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.

Examples) Orion, Taurus, Ursa Major (see next slides)

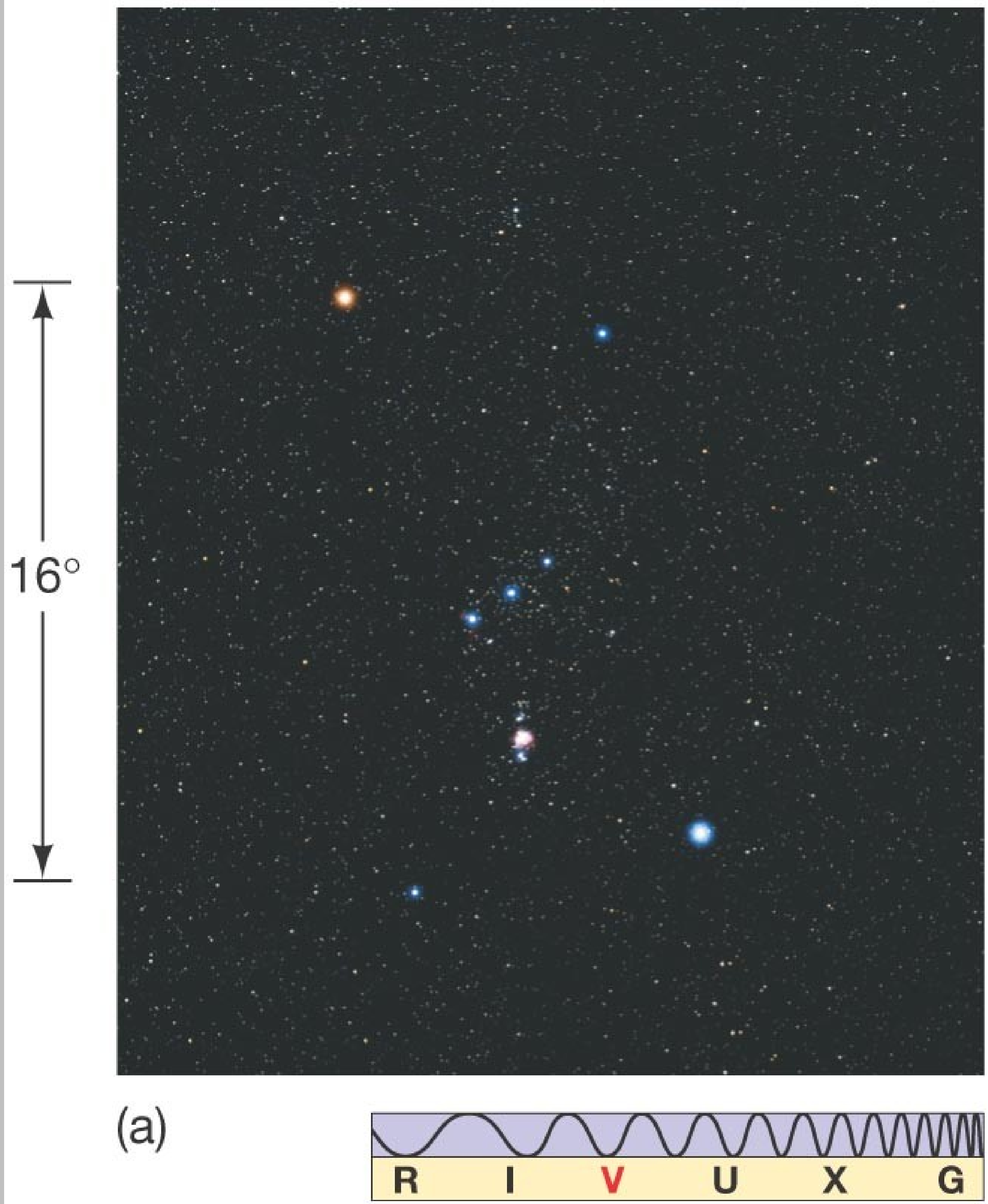
Asterism: a recognizable pattern of stars.

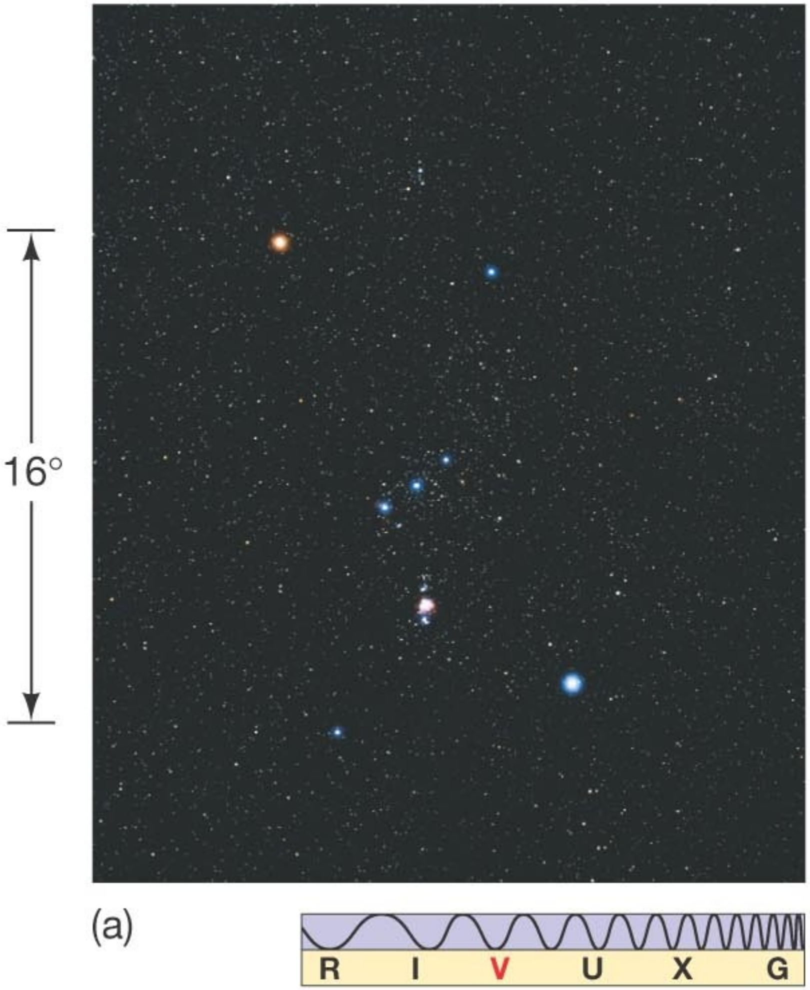
Ex) Orion, the hunter
Ex) Taurus, the bull; the Pleiades; the Hyades
Ex) Ursa Major (the great bear); the Big Dipper; La Cassarole
Ex) The Summer Triangle
Ex) The Coathanger (Brocchi's cluster)

* 88 total constellations
* More than 88 asterisms
* Northern constellations named after Greek Mythological characters

Example: Orion.

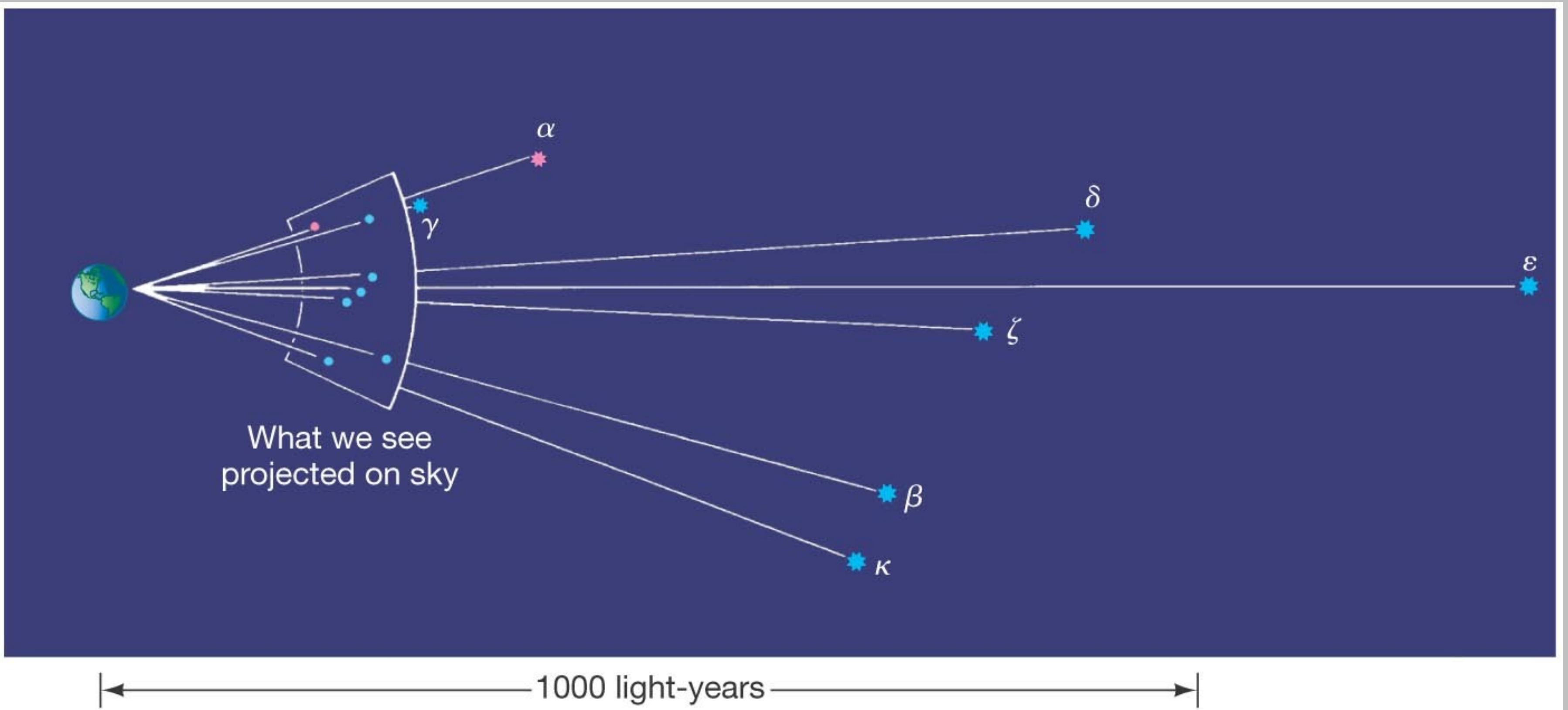
An easily recognized asterism and constellation!

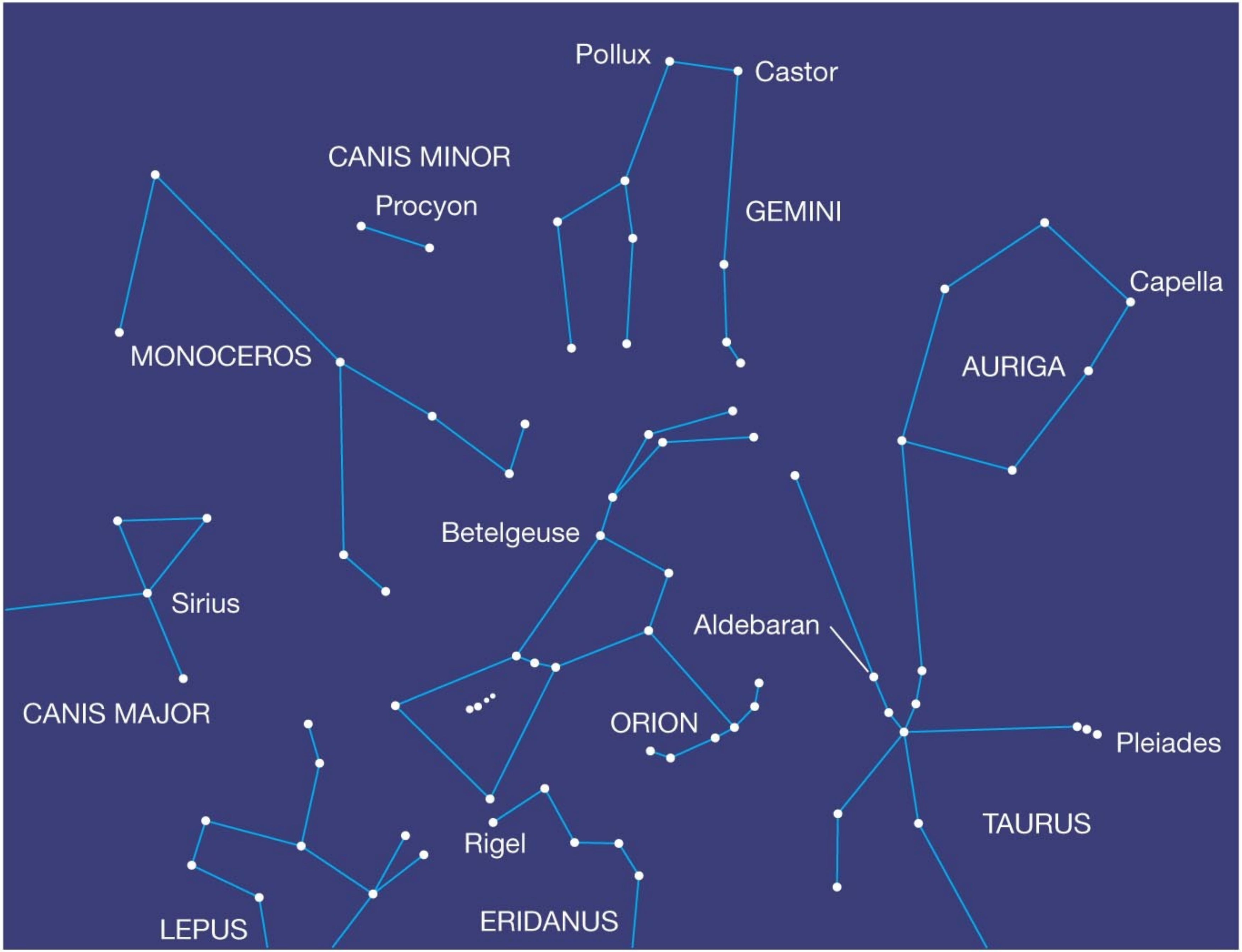




(a)

(b)


α
δ
γ
ε
ζ
What we see
projected on sky
β
κ
1000 light-years



Try a planetarium program like "Stellarium" to see the sky in motion.

