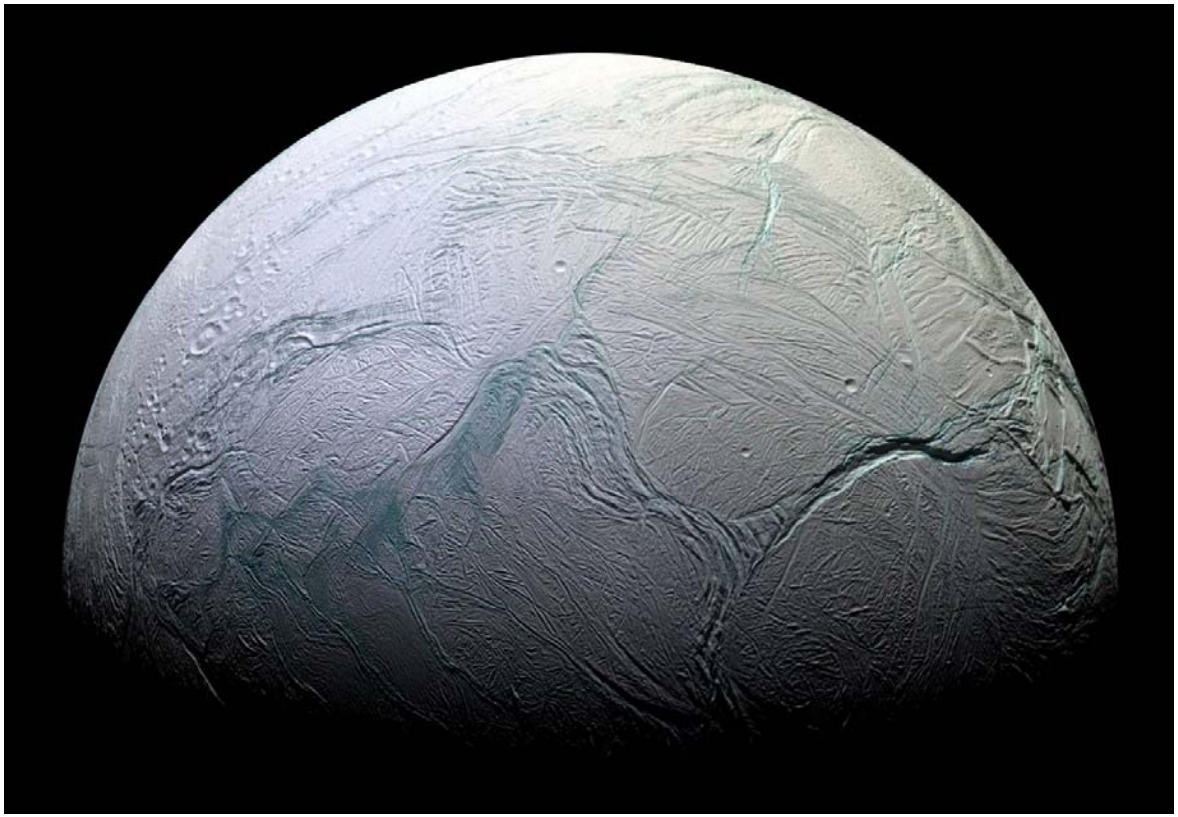
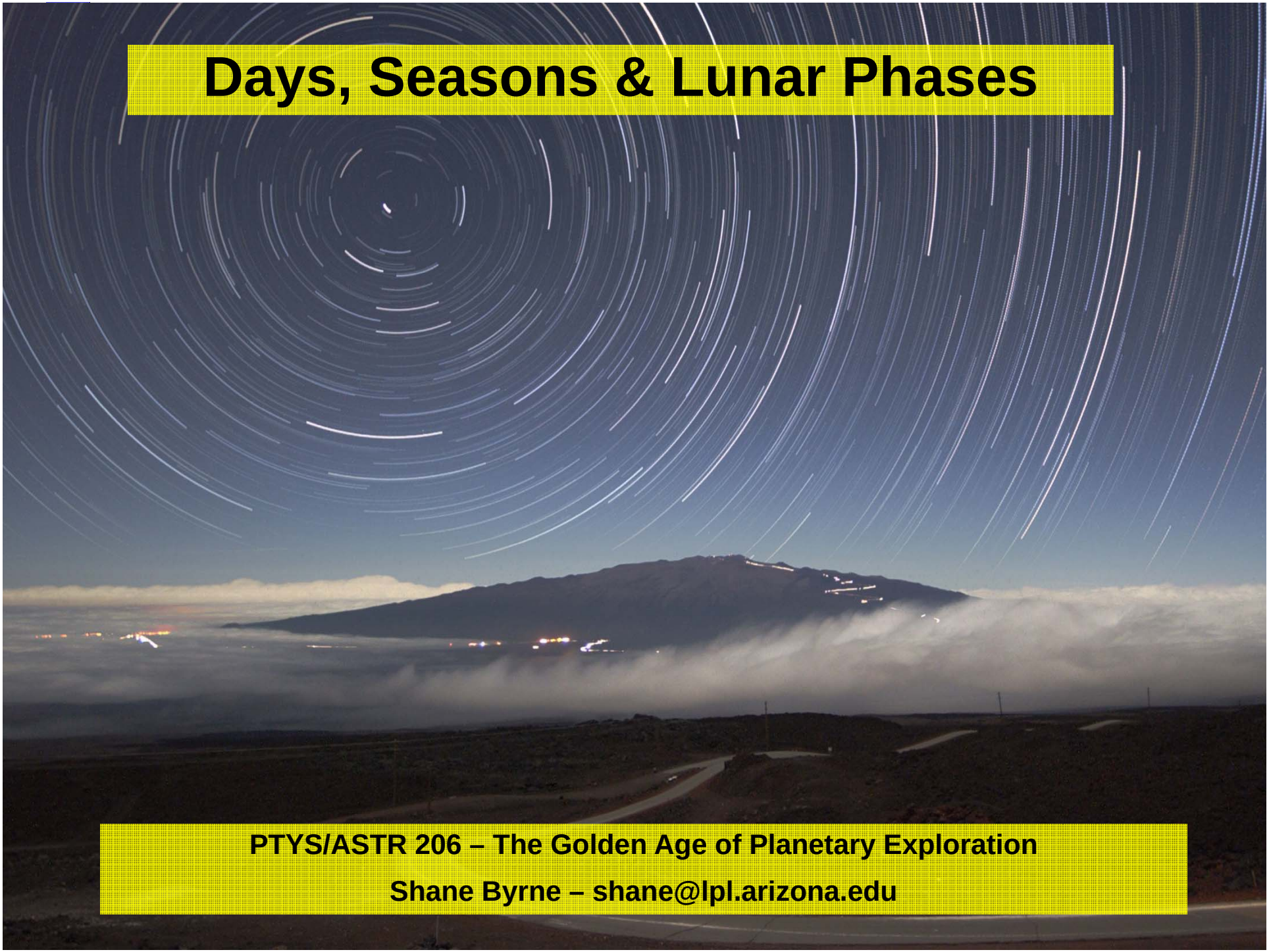
- **Announcements**
  - **D2L site "up soon" – will only have link to class webpage**
  - **The order of the next few lectures has changed a little – see class website for new schedule**
    - **Timing of homeworks, exams etc is unaffected**



- **Observations**
  - **Craters…**
  - **Bright/white surface**
  - **Trenches**

Days, Seasons & Lunar Phases



PTYS/ASTR 206 – The Golden Age of Planetary Exploration

Shane Byrne – shane@lpl.arizona.edu

- **What makes planetary astronomy different from other kinds of astronomy?**

- **What makes planetary astronomy different from other astronomy?**
  - **Most light is reflected light**
    - **Coming soon**
  - **We're part of the dynamical system we're trying to observe**
    - **Today's lecture**

In this lecture…

- Our spinning solar system
- Rotation
  - Day vs. Night
- Seasons
  - Obliquity, incidence angle
- Lunar Phases
- Synchronous rotation
- Eclipses
  - Solar and Lunar

Everything around us is spinning – and we are too

- **The solar system is shaped like a flat disk**
  - **Looking down from 'above' it spins anti-clockwise**
  - **'above' = north**
- **Inclinations are low**

Planetary Inclinations	
Mercury	7°
Venus	3.4°
Earth	0° The Ecliptic
Mars	1.9°
Jupiter	1.3°
Saturn	2.5°
Uranus	0.8°
Neptune	1.8°

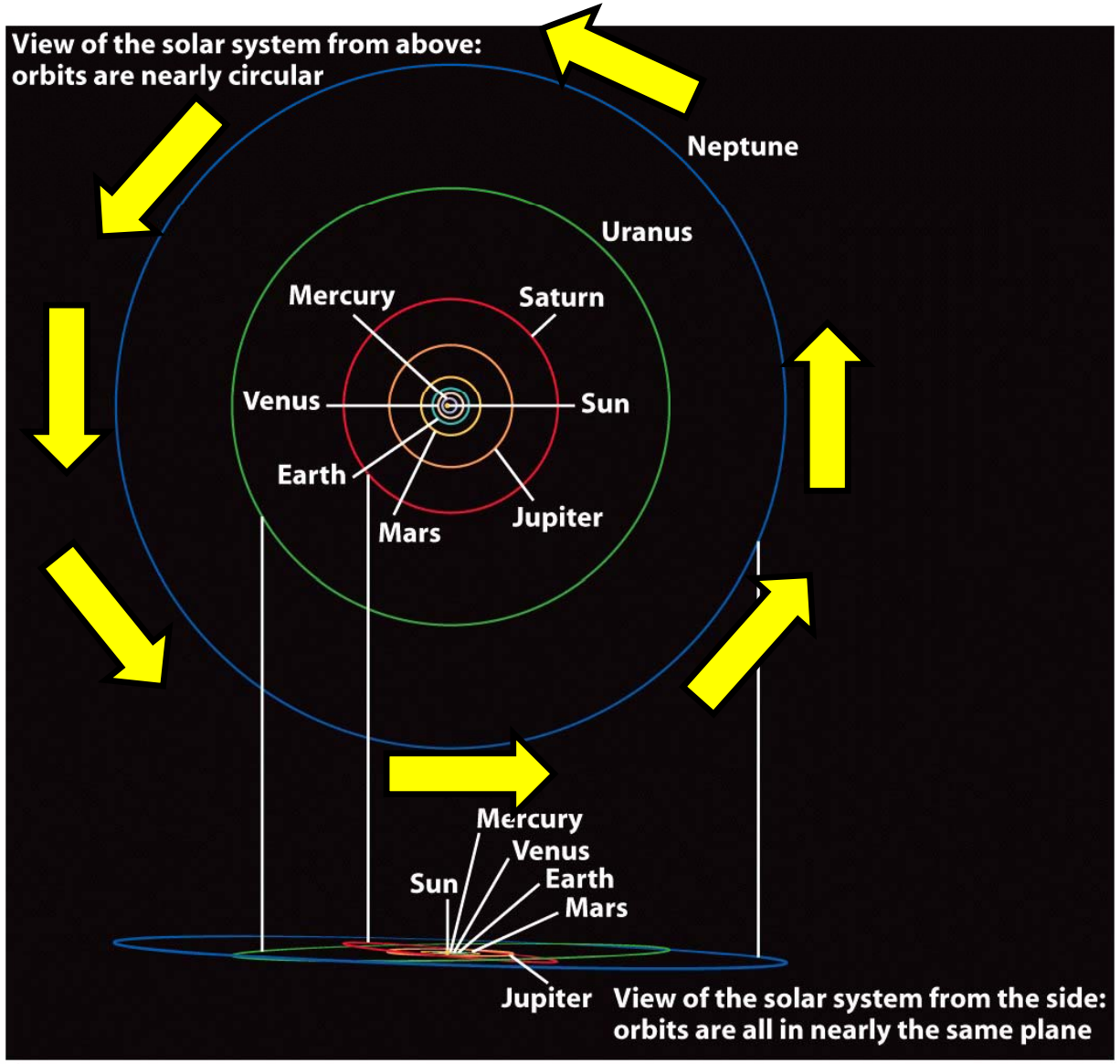
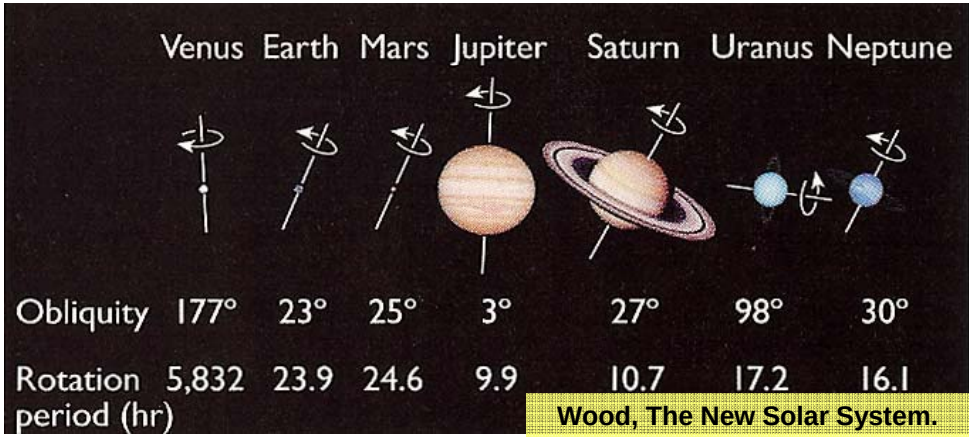
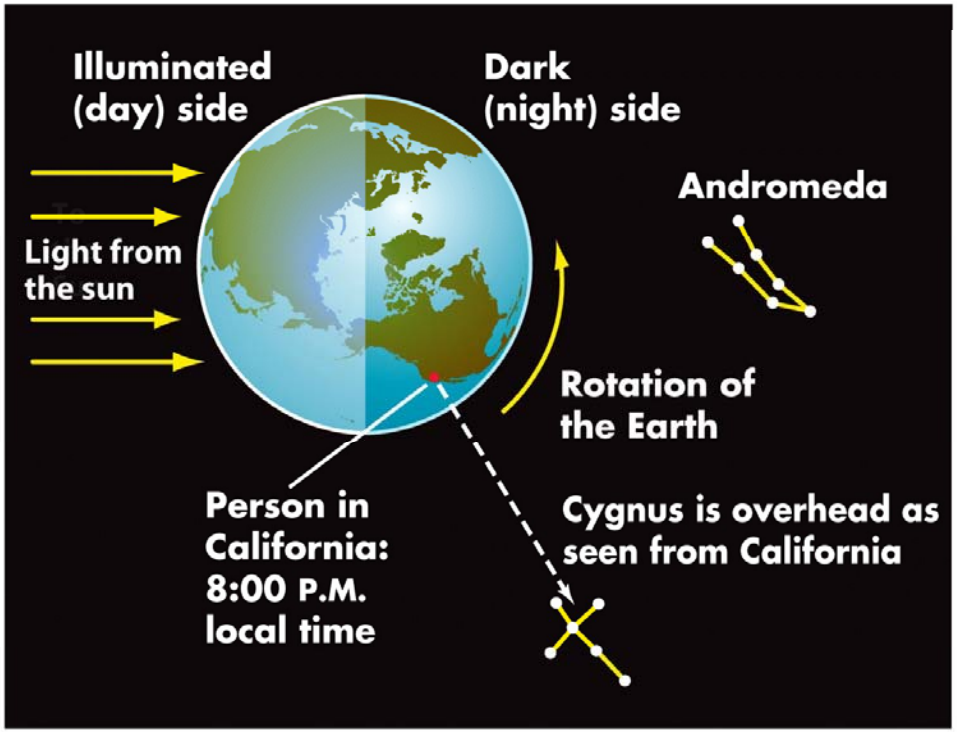


