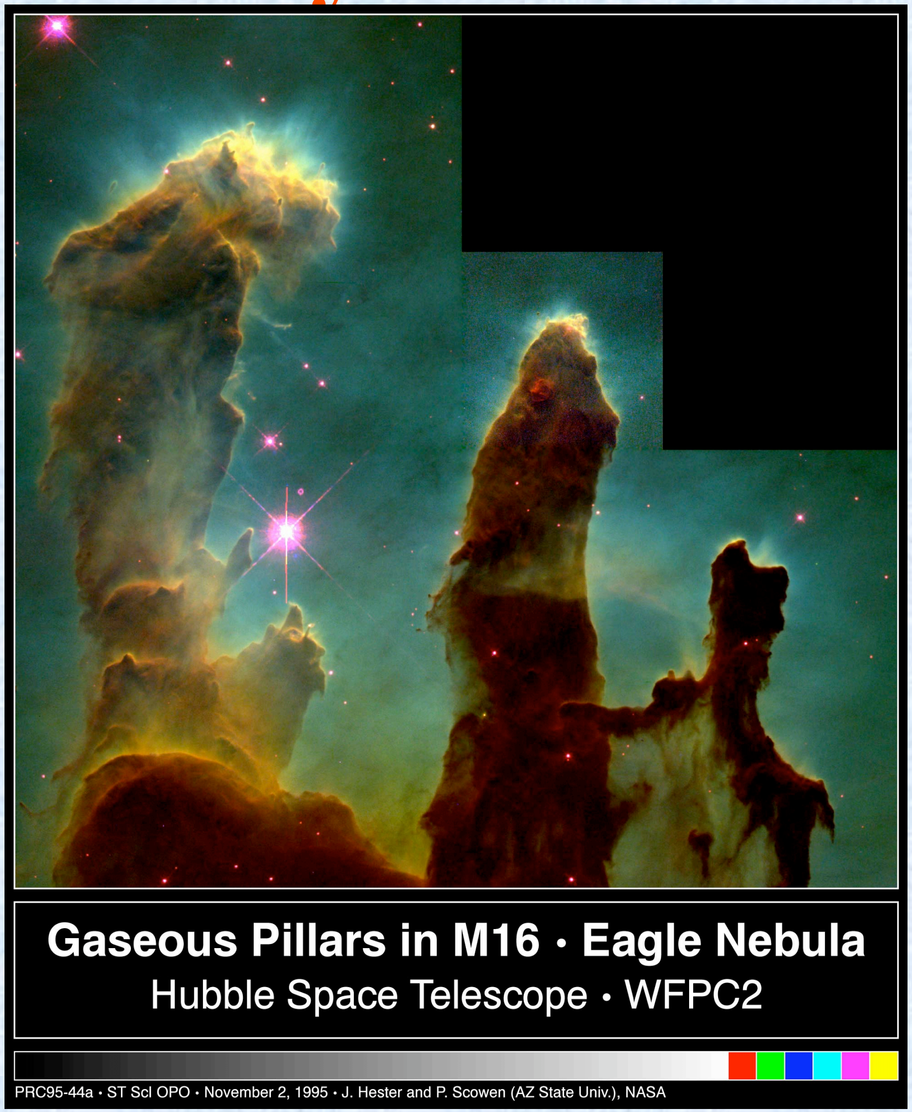
Astronomy 1 – Winter 2011



Lecture 2; January 5 2011

Previously on Astro-1

- Goal 1 – The big picture
  - The Universe is huge and awesome and we will make a "Grand Tour"
- Goal 2 – The scientific method
  - Demarcation: what is science?
  - Falsification: how do you test scientific theories?
  - Corroboration: what is a "good" scientific theory?
- Goal 3 – Learning scientific language
  - Science terms have very precise definitions, with sometimes somewhat different meaning than in the current language

Today on Astro-1

- Powers of Ten
- Units
- Measuring Angles
- The night sky
- Seasons

Powers of 10: large numbers

Exponent tells how many times to multiply a number by itself: $10^2 = 10 \times 10 = 100$

$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$
$10^6 = 1,000,000$ (one million)
$10^9 = 1,000,000,000$ (one billion)
$10^{12} = 1,000,000,000,000$ (one trillion)

A positive exponent on the number 10 tells you how many zeros are in the number.

Powers of 10: small numbers

Negative exponents tell how many times to divide by ten: $10^{-2} = 1/10 \times 1/10 = 1/10^2 = 0.01$

$10^0 = 1$
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/10 \times 1/10 = 0.01$ (one hundredth)
$10^{-3} = 1/10 \times 1/10 \times 1/10 = 1/10^3 = 0.001$ (one thousandth)
$10^{-4} = 0.0001$ (one ten-thousandth)
$10^{-6} = 0.000001$ (one millionth)

You can also think of the negative exponent as how many decimal places are in the number.

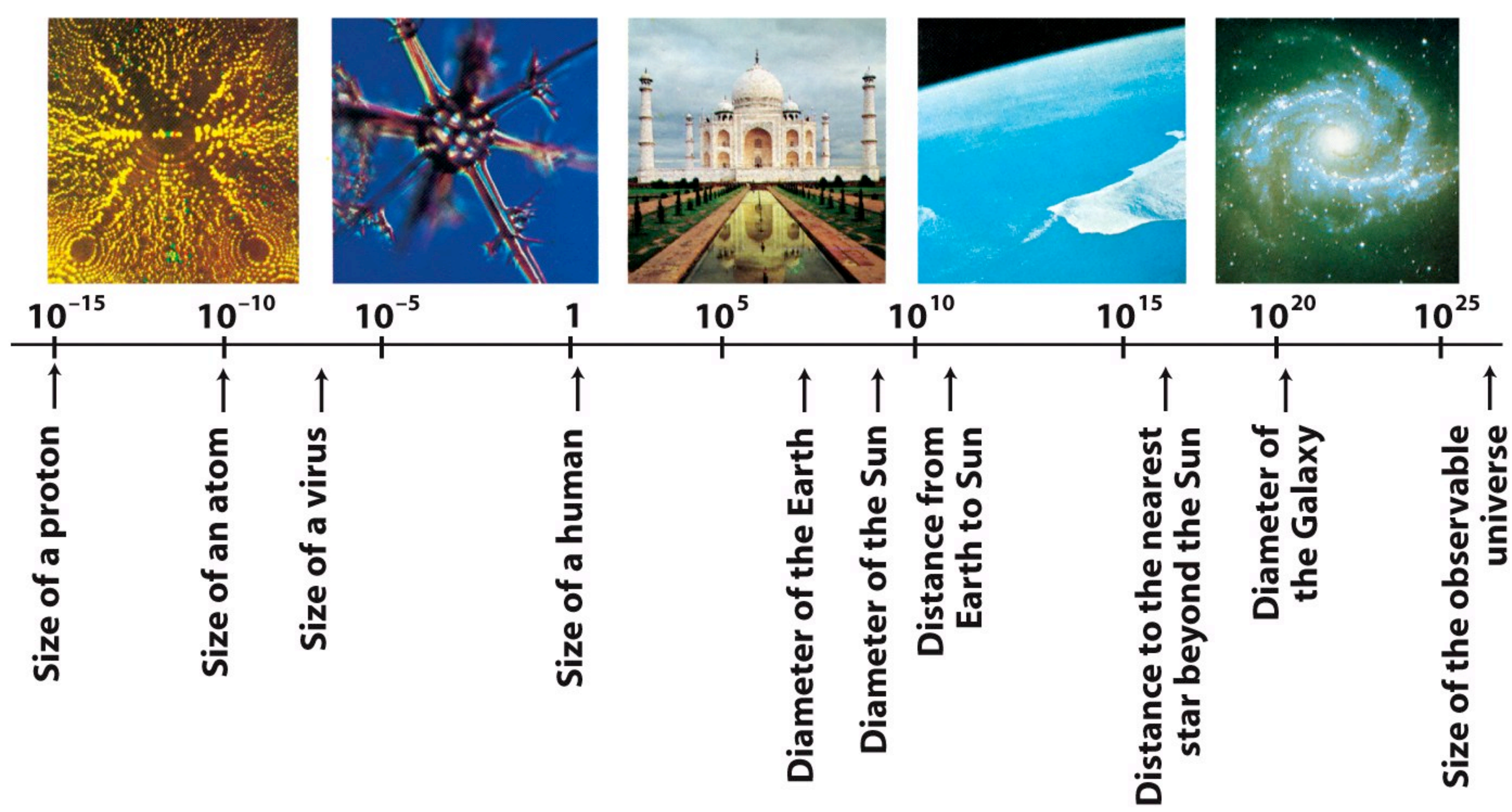
Scientific notation

A way of expressing large or small numbers

$2,230,000 = 2.23 \times 1,000,000 = 2.23 \times 10^6$

$0.0095 = 9.5 \times 0.001 = 9.5 \times 10^{-3}$

To use scientific notation on your calculator, use the EE or EXP key. For example, 2.23 EE 6.



10^{-15}
10^{-10}
10^{-5}
1
10^{5}
10^{10}
10^{15}
10^{20}
10^{25}
Size of a proton
Size of an atom
Size of a virus
Size of a human
Diameter of the Earth
Diameter of the Sun
Distance from Earth to Sun
Distance to the nearest star beyond the Sun
Diameter of the Galaxy
Size of the observable universe

Dimensional quantities have units

- How much does your Universe textbook weigh?
- How tall are you?
- Although units are arbitrary, dimensions are not!
- If you quote a length it should be in units of length, so time etc etc. You cannot be 5 hours tall!

Standard Units in Astronomy

- The standard system of units is the so-called international system, based on meters, kg, etc.
- The system is convenient because conversion are trivial in exponential notation:
  - 1 km = 1000 m vs 1 mile = ?? feet?
- Astronomy often uses non IS units for historical reasons.
- For example 1 solar mass ~ 2e30 Kg
- When in doubt convert to IS