The Celestial Sphere

- a conceptual model of the sky.

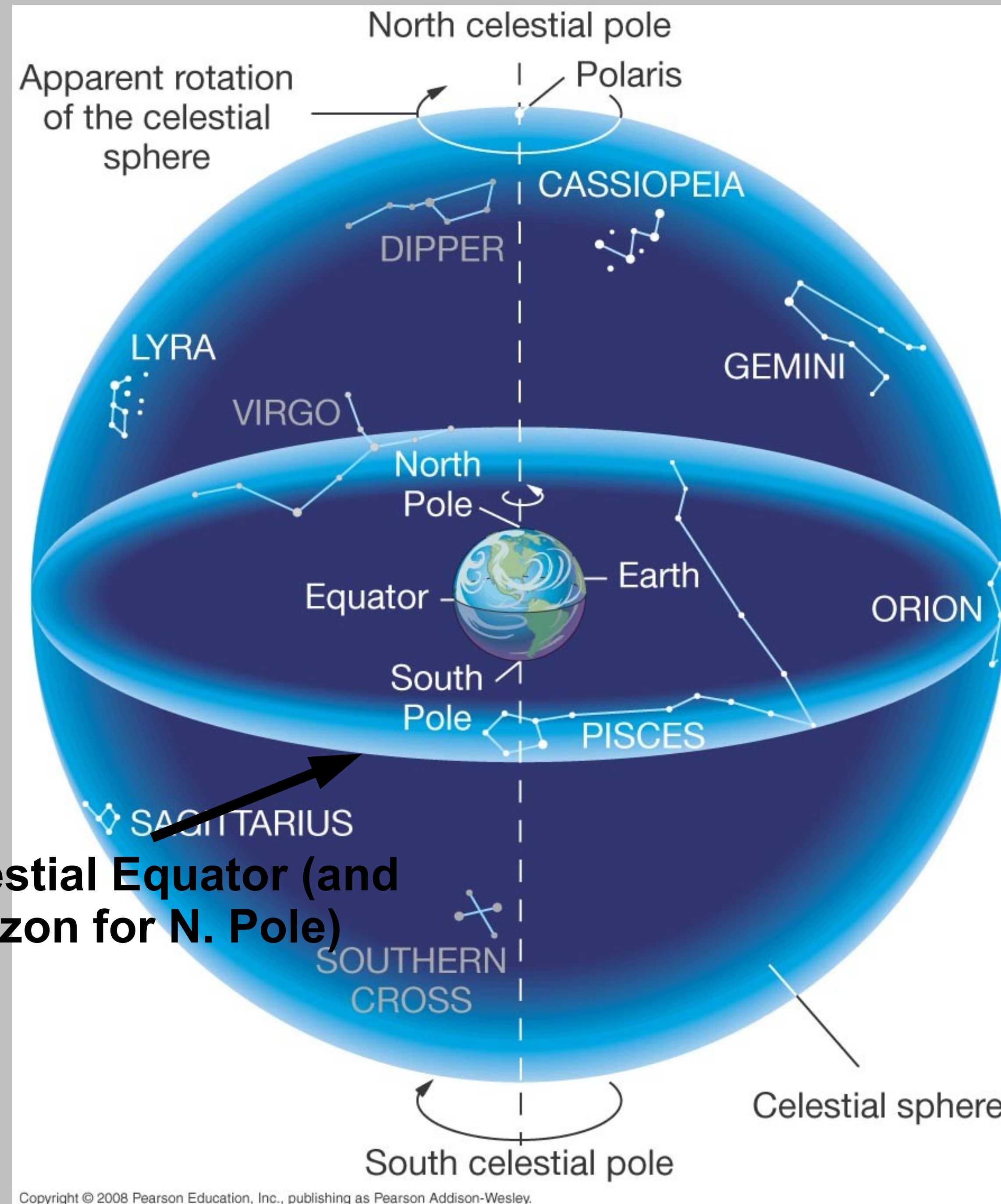
-geocentric (wrong)

-all stars at same distance (wrong)

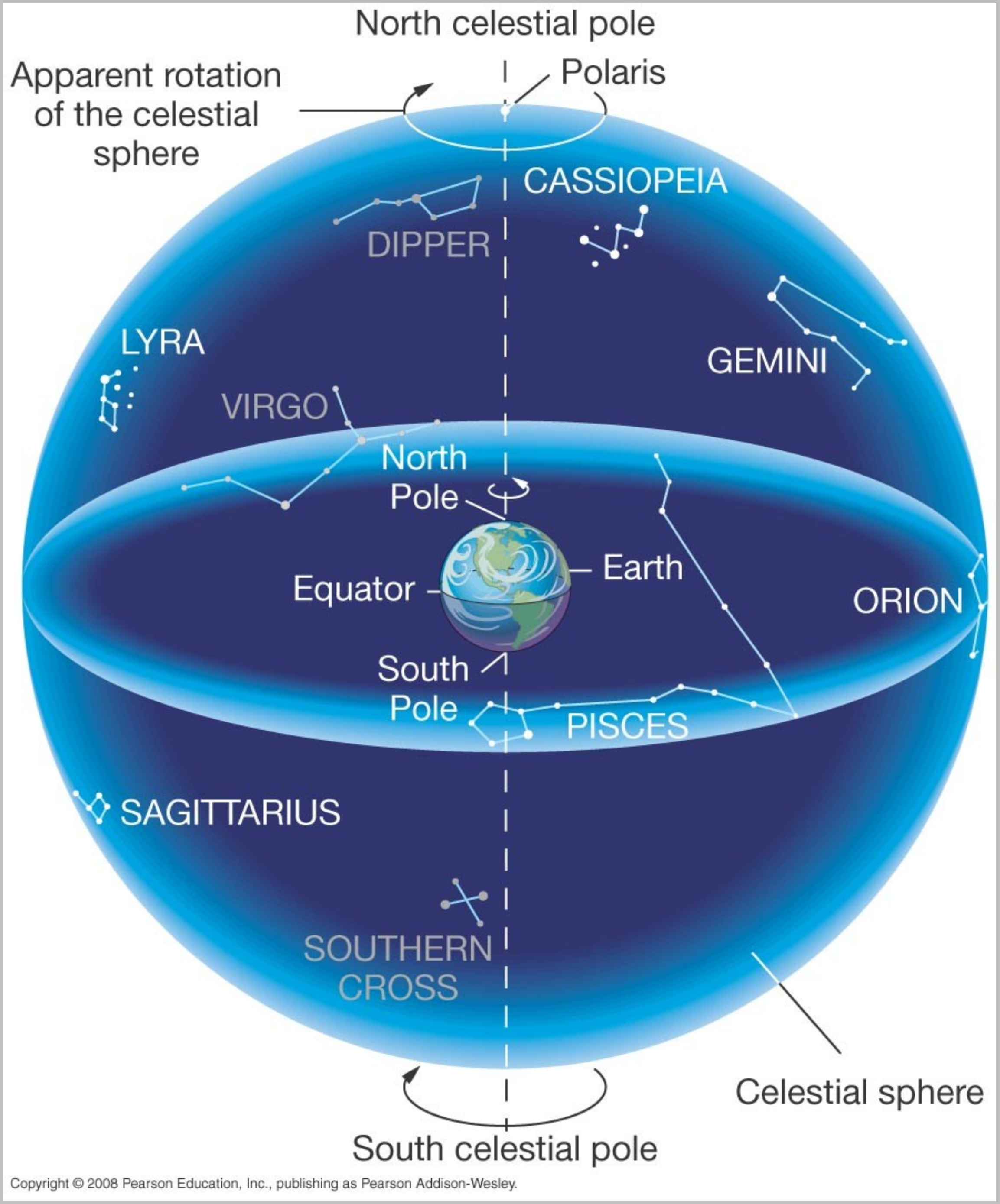
-a distortion-free sky map

-reproduces daily rising and setting motions for any latitude on Earth

-Cel. Sphere is infinitely bigger than the Earth.



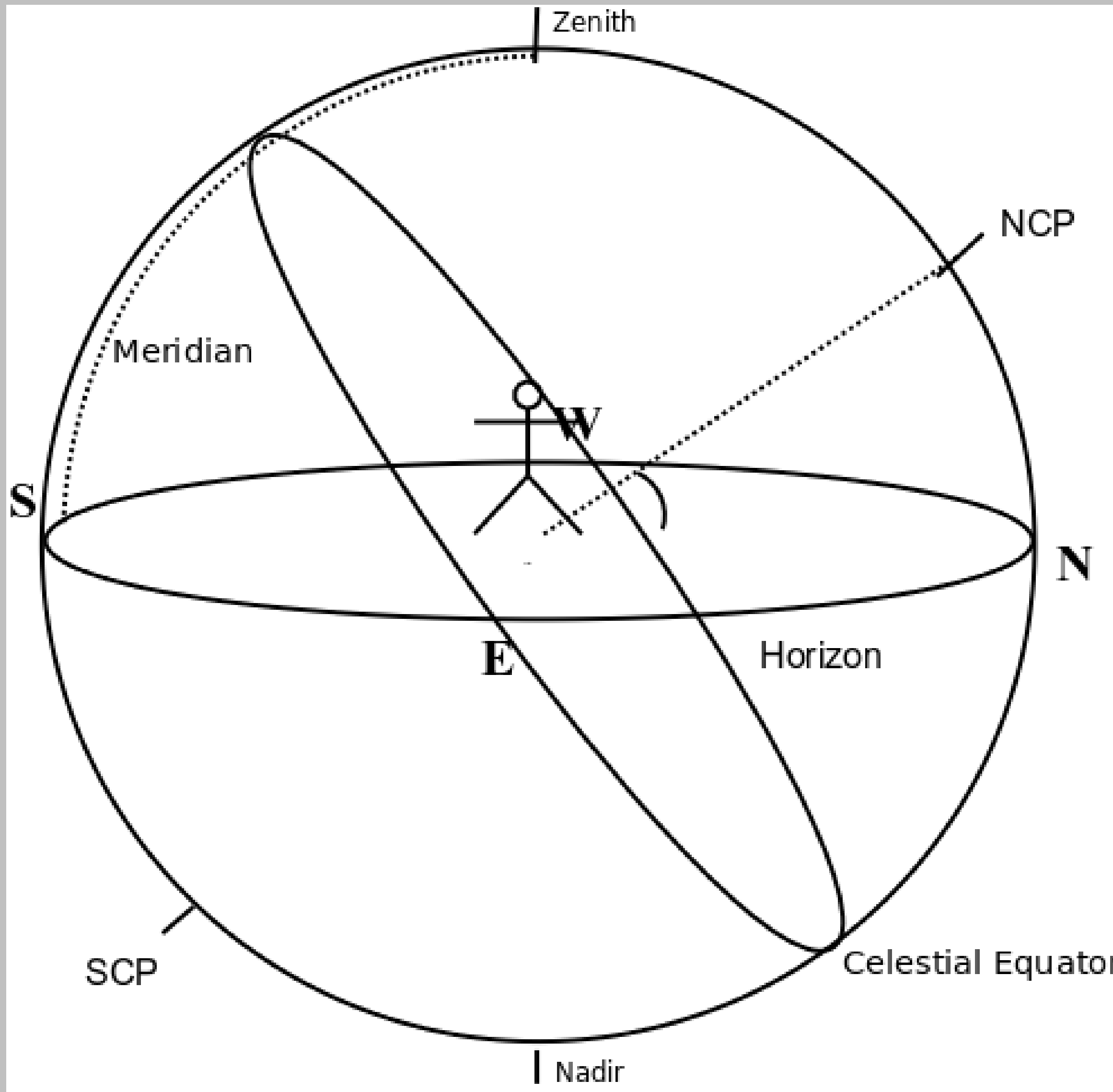
Celestial Equator (and Horizon for N. Pole)



The Celestial Sphere

Features:

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

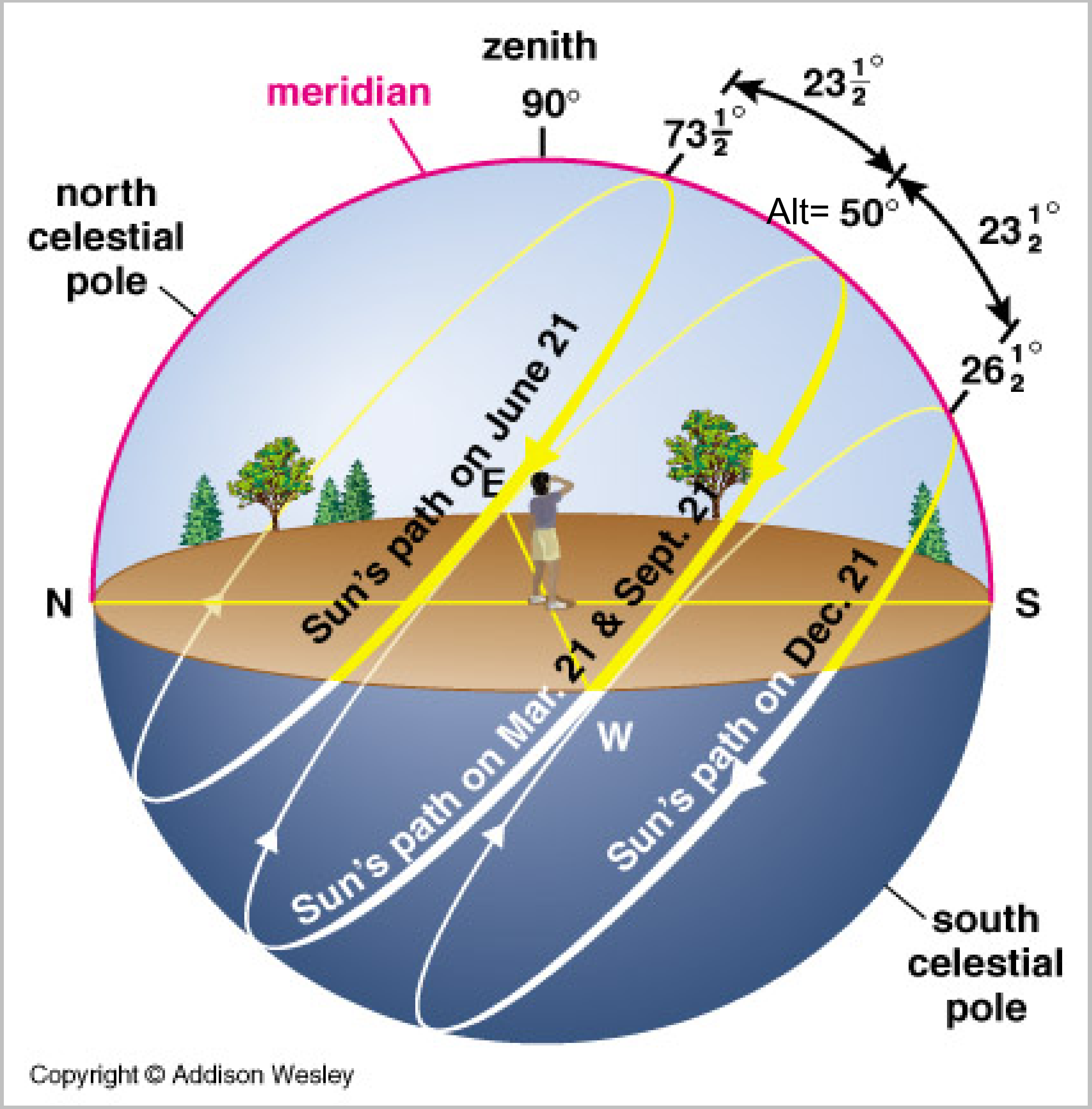


The Celestial Sphere

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

See celestialhorizon.swf for animation that switches between horizon diagram view and celestial sphere view.

Motion of the Earth and Seasons



See: /home/jpinkney/classes/ClassAction/animations/coordsmotion/sunmotions.swf

Coordinate Systems for the sky

Location-dependent marks on Cel. Sphere:

These marks move relative to the stars.

Horizon
Cardinal points (N,S,E,W)
Zenith
Nadir
Meridian
→ Altazimuth coordinate system uses these marks.

Location-independent marks on Cel. Sphere:

These marks are fixed relative to the stars (on a daily basis).

Celestial Equator
NCP and SCP
ecliptic, vernal equinox, autumnal equinox
→ Equatorial coordinate system uses these marks.

Coordinate Systems for the sky

<u>Altazimuth coordinate system</u>

Uses the horizon for it's zeropoints.

A star's coordinates are different for observers on different parts of Earth, i.e., location dependent.

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

***Azimuth* = angle measured along the horizon in degrees such that 0º azimuth is due North, 90º 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

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 0º azimuth is due North, 90º is due East, etc.

Ex) Polaris

Altitude = 40.75 degrees (our latitude)

Azimuth = 0 degrees (straight above N on horizon)

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 = 0º on the cel. equator, increasing to +90º at the NCP and -90º at the SCP.

Coordinate Systems for the sky

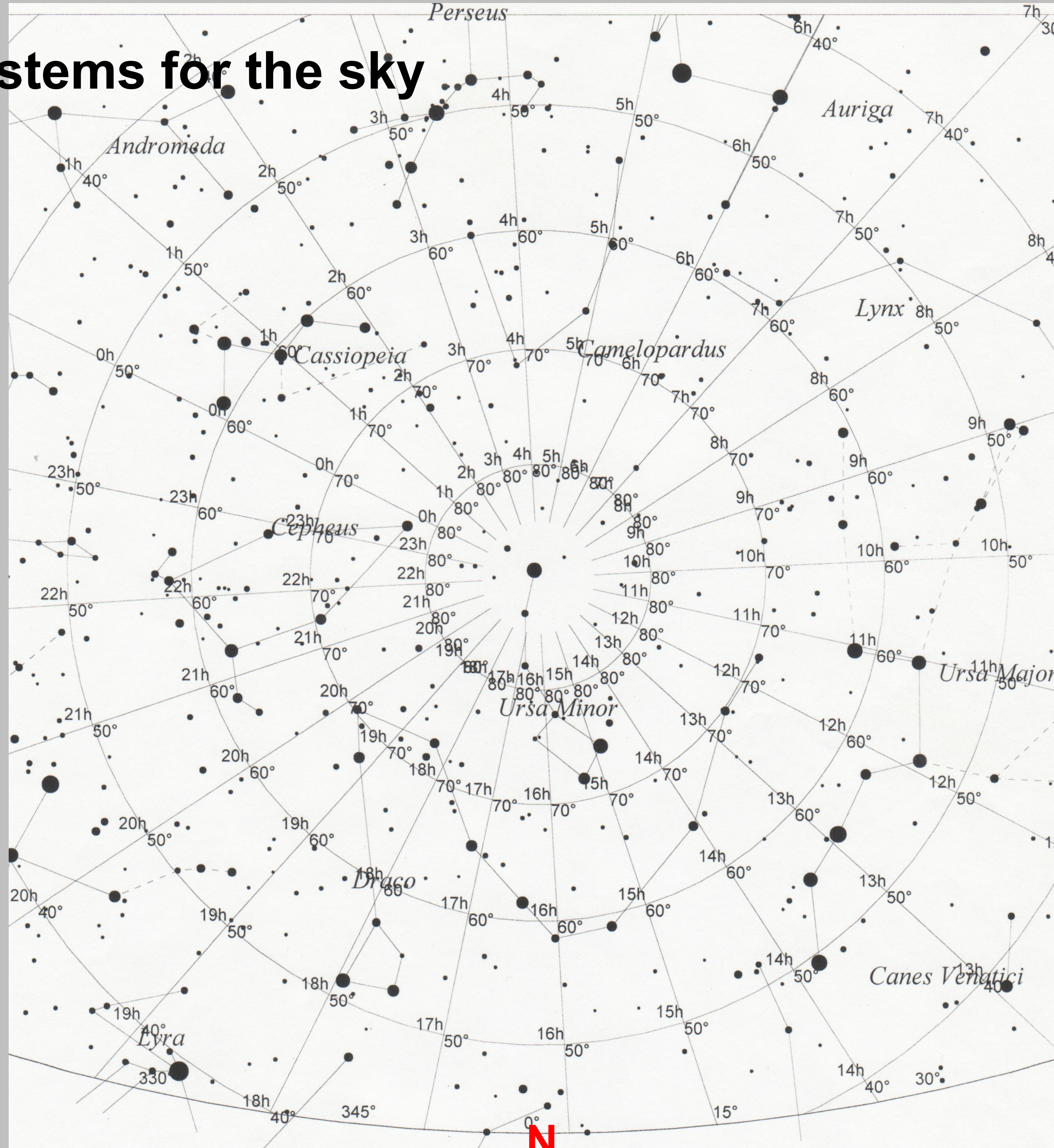
Example 1)

Equatorial:

Polaris at
Dec=90º
RA = ~2hr

Altazimuth:

Polaris has
Alt = 46º
Azim = 0º



Coordinate Systems for the sky

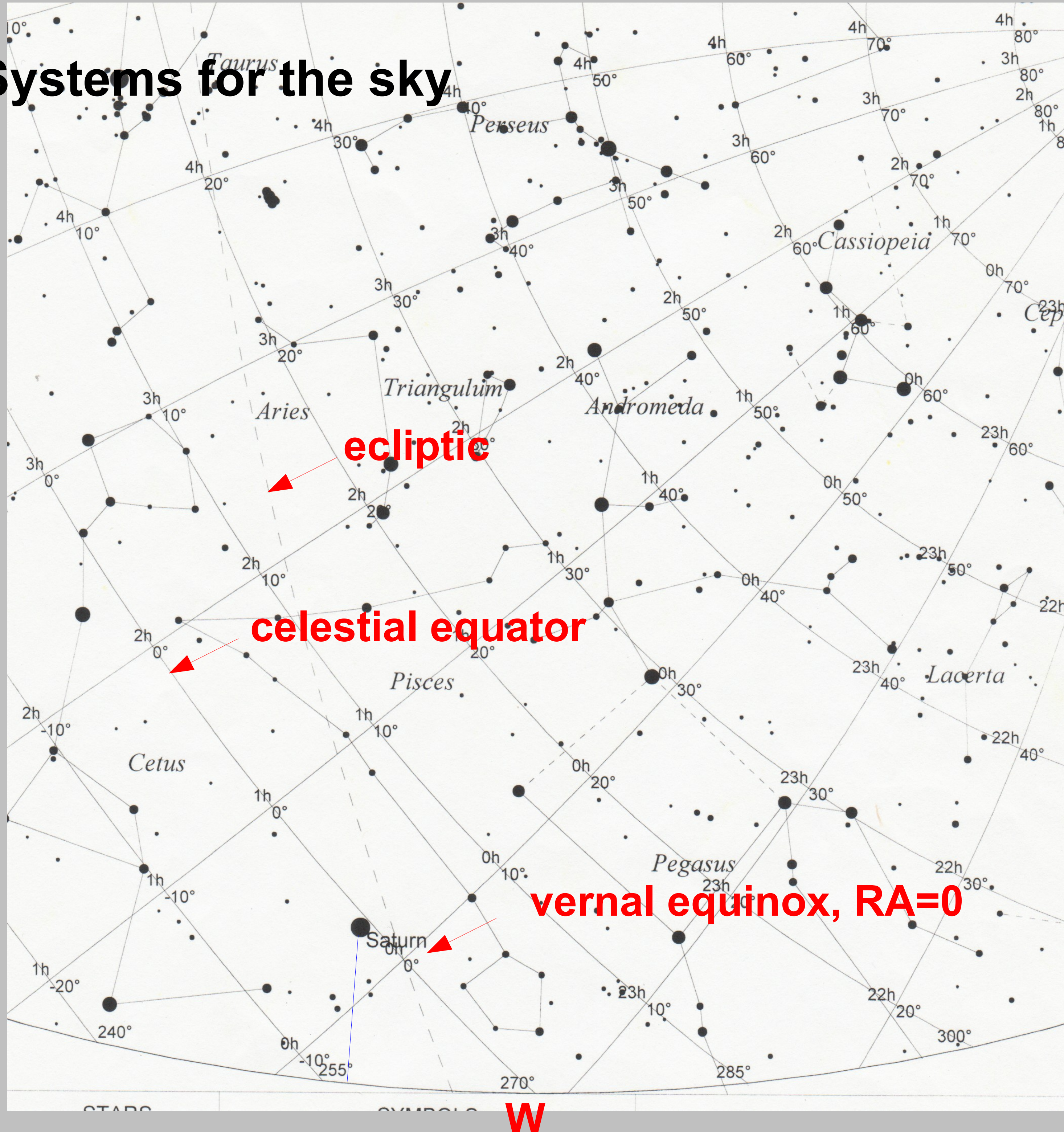
Example 2)

Equatorial:

Saturn has
Dec=-1º
RA = 0h 15m

Altazimuth:

Saturn has
Alt = 13º
Azim = 257º



Angles, distances and widths

Angles are measured in degrees, arcminutes, and arcseconds.

1 degree (º) is 1/360 of a complete rotation

- Twice the angle subtended by the full moon

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

- A little less than the resolution limit of the human eye (about 1.6 arcmin)

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

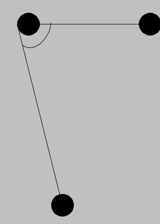
- A penny seen at 2.43 miles

Angles, distances and widths

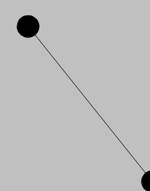
Angles are measured in degrees, arcminutes, and arcseconds.
1 degree (º) is 1/360 of a complete rotation
1 arcminute (') is 1/60 of a degree
1 arcsecond (") is 1/60 of an arcminute

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.

