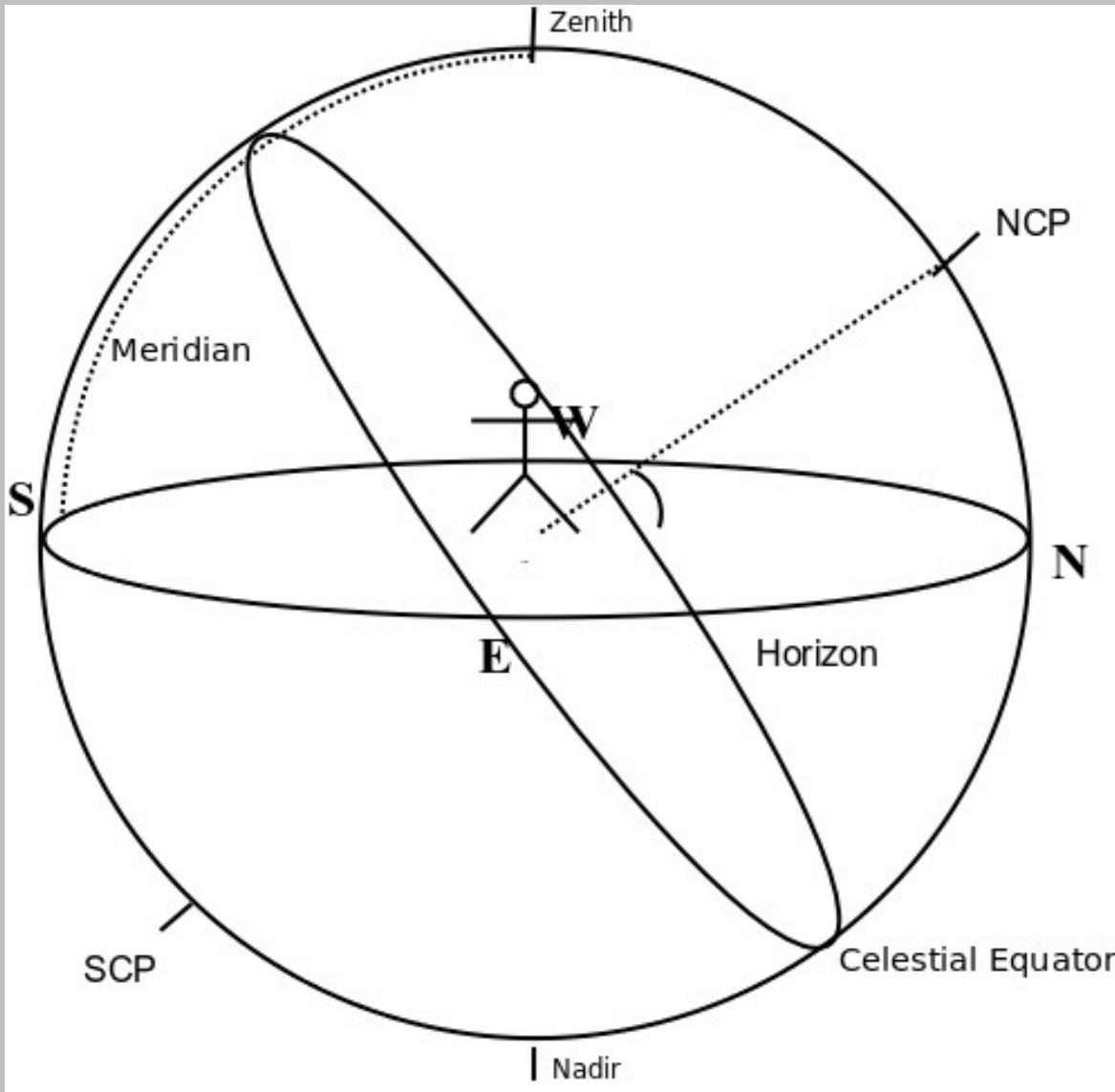
# The Celestial Sphere



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## Features:

1. stars
2. Earth/observer
3. N. Celestial Pole
4. S. Celestial Pole
5. Celestial Equator



## The Celestial Sphere

### More Features:

1. stars
2. Earth/observer
3. N. Celestial Pole
4. S. Celestial Pole
5. Celestial Equator
6. Horizon
7. Cardinal points, (N,S,E,W)
8. Zenith
9. Nadir
10. Meridian

# Coordinate Systems for the sky

## Altazimuth coordinate system

Uses the horizon for it's zeropoints.

A star's coordinates are different for observers on different parts of Earth

**Altitude** = angle measured above (or below) the horizon in degrees.

**Azimuth** = angle measured along the horizon in degrees such that  $0^\circ$  azimuth is due North,  $90^\circ$  is due East, etc.

Ex) Polaris

Altitude = 40.75 degrees (our latitude)

Azimuth = 0 degrees (straight above N on horizon)

# Coordinate Systems for the sky

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## Equatorial (or Celestial) coordinate system

Uses the Celestial equator and ecliptic to define zeropoints.

A star's coordinates are the same for all observers!

*Right Ascension*, RA = distance measured in hours, minutes and seconds along the celestial equator such that RA=0h at the vernal equinox and RA=6h at the Summer Solstice.

*Declination*, DEC = Angle measured in degrees, arcminutes and arcseconds above the celestial equator such that DEC =  $0^\circ$  on the cel. equator, increasing to  $+90^\circ$  at the NCP and  $-90^\circ$  at the SCP.

# Coordinate Systems for the sky

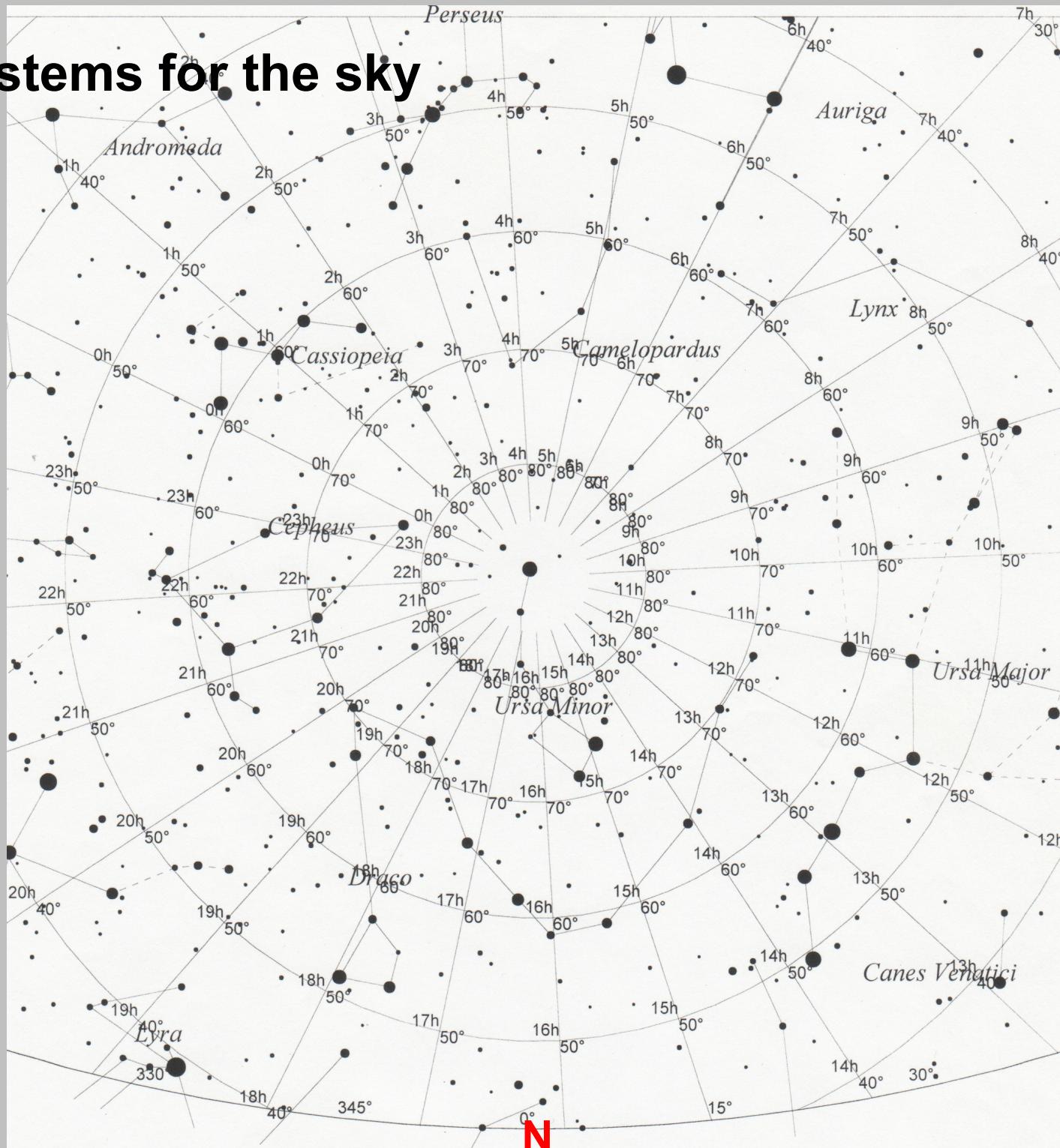
Example 1)