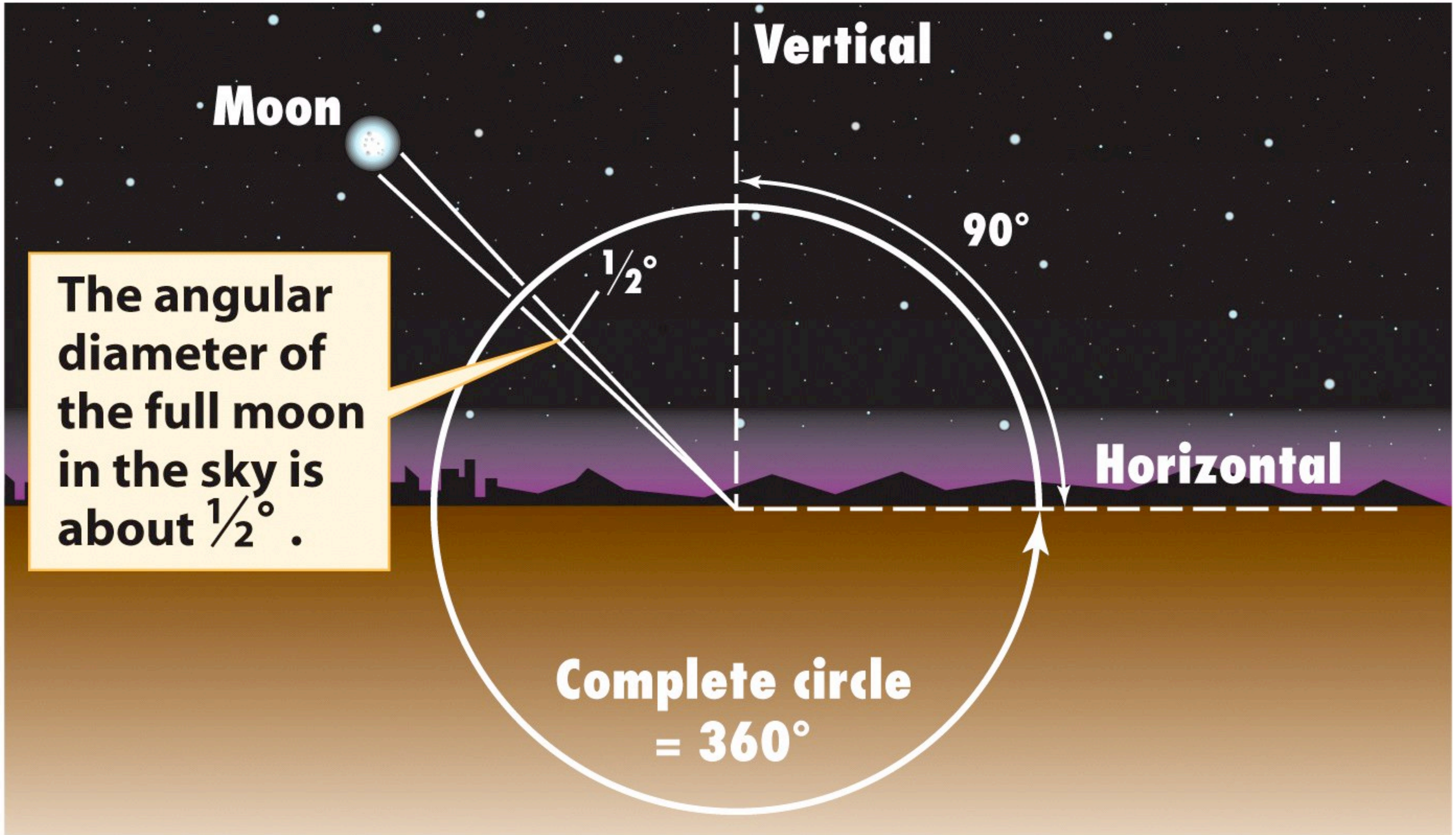
Example: length

Astronomers use the metric system (meters for distance or length).

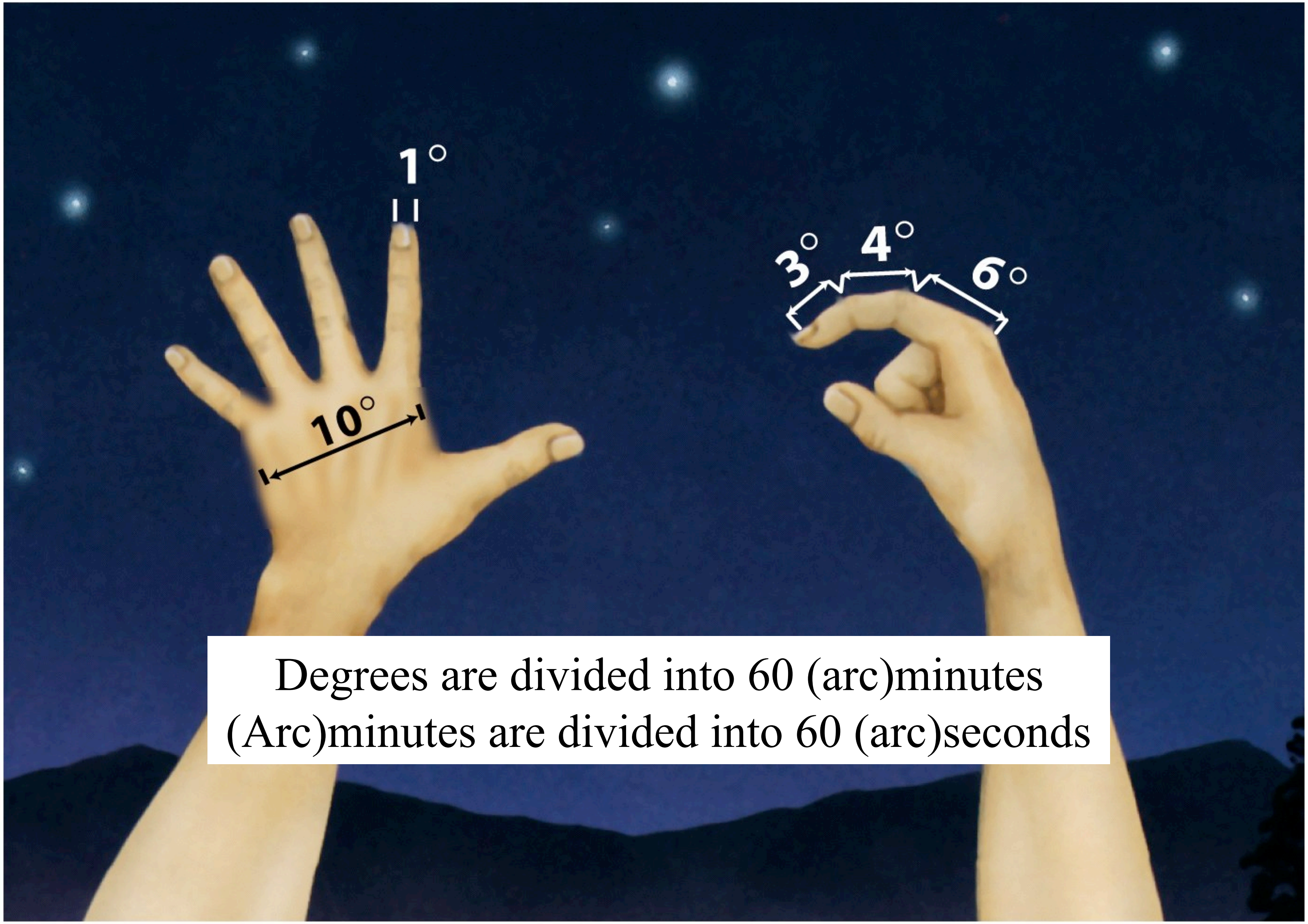
But sometimes it is convenient to use other units. The average distance from the Earth to the Sun is called an astronomical unit. 1 AU = 1.496×10^8 km

The distance light travels in a year is a lightyear (ly). The nearest star, Proxima Centauri is 4.2 lyr away, so the light we see today left it 4.2 years ago. Note that a lightyear is a unit of distance, not time. The farthest thing you can see with your naked eye is M33, the Pinwheel Galaxy, 3 million lightyears away.

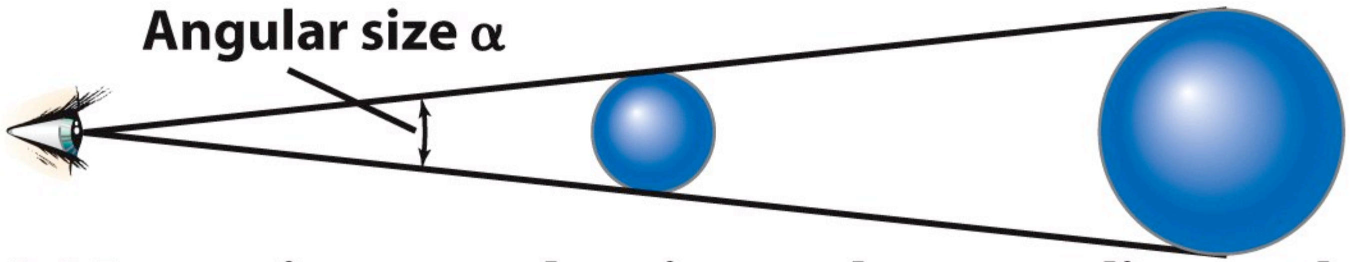
Angles



Measuring angles in the sky

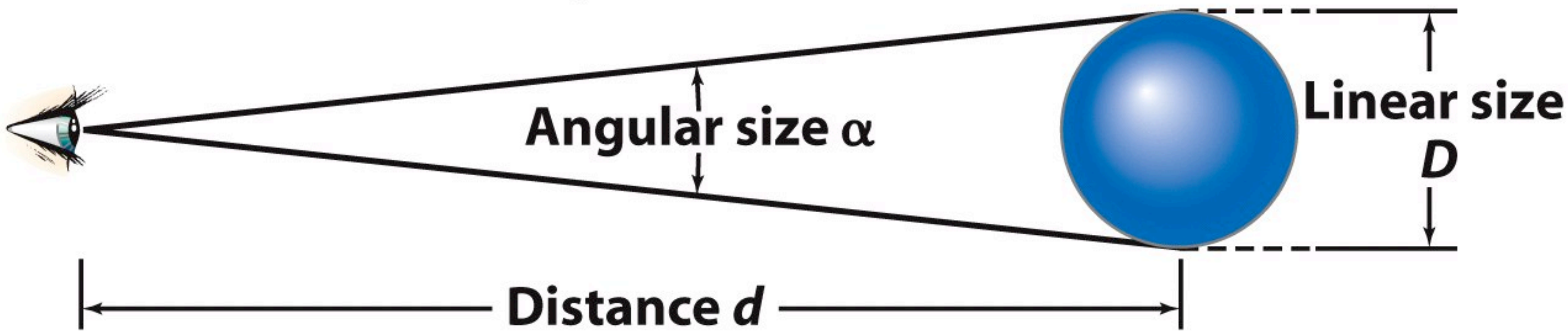


Degrees are divided into 60 (arc)minutes
(Arc)minutes are divided into 60 (arc)seconds



(a) For a given angular size α, the more distant the object, the greater its actual (linear) size

(b) For a given linear size, the more distant the object, the smaller its angular size



(c) Relating an object's linear size D, angular size α, and distance d

Turning an angular distance (α) into a linear distance (D)

First need to know how far away the object is (d).