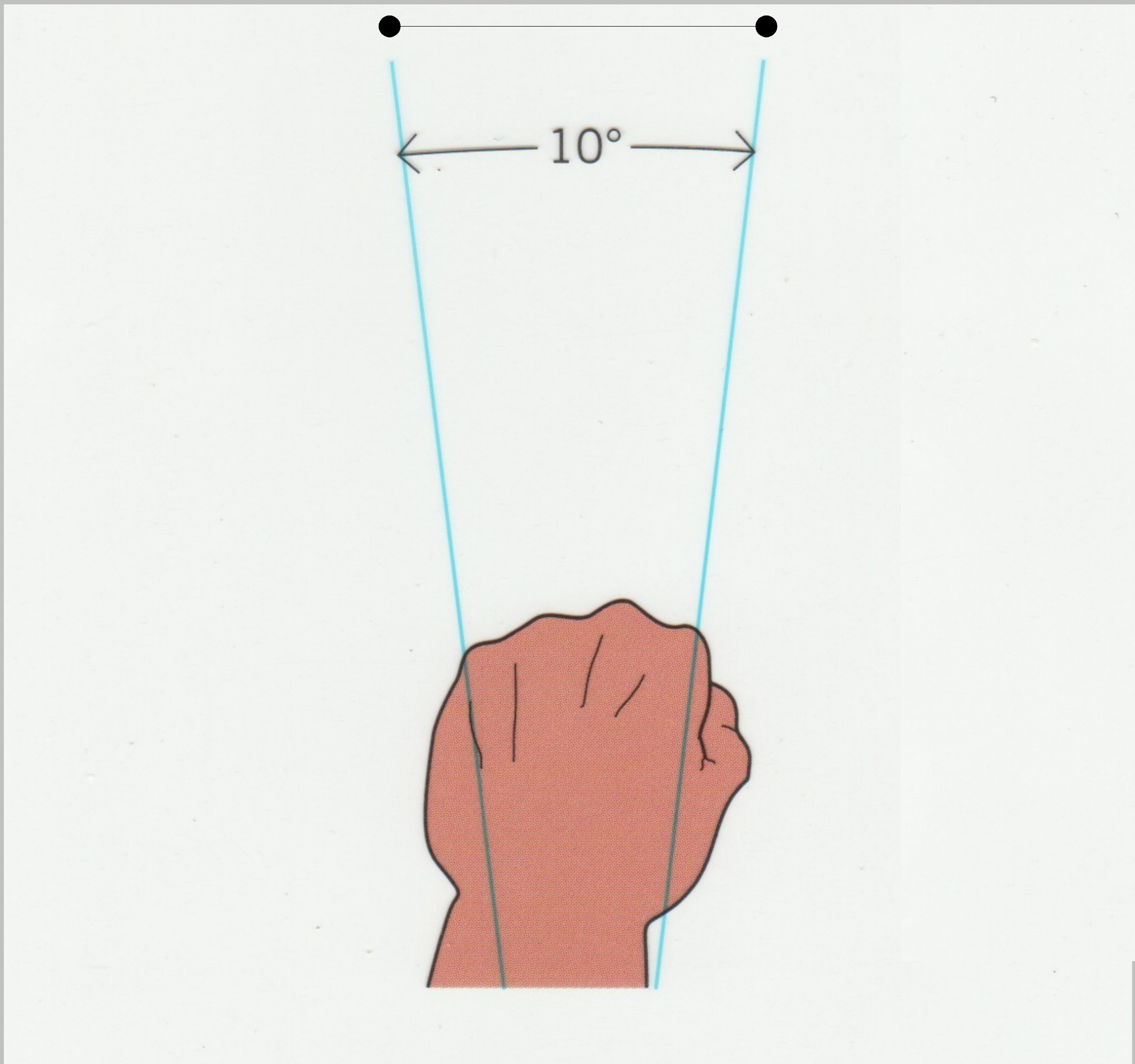


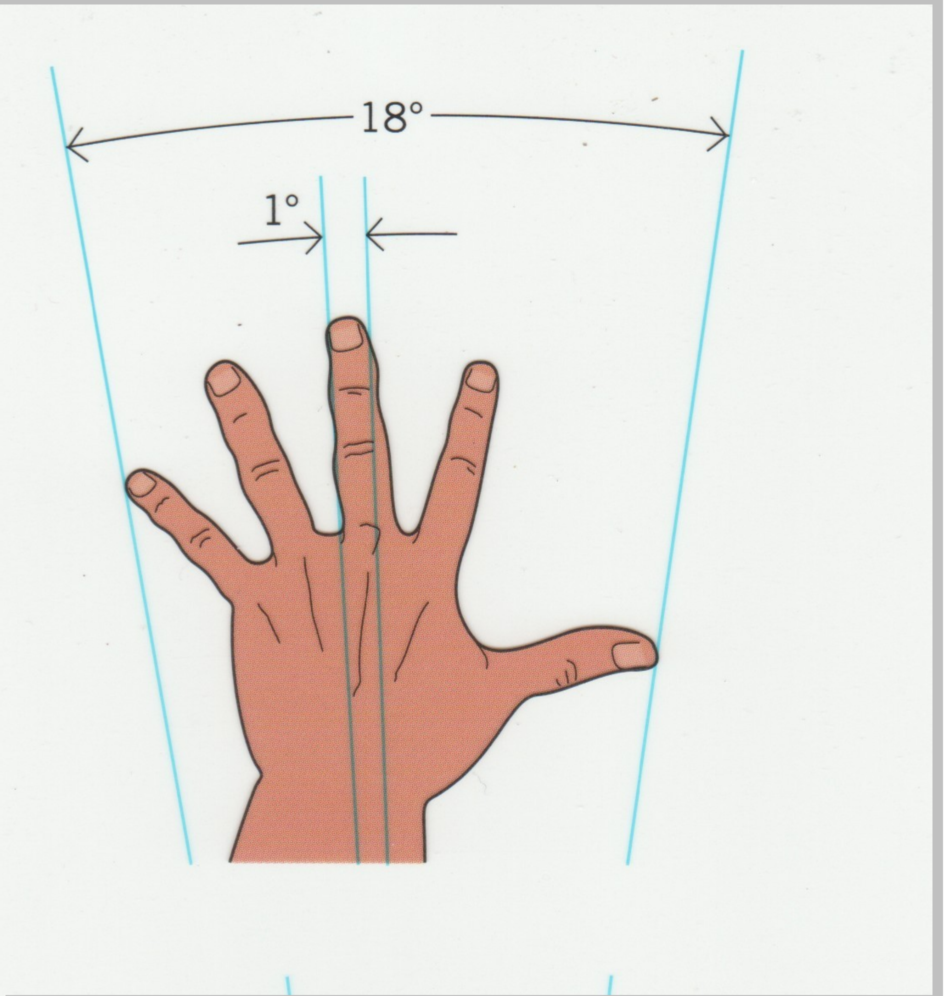
2) As angular separations between two stars, such as you would estimate using your fist at arm's length.



Mostly we use #2.

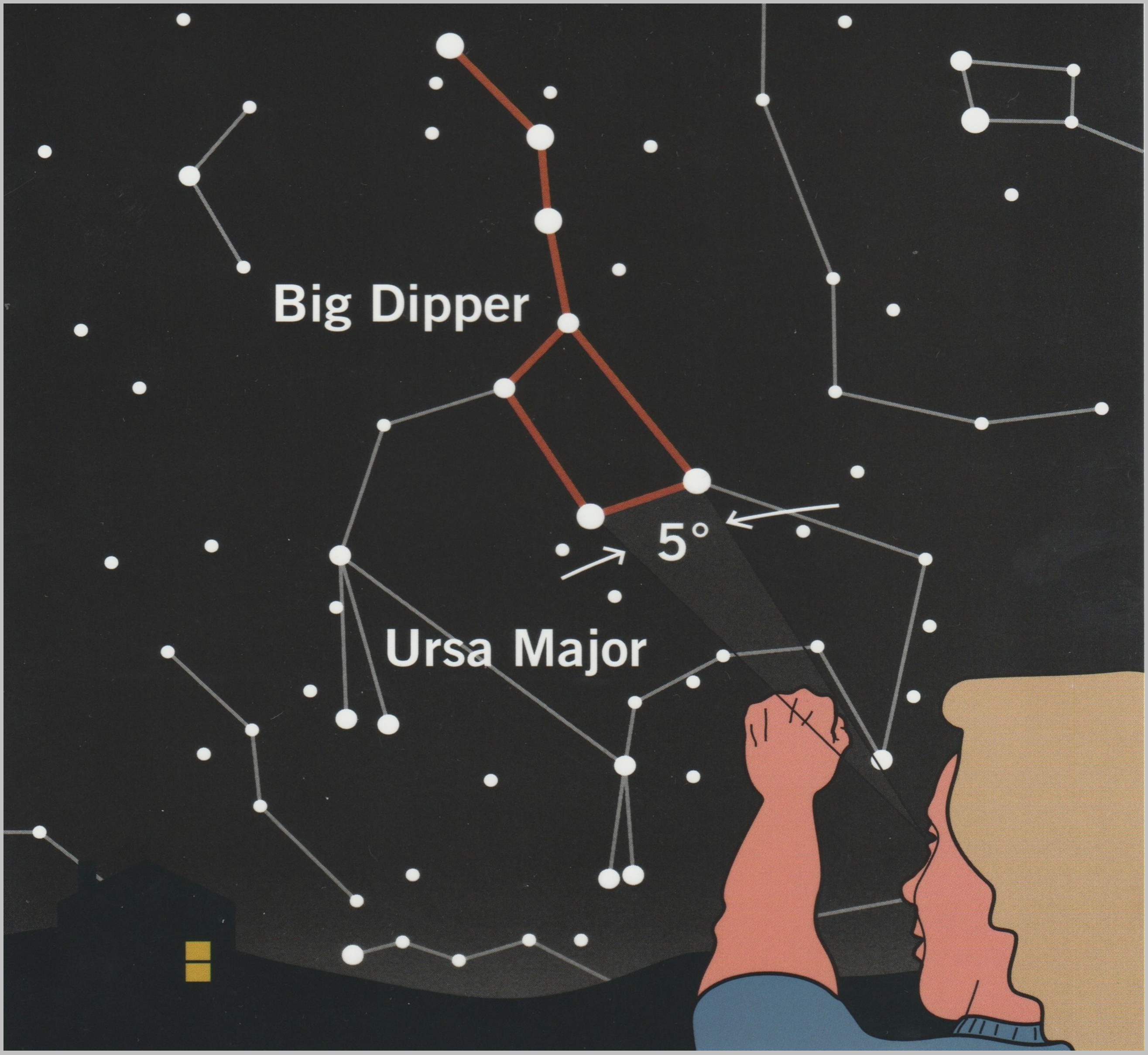
Angles, distances and widths





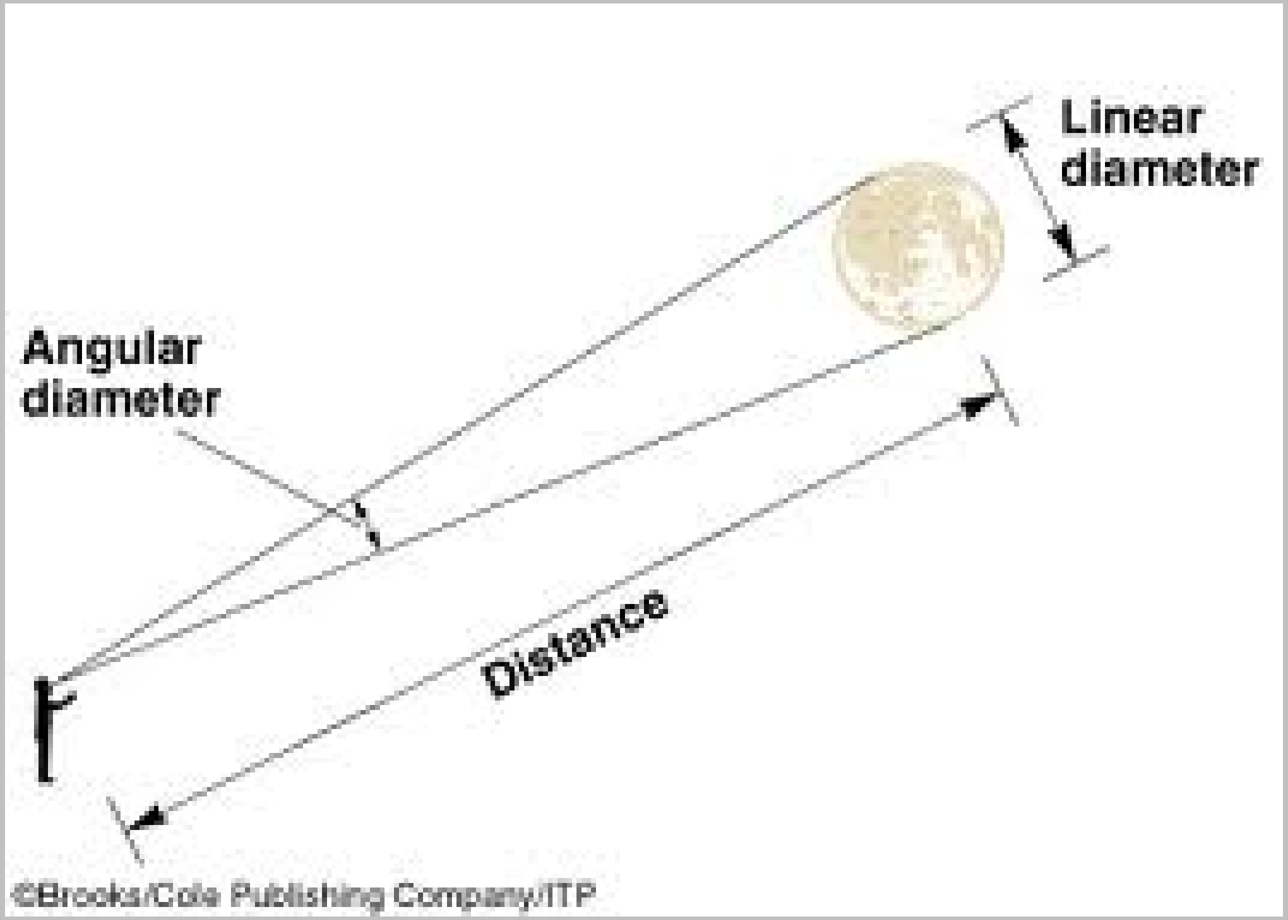
Angles, distances and widths

Calibrate using the Big Dipper!