Equatorial:

Polaris at  
Dec=90°  
RA = ~2hr

Altazimuth:

Polaris has  
Alt = 46°  
Azim = 0°



# Coordinate Systems for the sky

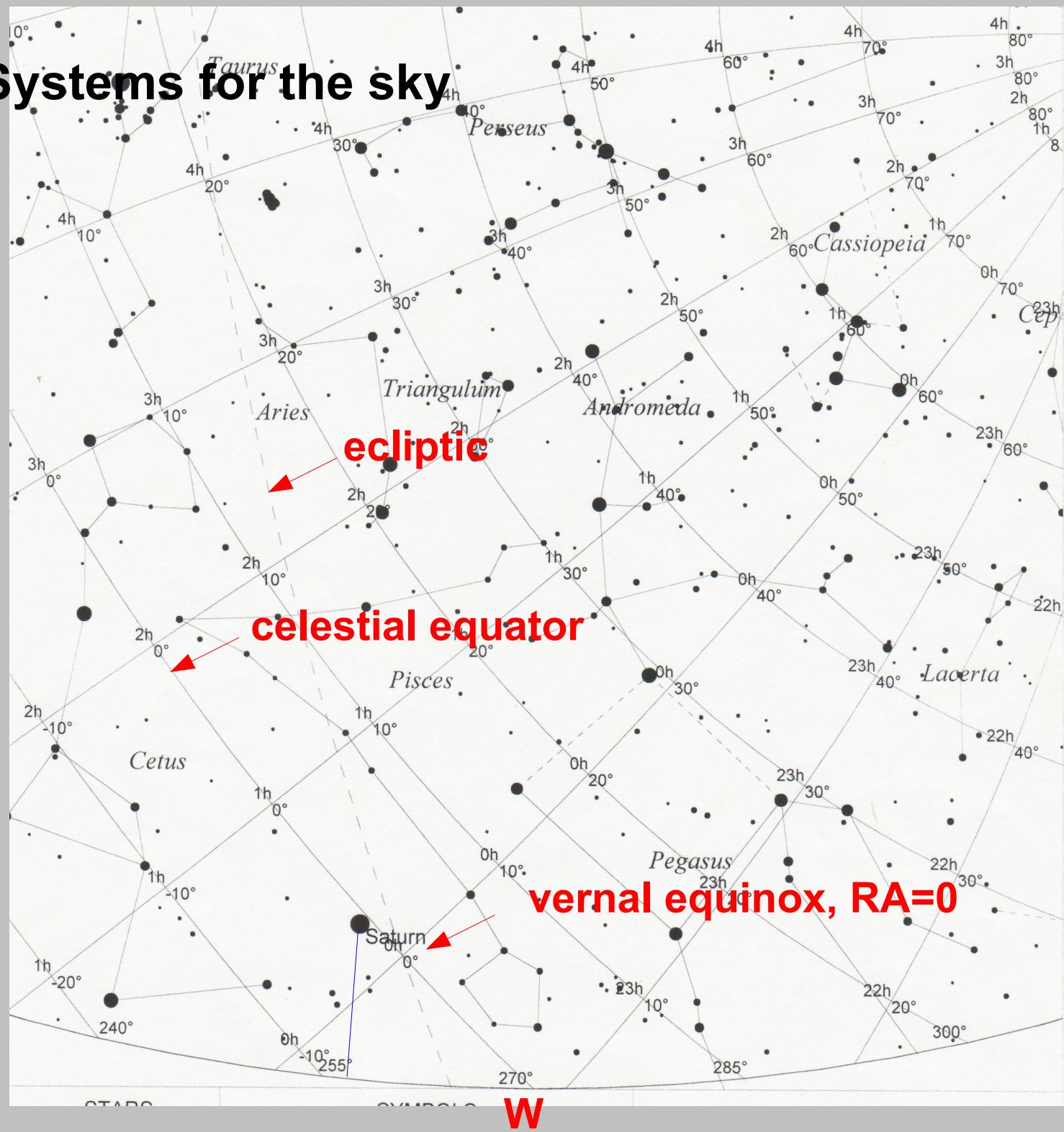
Example 2)

Equatorial:

Saturn has  
Dec= $-1^\circ$   
RA = 0h 15m

Altazimuth:

Saturn has  
Alt =  $13^\circ$   
Azim =  $257^\circ$



# **Angles, distances and widths**

**Angles are measured in degrees, arcminutes, and arcseconds.**

**1 degree ( $^{\circ}$ ) is  $1/360$  of a complete rotation**

**1 arcminute ( $'$ ) is  $1/60$  of a degree**

**1 arcsecond ( $''$ ) is  $1/60$  of an arcminute**

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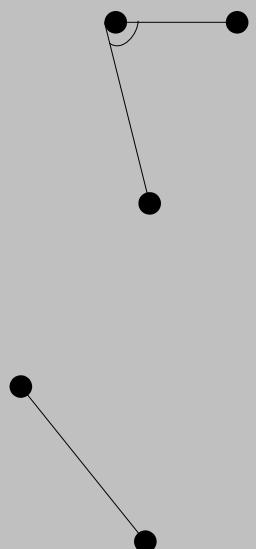
1 arcsecond ( $"$ ) is 1/60 of an arcminute

Angles on the sky can be defined in two ways:

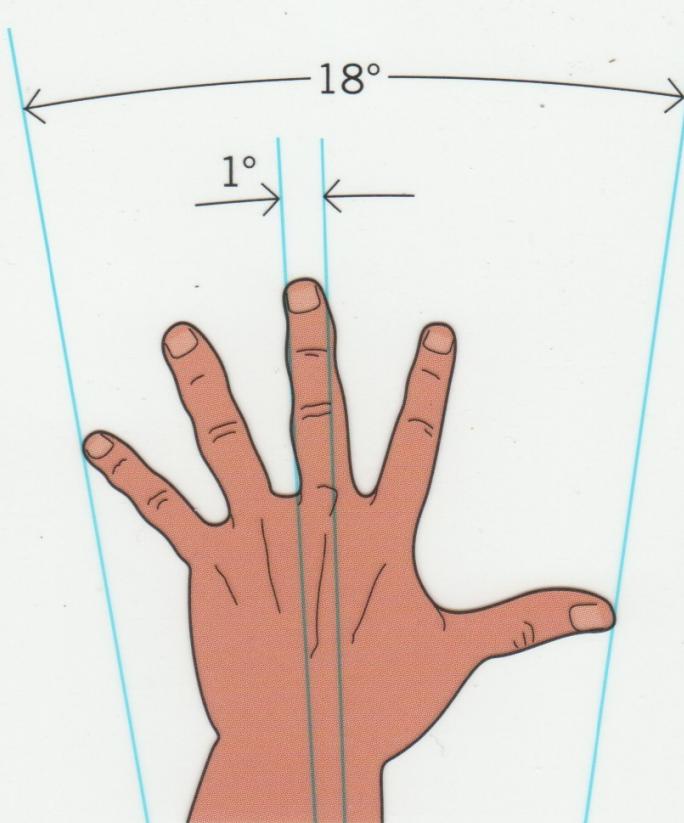
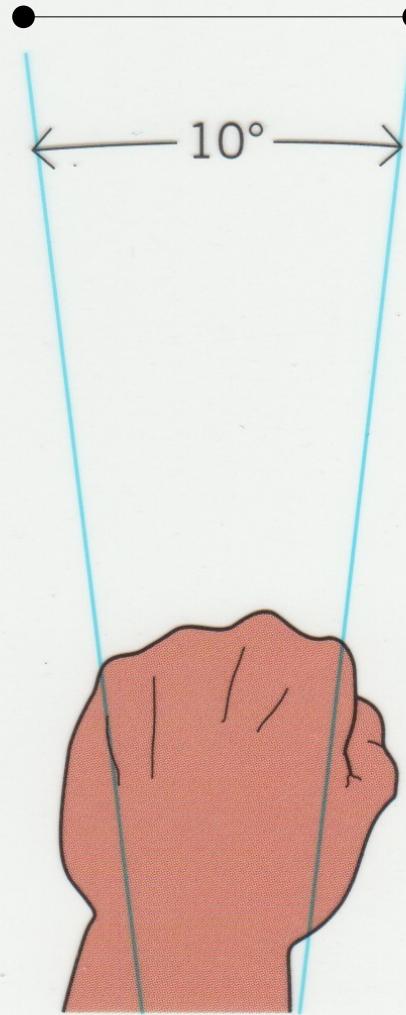
1) Think of the sky as a flat paper with lines connecting one star to two others. An angle can be drawn between those two lines where they intersect.

2) angular separations between two stars as you would estimate using your fist at arm's length.

Mostly we use #2.