$$D = \frac{\alpha d}{206265}$$

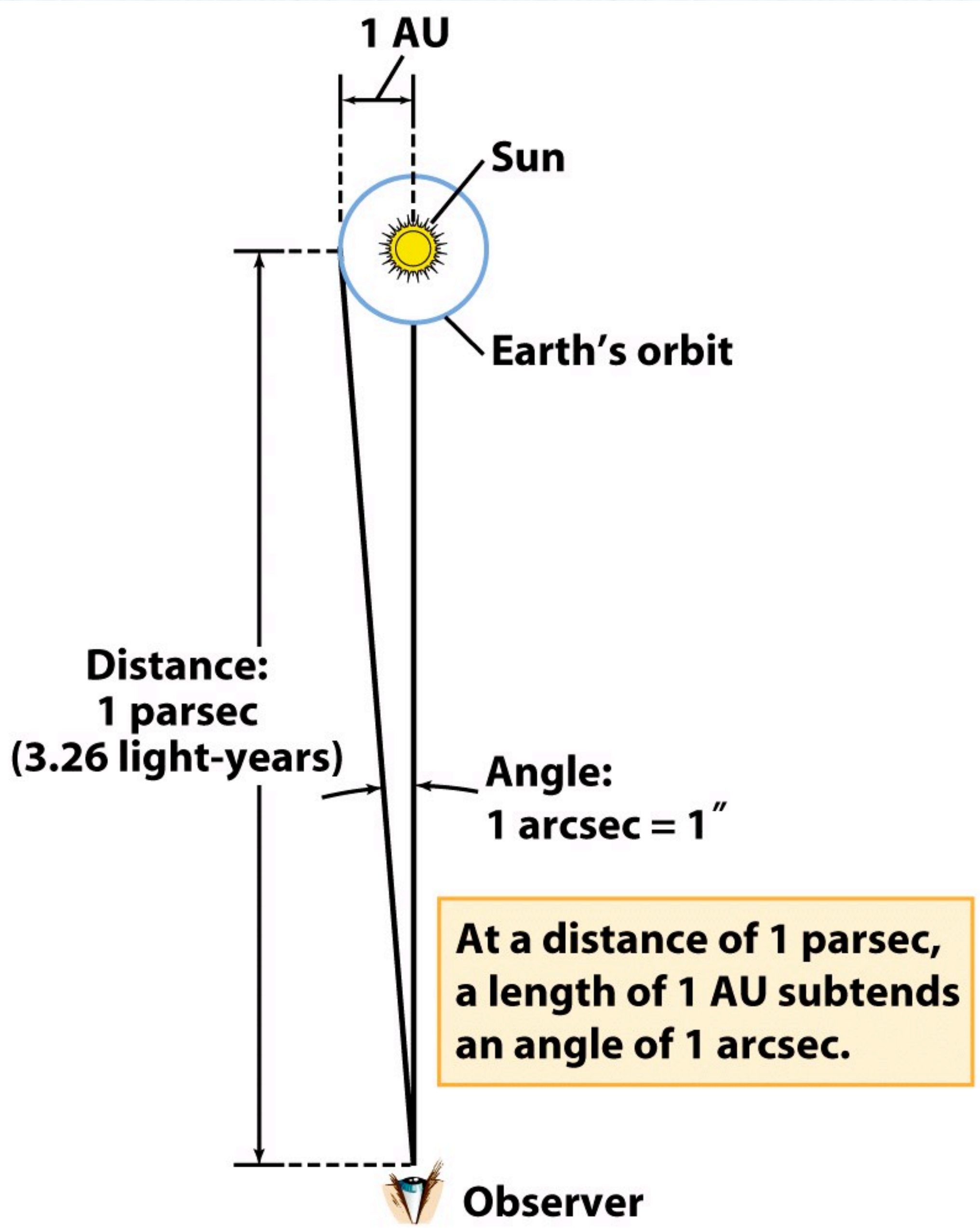
The angle α must be in arcseconds. The distances can be in any unit, as long as they are the same.

Example: What is the linear diameter of the moon if it is half a degree wide, and 400,000 km away?

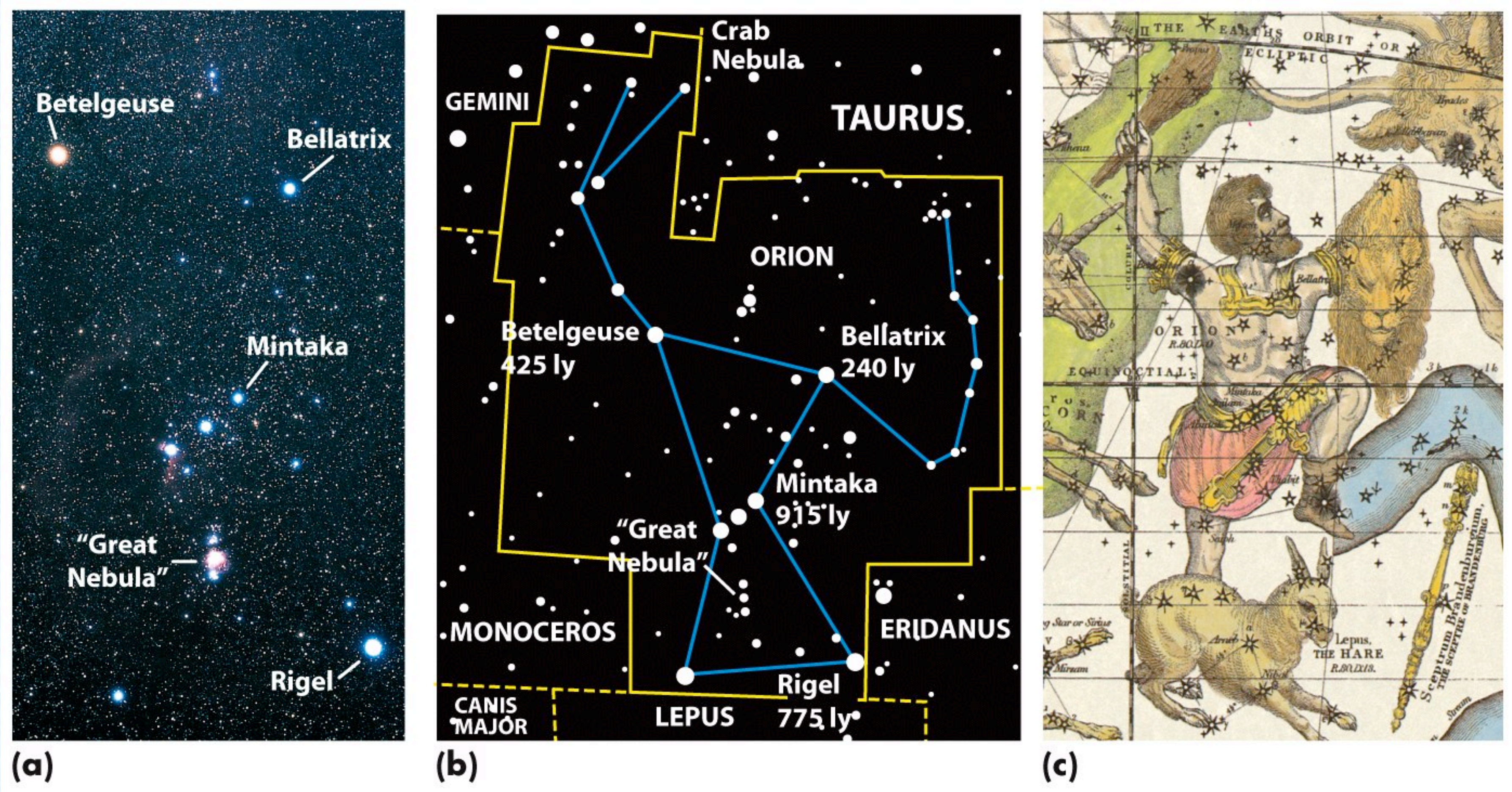
First, how many arcsec are in 0.5 deg?

$$0.5\,\mathrm{deg} = 0.5^{\circ}\left(\frac{60'}{1^{\circ}}\right)\left(\frac{60''}{1'}\right) = 1800''$$

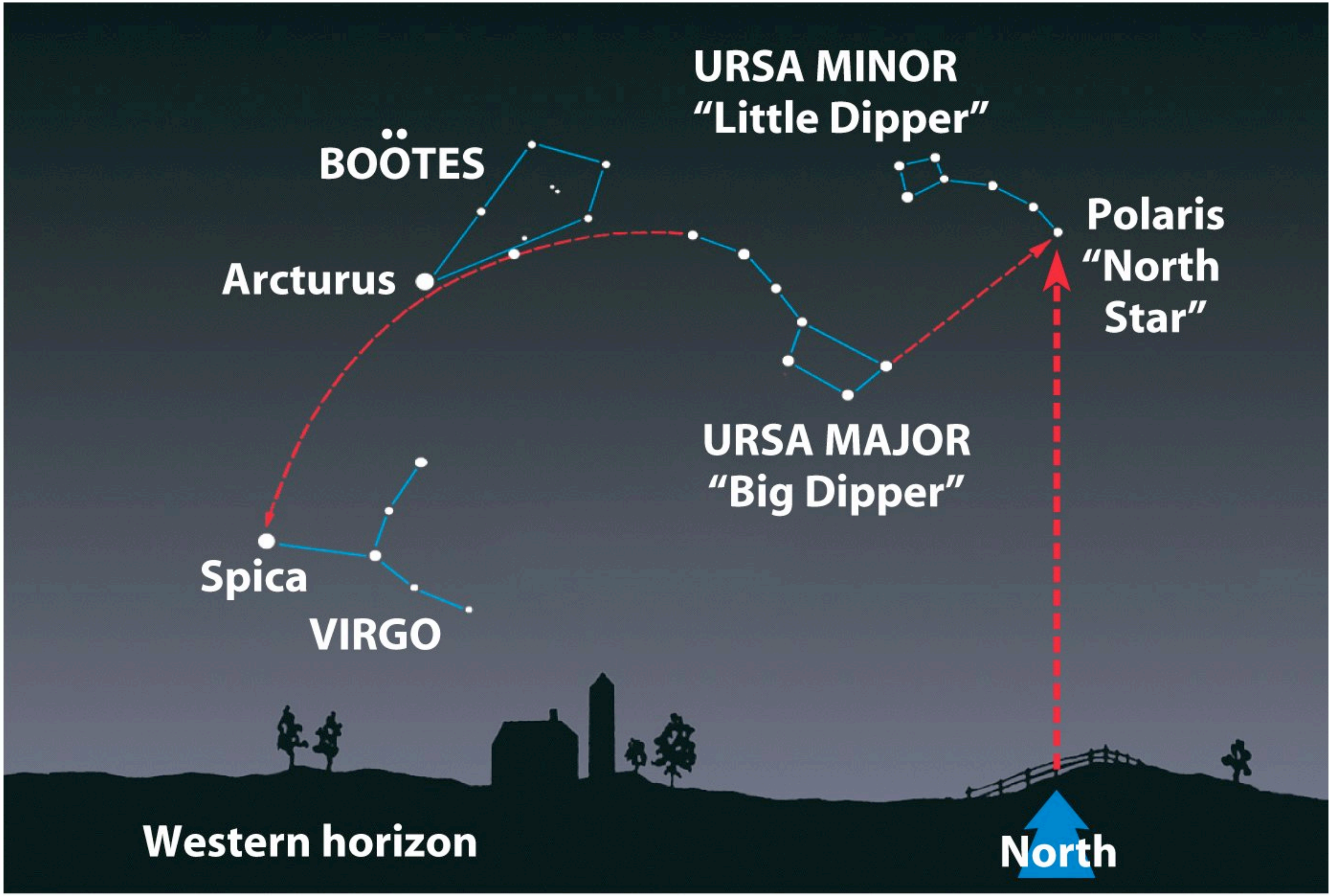
$$D = \frac{1800'' \times 400{,}000\,km}{206265} = 3491\,km$$