Angles, distances and widths

Relationship between linear diameter and angular diameter



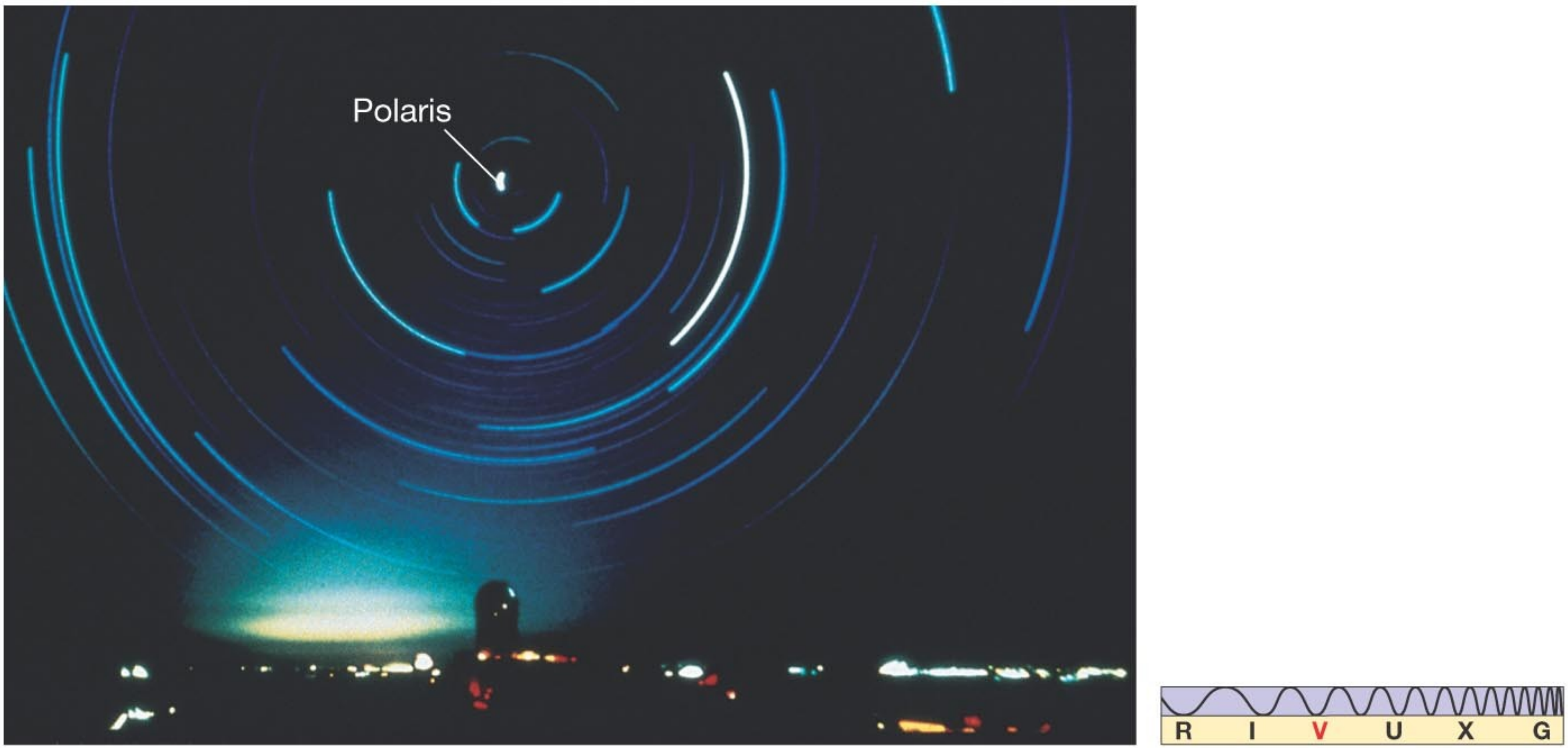
AD(radians) = LD/D

AD(degrees) = (57.3)LD/D

See http://astro.unl.edu/classaction/animations/intro/smallangledemo.html

Motion of the Earth - Daily

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



Now show the daily rotation with a Celestial Globe, and with
http://astro.unl.edu/classaction/animations/coordsmotion/celhorcomp.html

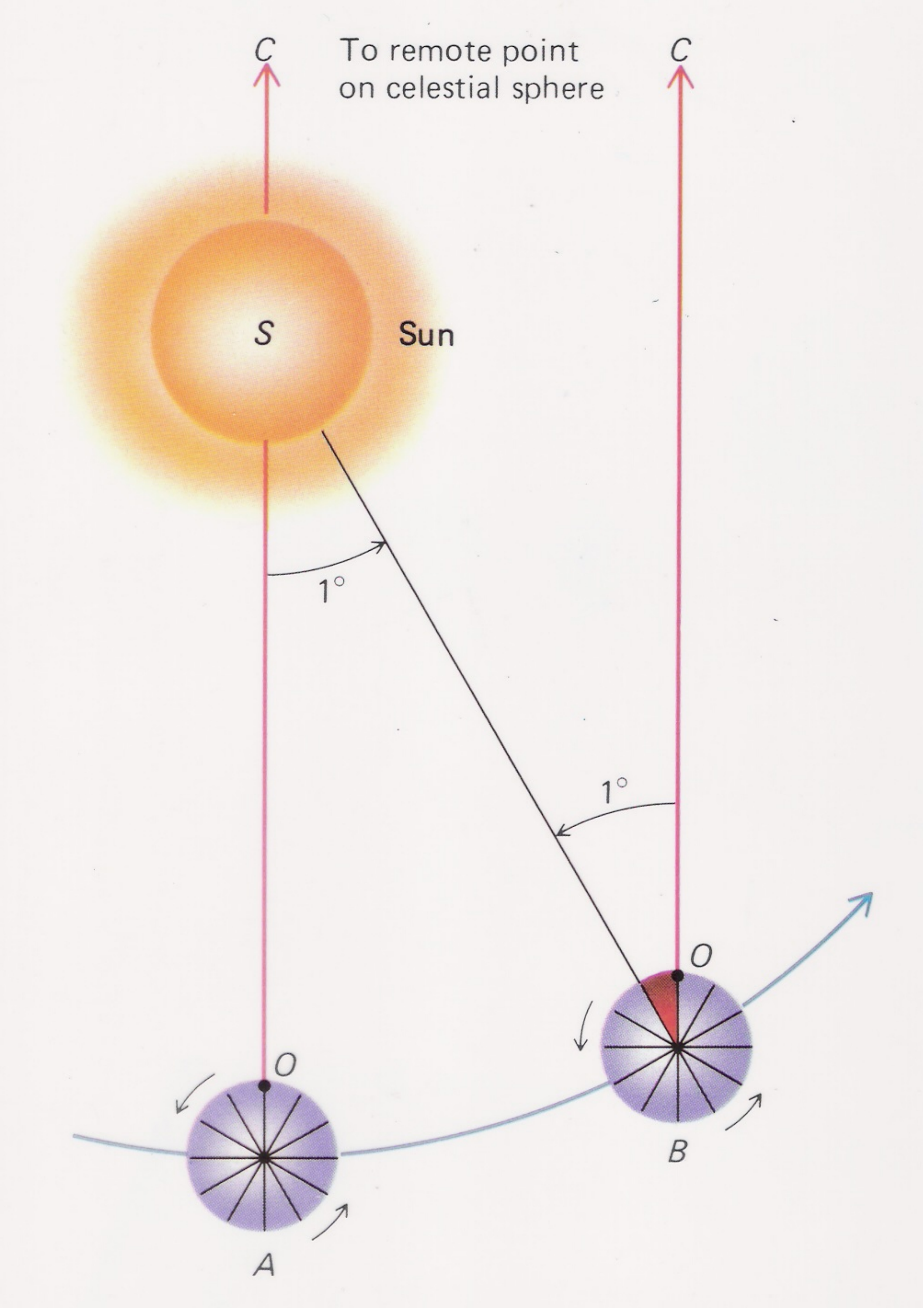
Motion of the Earth – Daily

The Day

Sidereal Day: the time that it takes for the Earth to rotate 360 degrees relative to the distant stars.
23 h 56 m 4 s

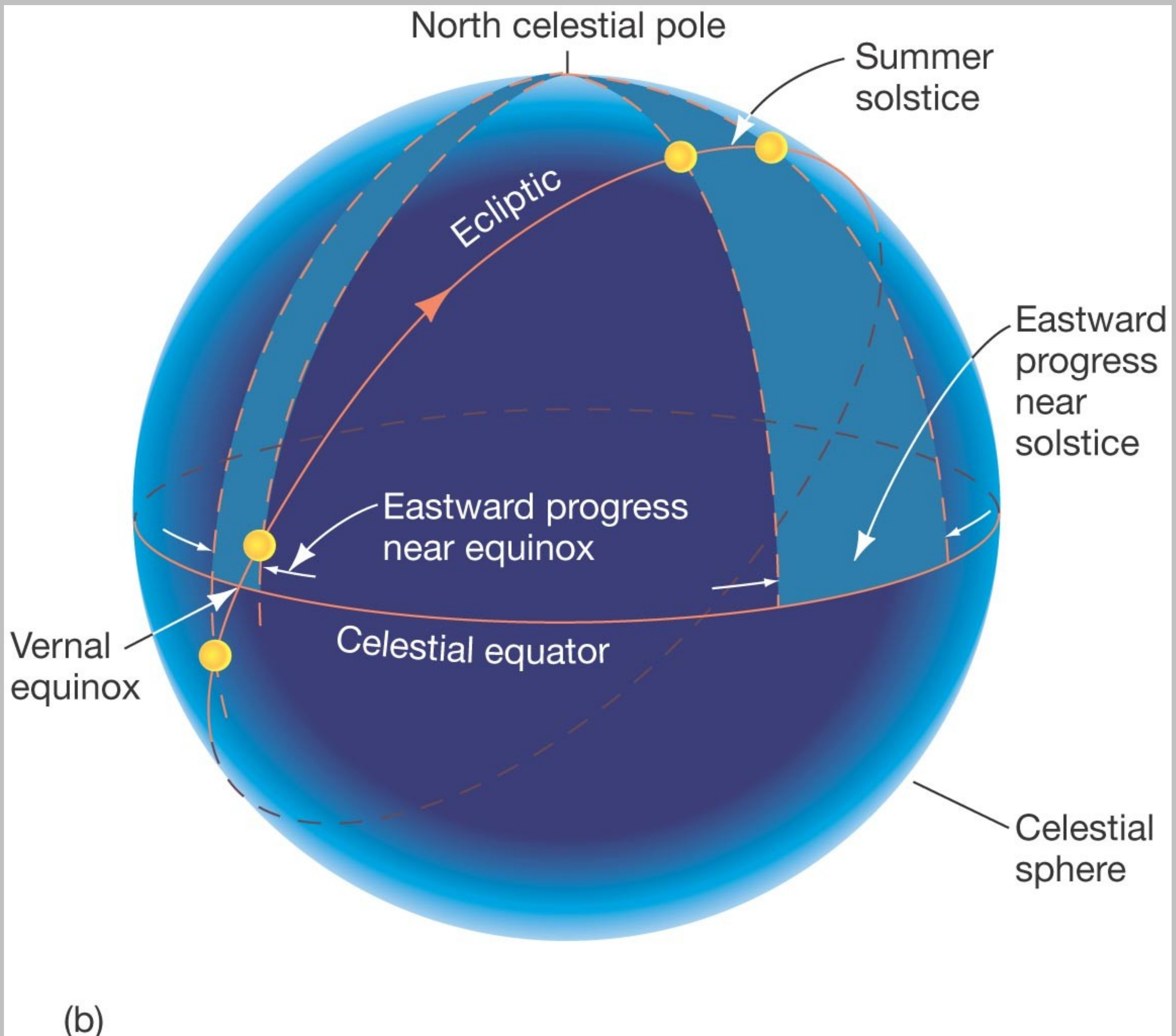
Mean Solar Day: the average time that it takes for the Earth
to rotate relative to the Sun. (E.g., from one noon to the next.)
* What your watch tells you.
* 24 h 0 m, (3 m 56 s longer than the sidereal day)
* "Mean" because the time between local noons varies.
  - Obliquity (tilt) of ecliptic
  - Elliptical orbit

http://astro.unl.edu/classaction/animations/coordsmotion/siderealSolarTime.html



Motion of the Earth - Yearly

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.



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.