Figure 7-1
Universe, Eighth Edition

- **Earth also rotates in this counter-clockwise sense**
  - **As do most of the other planets**
  - **Venus spins backwards**
    - **Very slowly…**
  - **Uranus spins sideways**



Wood, The New Solar System.



Earth as seen from above the North Pole

Figure 2-4a
Universe, Eighth Edition
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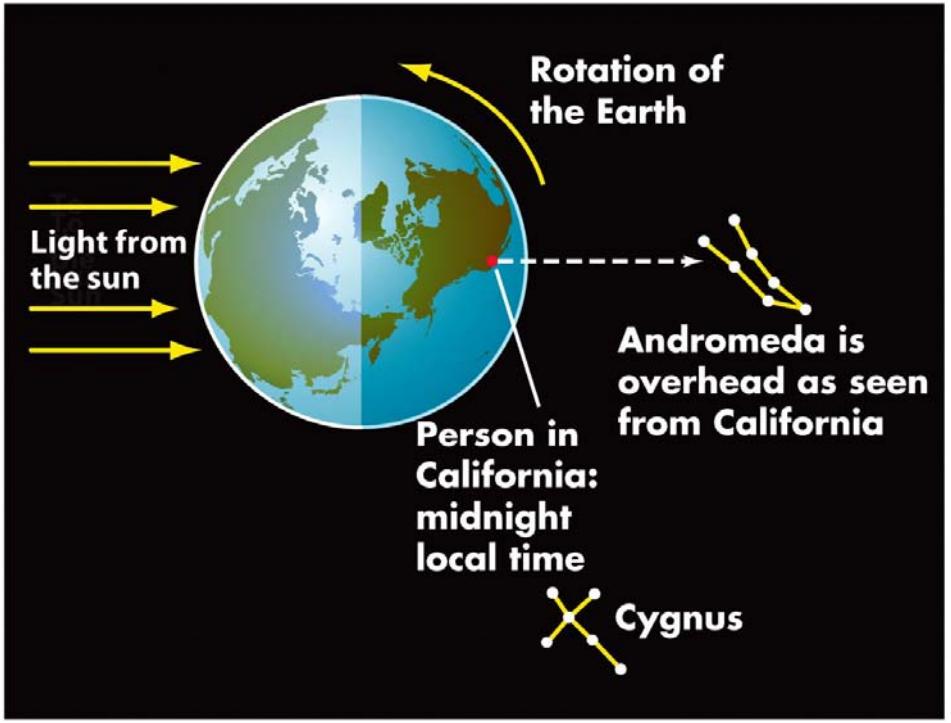

4 hours (one-sixth of a complete rotation) later

Figure 2-4b
Universe, Eighth Edition
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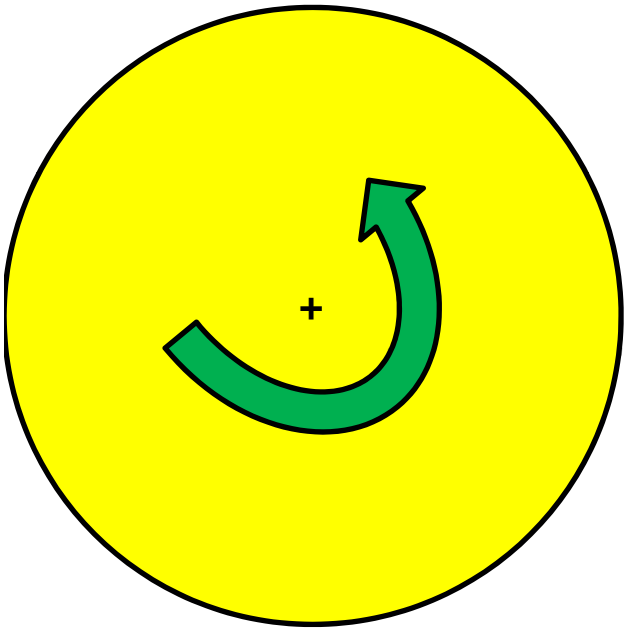
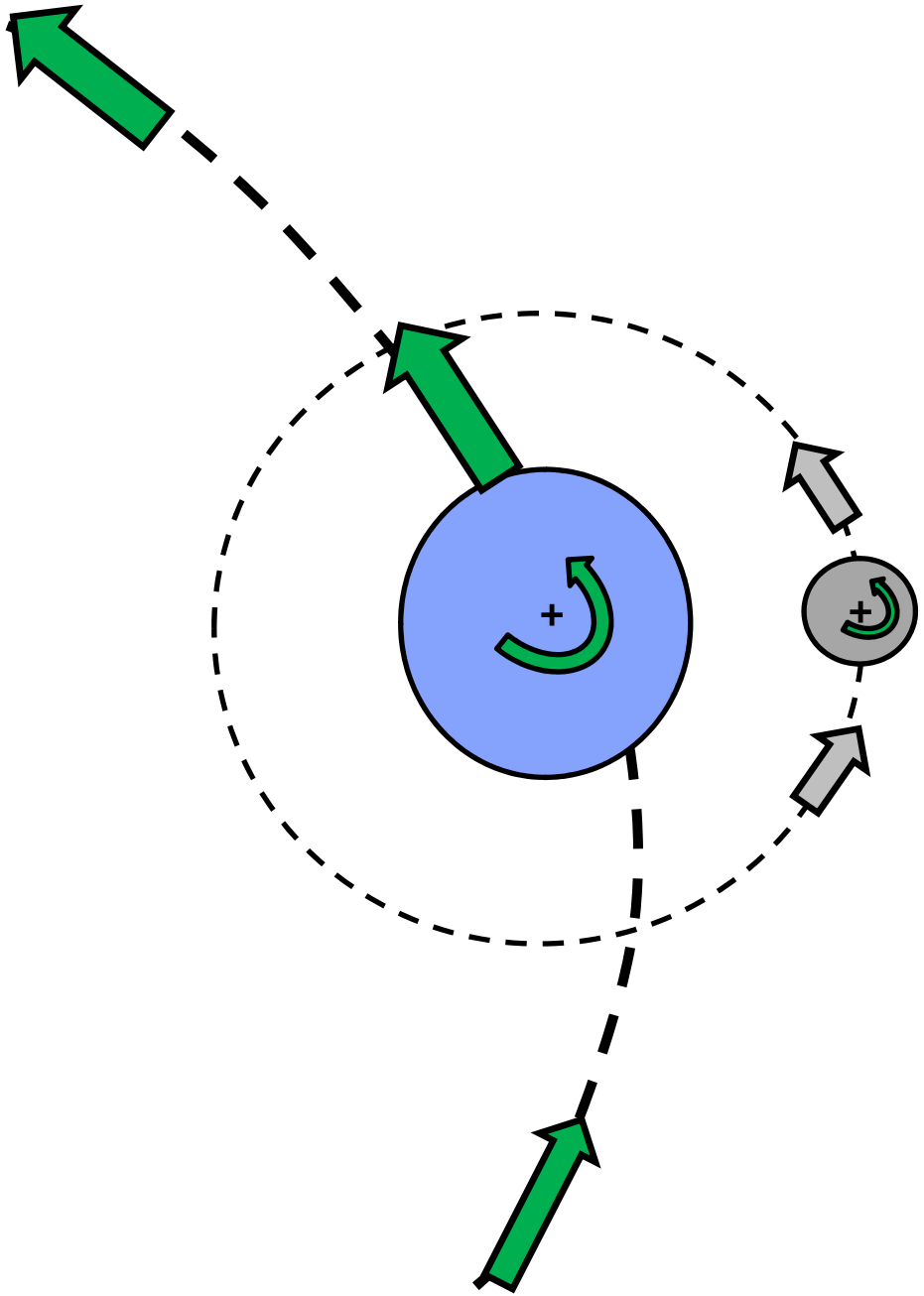
- **Common spin direction**
  - **Rotation of Sun, Earth, Moon**
  - **Orbit of Earth and Moon**





- **Earth's polar axis points to the celestial north pole**
  - **Nowadays it's conveniently marked by the star Polaris**
- **Earth's equator projects onto the sky to form the celestial equator**
  - **Right-ascension and declination measured like longitude and latitude on this celestial sphere**

Chapter 2 Opener
Universe, Eighth Edition

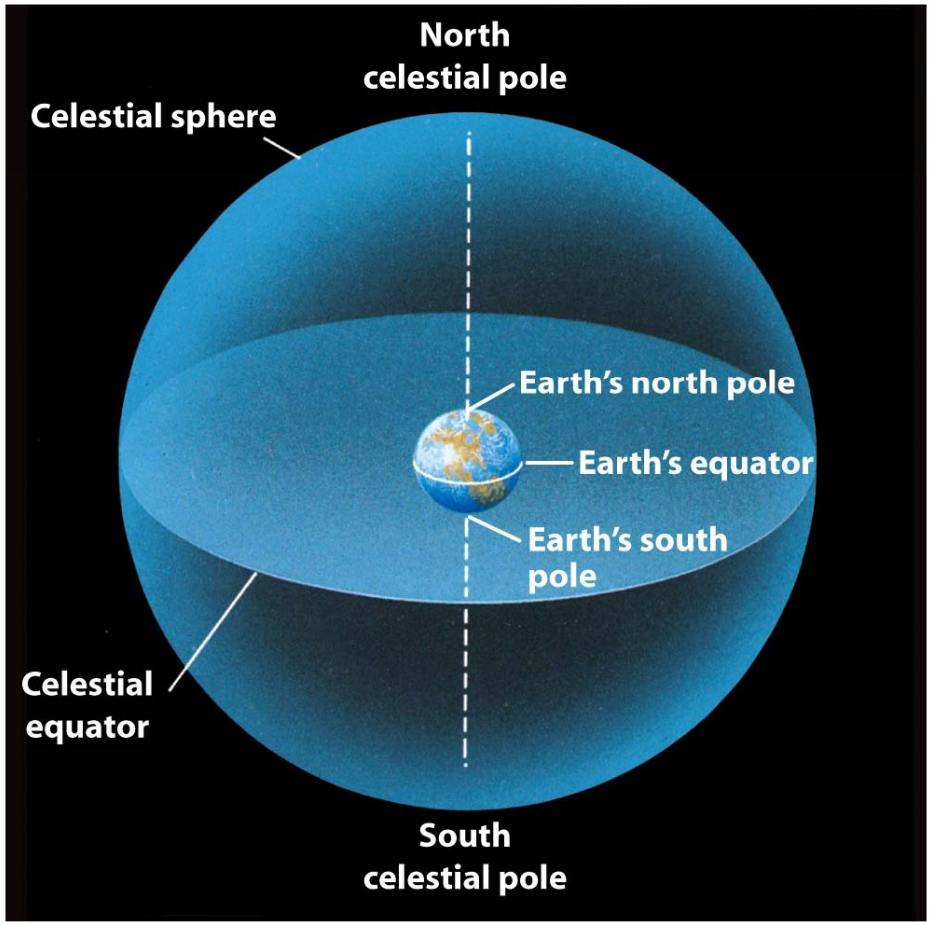


Figure 2-9
Universe, Eighth Edition

- **Astronomical objects appear to rotate around celestial north pole**
  - **Counterclockwise, every 23hrs 56minutes – a sidereal day**
  - **Sun appears to rotate every 24 hrs – a solar day**
- **Objects rise in the East and set in the West**
  - **Some stars never set**