# Angles, distances and widths



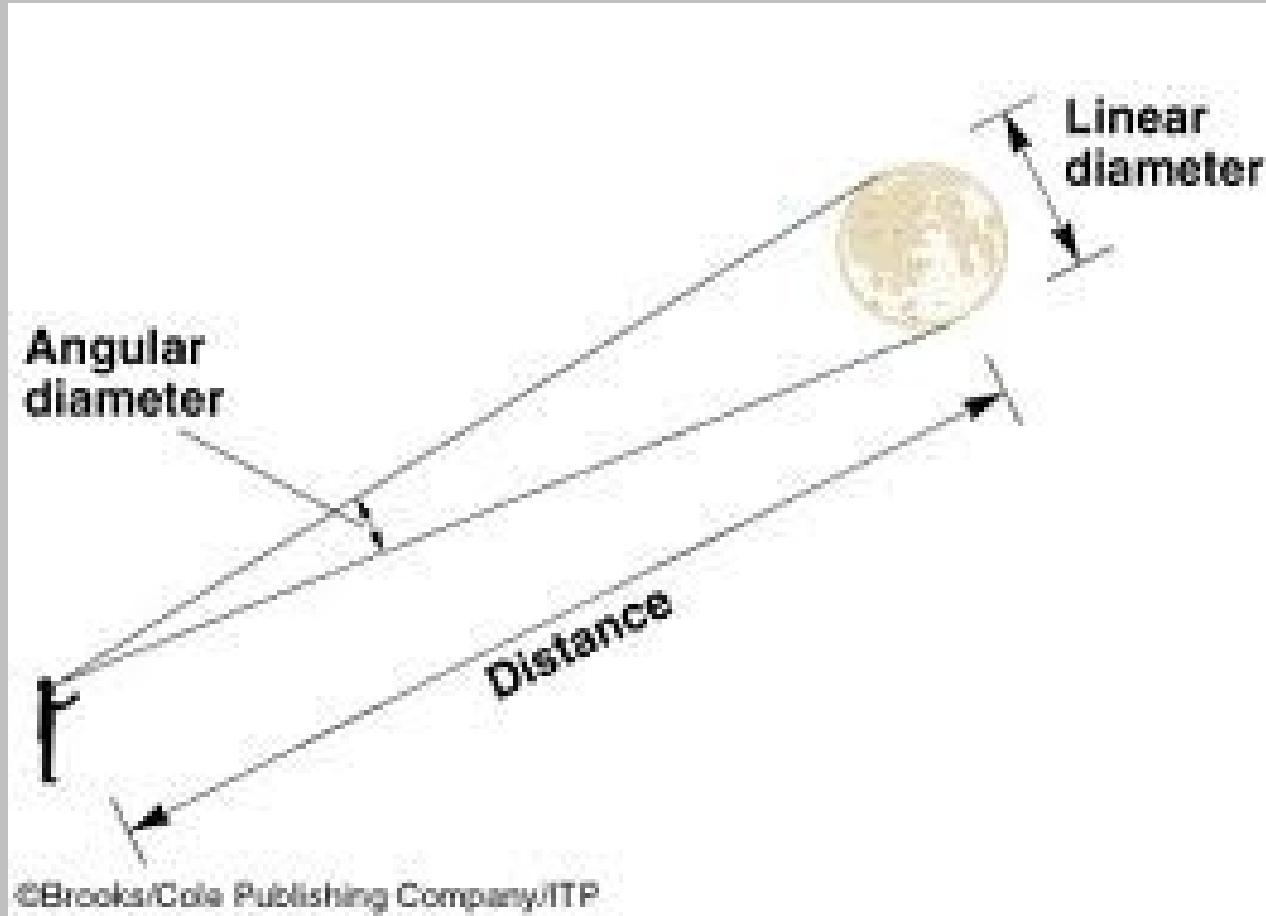
# Angles, distances and widths

Calibrate using the Big Dipper!



# Angles, distances and widths

## Relationship between linear diameter and angular diameter

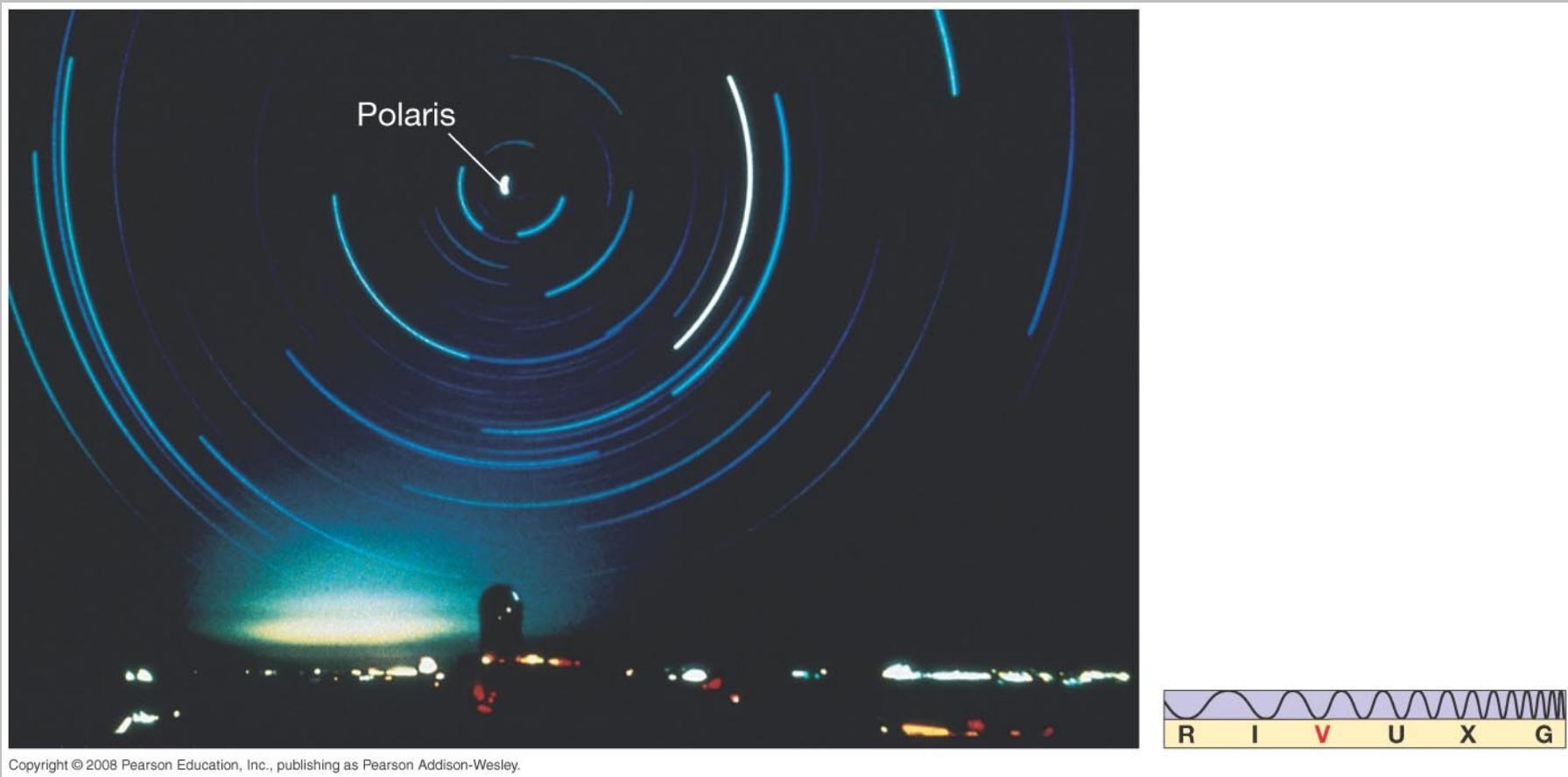


$$AD(\text{radians}) = LD/D$$

$$AD(\text{degrees}) = (57.3)LD/D$$

# Motion of the Earth - Daily

Star Trail – an actual photo of Northern horizon. Exposure time was about 5 hours.



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Now show the daily rotation with a Celestial Globe.