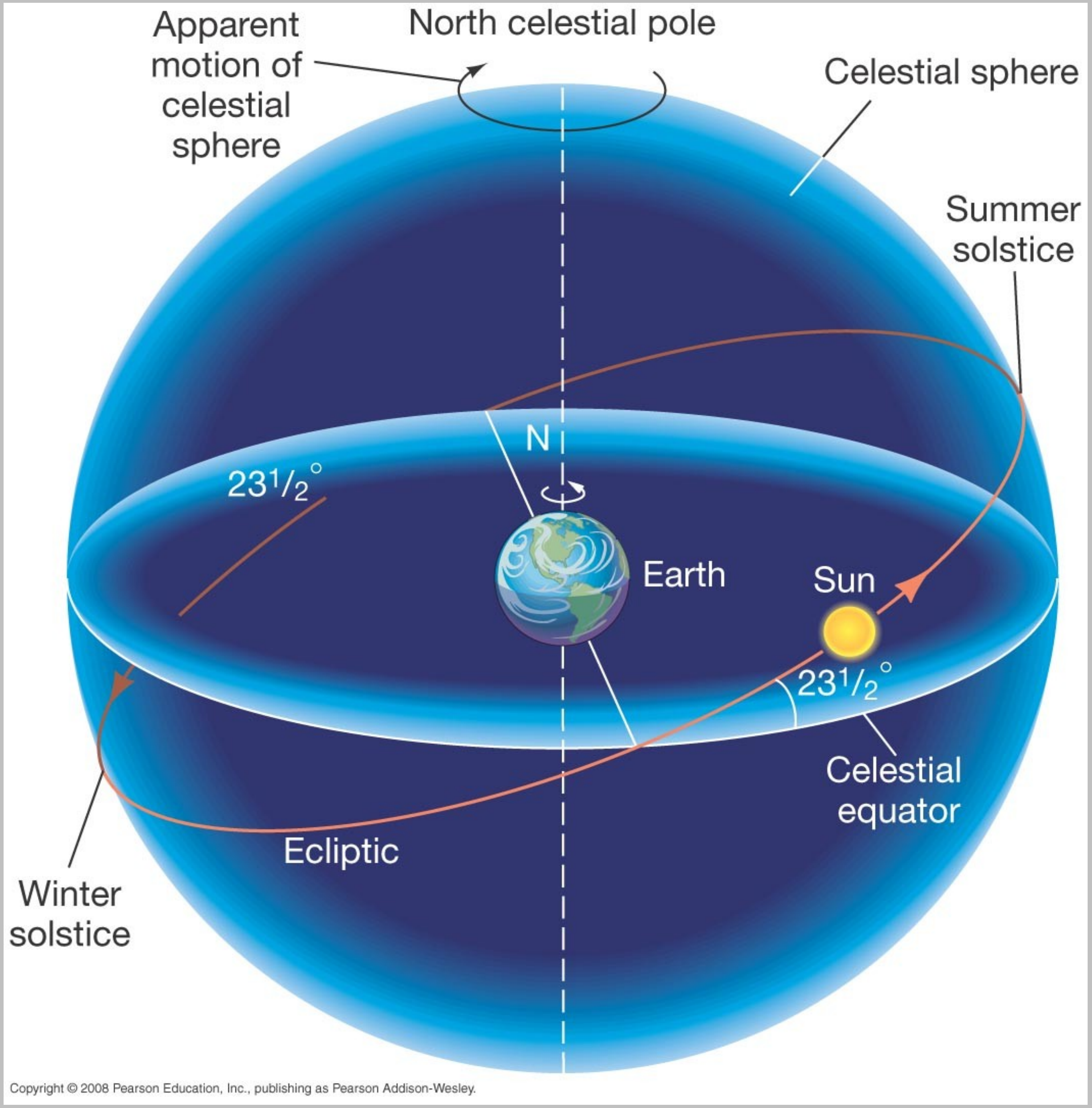
The ***analemma*** is asymmetric because the Earth's orbit is an ellipse.

The summer solstice is a little before aphelion (July 4, when we are farthest from Sun). The winter solstice is a little before perihelion (Jan 3-4, when we are closest to the Sun.)

(See sunmotions.html)

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 mean solar days

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

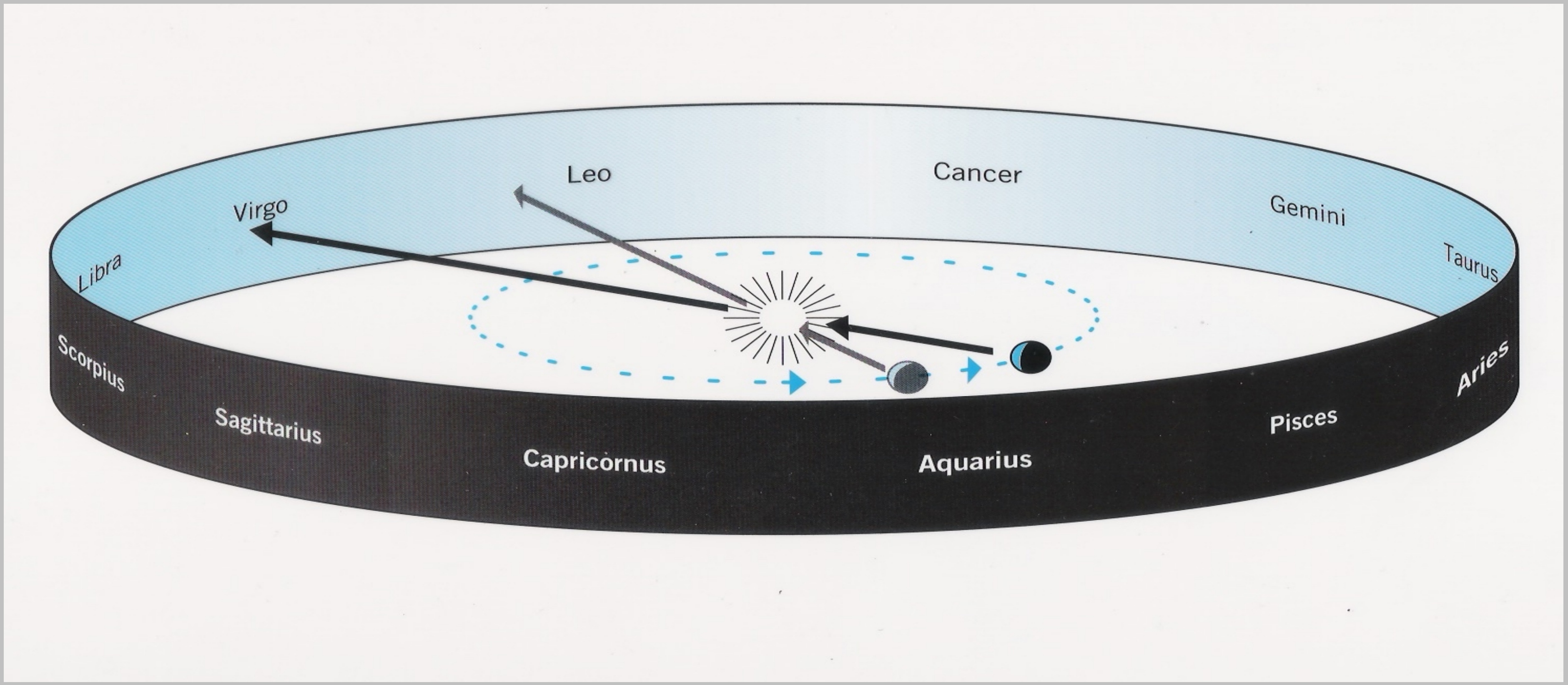
Short Answer: Precession

The vernal equinox point moves westward by 50'' per year relative to the stars because the Earth's Spin axis and celestial equator are wobbling.

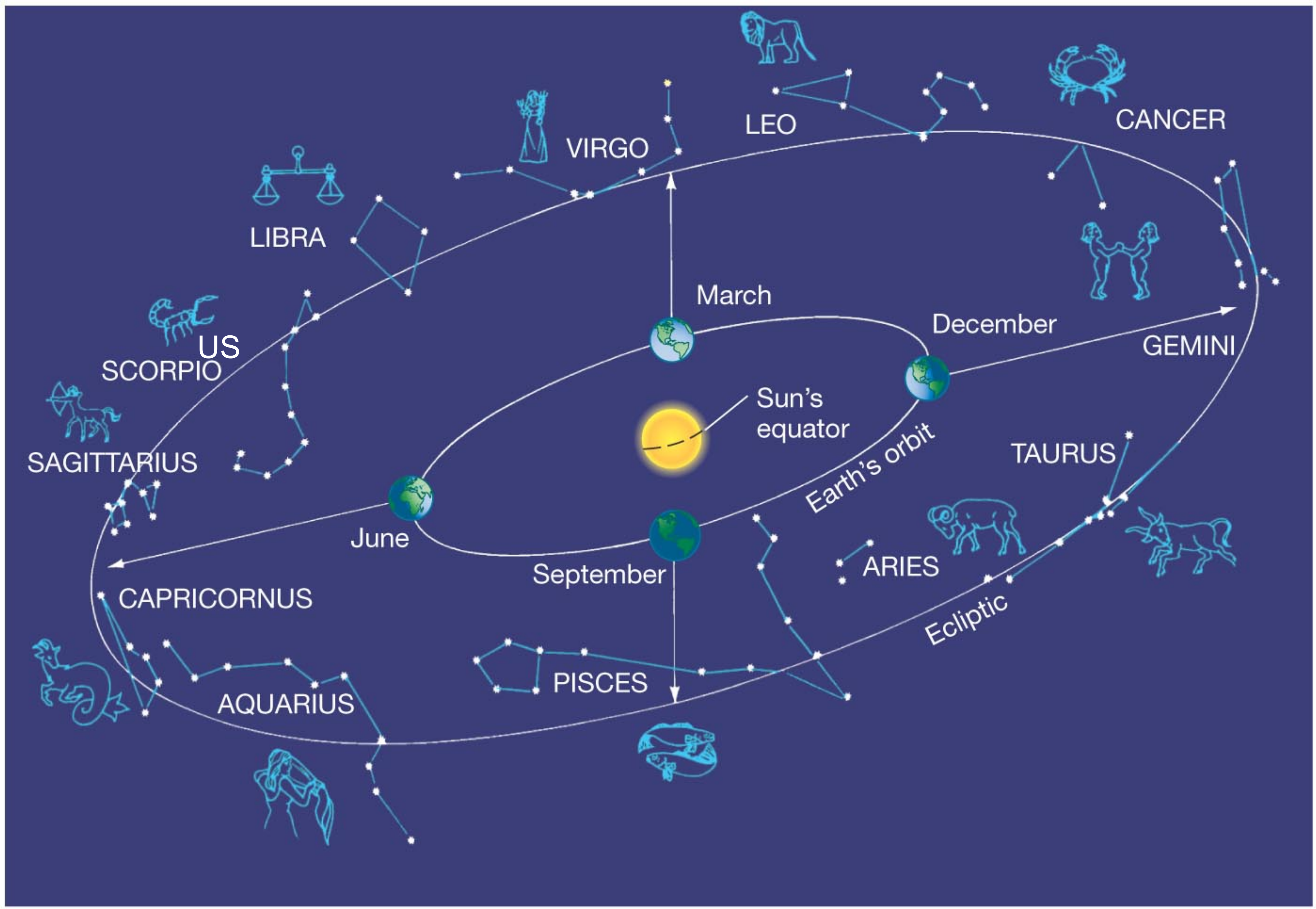
Motion of the Earth – Annual

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.