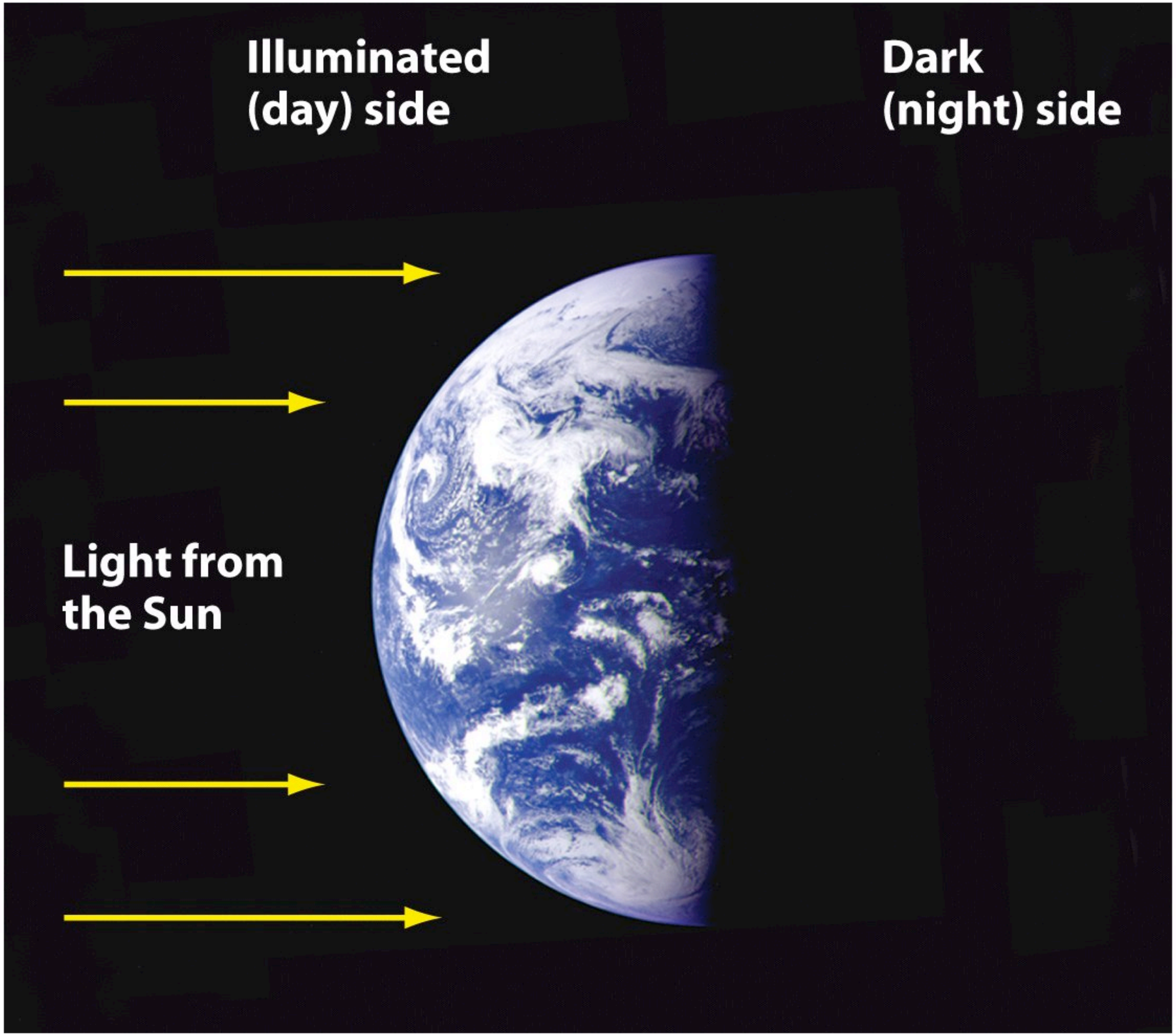

1 AU
Sun
Earth's orbit
Distance:
1 parsec
(3.26 light-years)
Angle:
1 arcsec = 1″
At a distance of 1 parsec, a length of 1 AU subtends an angle of 1 arcsec.
Observer

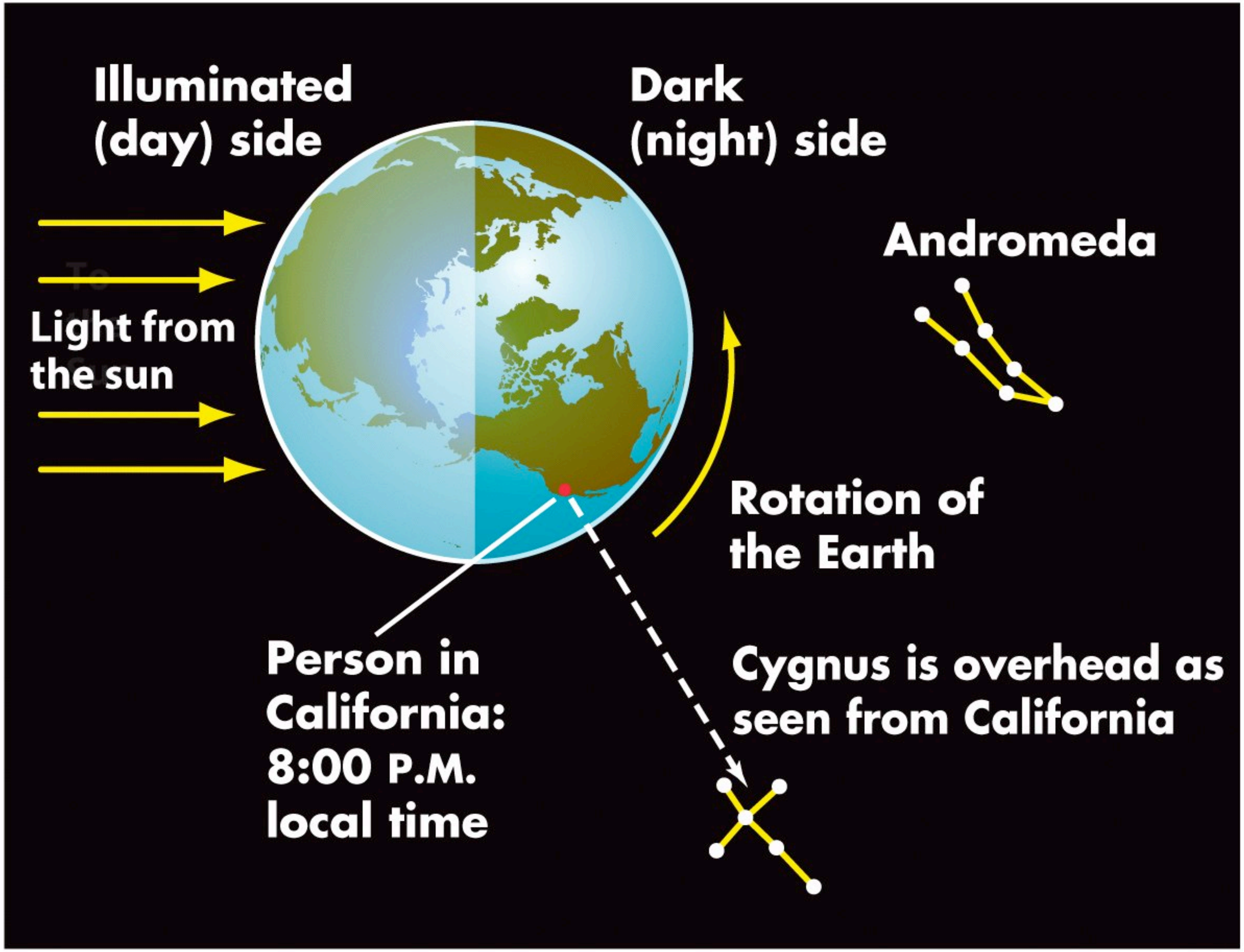

The night sky



The sky is divided into 88 constellations, but of course the stars are at different distances

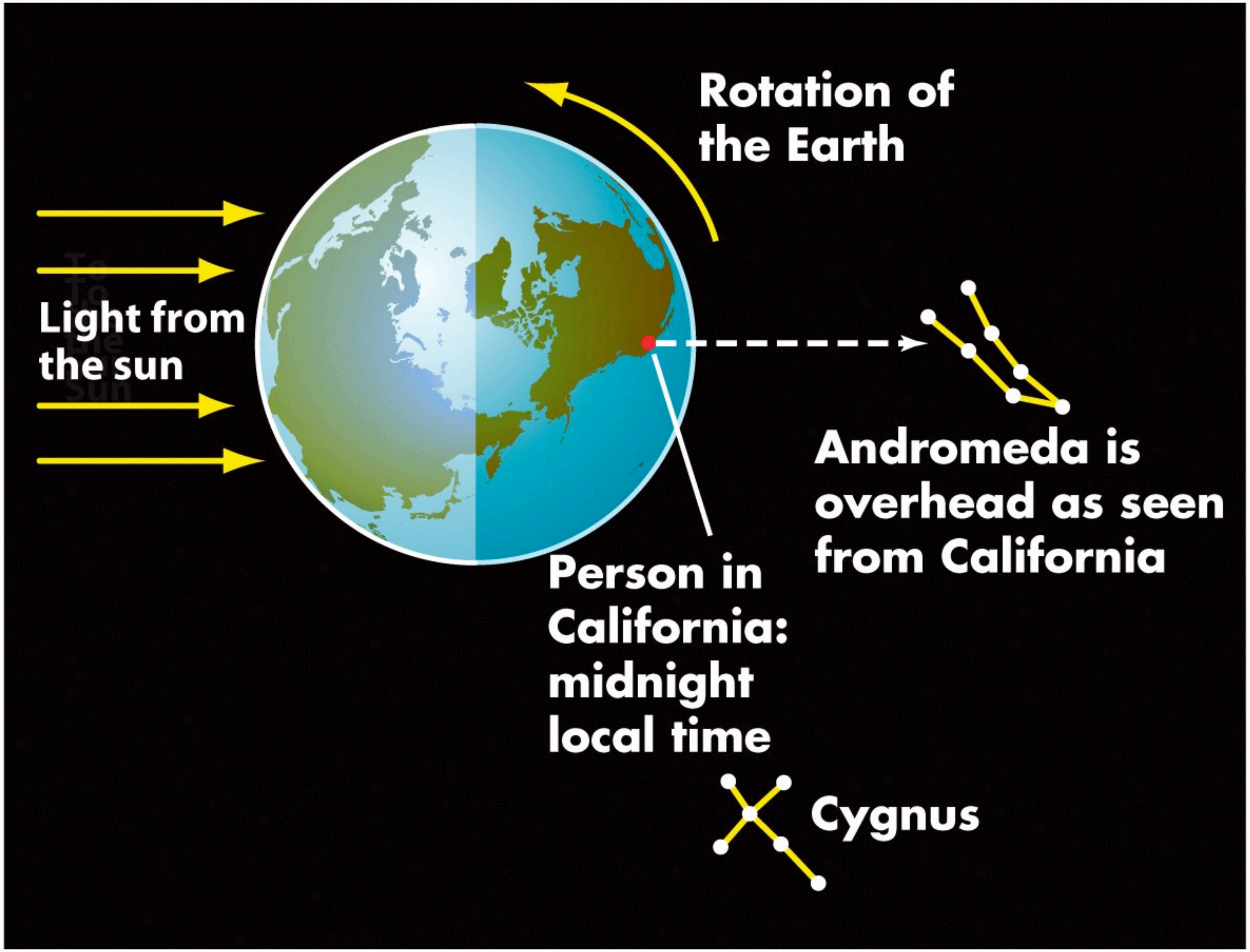

URSA MINOR
"Little Dipper"
BOÖTES
Polaris
"North
Star"
Arcturus
URSA MAJOR
"Big Dipper"
Spica
VIRGO
Western horizon
North


Illuminated
(day) side
Dark
(night) side
Light from
the Sun



Earth as seen from above the North Pole

The diurnal (daily) motion of the stars.



4 hours (one-sixth of a complete rotation) later

Figure 2-4b
Universe, Eighth Edition

The diurnal (daily) motion of the stars.