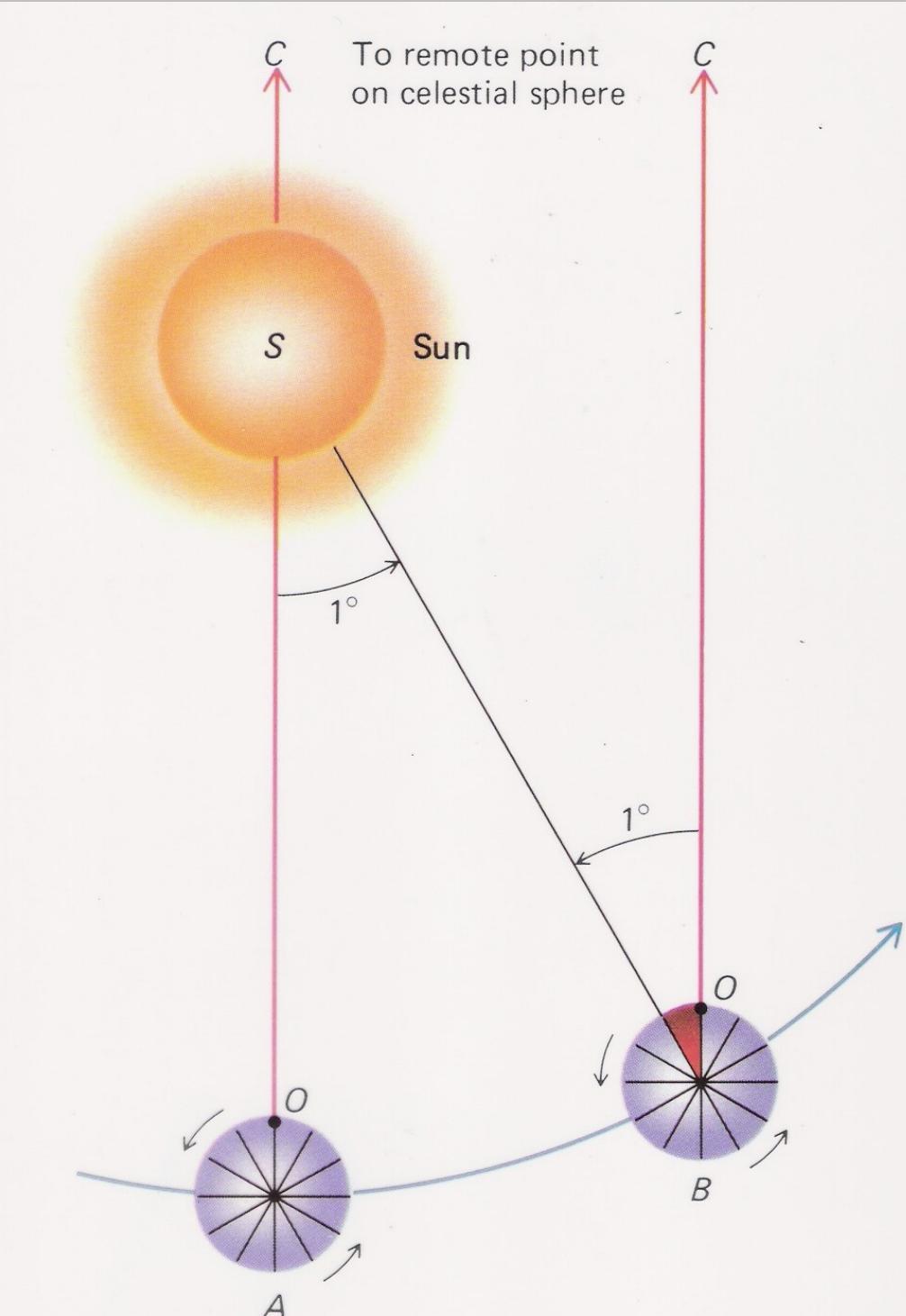
# Motion of the Earth – Daily

## The Day

**Sidereal Day:** the time that it takes for the Earth to rotate 360 degrees relative to the distant stars

**Mean Solar Day:** the average time that it takes for the Earth to rotate relative to the Sun.  
(E.g., from one noon to the next.)

- \* What your watch tells you
- \* 3 m 56 s longer than the sidereal day
- \* “Mean” because the time between local noons varies.
  - Obliquity (tilt) of ecliptic
  - Elliptical orbit

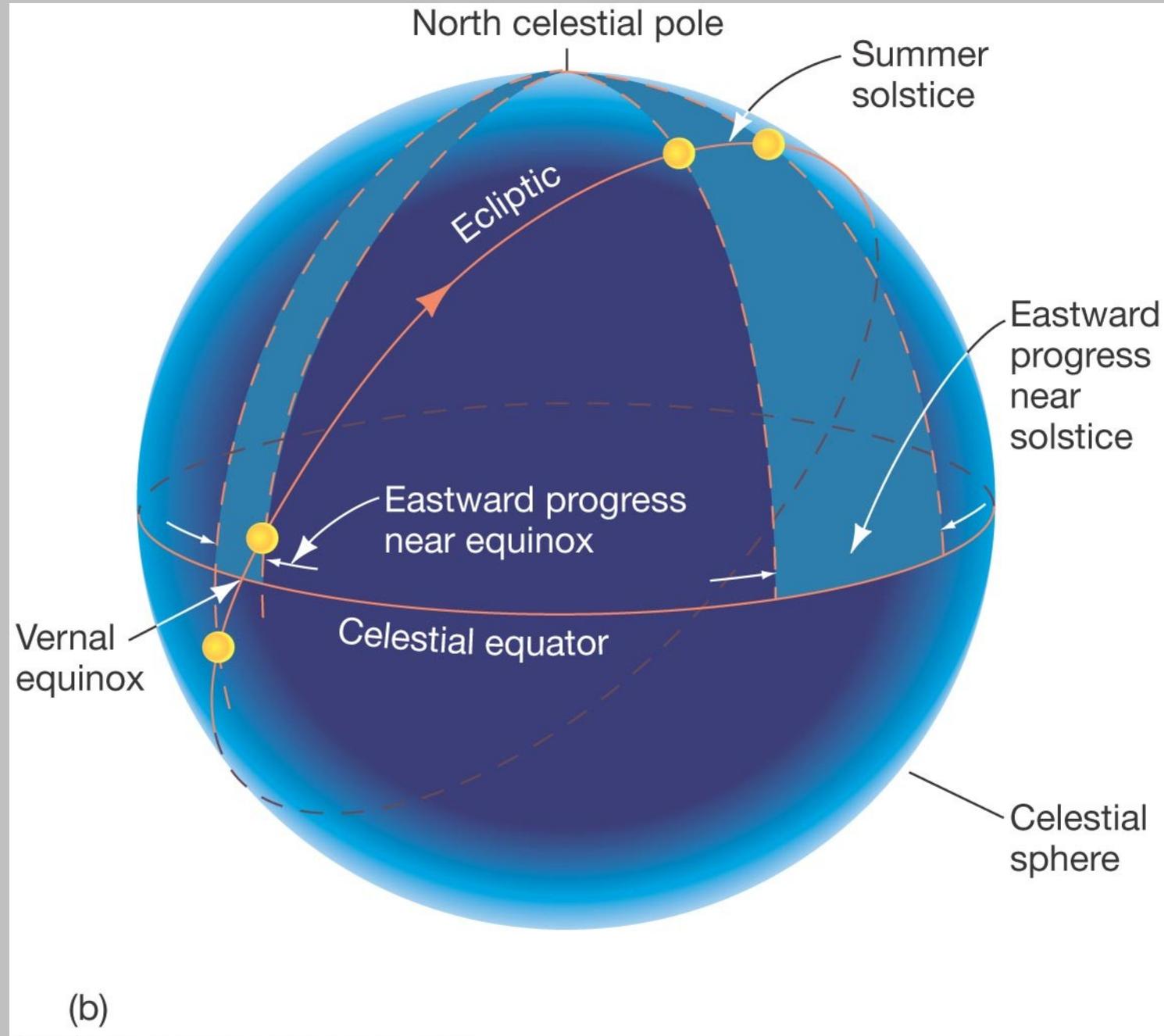


# Motion of the Earth - Daily

Since the ecliptic is tilted, the rate of the Sun's apparent motion *Eastward* relative to the stars changes.

(It is fast during the solstices and slow during the equinoxes.)

So the length of the *Apparent Solar Day* changes.



The ASD is *longer* during solstices

# Motion of the Earth – Daily

Here's what you get when you take a picture of the Sun at the same time (standard time) once every couple of weeks for a year.

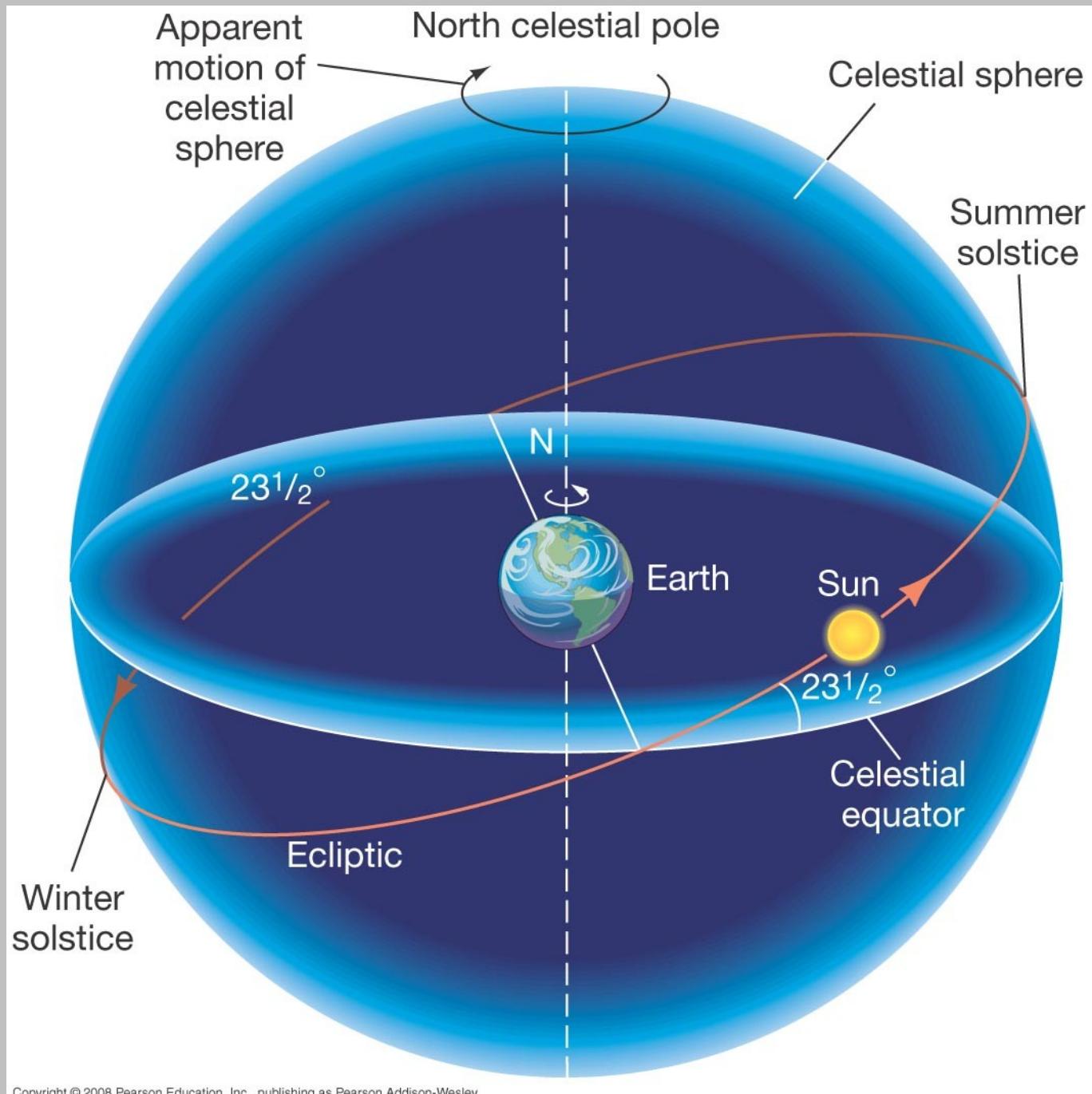
The ***analemma*** is asymmetric because the Earth's orbit is an ellipse.