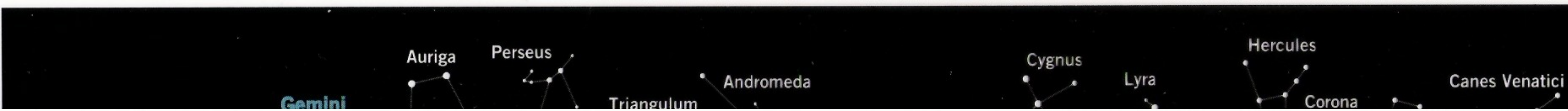
Motion of the Earth - Annual

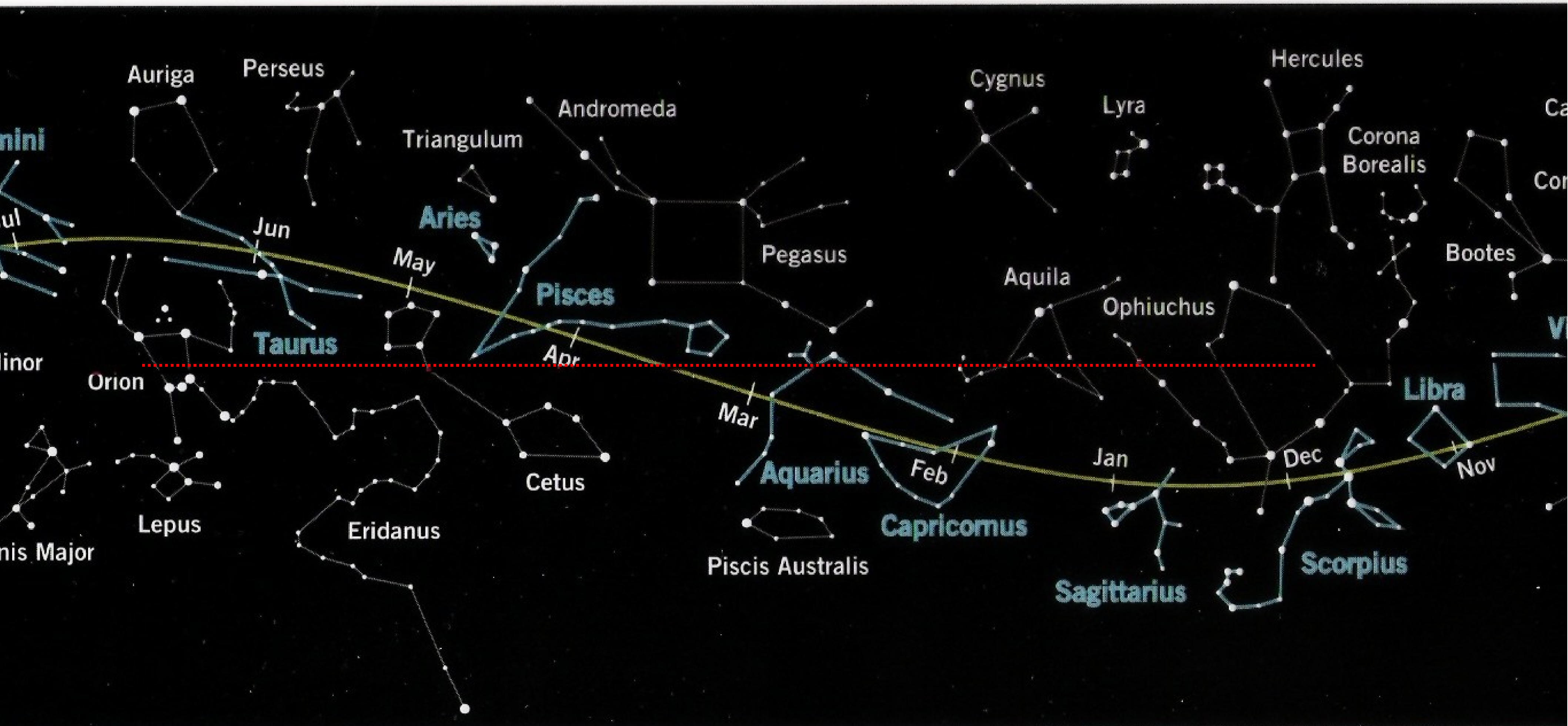


The Zodiacal Constellations

Motion of the Earth – Annual

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





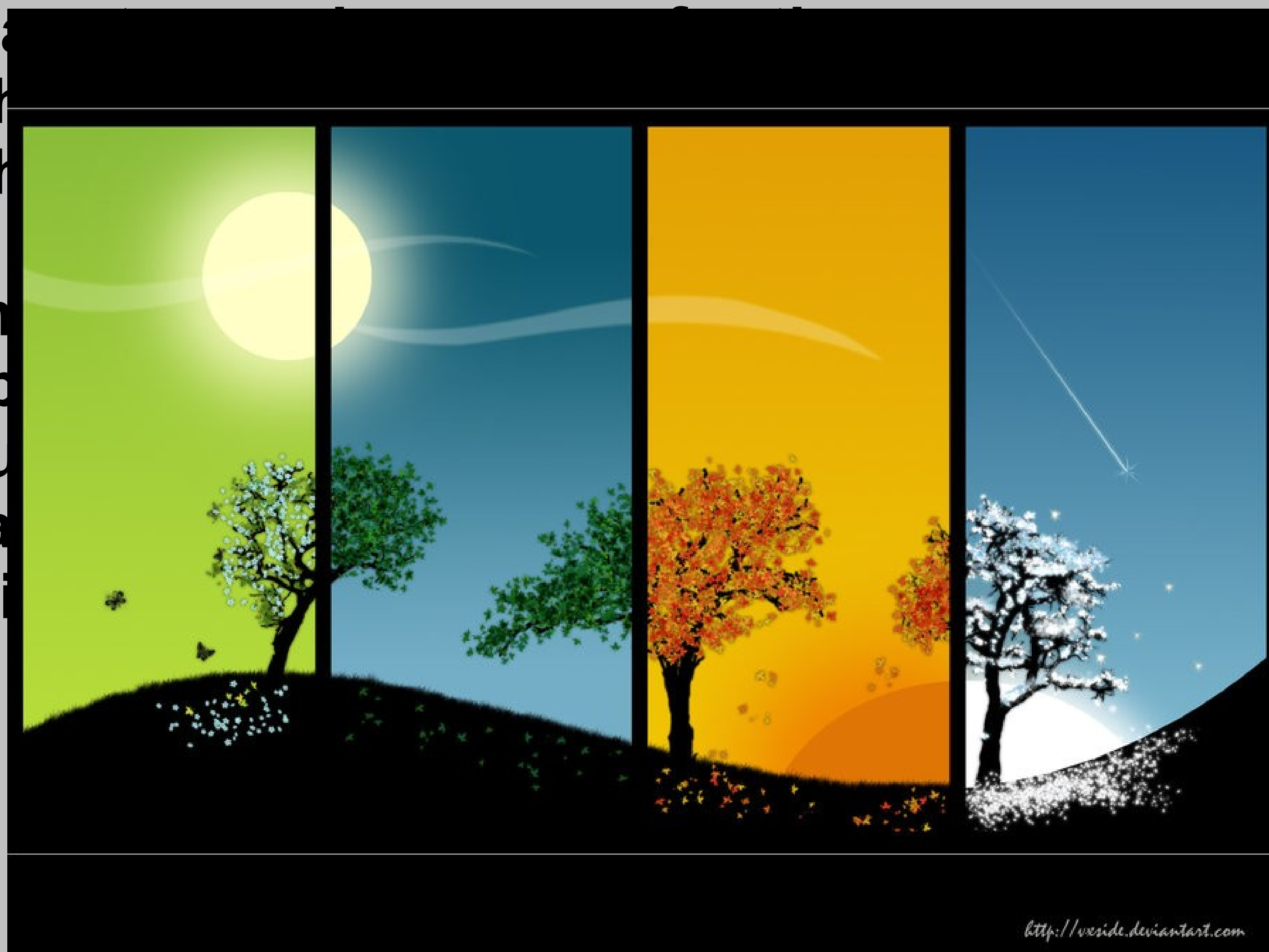
Motion of the Earth and Seasons

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

There a

1. Th ... anges.

2. Th



Astron

*** Sp ...)**

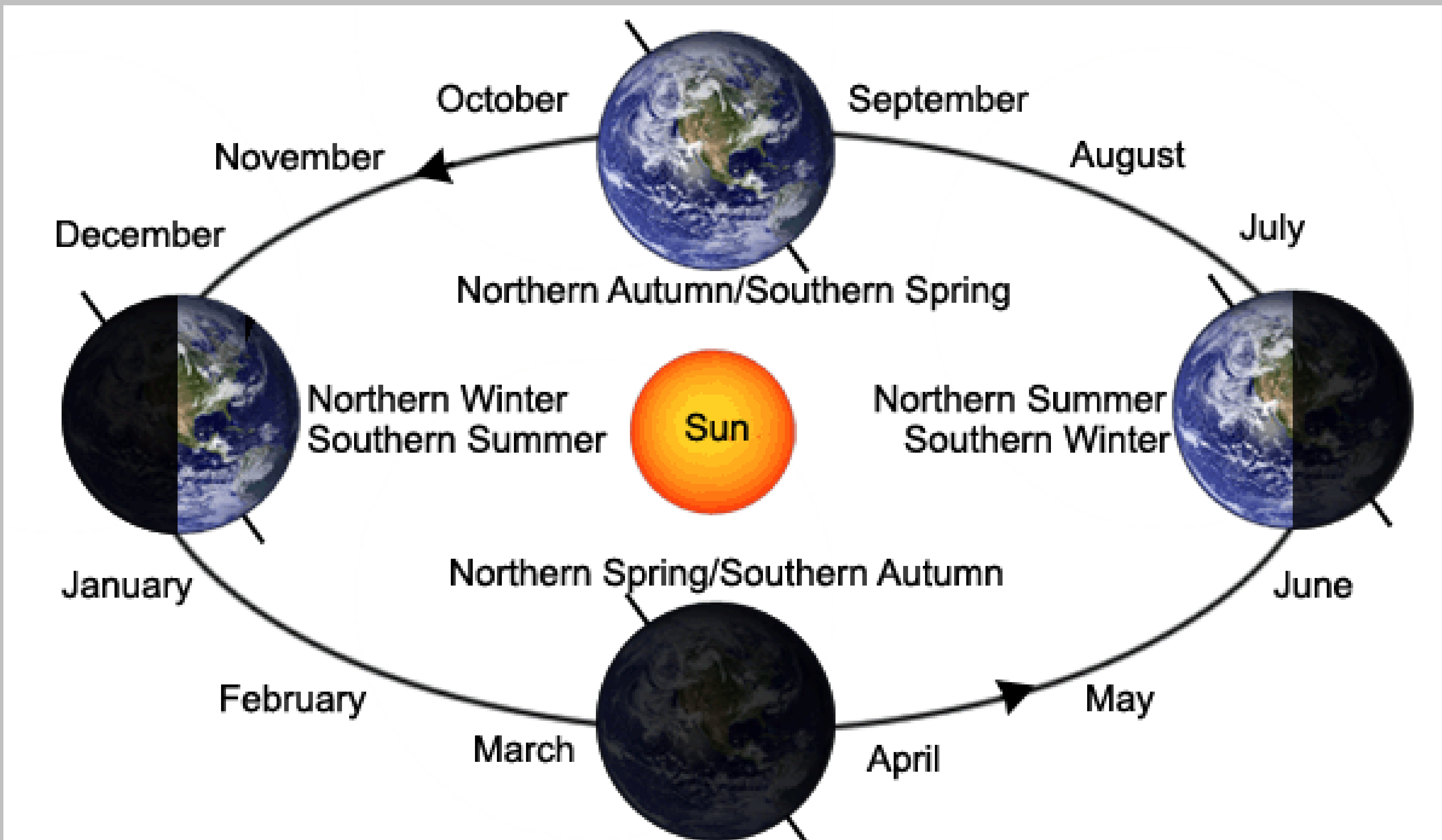
*** Su ... ,21)**

*** Fa ... 3)**

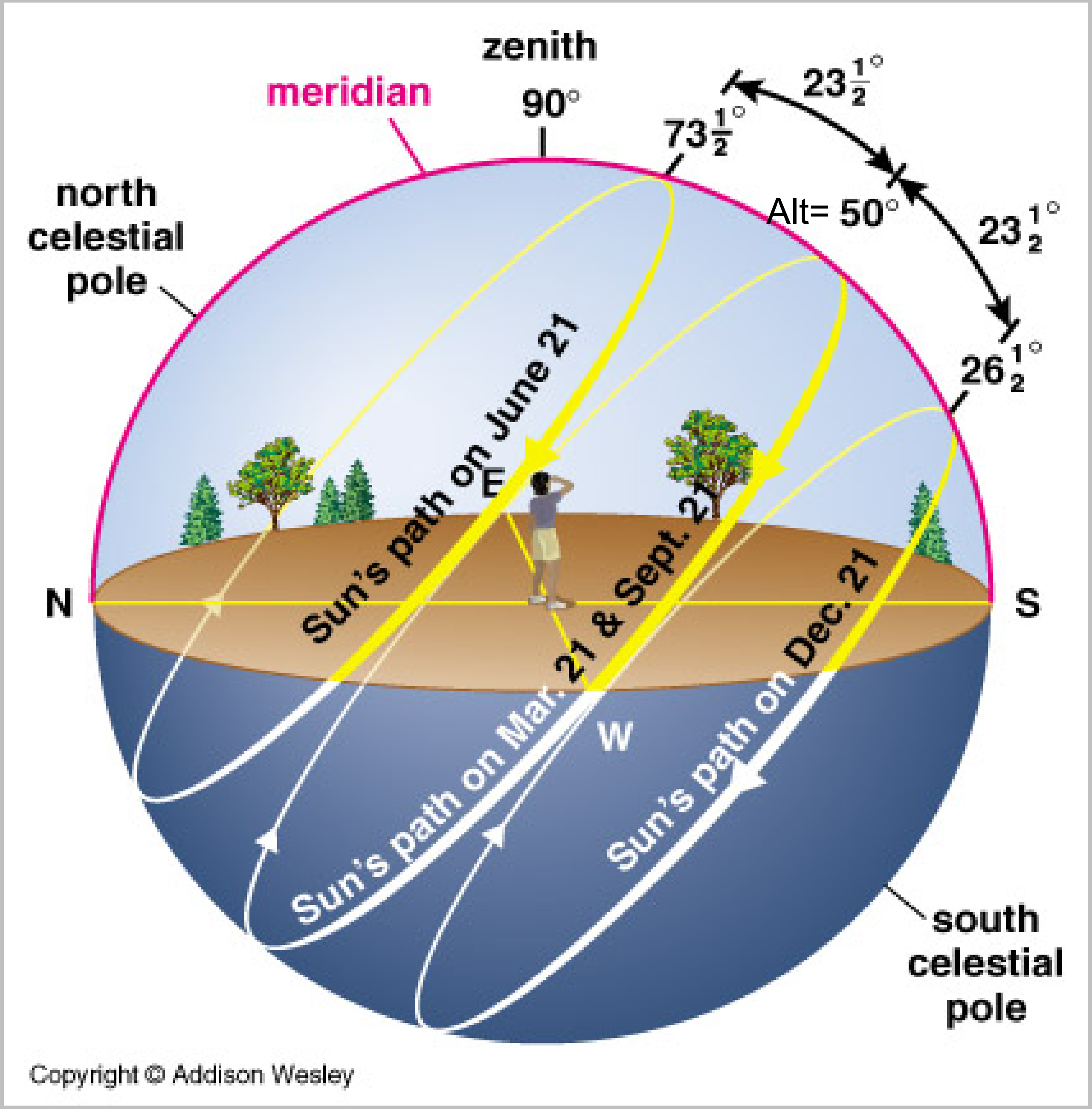
*** Wi ...)**

Motion of the Earth and Seasons

Seasons: natural periods into which the year is divided by the equinoxes and solstices