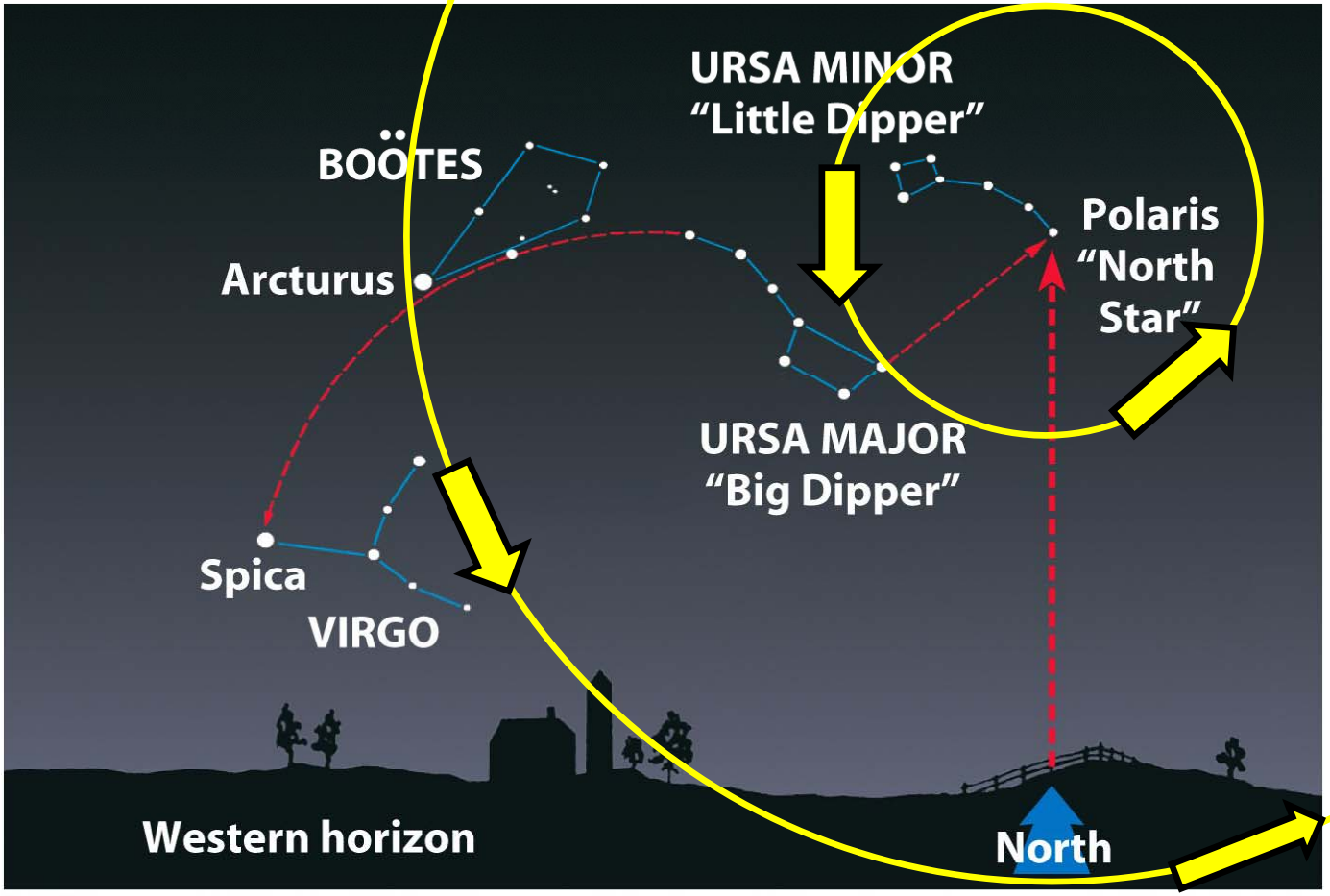


Figure 2-6
Universe, Eighth Edition

- **Where's the celestial pole?**
  - **At the north pole – it's straight overhead**
  - **At the equator – it's on the northern horizon**
  - **At a latitude X°, it's X° above the horizon**

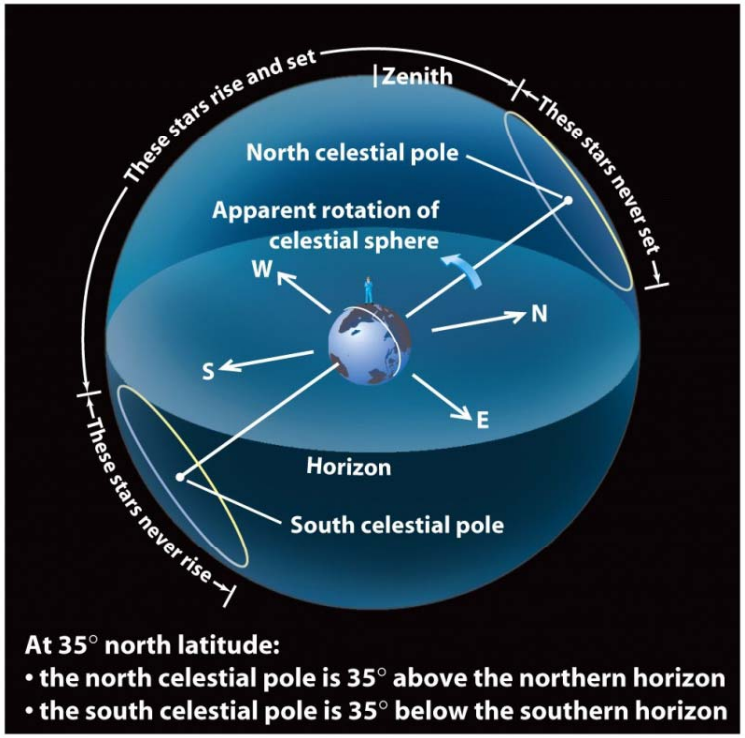


Figure 2-10
Universe, Eighth Edition
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At the equator

Figure 2-11c
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At middle northern latitudes

Figure 2-11a
Universe, Eighth Edition
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At the north pole

Figure 2-11b
Universe, Eighth Edition
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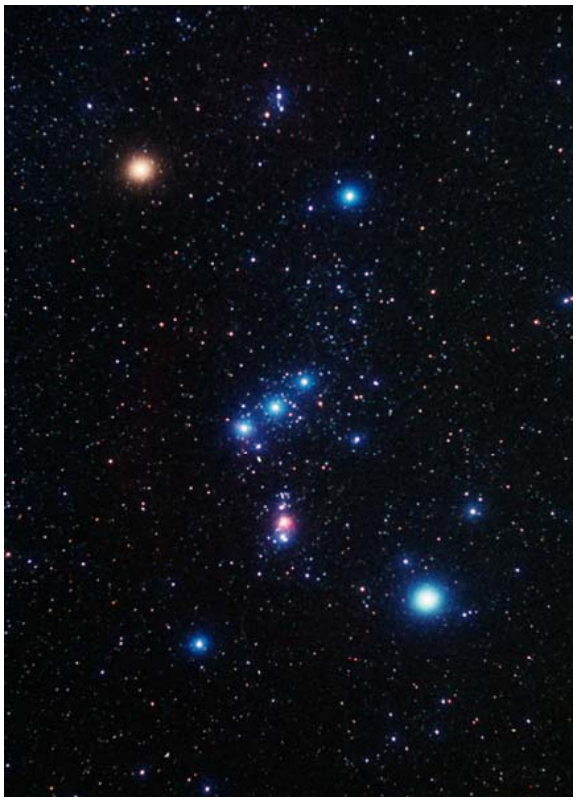
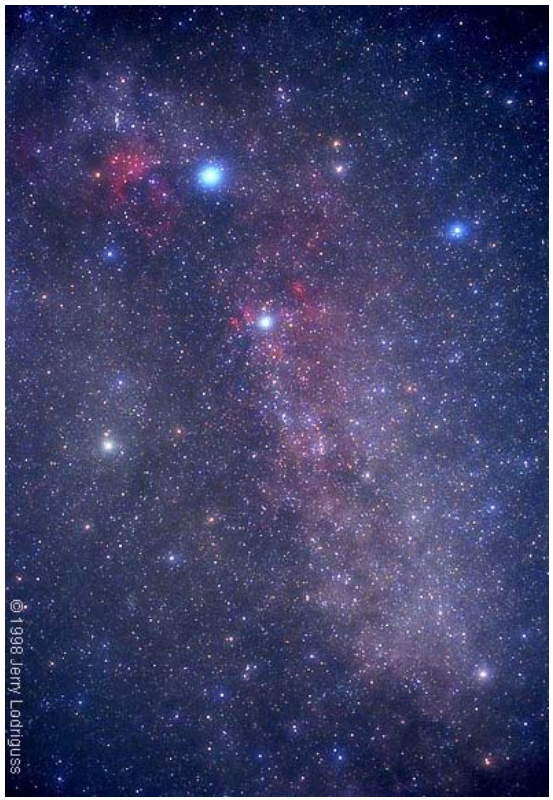
Seasons

- **Visible constellations depend on season**
  - **We can only see stars at night**
  - **The part of the sky that the night-side of the Earth faces changes with season**
  - **The sun appears to move through the background stars**





e.g. Orion – winter & Cygnus - summer

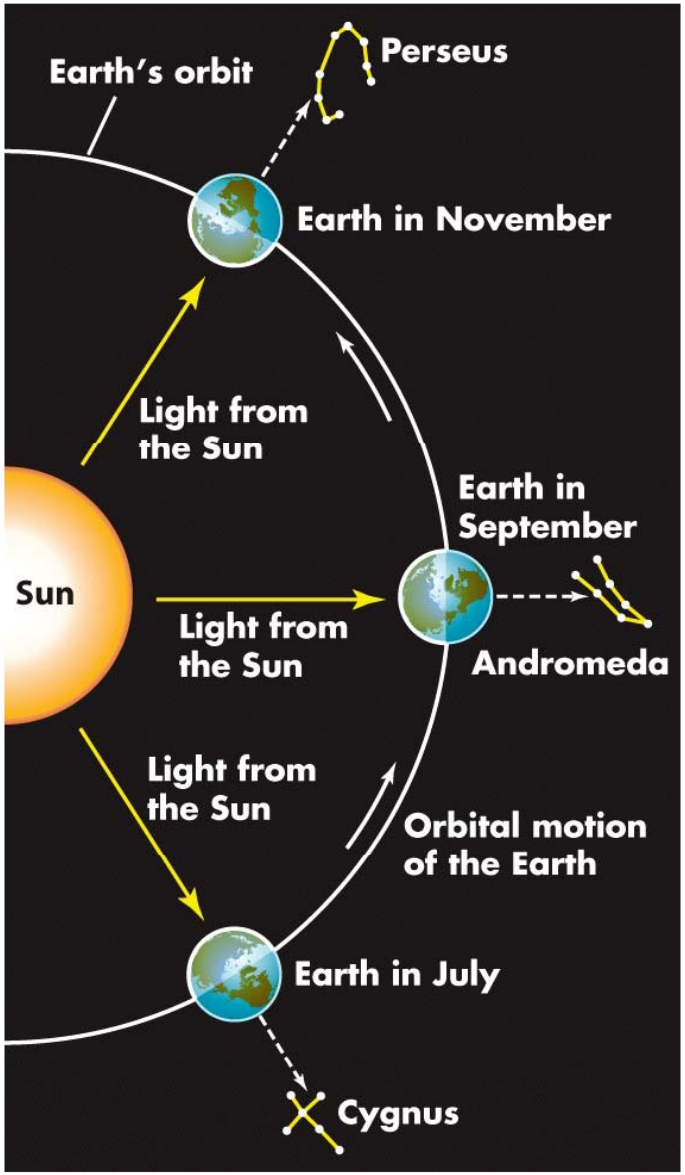


Figure 2-5
Universe, Eighth Edition

- **Earth's orbital plane is not the same as the celestial equator**
  - **Orbital plane is called the ecliptic**
  - **There is a difference of 23½° - obliquity**
  - **Earth doesn't wobble (much), the pole always points at the same spot in the sky**
- **Northern hemisphere tilts towards the sun in the summer**
  - **Vice-versa in the winter**

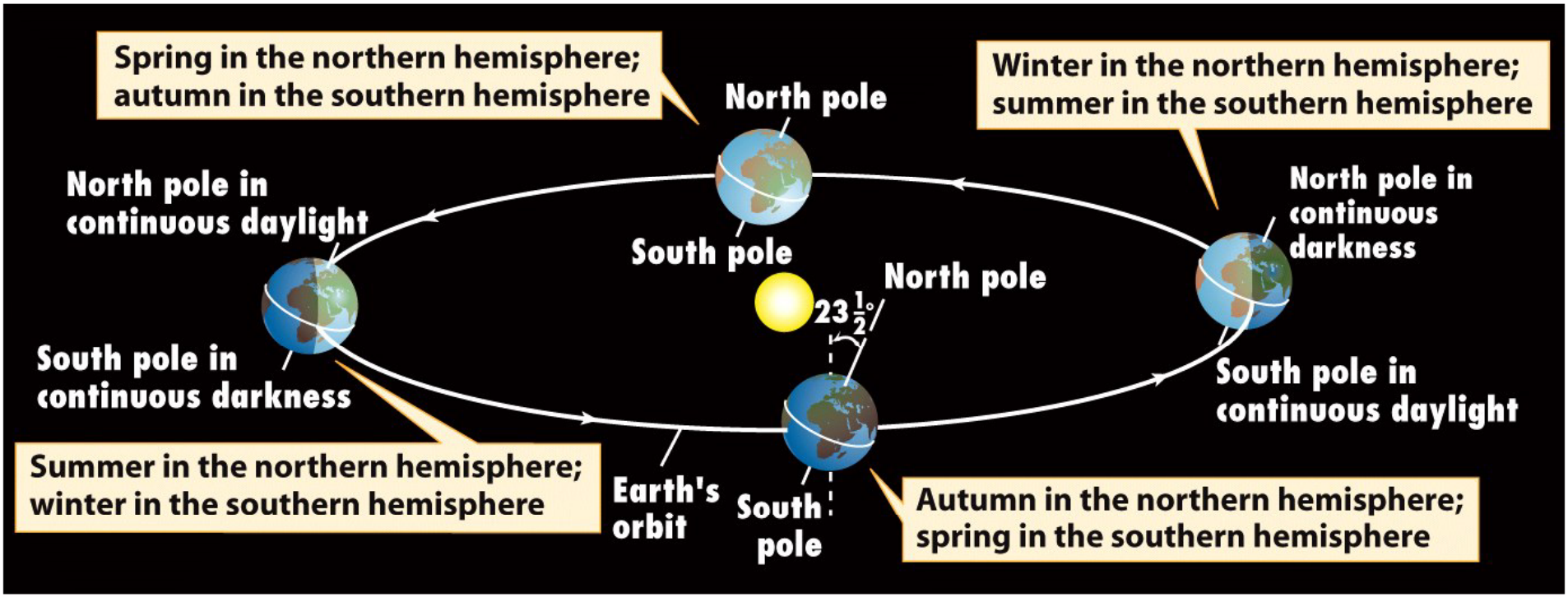


Figure 2-12
Universe, Eighth Edition

- The Sun and all other planets appear to move around the Earth on the Ecliptic
- The stars stay (mostly) fixed on the celestial sphere
- The Sun and planets move