The summer solstice is a little before aphelion (when we are farthest from Sun). The winter solstice is a little before perihelion (Jan 4, when we are closest to the Sun.)



# Motion of the Earth - Annual

The Sun appears to go around the Earth once per year, but it is the Earth that goes around the Sun.



# Motion of the Earth – Annual

## The Year

***Sidereal year:*** the time it takes for the Earth to revolve around the Sun with respect to the stars.

\* 365.2564 mean solar days

***Tropical Year*** = time between two successive passages of the Sun past the *Vernal Equinox*

\* 365.2422 days

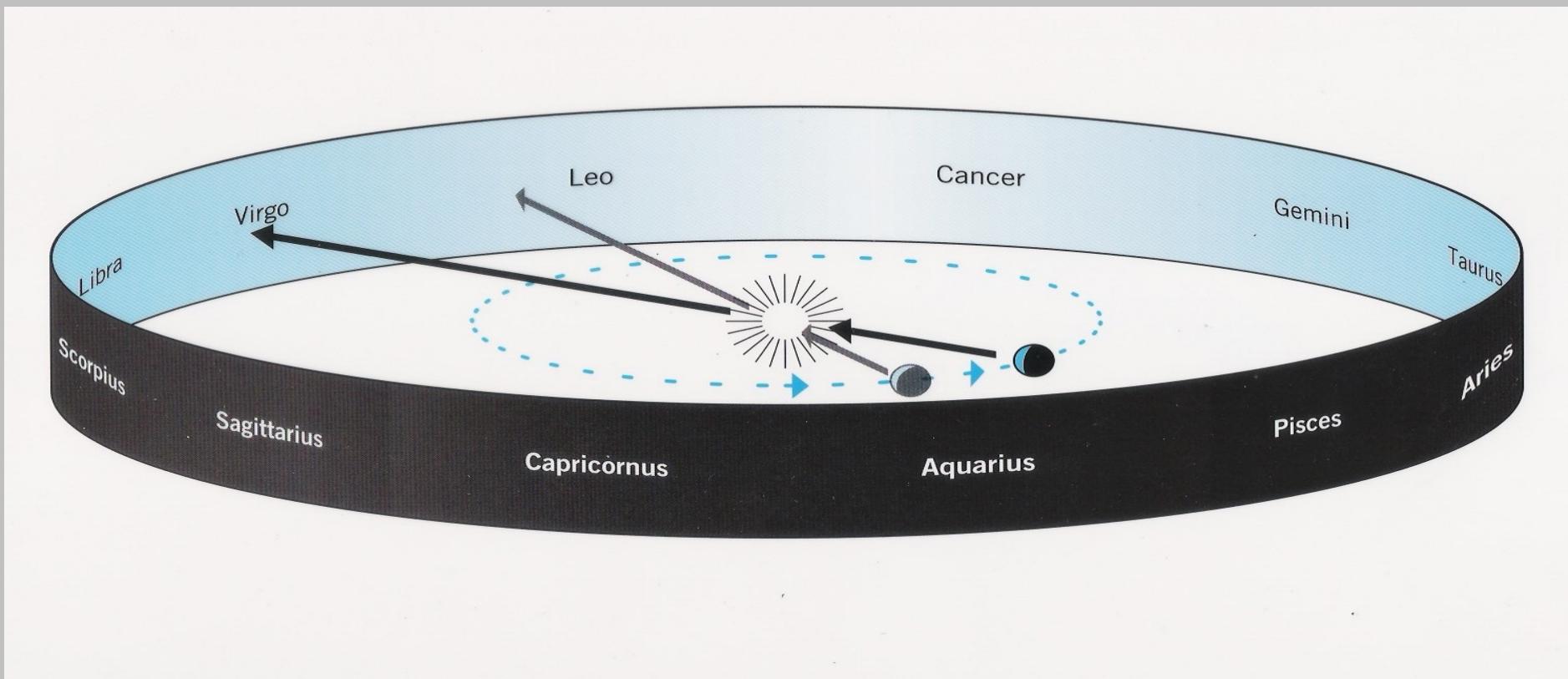
**Q: Why is the tropical year shorter than the sidereal year?**

**A: Precession**

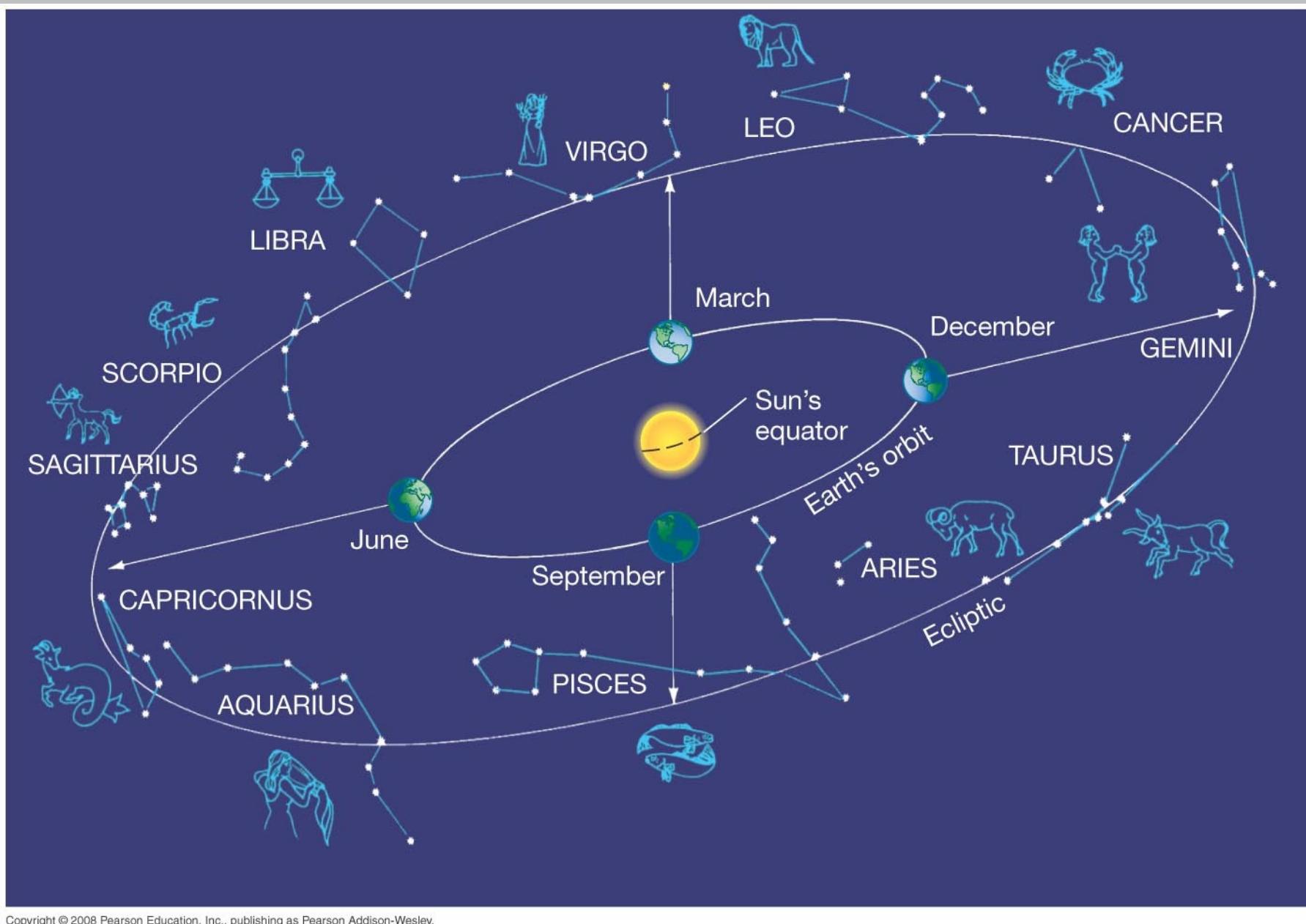
# Motion of the Earth – Annual

The Zodiac = the 12 (or 13 counting Ophiuchus) constellations through which the Sun passes in a year.

