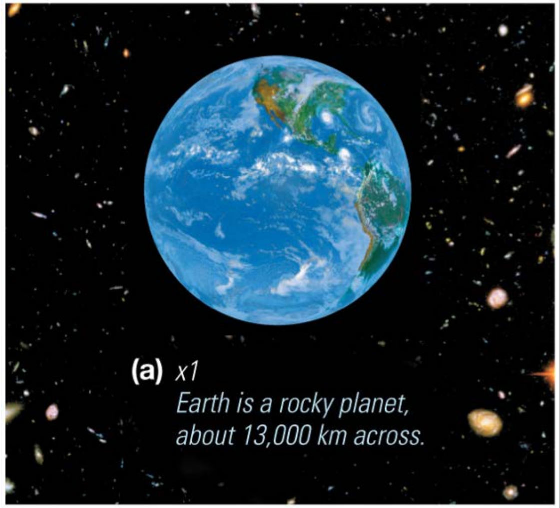
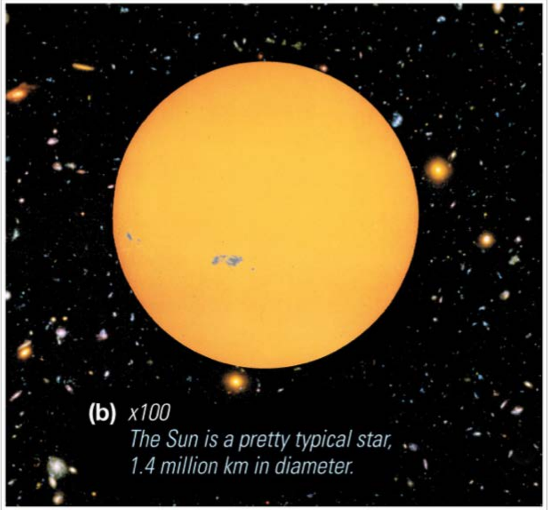
Chapter 1:
Charting the Heavens