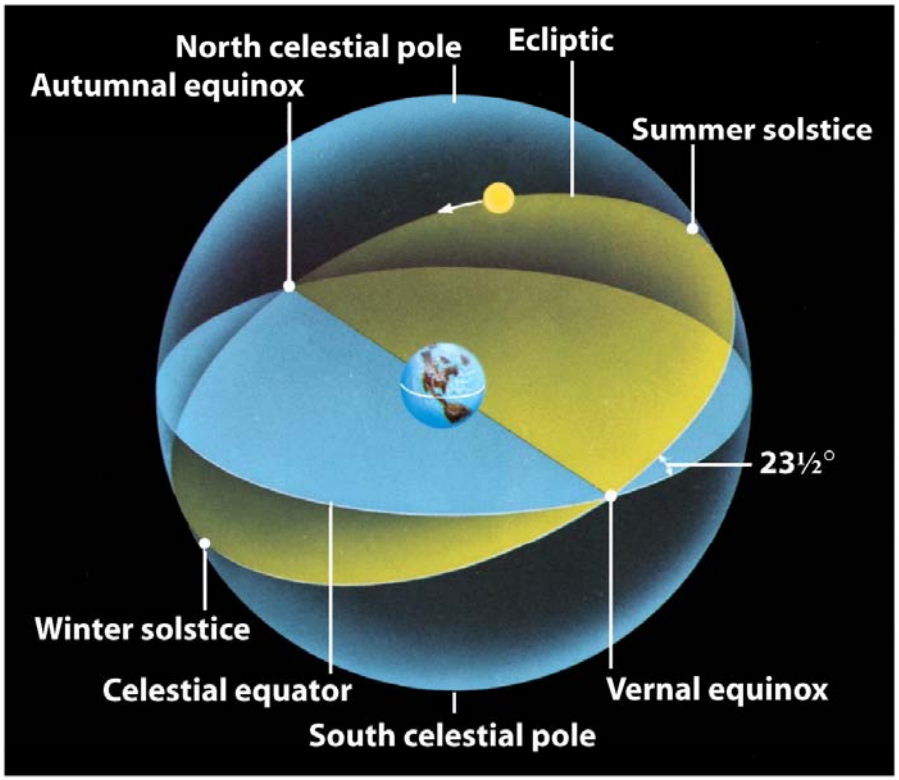


Figure 2-15
Universe, Eighth Edition

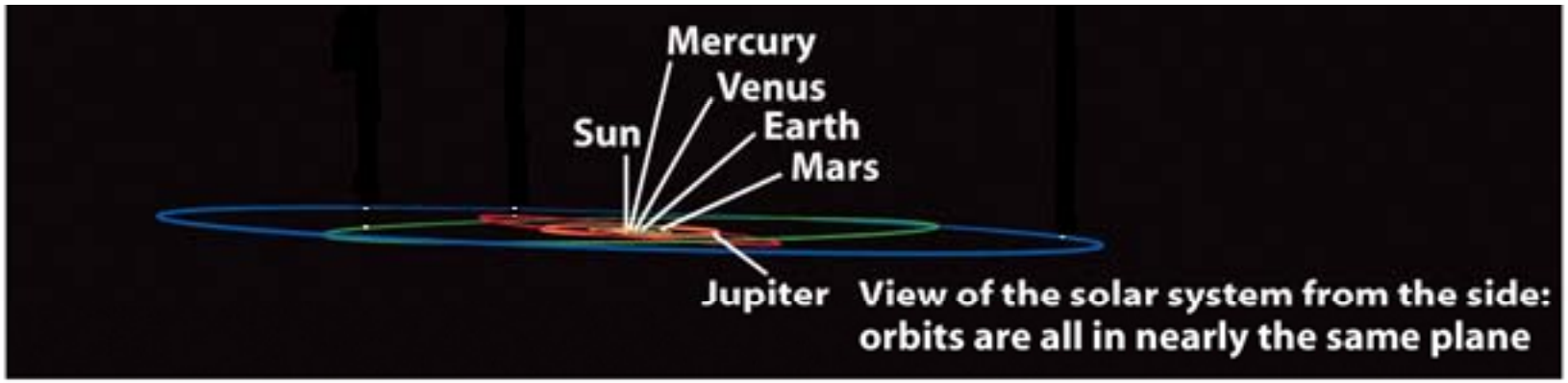
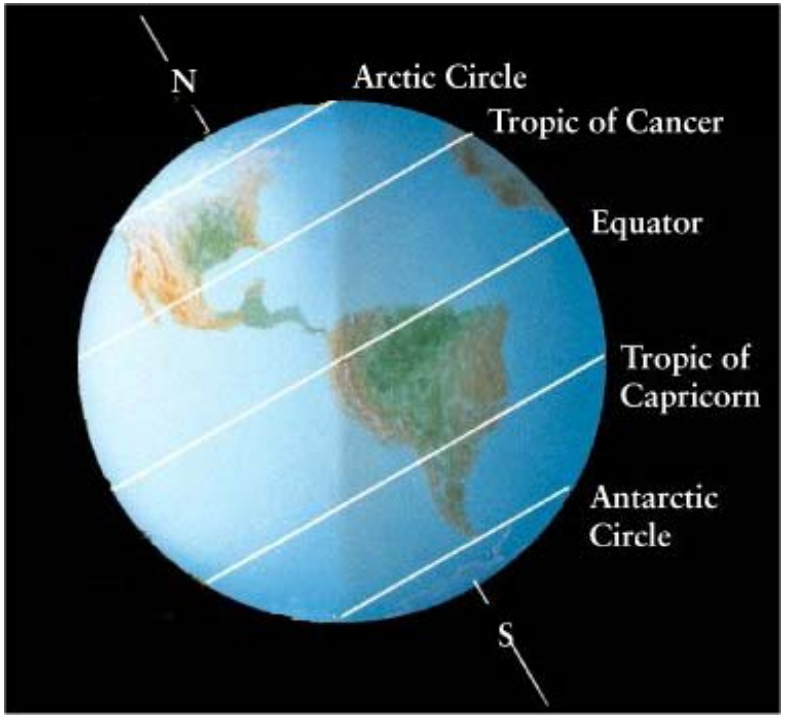


Figure 7-1
Universe, Eighth Edition

- **At (northern) summer solstice**
  - **Sun is overhead at Tropic of Cancer**
  - **Northern hemisphere days are long**
  - **Permanent daylight north or arctic circle**

- **At equinoxes**
  - **Sun is overhead at the equator**
  - **Length of day is the same everywhere**
  - **No permanent daylight anywhere**

- **At (northern) winter solstice**
  - **Sun is overhead at Tropic of Capricorn**
  - **Northern hemisphere days are short**
  - **Permanent darkness north or arctic circle**

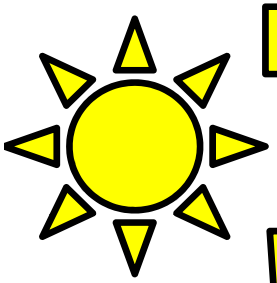


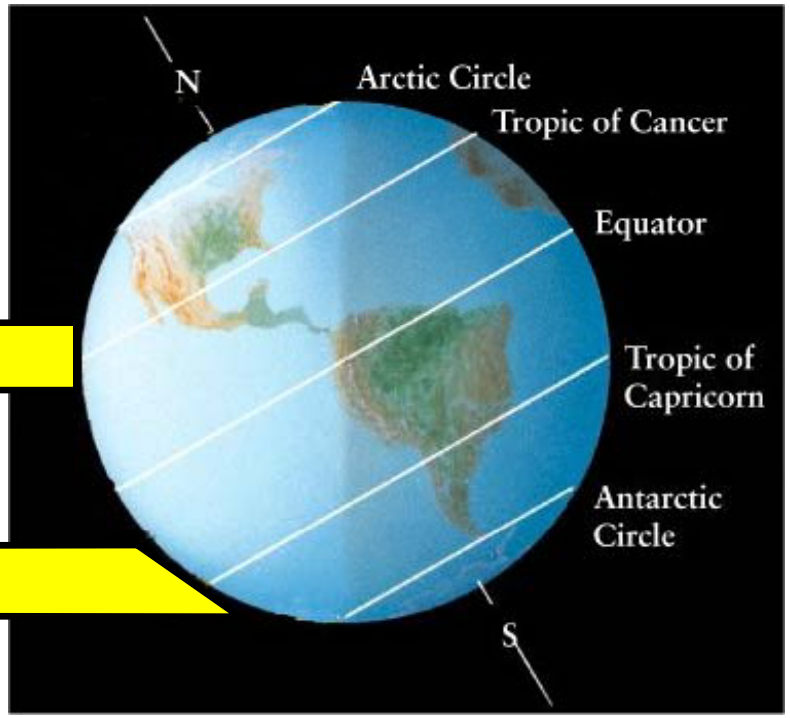
Tropics: 23½° South to 23½° North. The region where the Sun is directly overhead at some season.

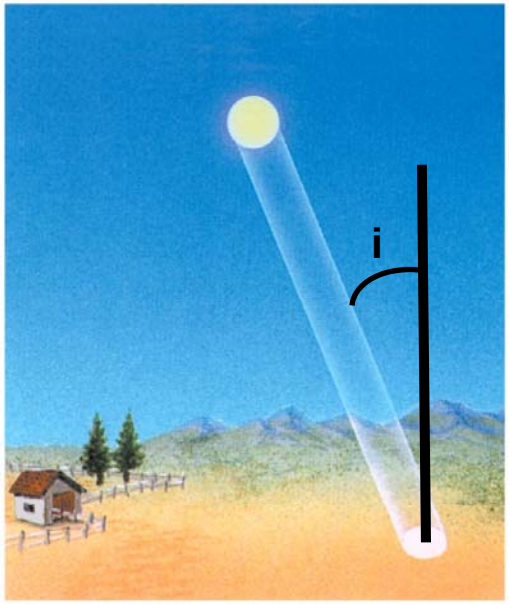
Mid-latitudes: 23½° to 66½° North and South. The Sun is never directly overhead. The sun sets and rises every day.

Polar regions: 66½° to 90° North and South. The Sun never sets in the summer and never rises in the winter.

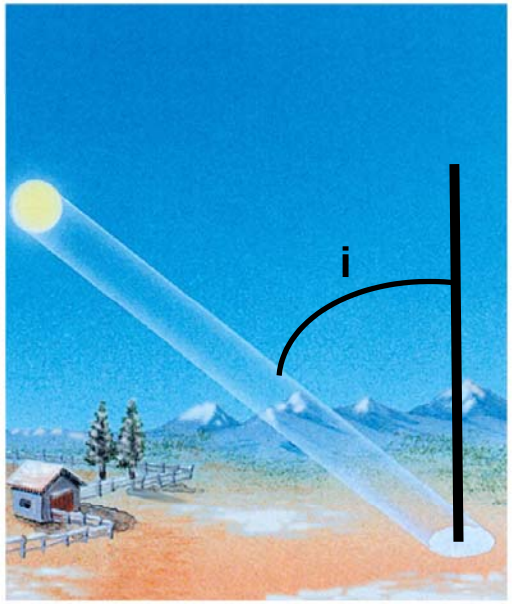
- **Tilt of ground towards the sun determines how much the solar energy is spread out**
  - **Depends on latitude and season**







(a) The Sun in summer

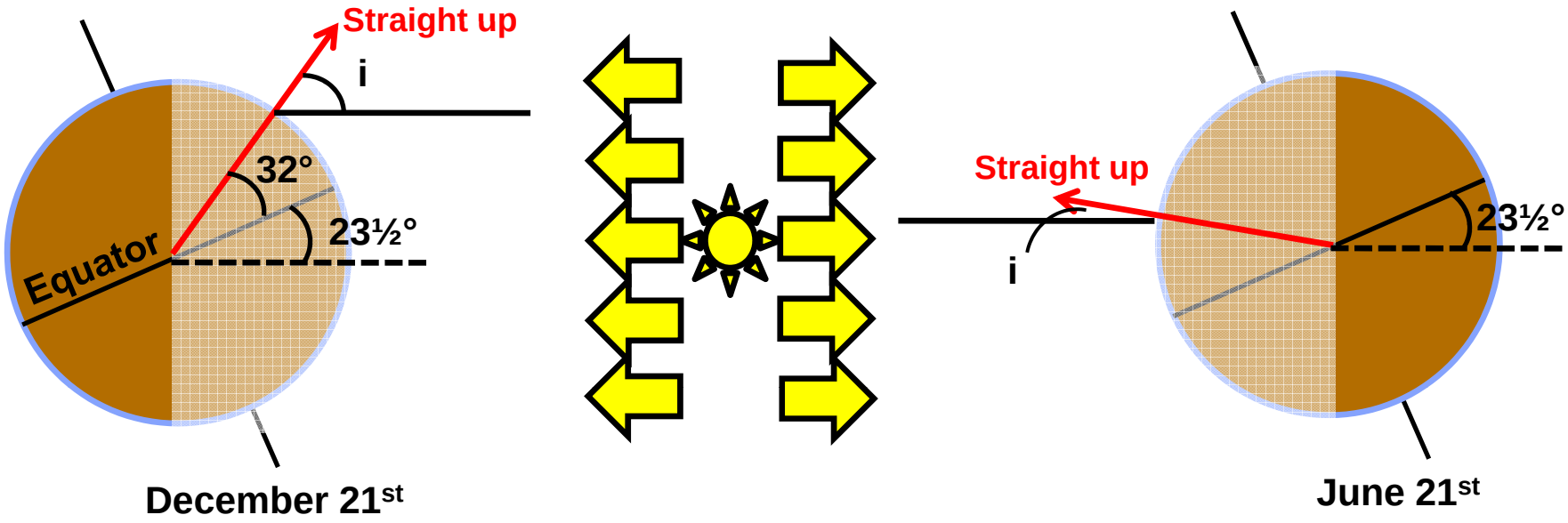


(b) The Sun in winter

Figure 2-13
Universe, Eighth Edition

- **Solar power at Earth**
  - **~1370 W/m^2**
- **Incidence angle (i)**
  - **i = 90° – solar elevation**
  - **Power reduced by cos(i)**
  - **i=0°, Sun directly overhead**
  - **I=90°, Sun on the horizon**
    - **Zero solar power**