Ecliptic = The apparent path of the Sun on the sky as seen from Earth.



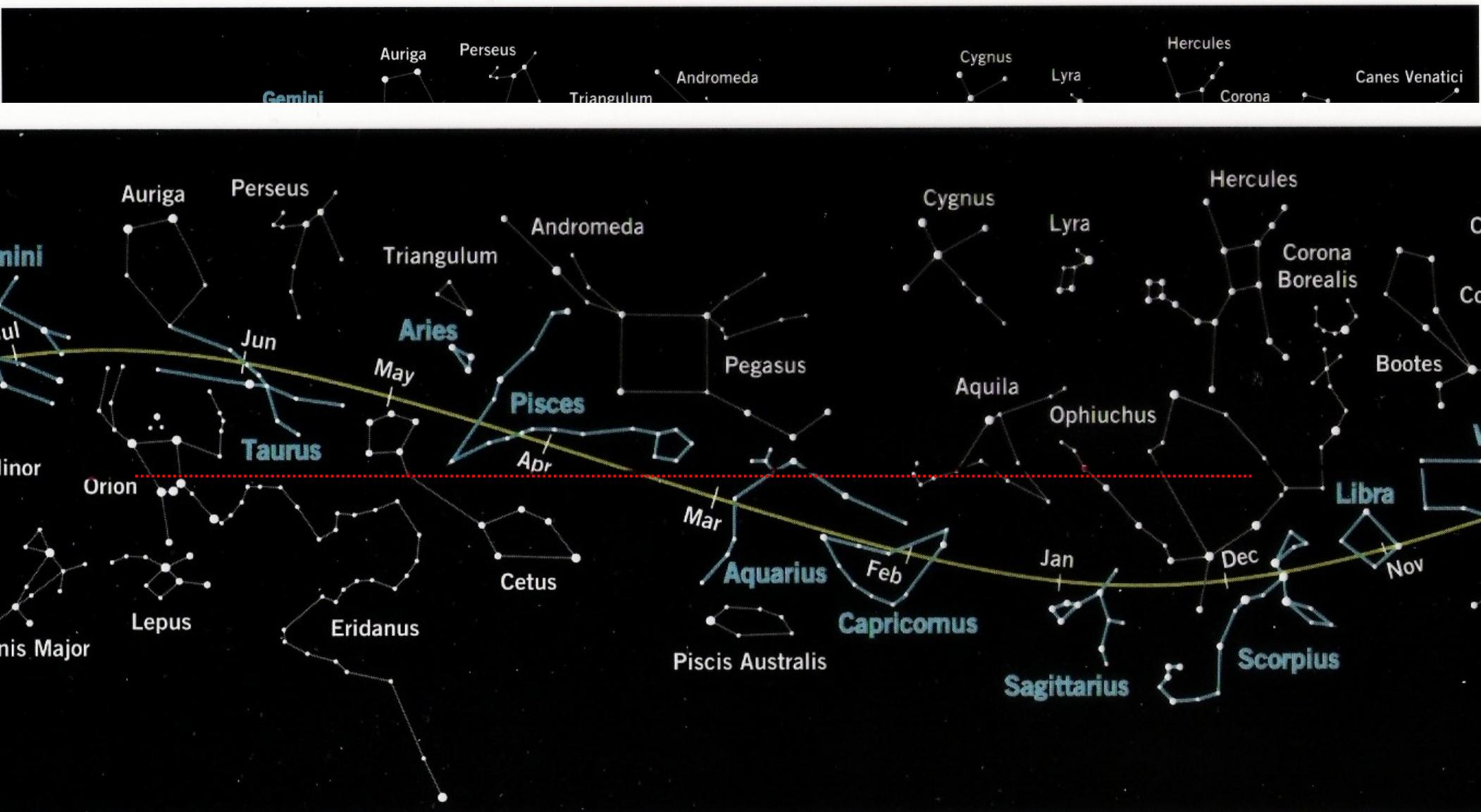
# Motion of the Earth - Annual



## The Zodiacal Constellations

# Motion of the Earth – Annual

## Ecliptic = The apparent path of the Sun on the sky as seen from Earth.



# Motion of the Earth and Seasons

**Seasons: an oscillation of average temperature with a period of 1 tropical year.**

**There are two main reasons for the seasons:**

- 1. The length of daytime (when Sun is “up”) changes.**
- 2. The directness of the Sun's rays changes.**

**Astronomical Definitions of the 4 seasons:**

- \* Spring: begins on vernal equinox (Mar 20, 21)**
- \* Summer: begins on summer solstice (June 20,21)**
- \* Fall: begins on autumnal equinox (Sept 22, 23)**
- \* Winter: begins on winter solstice (Dec 21, 22)**

**Equinoxes: when Sun crosses celestial equator (CE).**

**Solstices: when Sun is the maximum angle from CE.**

# Motion of the Earth and Seasons

**Seasons: an oscillation of average temperature with a period of 1 tropical year.**

The

1.

cha

2.

Ast

\*

\*

\*

\*



21)

e 20,21)

2, 23)

22)

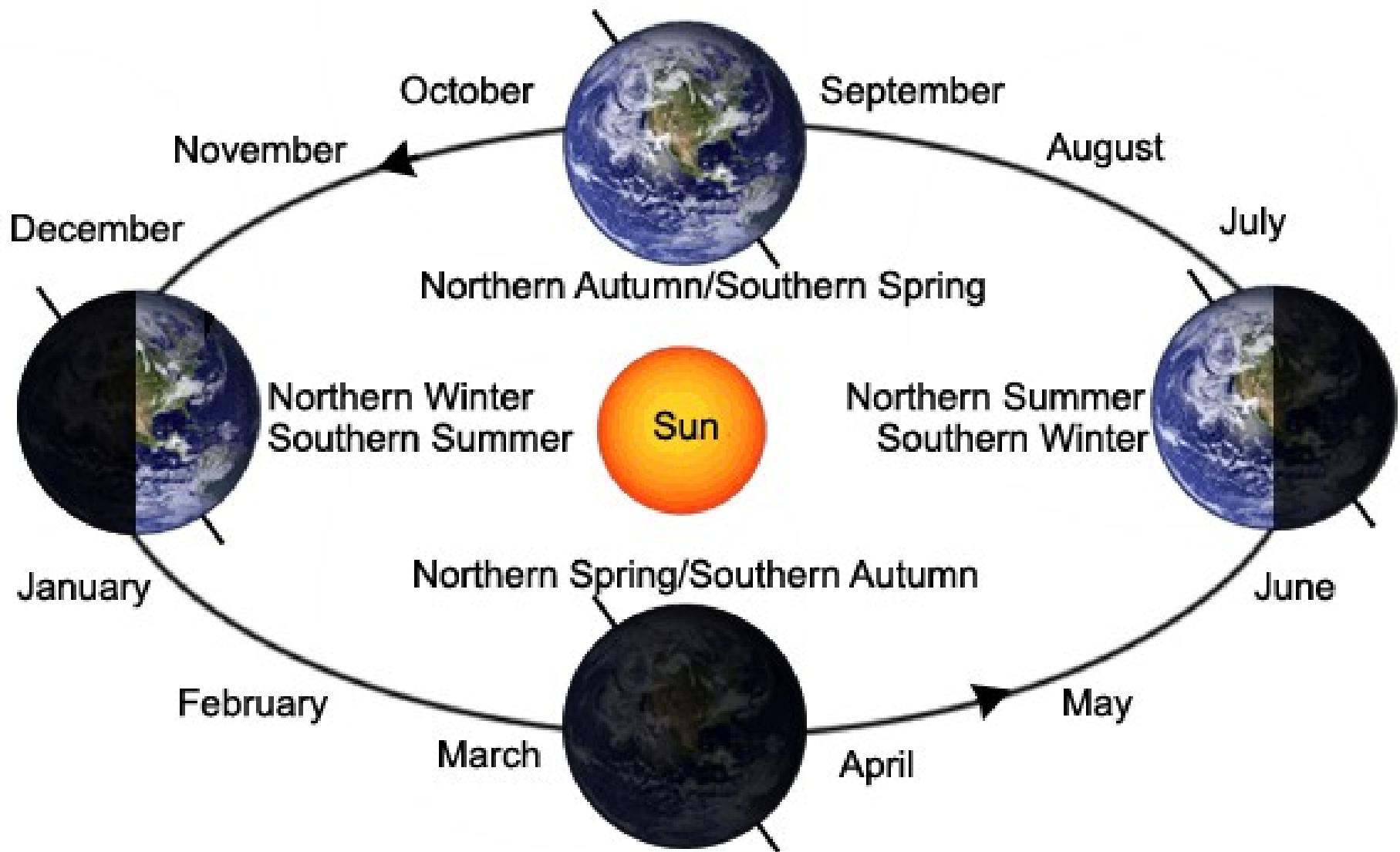
Equ

Sols

toes, when our S. hemisphere gets from C.E.!  
EQUATOR!