Motion of the Earth and Seasons



See: http://astro.unl.edu/classaction/animations/coordsmotion/sunmotions.html

Precession of the Equinoxes

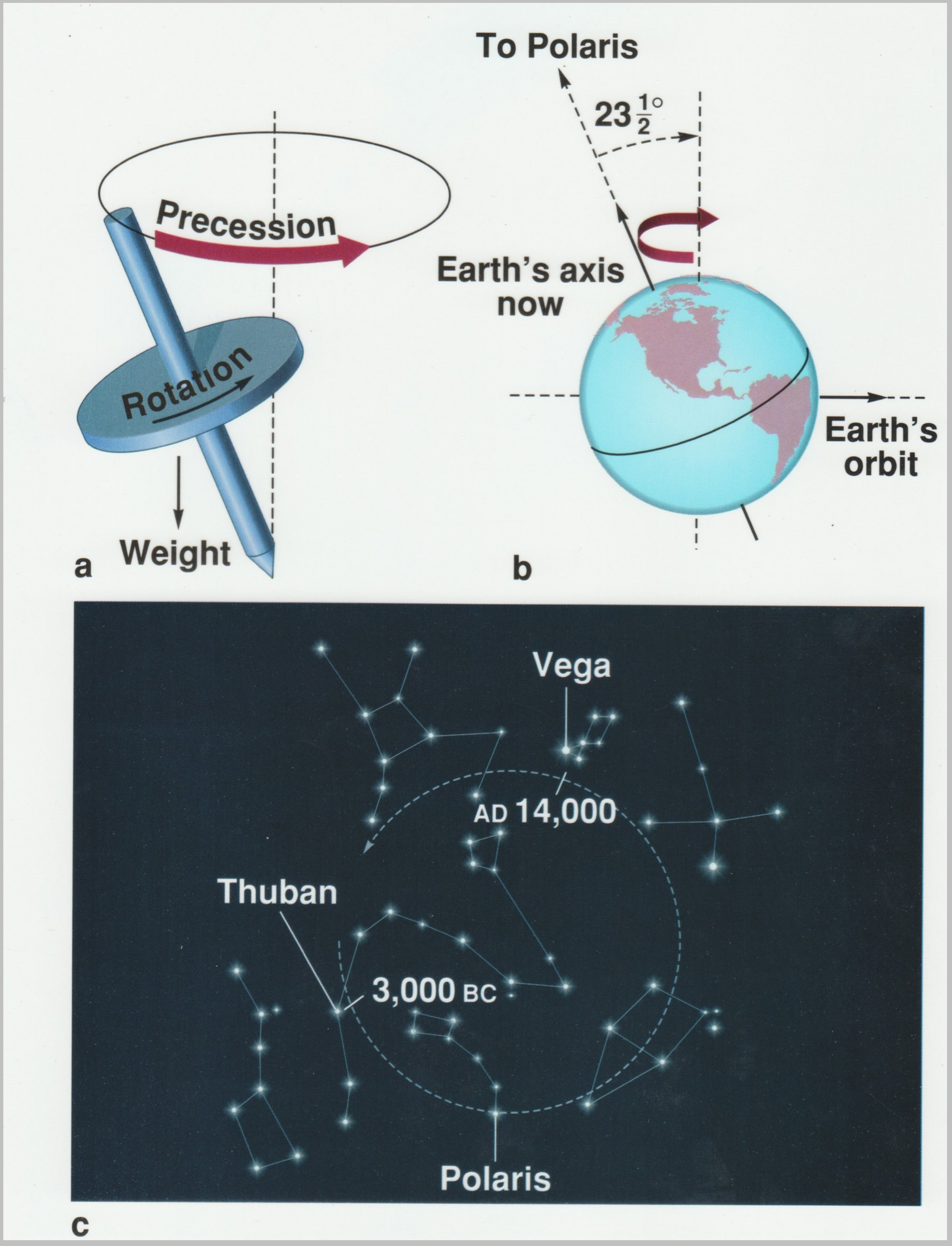
The reason for the tropical year being shorter than the sidereal year.

The vernal equinox point moves westward by 50” per year relative to the stars because the Earth’s spin axis (and equator) are wobbling.

The Earth's spin axis is “wobbling”.

- **26,000 year period**
- **Tilt remains (about) 23.5 degrees**
- **Seasons remain (about) the same severity**

Precession



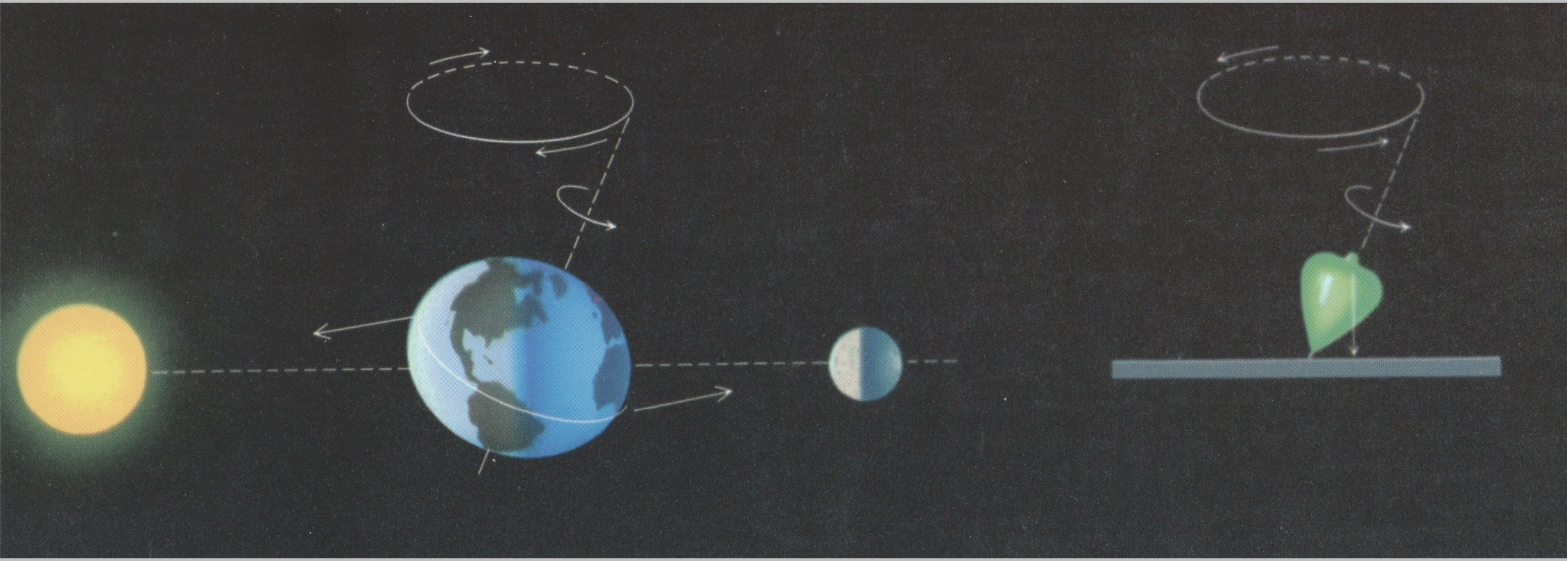
Gradual change of the NCP position.
Polestar was not always Polaris!

Precession

CYGNUS
Deneb
CASSIOPEIA
AD 8000
CEPHEUS
LYRA
Vega
AD 15,000
Polaris
TODAY
DRACO
Path of north
celestial pole
URSA
MINOR
AD 1
Thuban
5000 BC
CORONA
BOREALIS
URSA MAJOR

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 and SCP change position rel to stars
2) The equatorial coordinates (RA and DEC) of stars slowly change with time. → We need to specify "Epoch" of coordinates.
3) Constellations visible at midnight on a given date (say, Mar 20) change gradually.
    - 3/20/2021 – Leo on meridian @midnight
    - 3/20/15021 – Aquarius on meridan @midnight
4) Calendar years must average 365.2422 days over thousands of years.
    - Leap year every 4 years → 365.25 days
    - No leap year every 400 years → 365.2425 days

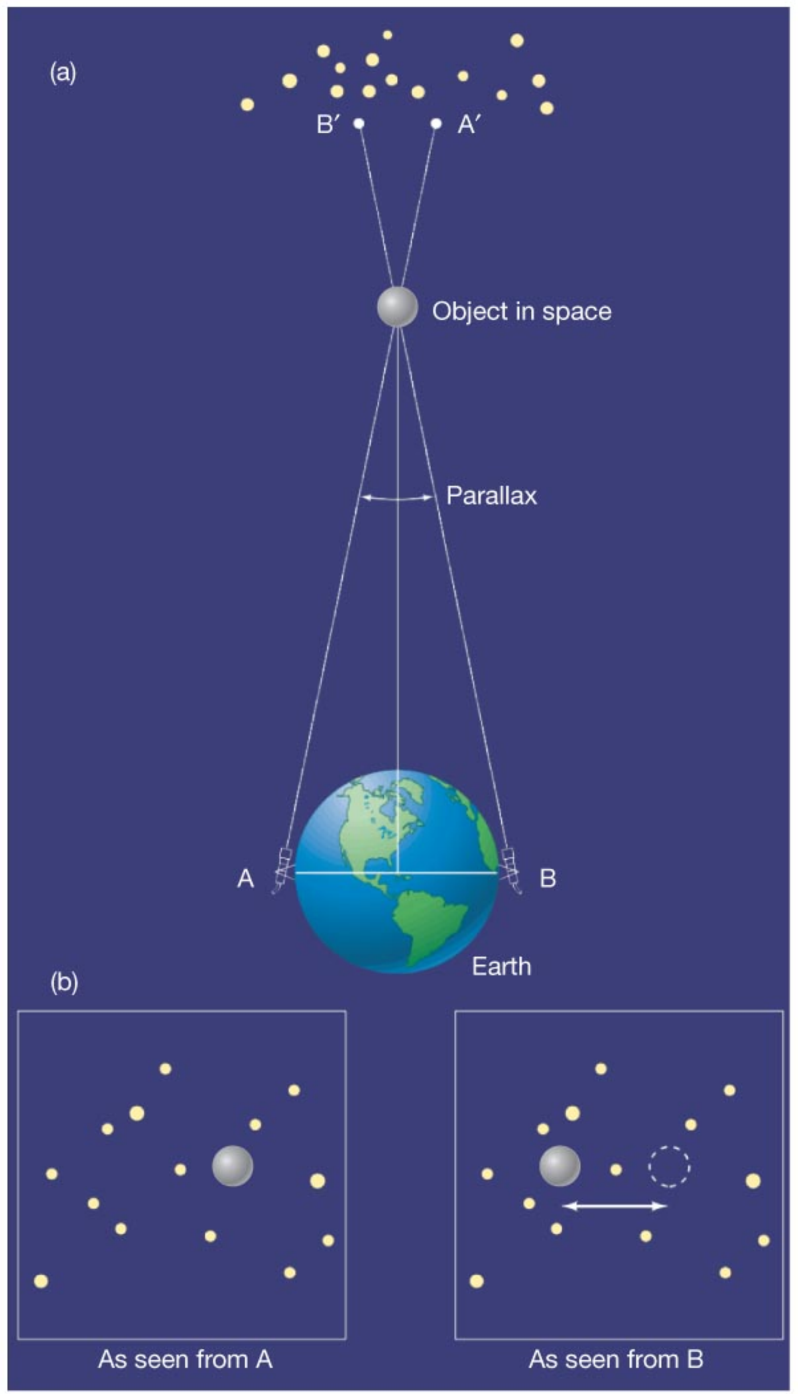
Parallax

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

Stellar parallax – apparent motion of foreground stars due to Earth's orbital motion. (Typically <~ 0.1", biggest ~1.0" Proxima Cen.)

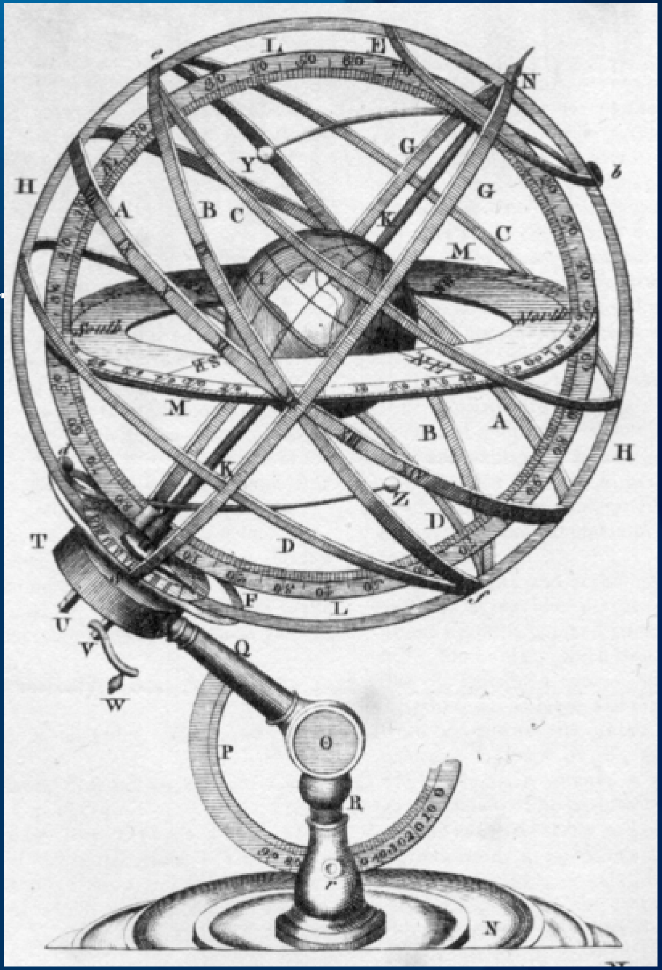
Relation between parallax p(arcsec) and distance, d(parsec):

$$1/p = d$$



Knowledge of the Ancient Greeks

- Eratosthenes (276-195 BC)
  - –Measured circumference of the Ear
  - –Invents armillary sphere



- Hipparchus (190-120 BC)
  - –Discovered precession of Earth's spin axis
  - –Discovered difference between sidereal and tropical year

Eratosthenes' method