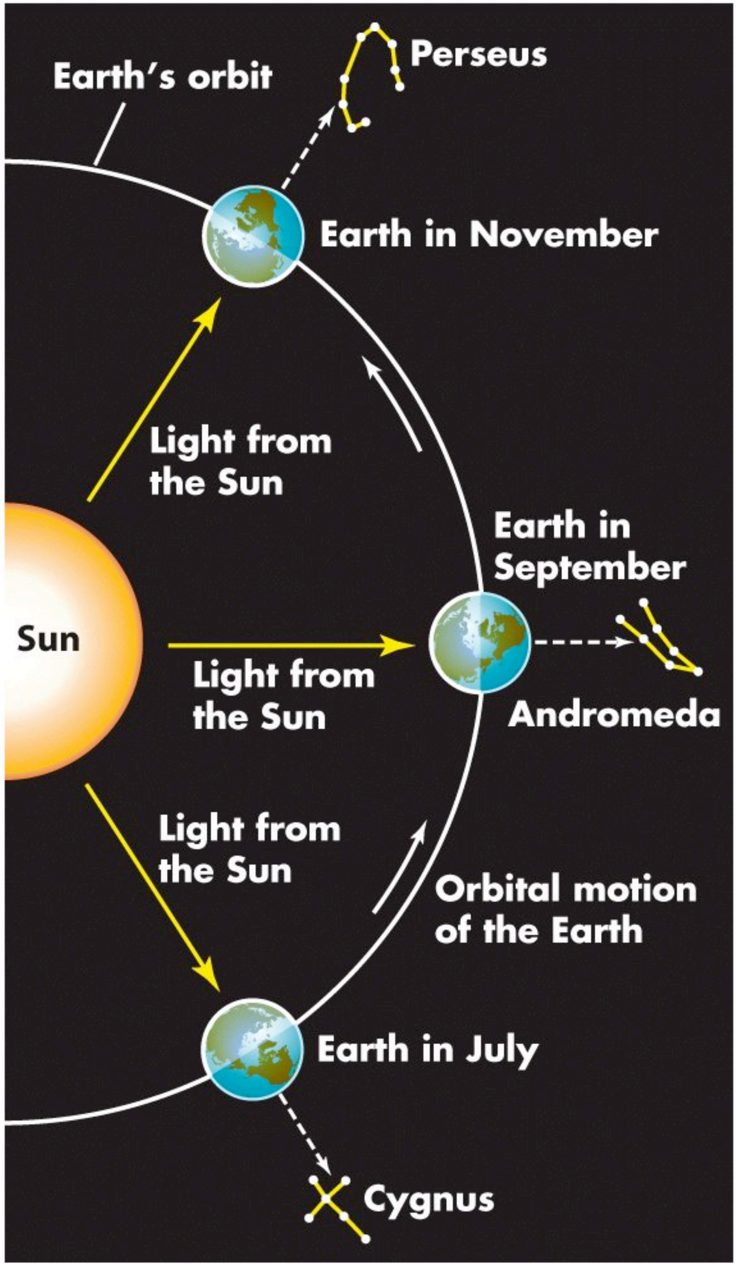


Figure 2-5
Universe, Eighth Edition

- The night sky changes during the year
- How fast does the position of the Earth move around the sun every day?

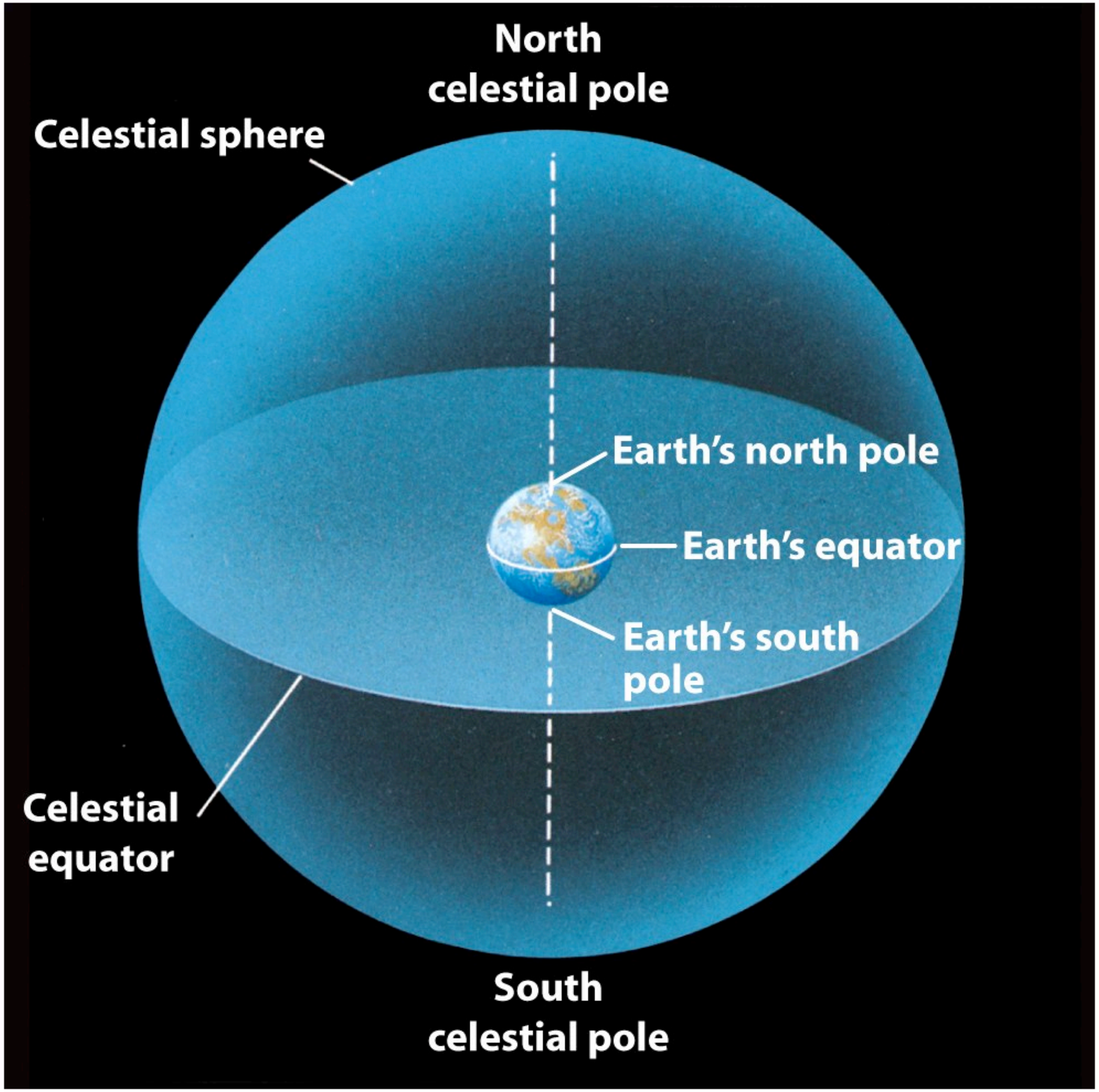
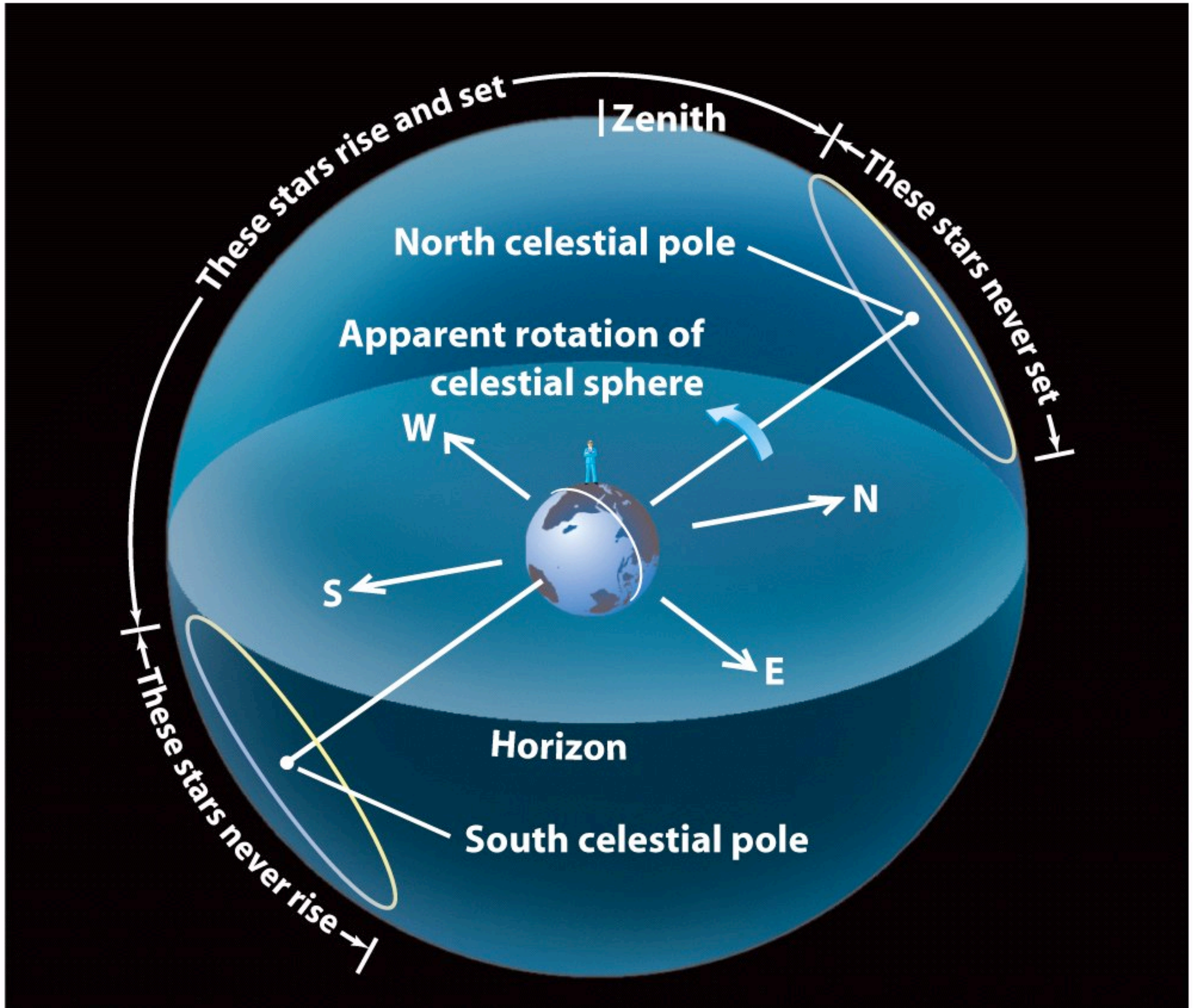


Figure 2-9
Universe, Eighth Edition

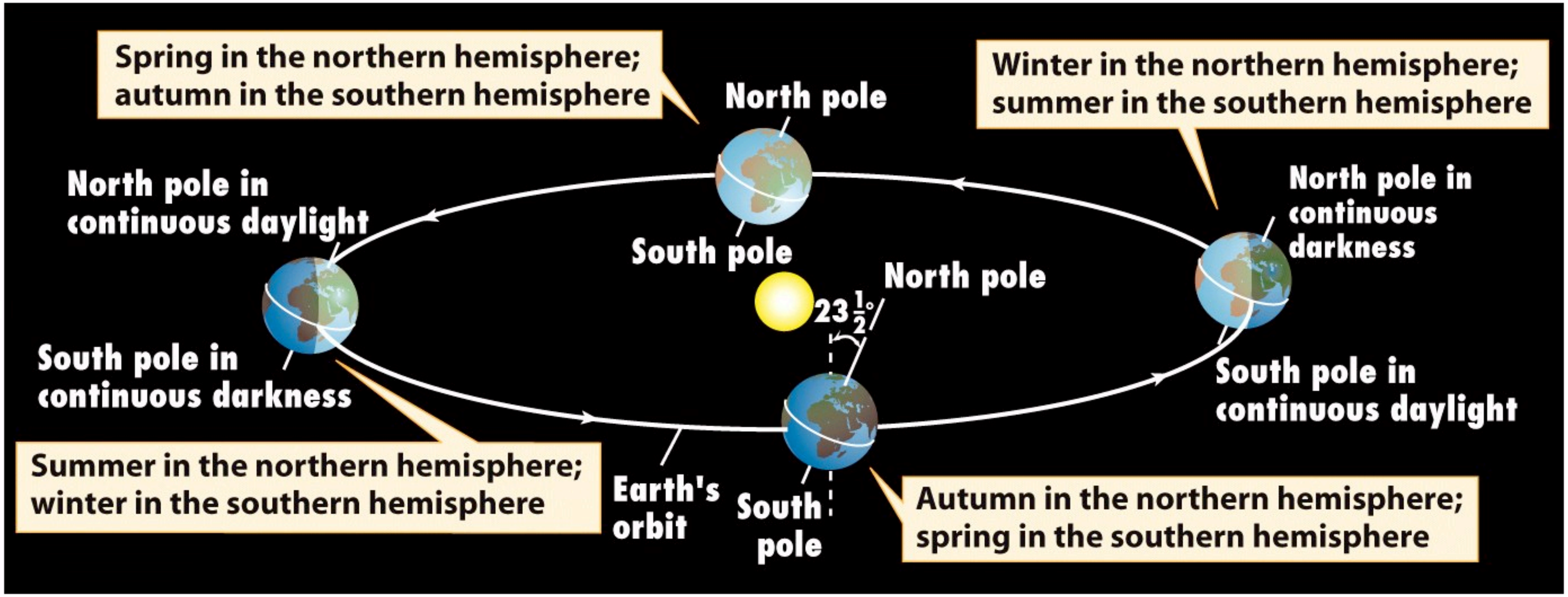
The imaginary celestial sphere. The celestial equator and poles are projections of the Earth's axis of rotation out into space.