- **How about Tucson (32° North latitude), winter vs. summer?**

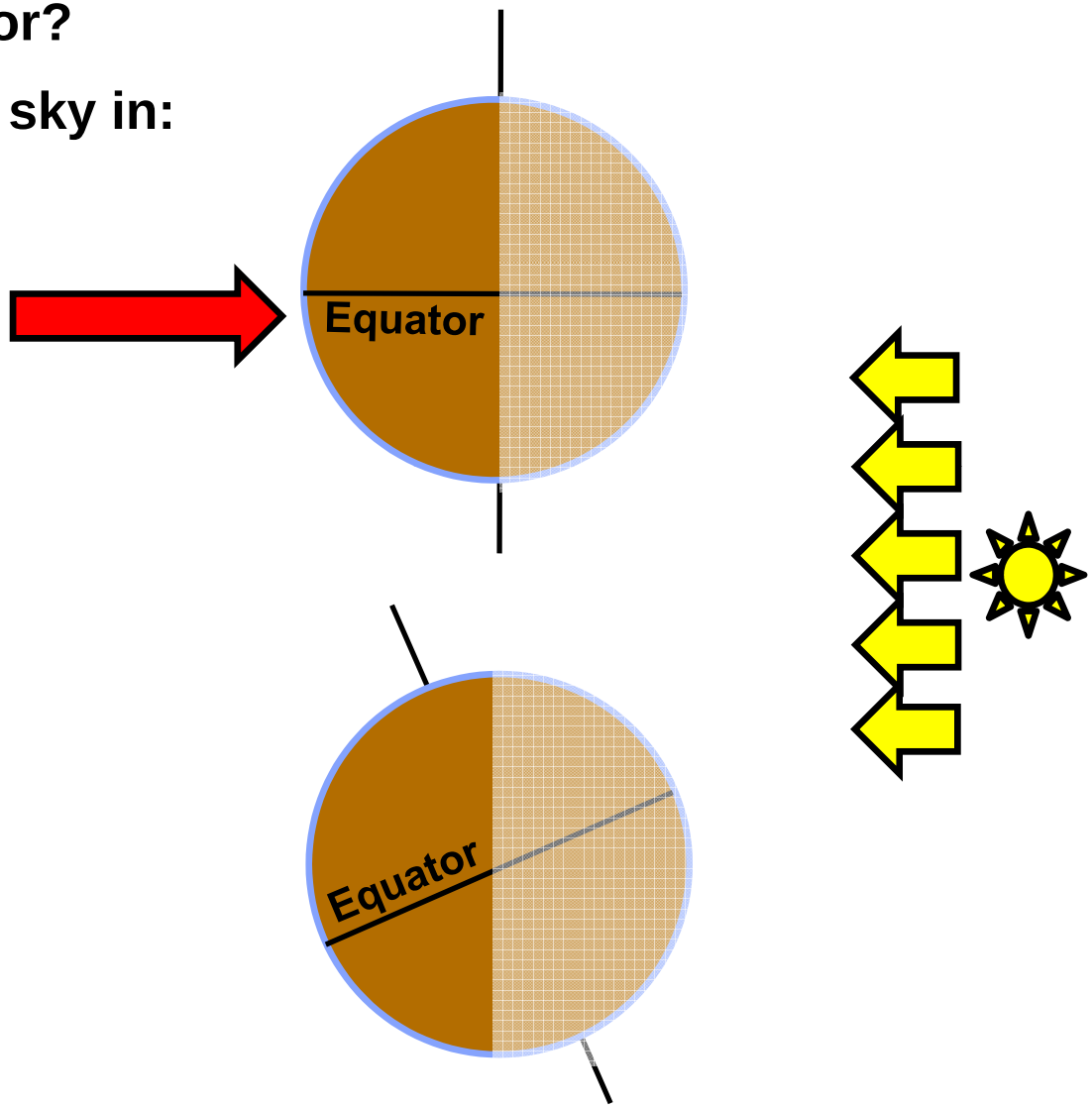


	Noon Winter Solstice	Noon Summer Solstice	Noon Equinox
Solar elevation	34½°	81½°	58°
Incidence Angle	55½°	8½°	32°
Solar power **cos(i)*1370 W/m²**	776 W/m²	1355 W/m²	1162 W/m²

A big difference!

- **What about at the equator?**
- **Is the sun highest in the sky in:**
  - **A) June**
  - **B) December**
  - **C) March or September**
  - **D) It's the same all year**

- **What about at the equator?**
- **Is the sun highest in the sky in:**
  - **A) June**
  - **B) December**
  - **C) March or September**
  - **D) It's the same all year**



Phases

- Every planet/moon is half-illuminated
  - Except during eclipses
  - Our point of view makes planetary objects have ‘phases’
  - Phases of the Moon are easiest to see
  - The phase of an object can be expressed as a ‘phase angle’ – more on this later

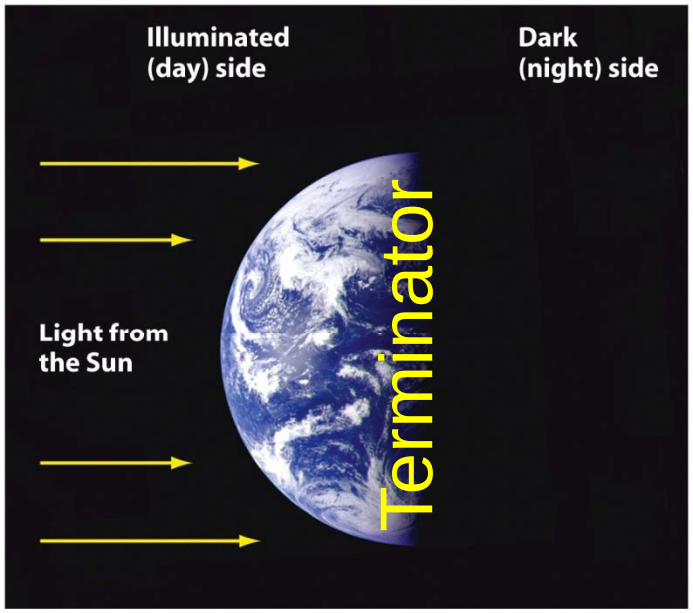
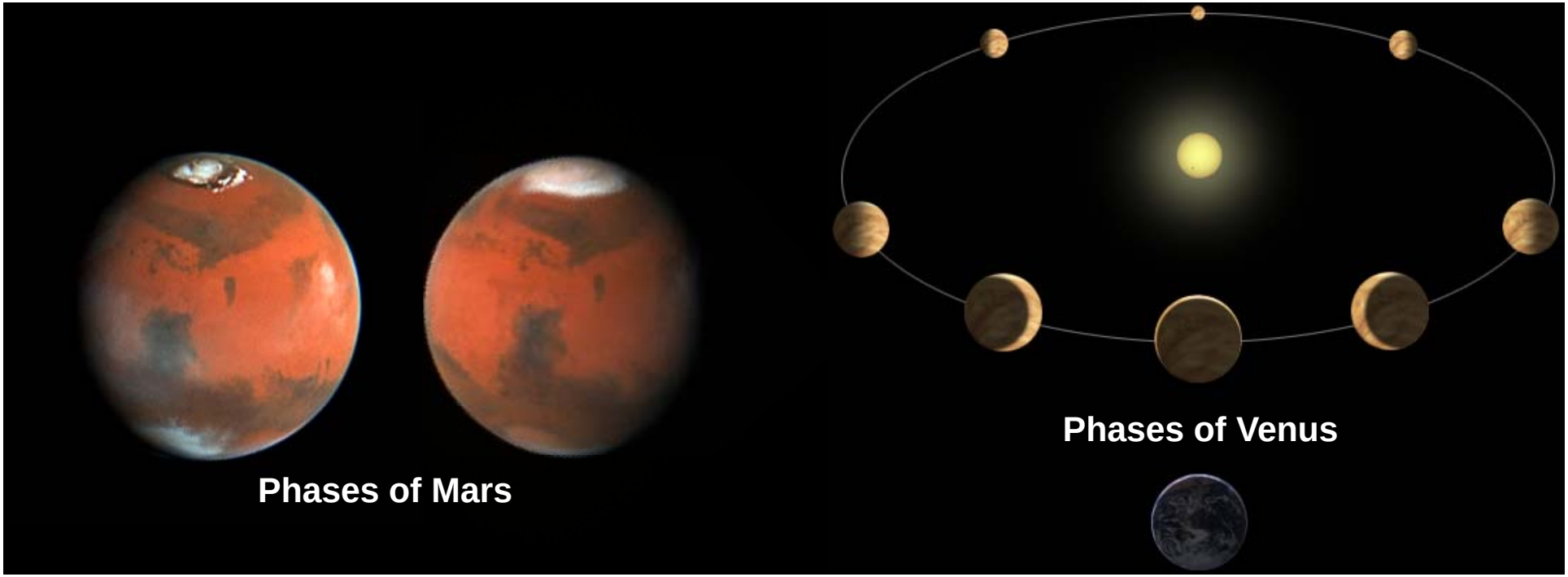


Figure 2-3
Universe, Eighth Edition



- **The Moon shows the most dramatic phase changes as it's nearby**
  - **Orbits Earth every 27.3 days…**
  - **…but new-moon to new-moon period is 29.5 days**
    - **Any ideas why?**