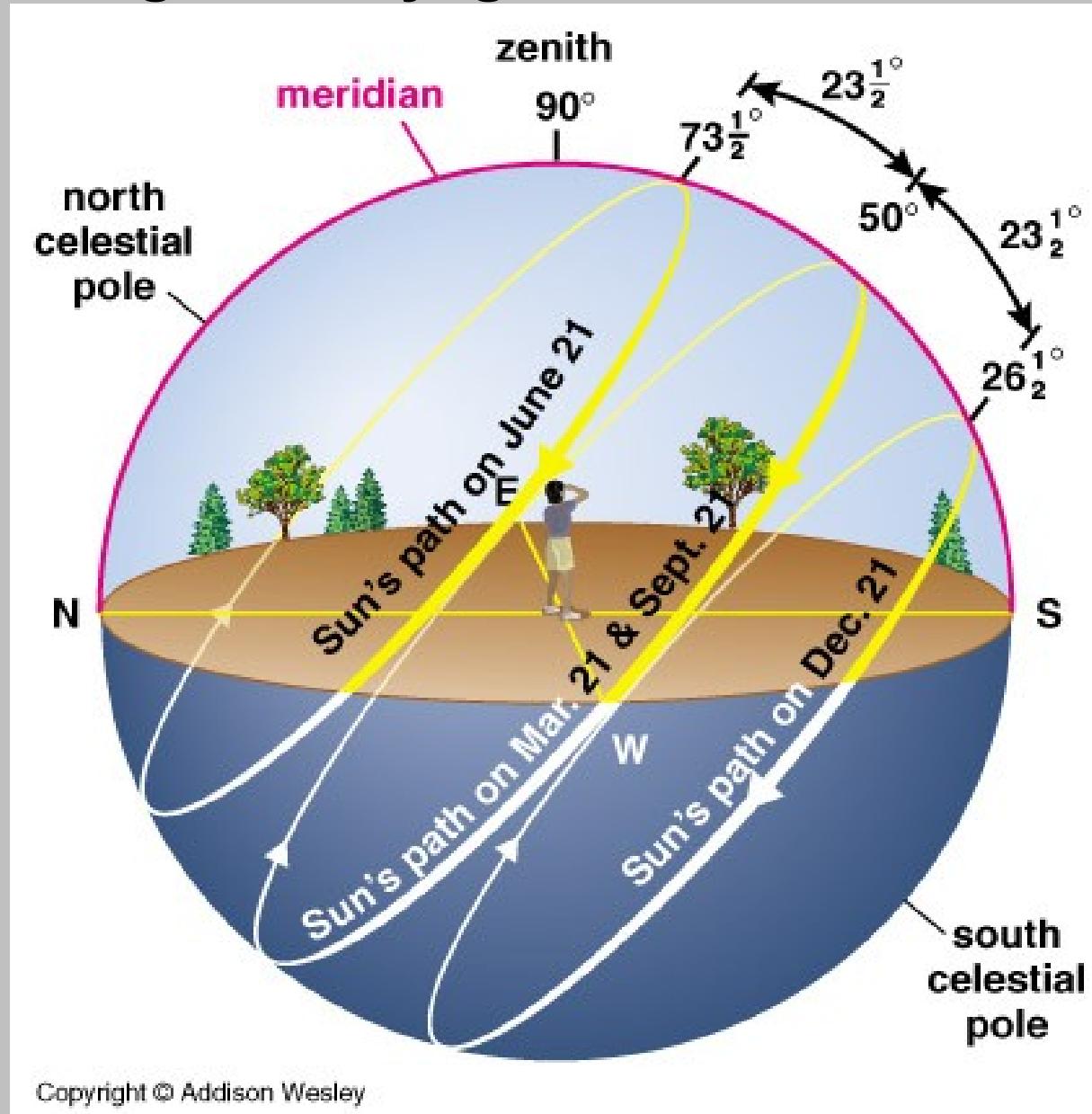
# Motion of the Earth and Seasons

## Factor 1: directness of Sun's rays.



Q: If the spin axis pointed strait up, would that make our seasons more or less severe?

## Factor 2: length of daylight hours.



T or F? The Sun will be above the horizon much longer on June 21 than on December 21.

**Precession of the Equinoxes** – *the reason the calendar year is different than the sidereal year.*

**The Earth's spin axis is “wobbling”.**

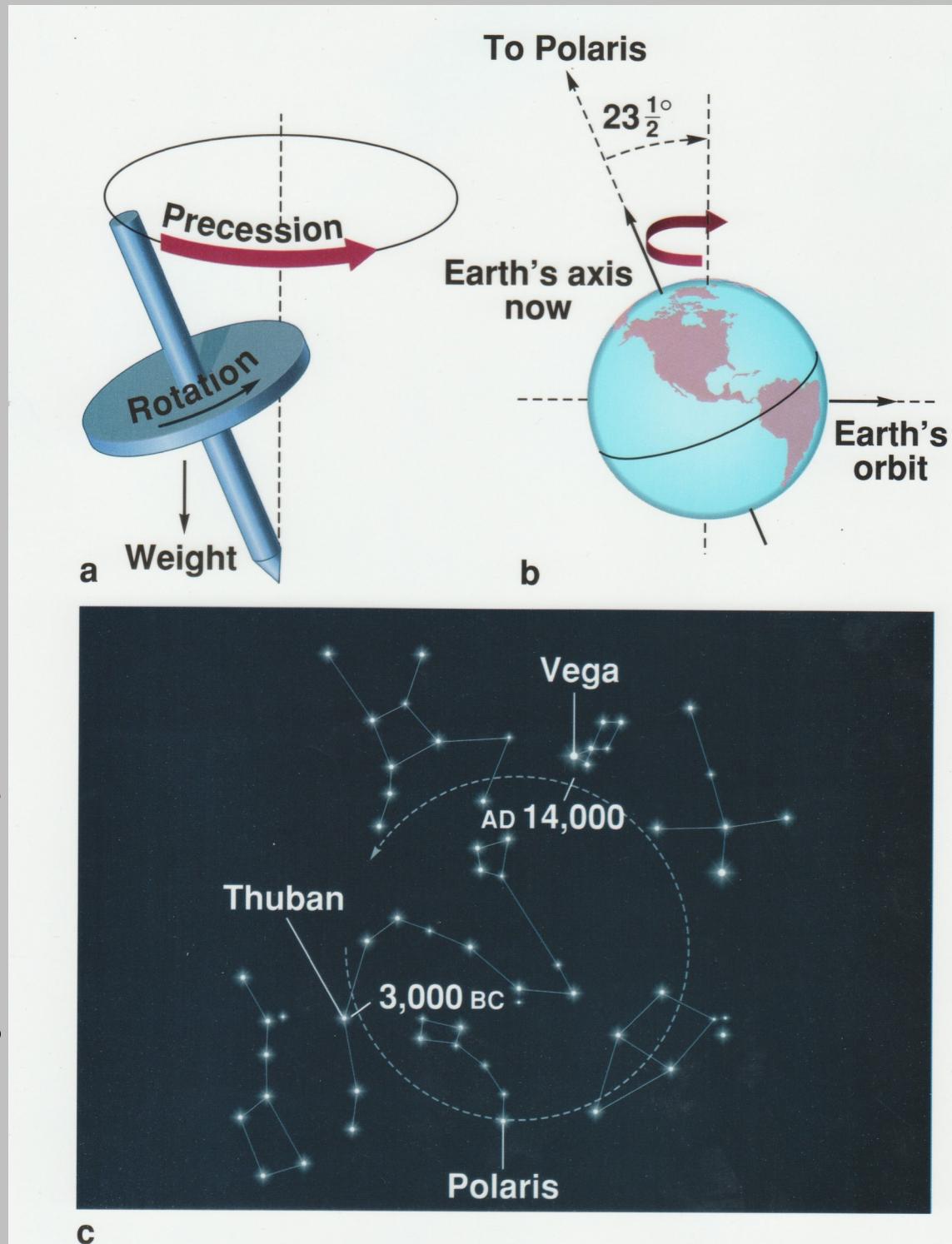
- **26,000 year period**
- **The tilt remains 23.5 degrees**
- **Seasons remain the same severity**

# Precession

The different direction of the red arrows is correct because the torques are different.

The NCP's position changes relative to the stars over 26,000 years.

The polestar was not always Polaris! It was Thuban for the ancient Egyptians.