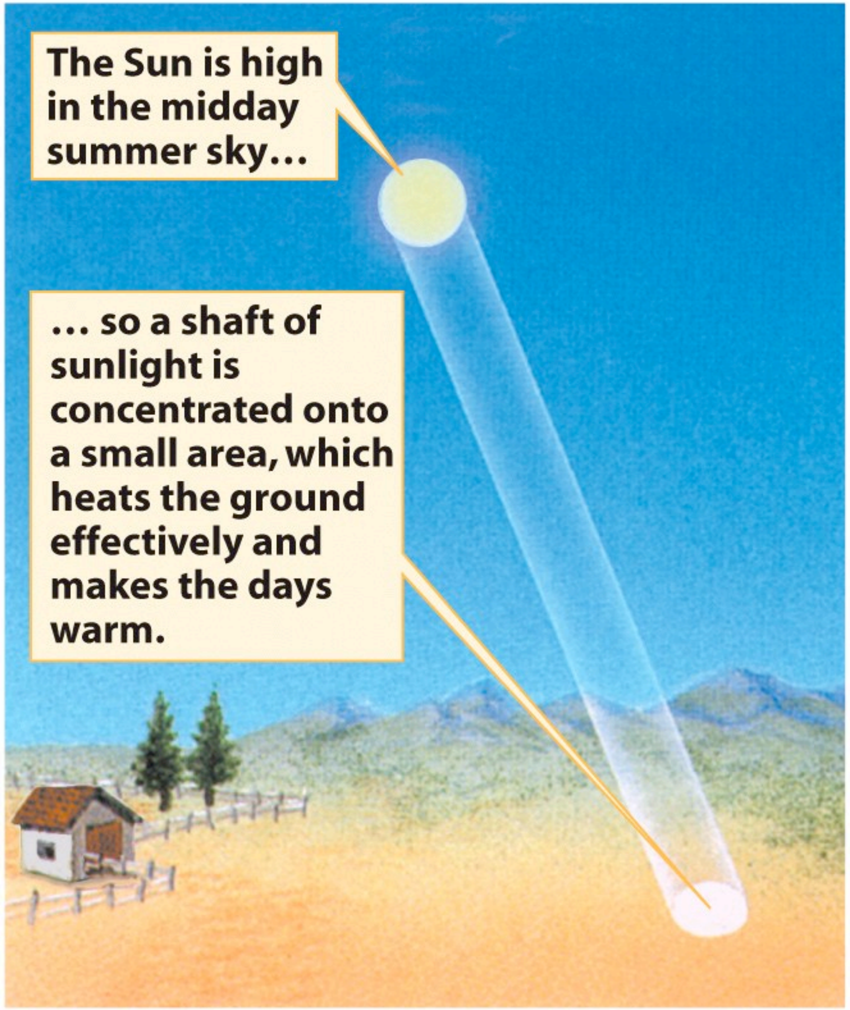


At 35° north latitude:

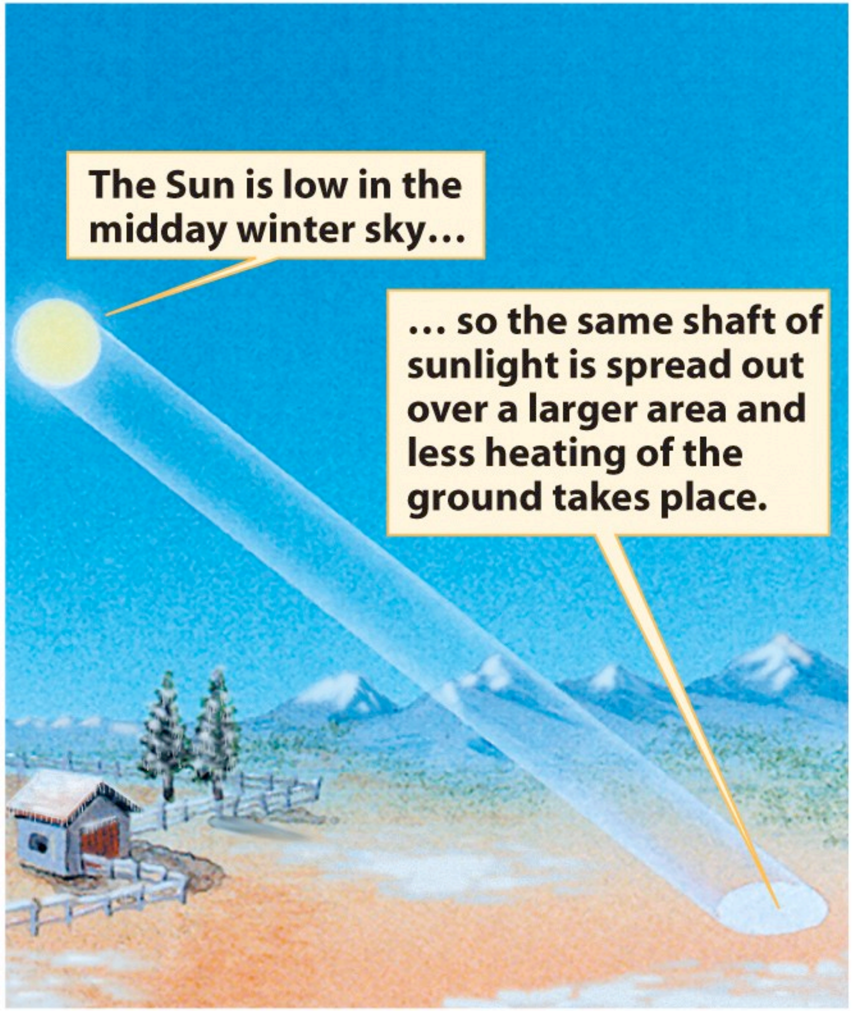
- **the north celestial pole is 35° above the northern horizon**
- **the south celestial pole is 35° below the southern horizon**

Seasons

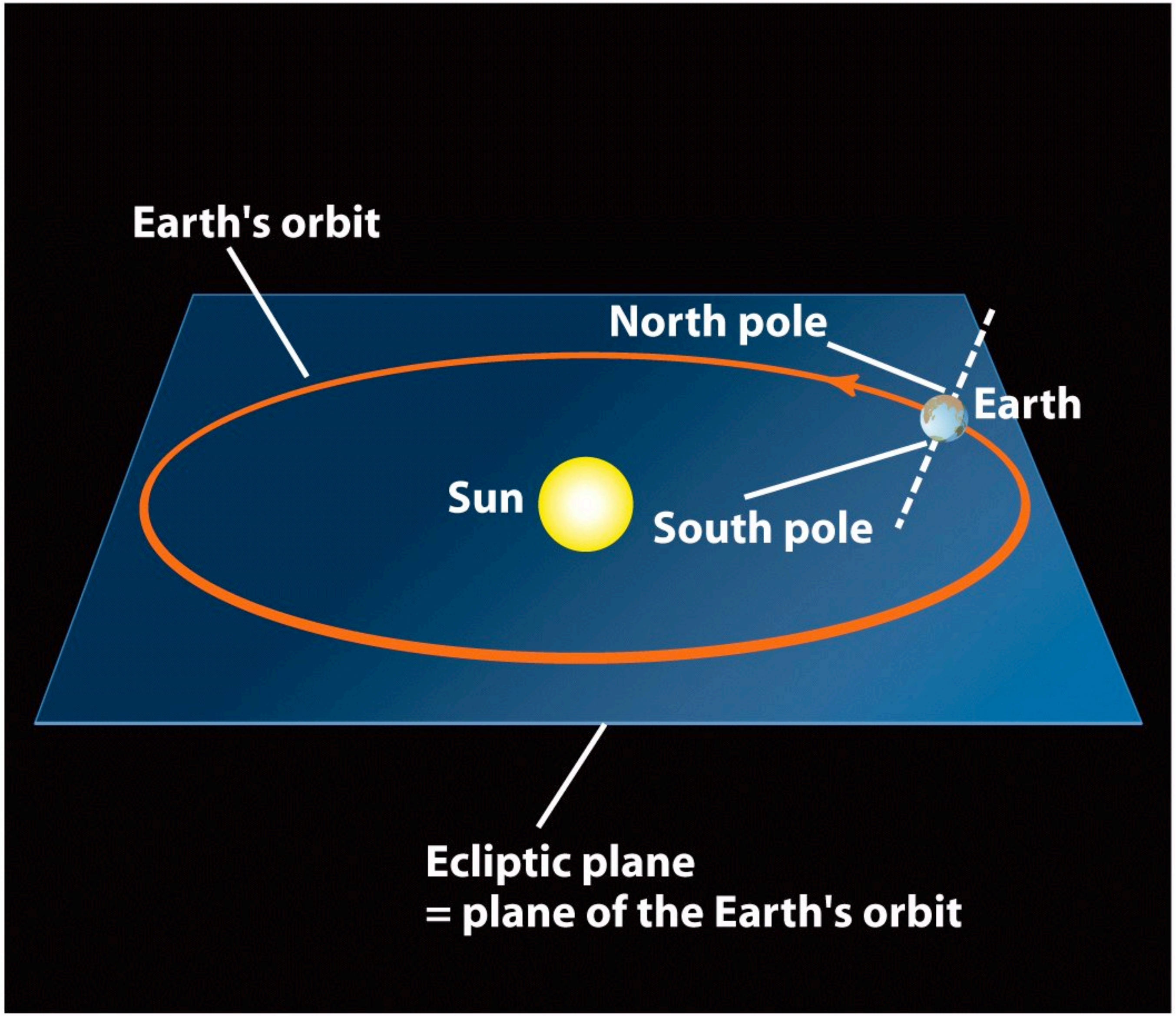

Spring in the northern hemisphere; autumn in the southern hemisphere
North pole
Winter in the northern hemisphere; summer in the southern hemisphere
North pole in continuous daylight
South pole
North pole in continuous darkness
North pole
23½°
South pole in continuous darkness
South pole in continuous daylight
Summer in the northern hemisphere; winter in the southern hemisphere
Earth's orbit
South pole
Autumn in the northern hemisphere; spring in the southern hemisphere