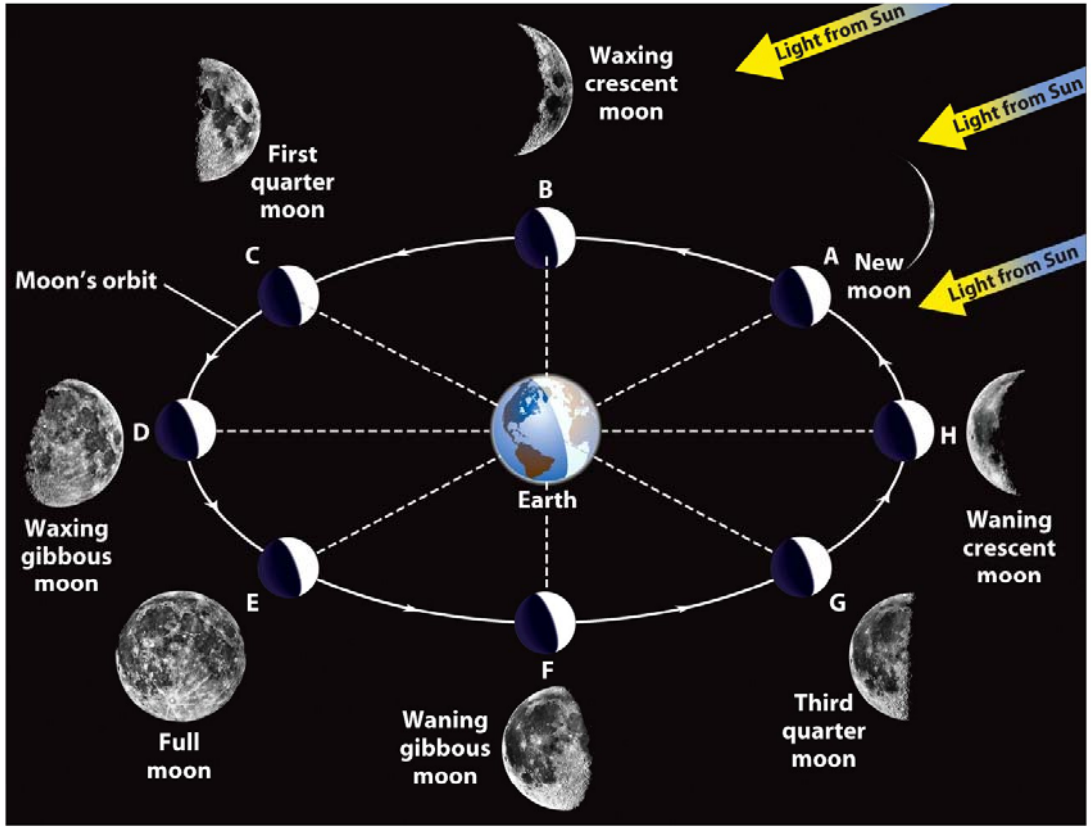


Figure 3-2
Universe, Eighth Edition

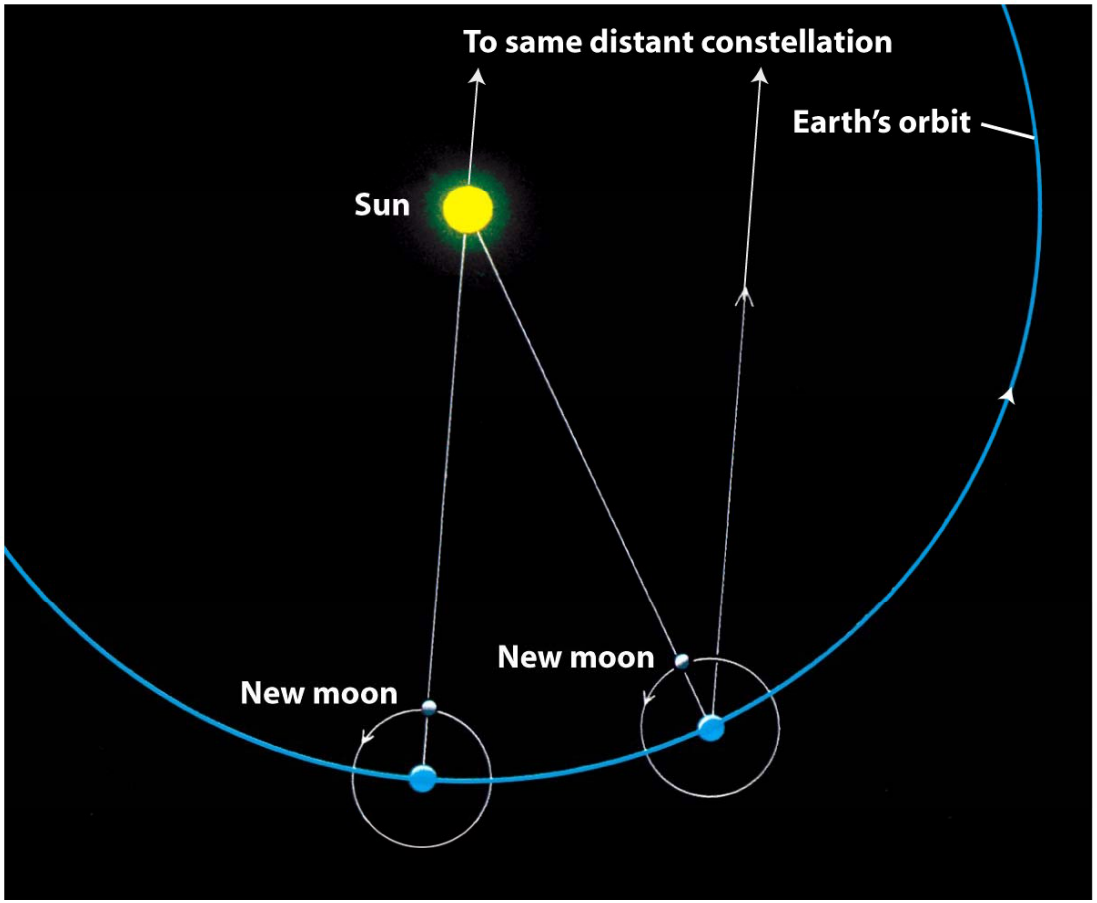
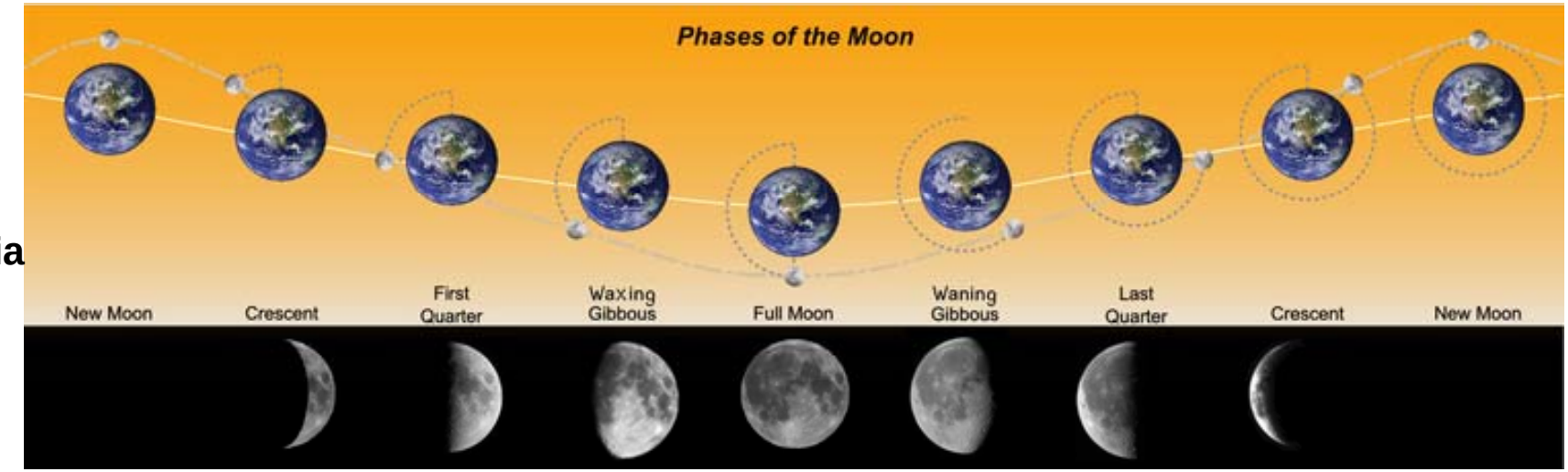


Figure 3-5
Universe, Eighth Edition

- **Sidereal period**
  - Measured relative to the fixed stars
  - 27.3 Days
- **Synodic Period**
  - Measured by illumination
  - 29.5 days

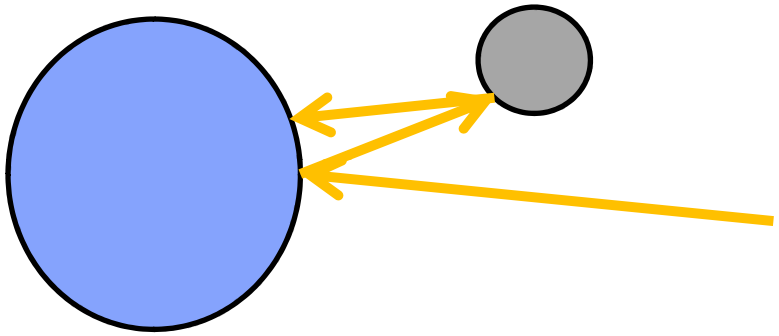
- **Waxing – Moon is growing from new to full**
  - **New, crescent, 1st quarter (half full), Gibbous, Full**
- **Waning – Moon is shrinking from full back to new**
  - **Full, Gibbous, 3rd quarter (half full), Crescent, New**

Wikipedia



- **Dark side vs. far side of the Moon**
  - **We never see the far-side from Earth**
  - **We always see part of the dark side (except at full Moon)**
- **Once in a 'Blue Moon'**
  - **Second full Moon in a calendar month**
  - **Once every 2.7 years**

- **Dark side of the Moon isn't completely dark….**
  - **Reflected sunlight from the Earth hits the Moon…**
  - **…and is reflected back to us.**



Synchronous rotation

- Why do we only see one side of the Moon?
  - The Moon rotates every 27.32 days – just like its orbital period
  - Ensures that one face always points to the Earth

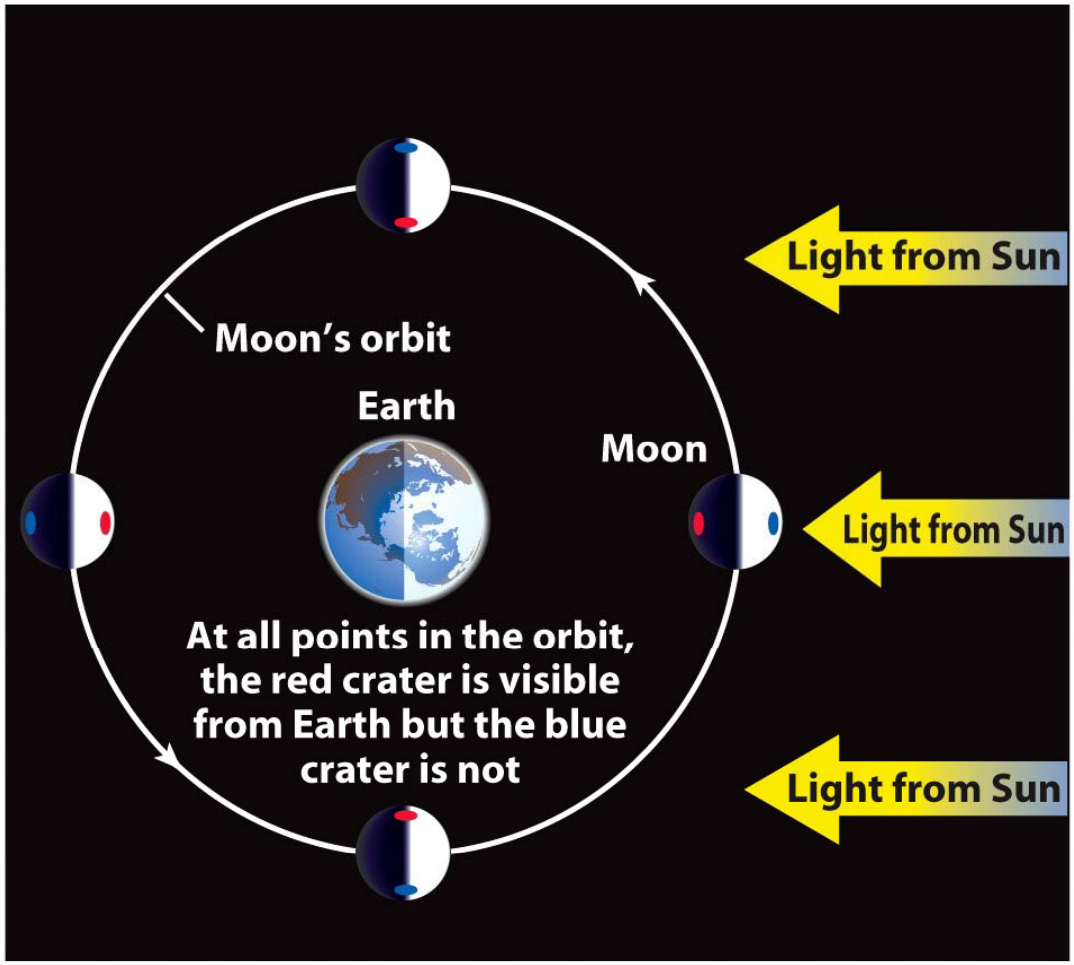


Figure 3-4b
Universe, Eighth Edition

- This is synchronous rotation
  - Not an accident!
  - Nobody saw the far side of the Moon until the first spacecraft passed by.
  - Gravitational tides cause this
    - Earth's spin has slowed down
    - Moon has drifted outwards
    - More on this later
  - Common in the solar system

Eclipses

- What is the lunar phase during a lunar eclipse?
  - Earth's shadow covers the Moon
- What is the lunar phase during a solar eclipse?
  - Moon covers the Sun.

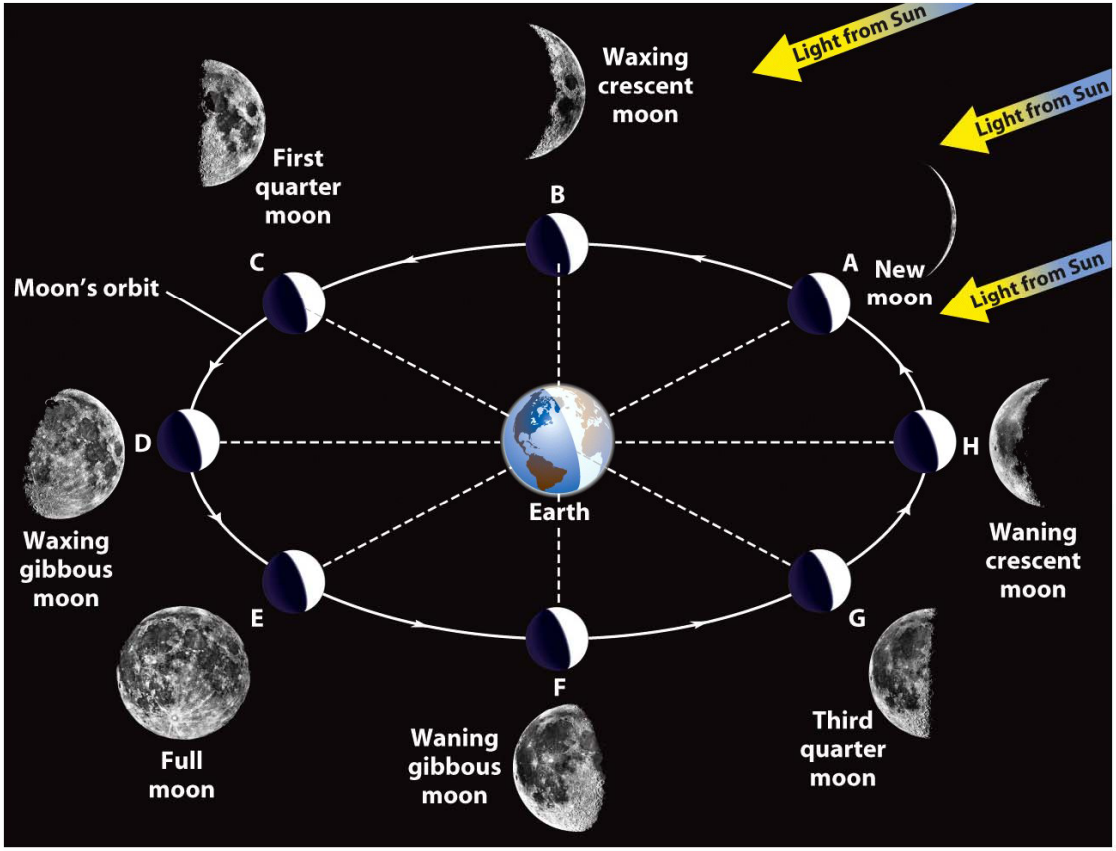


Figure 3-2
Universe, Eighth Edition

Eclipses

- **What is the lunar phase during a lunar eclipse?** **Full Moon**
  - Earth's shadow covers the Moon
- **What is the lunar phase during a solar eclipse?** **New Moon**
  - Moon covers the Sun.