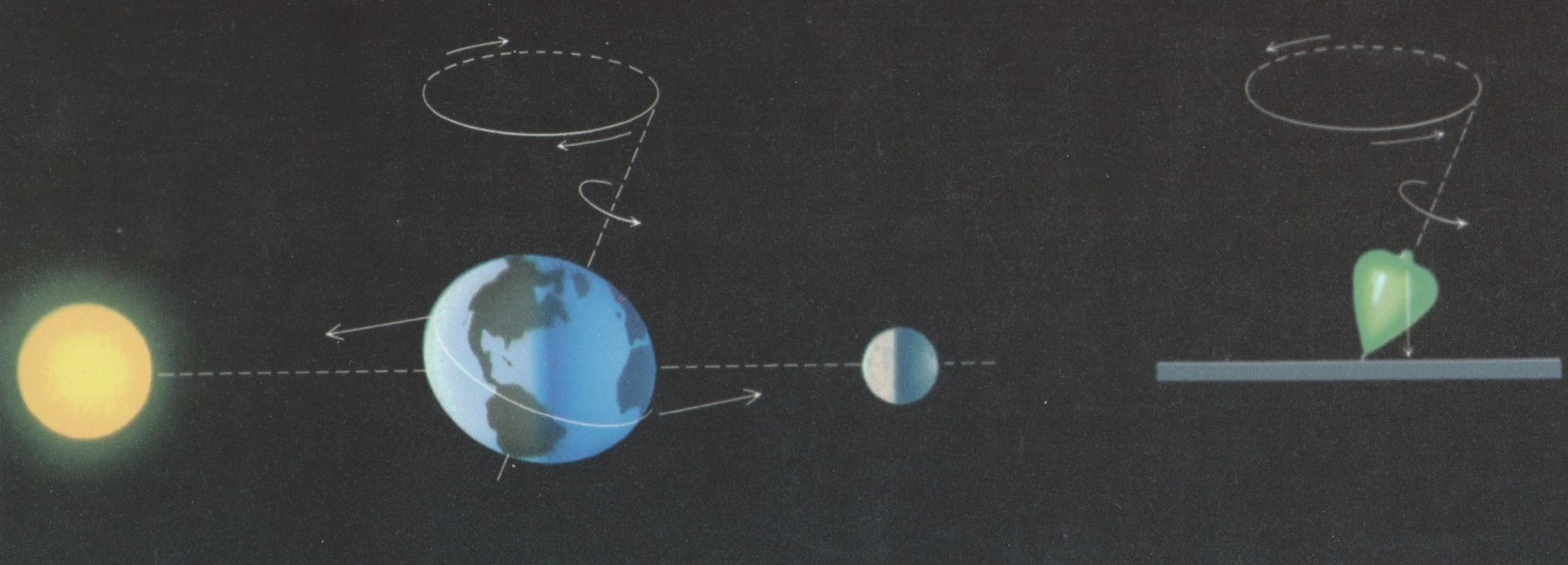


# Precession



# Precession

**Cause: the pull of the Moon and Sun on Earth's equatorial bulge exerts a Torque.**



**Left: gravity from S and M are trying to tip the spin axis UPRIGHT.  
Pole precesses CW seen from above.**

**Right: gravity is trying to tip the spin axis OVER.  
Pole precesses CCW seen from above.**

# Precession (of the Equinoxes)

## Consequences

- 1) The NCP is changing position rel to stars
- 2) The equatorial coordinates (RA and DEC) of stars slowly change with time. → We need to specify “Epoch” of coordinates.

Example: RA(2000.0)=13h 12m 10s

DEC(2000.0)= $78^{\circ} 18' 20''$

gives the coordinates for the year 2000.

That is, the zeropoint was on the vernal equinox as it appeared in the year 2000.

# Parallax and Distances

Parallax = the apparent motion or shifting of an object caused by the motion or shifting of the observer.

Everyday examples: 1) hold thumb in front of you and then see how it shifts back and forth when you switch between viewing it with the left eye and viewing it with the right eye.  
2) Watch nearby trees move relative to far away mountains as you drive down the highway.

**Stellar parallax – apparent motion of foreground stars (relative to background stars & galaxies) due to Earth's orbital motion.**

**Represented with  $p$  and  $\pi$ .**

**Typically stellar parallax:  $p \sim 0.1''$ .**

**Biggest  $p \sim 1.0''$  for Proxima Centauri.**

# Parallax and Distances

This Ch. 1 figure uses a different definition of parallax than what astronomers use for stars. (Astronomers use  $\frac{1}{2}$  of the angle shown.)

This figure shows how the Earth's diameter can be used as a baseline (B) to measure the distance to a solar system object (like the Moon).

$$\text{Parallax (in radians)} = \frac{B}{\text{dist}},$$

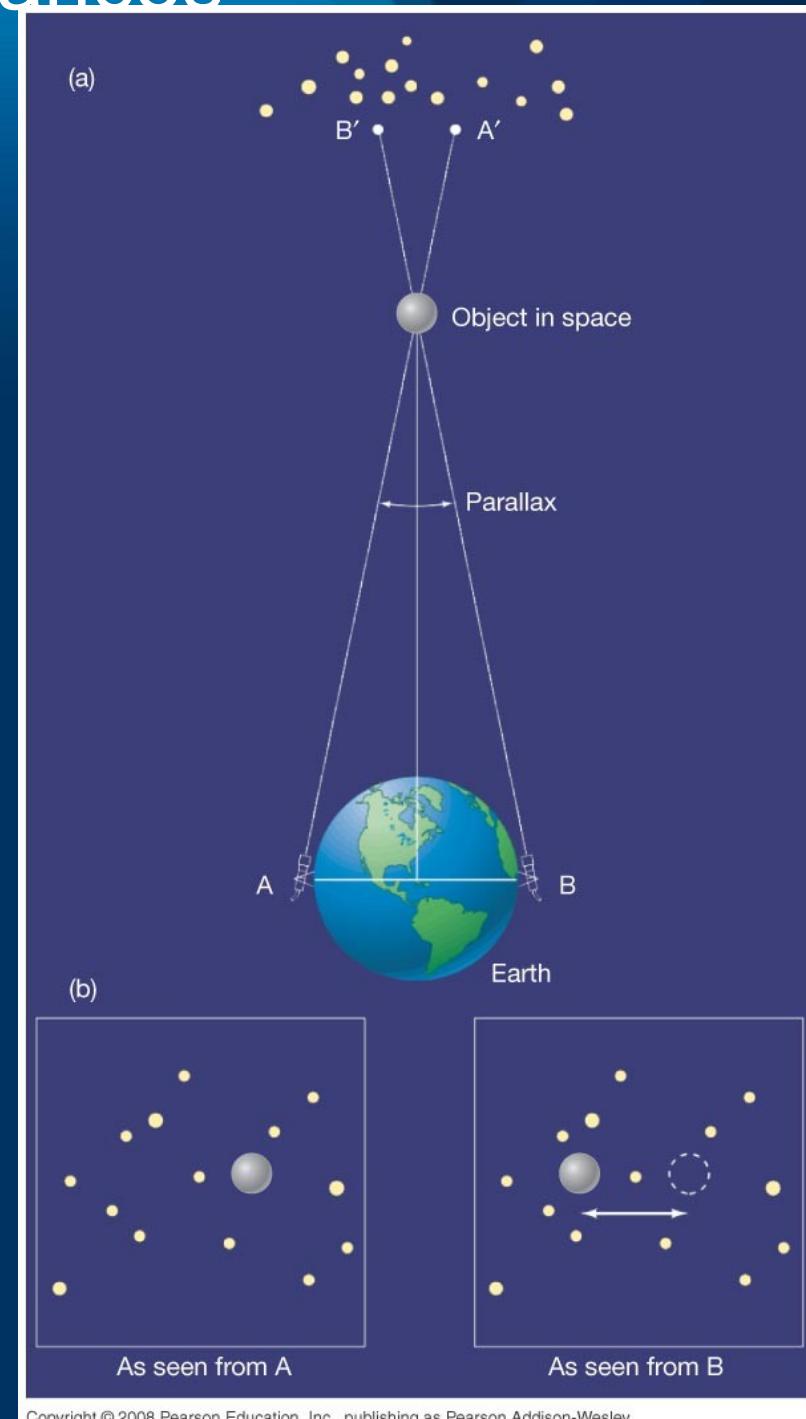
if Parallax is defined as shown in this figure.

For **stellar parallax**, we use:

$$\text{Parallax (in arcseconds)} = \frac{1}{\text{dist(in parsecs)}}$$

Or more simply:

$$p = \frac{1}{d}$$



# Parallax and Distances

For **stellar parallax**, we use:

$$\text{Parallax (in arcseconds)} = 1/\text{dist(in parsecs)}$$

$$p = 1/d$$

Example: How far away is a star with a stellar parallax of 0.01 arcsec?  
Ans:  $d = 1/p$  so  $d = 1/.01 = 100 \text{ pc}$ .

Example (like Prob. 5): At what distance is an object if its parallax, as measured from either end of a 10,000 km baseline is 1 degree?

$$\text{Ans: } p(\text{rad}) = (B/d), \text{ so } p(^{\circ}) = 57.3(B/d).$$

$$\text{Then } d(\text{km}) = 57.3(B/p) = 57.3(10,000/1^{\circ}) \\ = 573,000 \text{ km}$$