(a) The Sun in summer

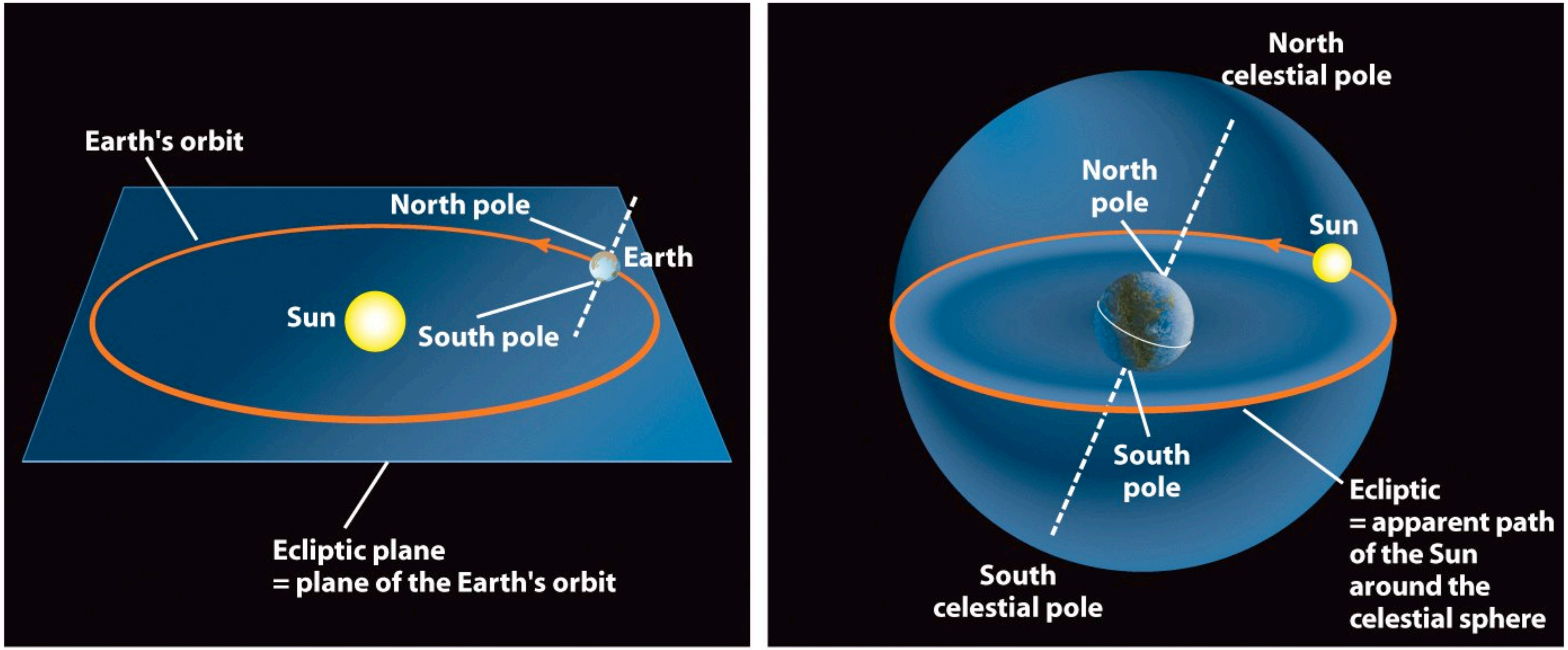


(b) The Sun in winter



In reality the Earth orbits the Sun once a year

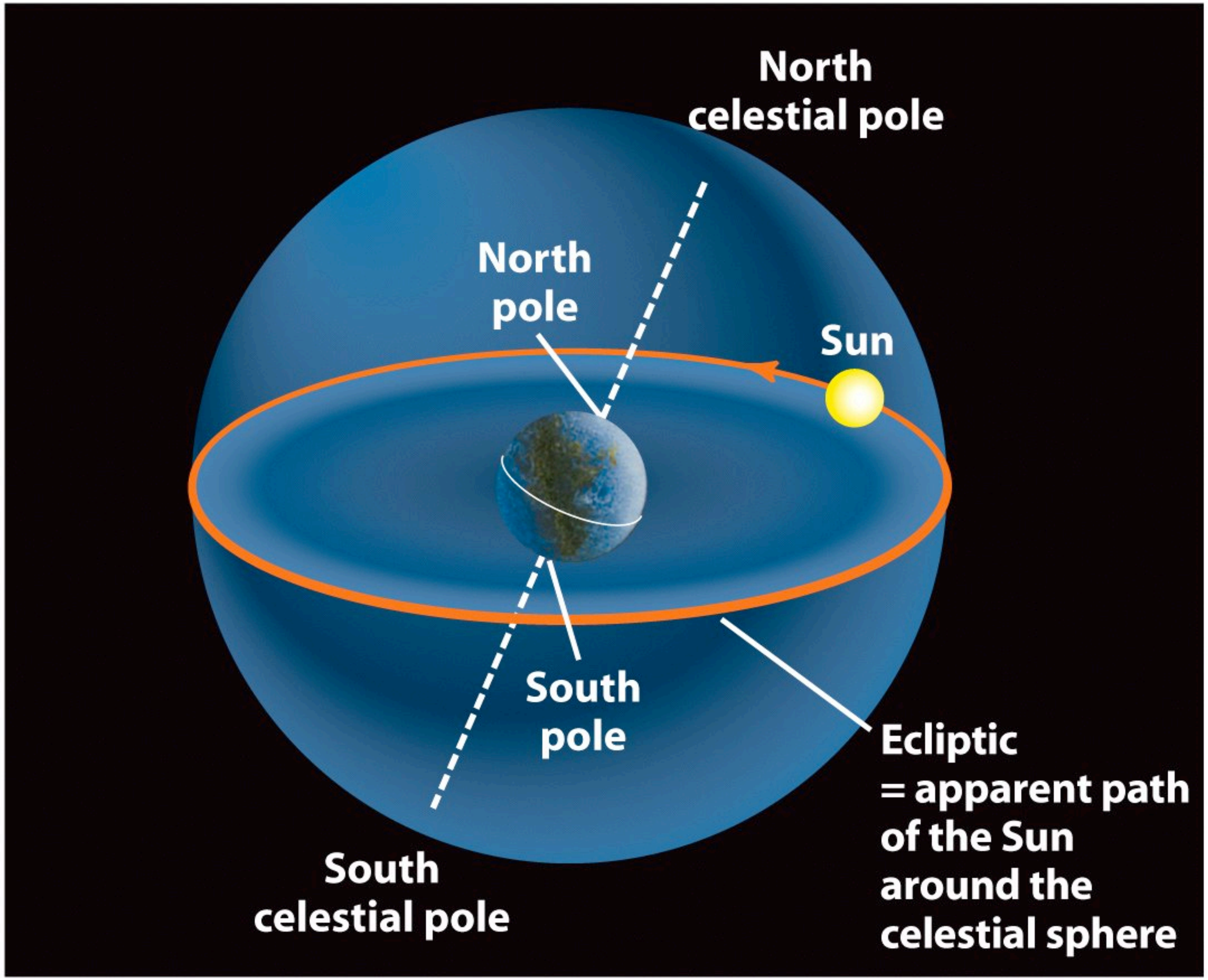
Ecliptic plane: the plane in which the Earth moves around the Sun.



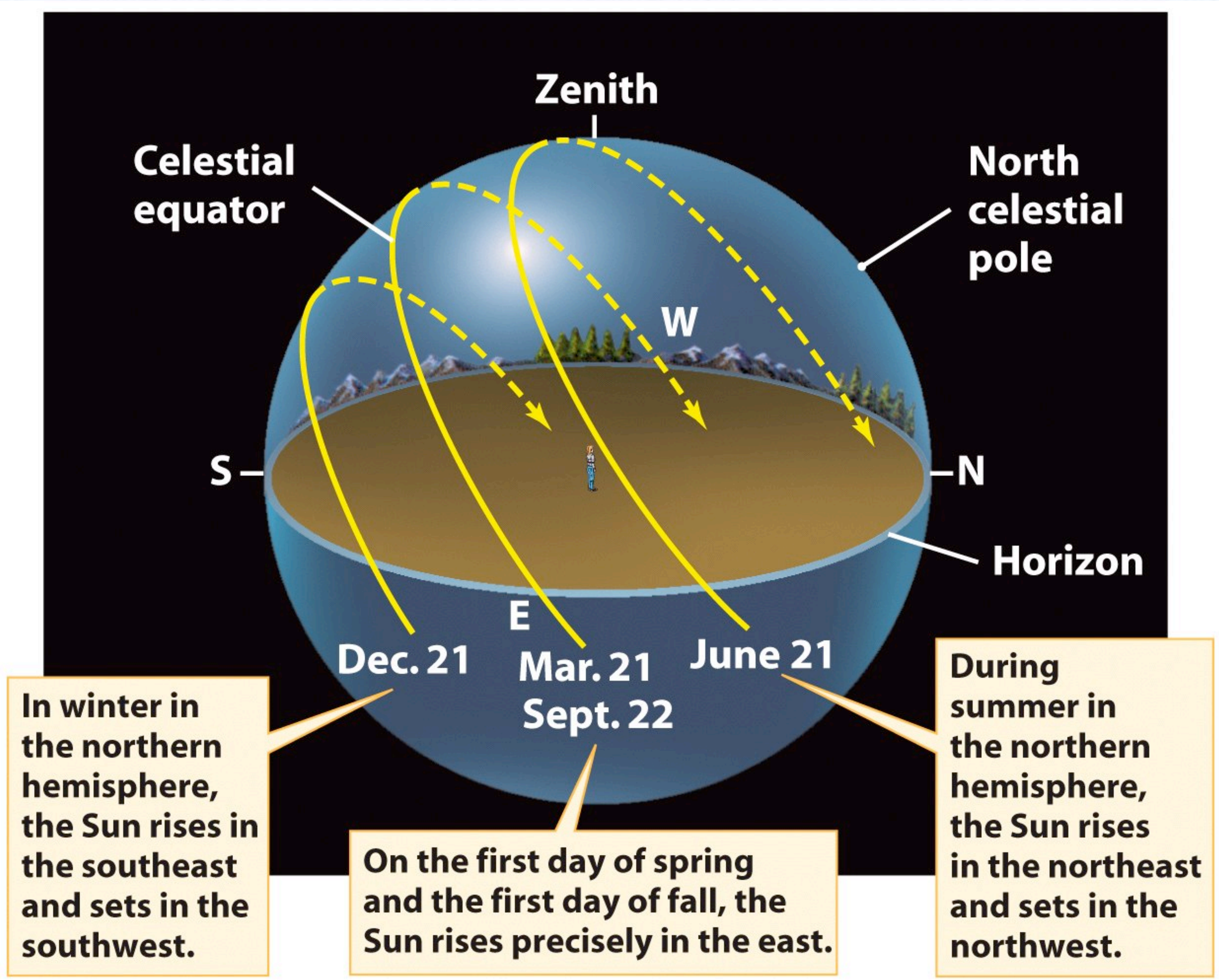
(a) In reality the Earth orbits the Sun once a year