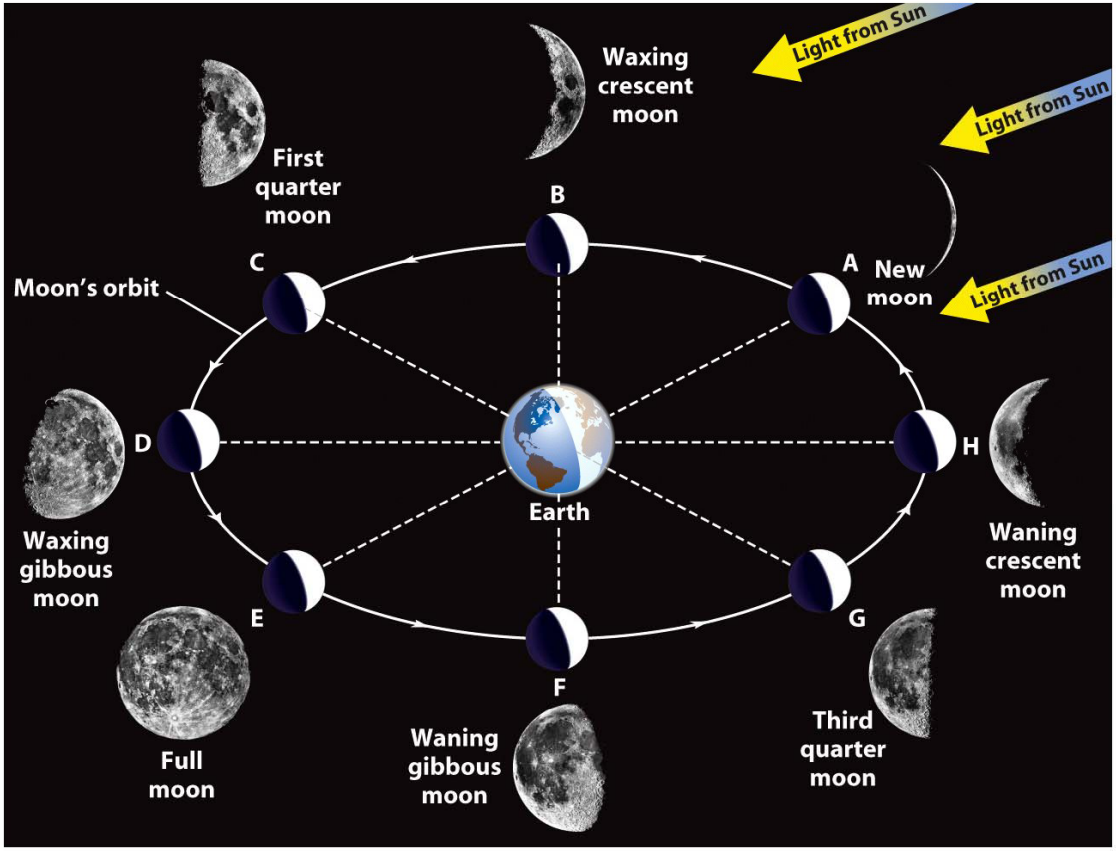


Figure 3-2
Universe, Eighth Edition

- **Earth-Moon-Sun need to be in a straight line.**
- **The Moon's orbit is slightly inclined to the Earth's orbit**
  - **These planes intersect along a line**
  - **The 'Line of Nodes'**
  - **Sun must lie in the line of nodes**
  - **Happens twice a year**

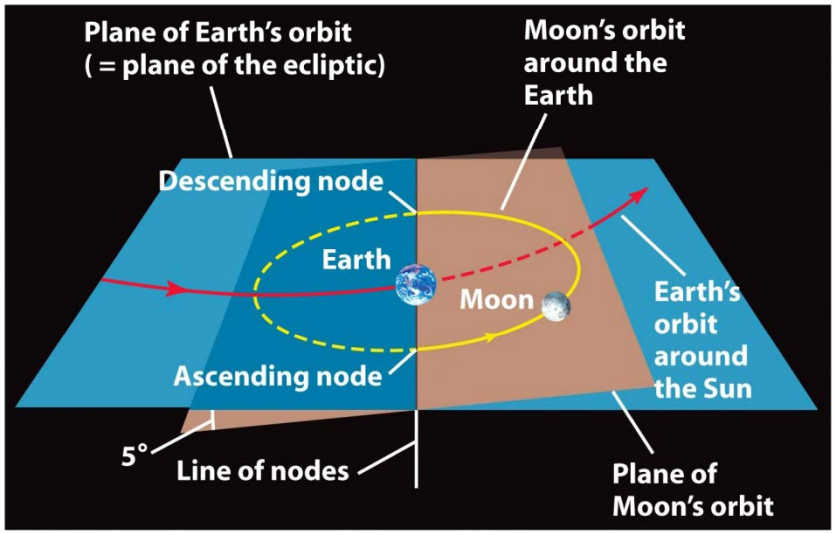


Figure 3-6
Universe, Eighth Edition

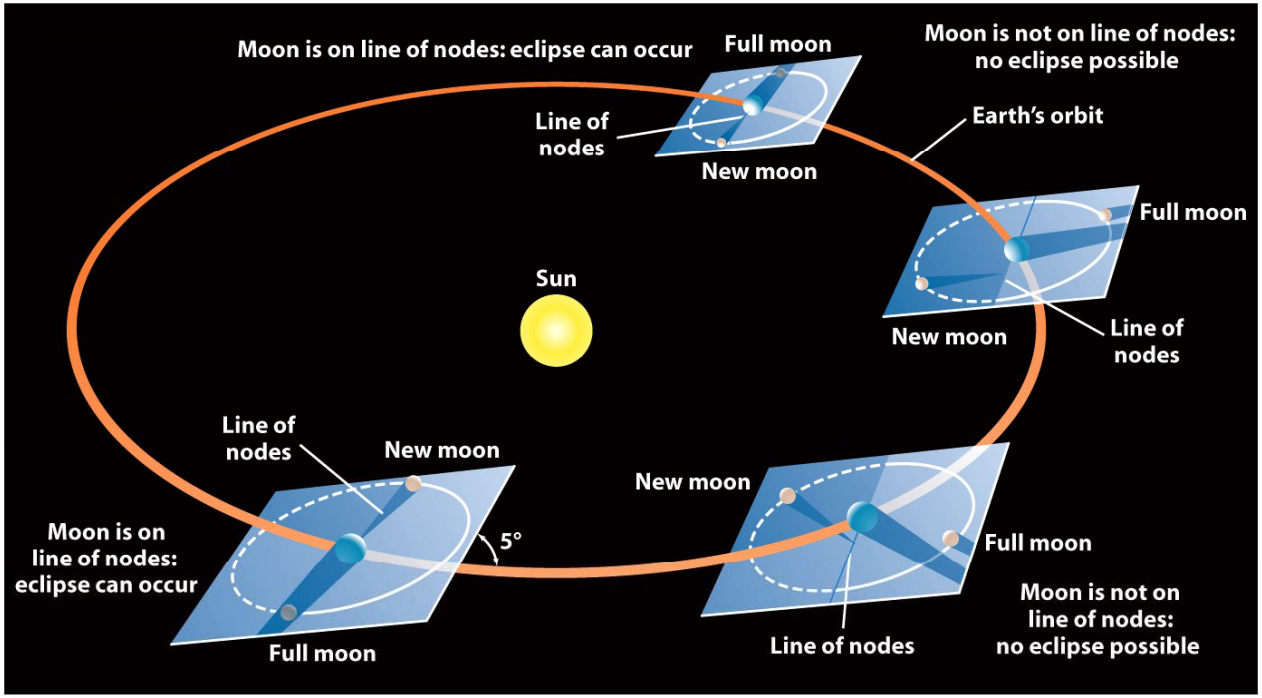


Figure 3-7
Universe, Eighth Edition

- **Lunar eclipse**
  - **Earth's shadow covers the Moon**
  - **Can only occur with a full Moon**
  - **Depending on how well centered the shadow is:**
    - **Penumbral eclipse**
    - **Partial eclipse**
    - **Total eclipse**

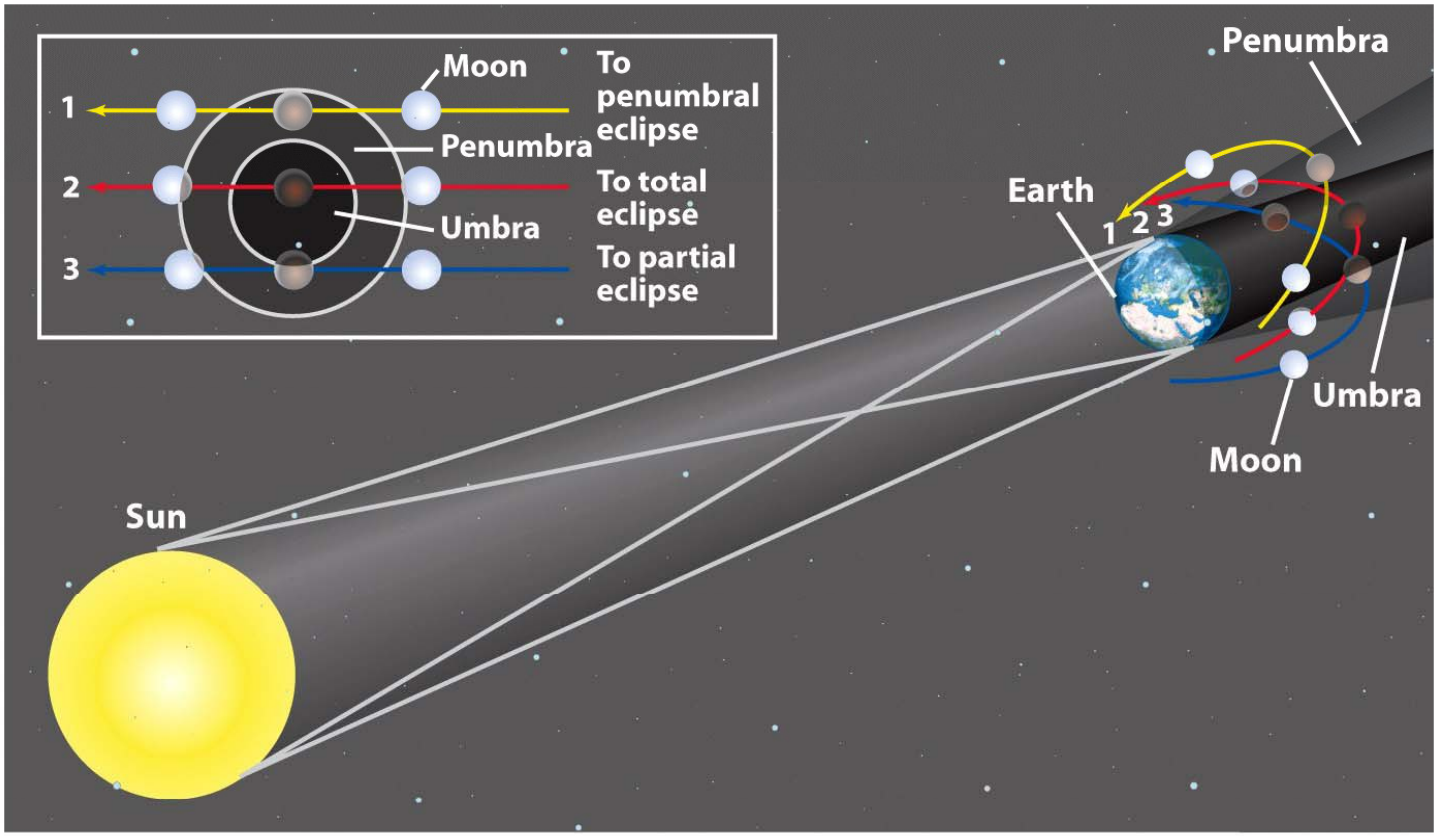


Figure 3-8
Universe, Eighth Edition

- **Lunar eclipse – cont.**
  - **Why does the Moon appear red during an eclipse?**

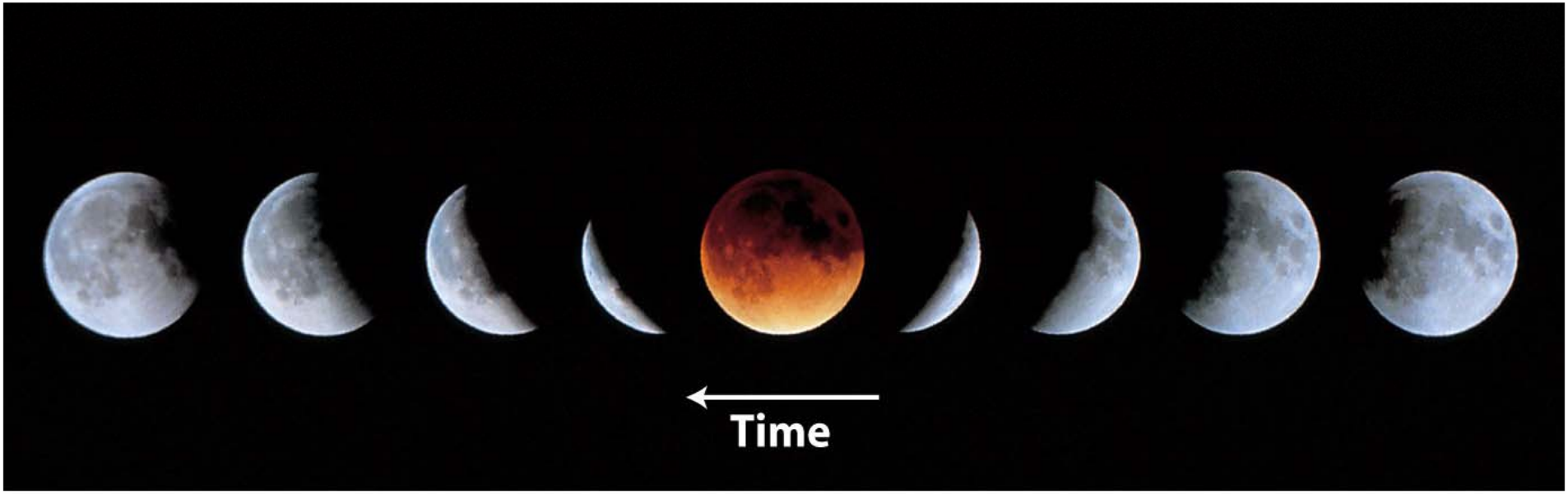


Figure 3-9
Universe, Eighth Edition

- **Lunar eclipse – cont.**
  - **Why does the Moon appear red during an eclipse? Earth's Atmosphere**
  - **Same reason a sunset appears red – blue light is scattered more easily**

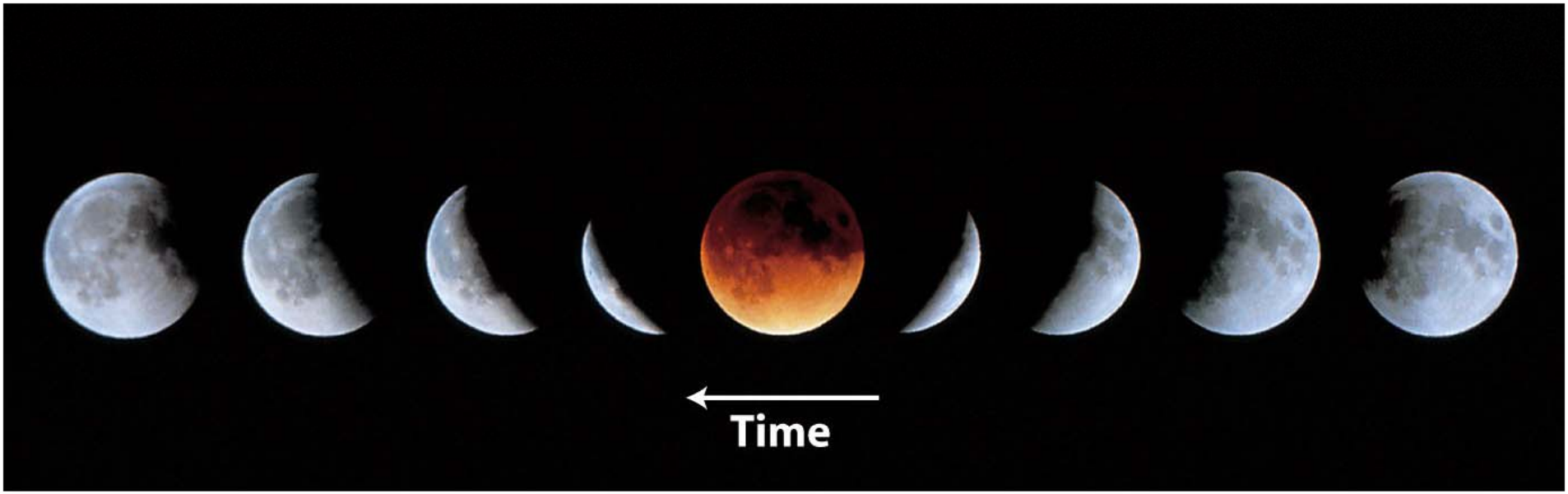
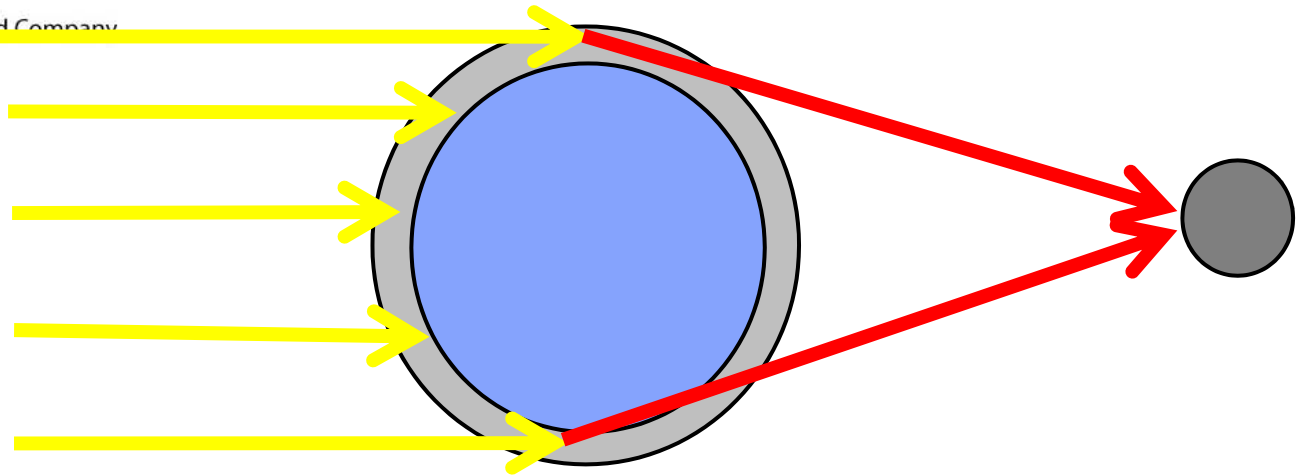
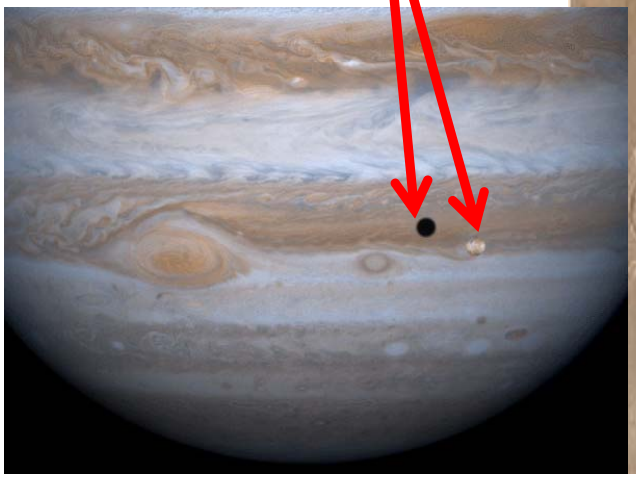


Figure 3-9
Universe, Eighth Edition



- **Solar eclipse**
  - Moon's shadow falls on the Earth
  - Can only occur with a new Moon
  - Eclipses can be
    - Total
    - Annular
    - Partial
  - Occurs on Mars
    - Phobos shadow
  - & Jupiter
    - From Io



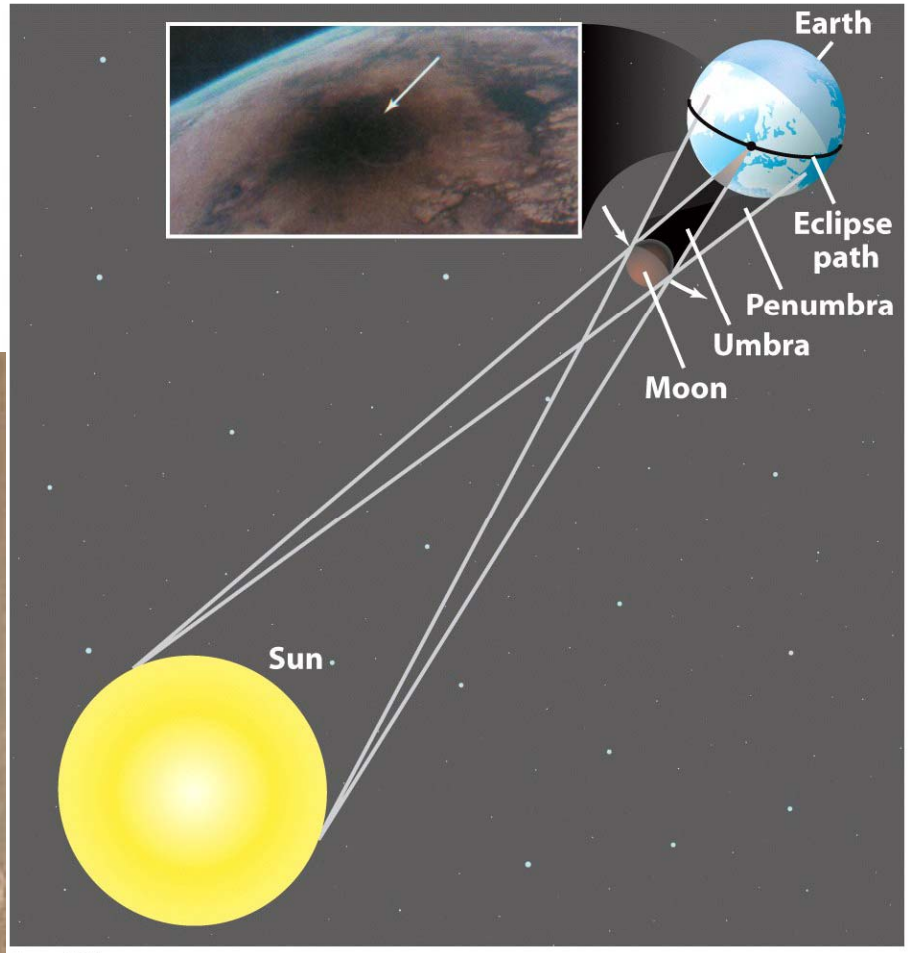
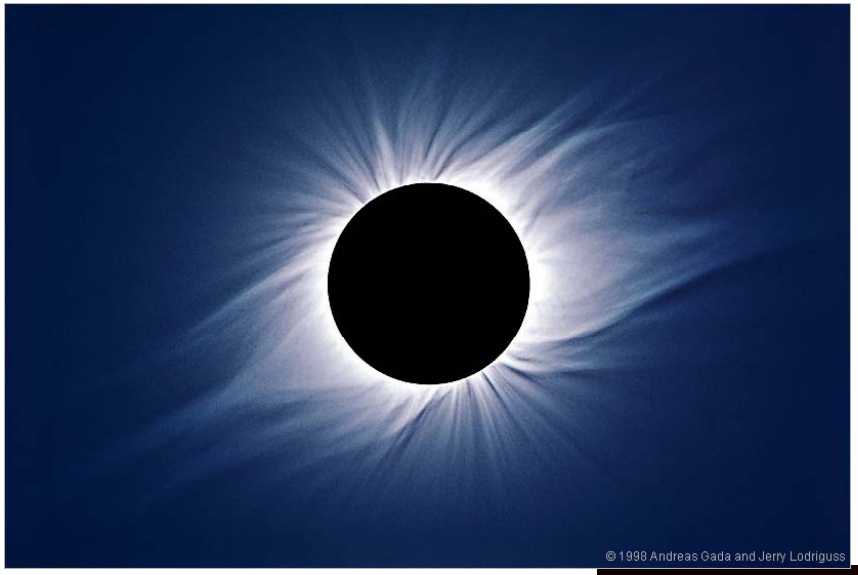
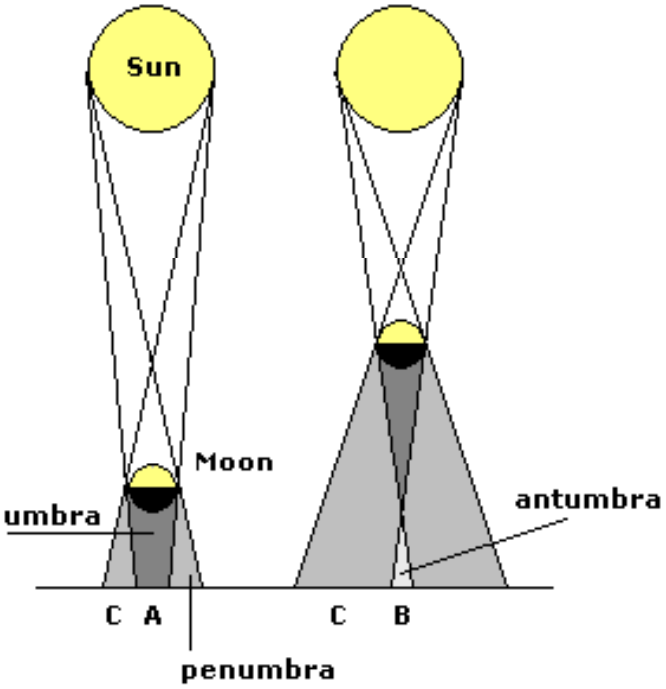
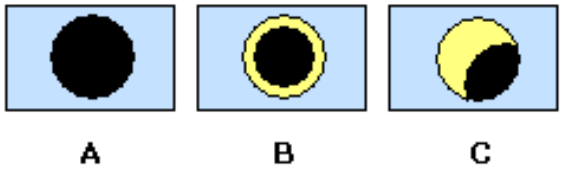


Figure 3-11
Universe, Eighth Edition

- **Annular vs. total eclipse depends on**
  - **Lunar distance**
  - **Location**







In this lecture…

- Our spinning solar system
- Rotation
- Seasons
- Lunar Phases
- Synchronous rotation
- Eclipses

Next: Orbits and Gravity

- Reading
  - Chapter 3 to revise this lecture
  - Chapter 4 for Thursday