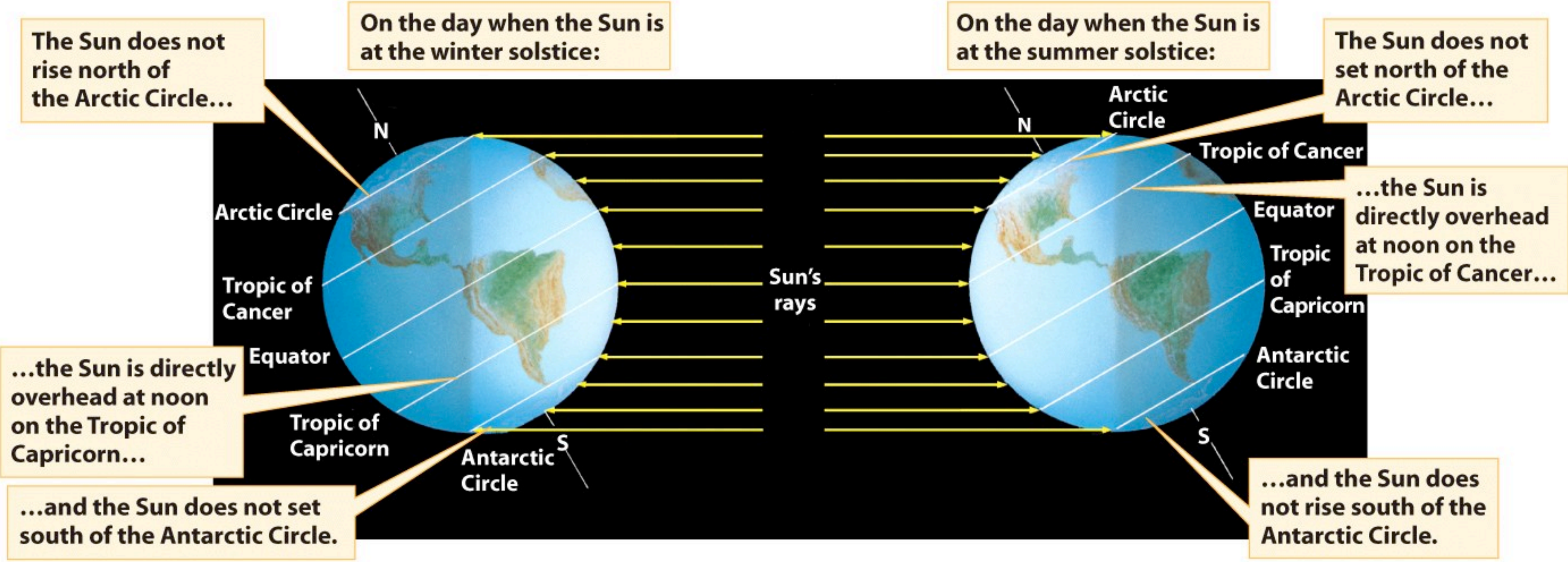
(b) It appears to us that the Sun travels around the celestial sphere once a year

Ecliptic plane and the ecliptic: just a matter of perspective



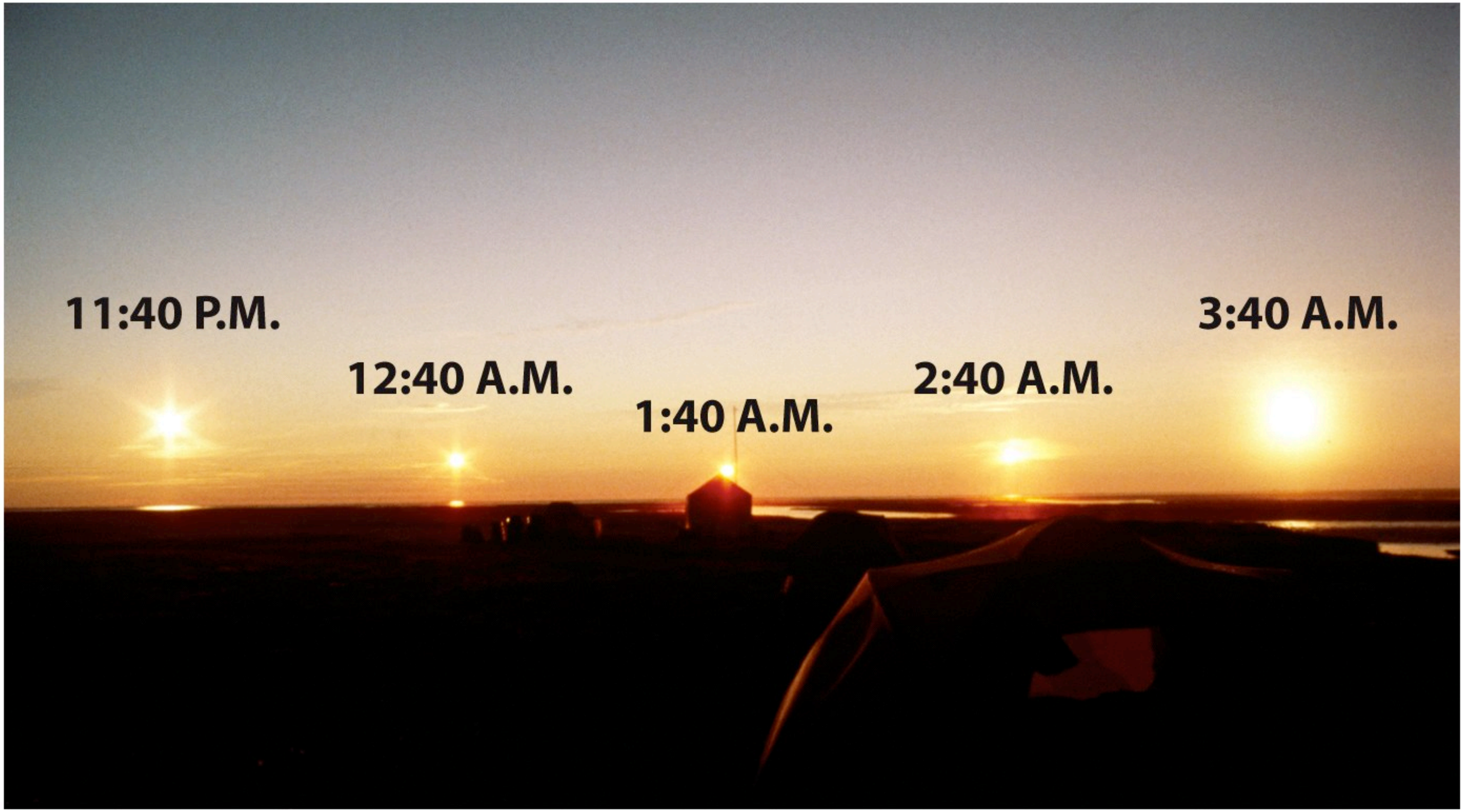
It appears to us that the Sun travels around the celestial sphere once a year

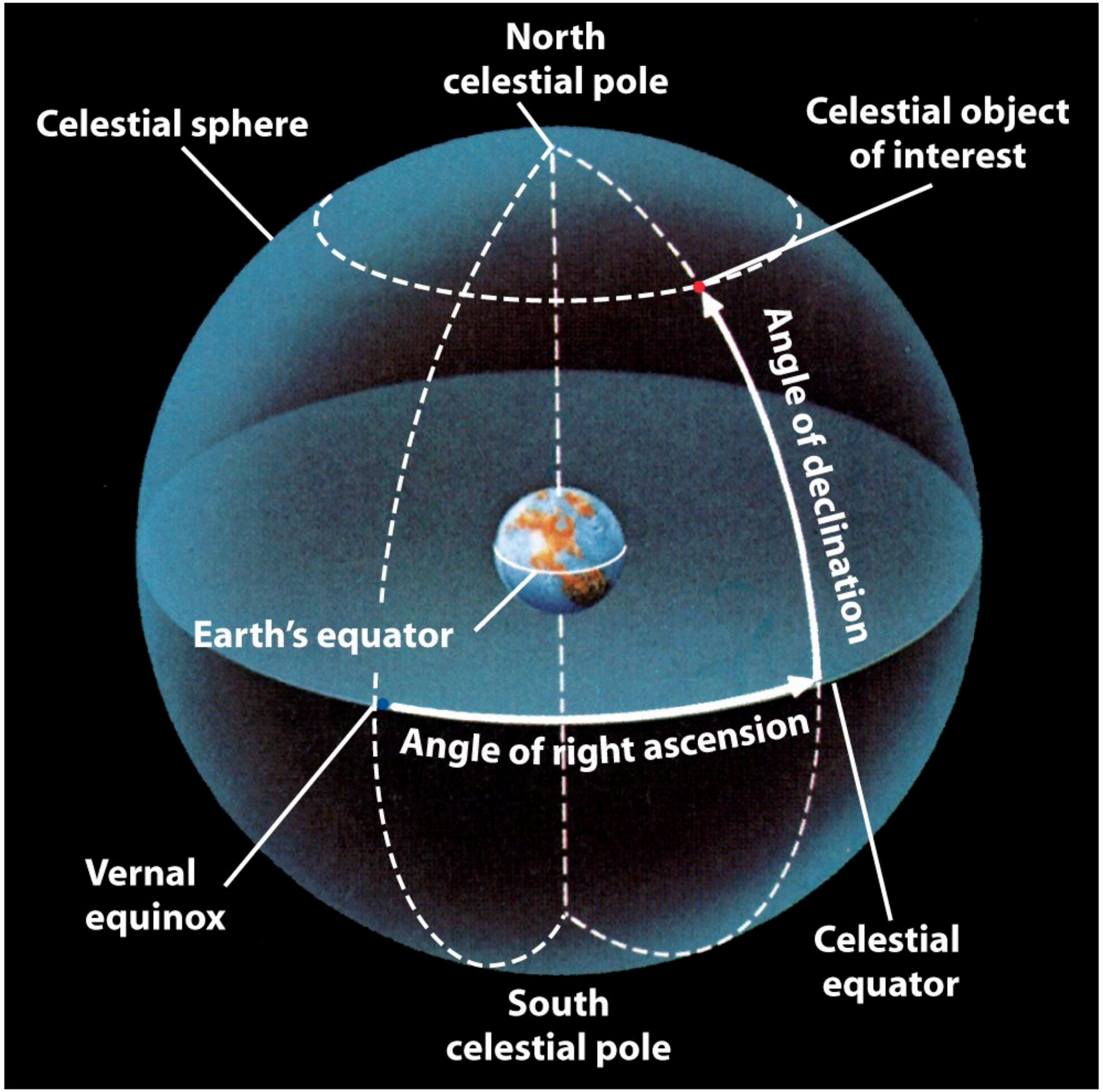

Zenith
Celestial equator
North celestial pole
W
S
N
Horizon
E
Dec. 21
Mar. 21
Sept. 22
June 21
In winter in the northern hemisphere, the Sun rises in the southeast and sets in the southwest.
On the first day of spring and the first day of fall, the Sun rises precisely in the east.
During summer in the northern hemisphere, the Sun rises in the northeast and sets in the northwest.



(a) Earth at winter solstice

(b) Earth at summer solstice


11:40 P.M.
12:40 A.M.
1:40 A.M.
2:40 A.M.
3:40 A.M.


North
celestial pole
Celestial sphere
Celestial object
of interest
Angle of declination
Earth's equator
Angle of right ascension
Vernal
equinox
Celestial
equator
South
celestial pole

Summary

- Powers of Ten
  - Familiarize yourself with this notation
- Units
  - We use the IS… expect when we don't
  - Dimensional analysis is a very useful tool
- Measuring Angles
  - What is a degree? An (arc)minute?
- The night sky
- Seasons
  - Why is it colder in winter?

A few questions

- Why are there leap years?
- Why are there time zones?

Homework – Due 01/12/09

- On your own: answer all the review questions in chapters 1 thru 3
- To TAs: answer questions 1.35, 1.39, 2.40, 2.46, 3.31, 3.43

The End

See you on Friday!