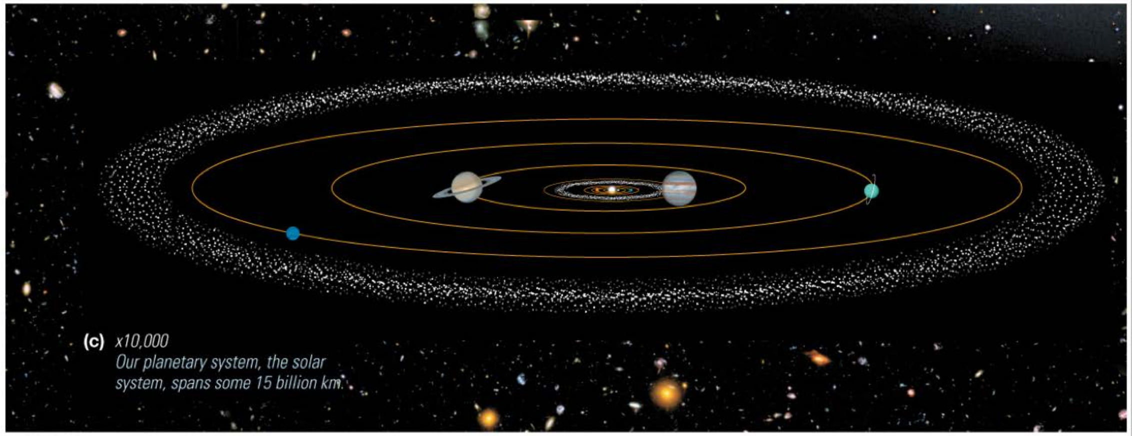
Prof. Douglas Laurence

AST 1004

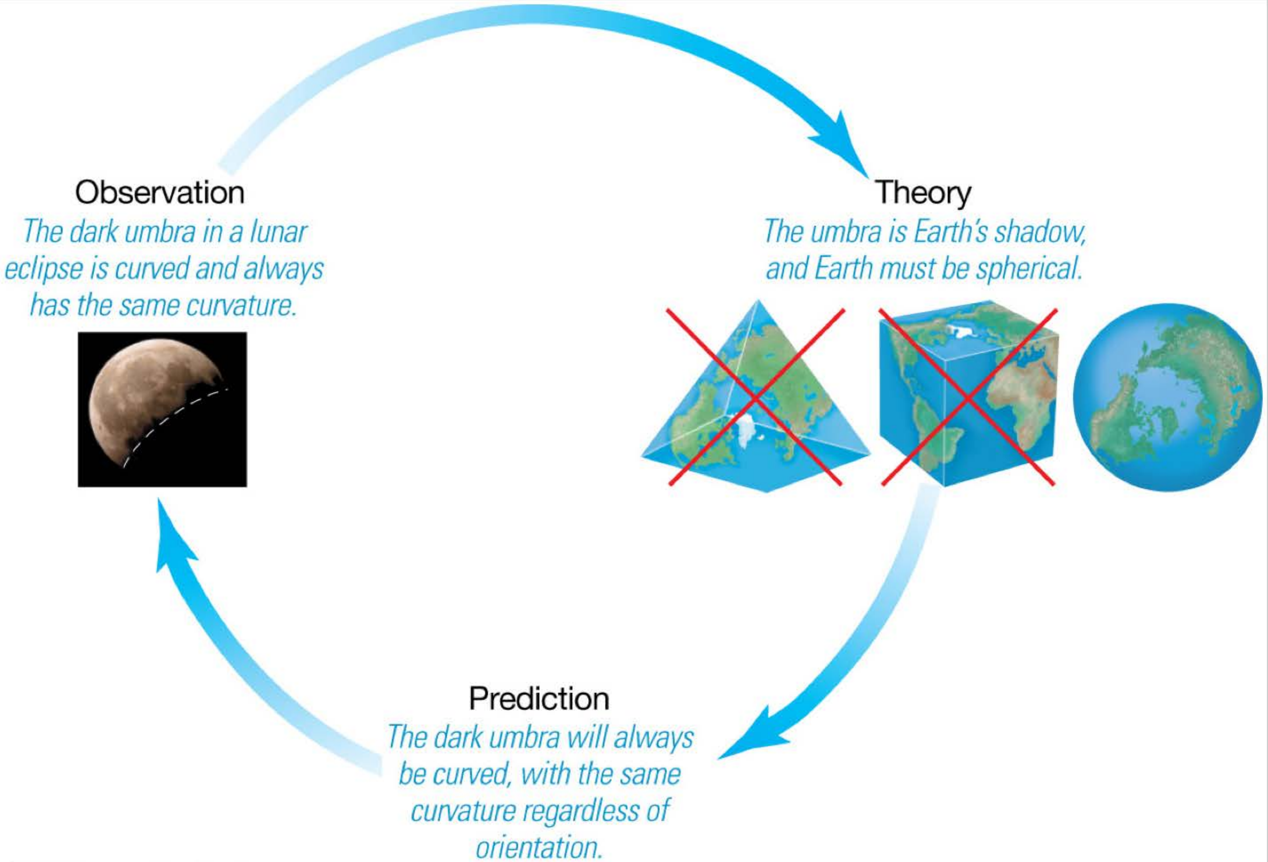
Order of Magnitude

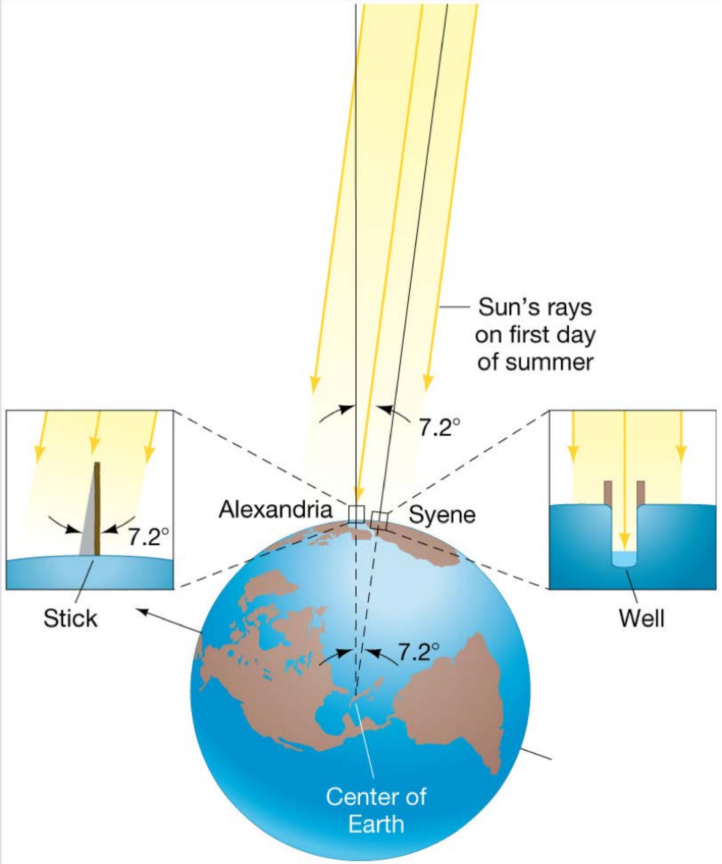






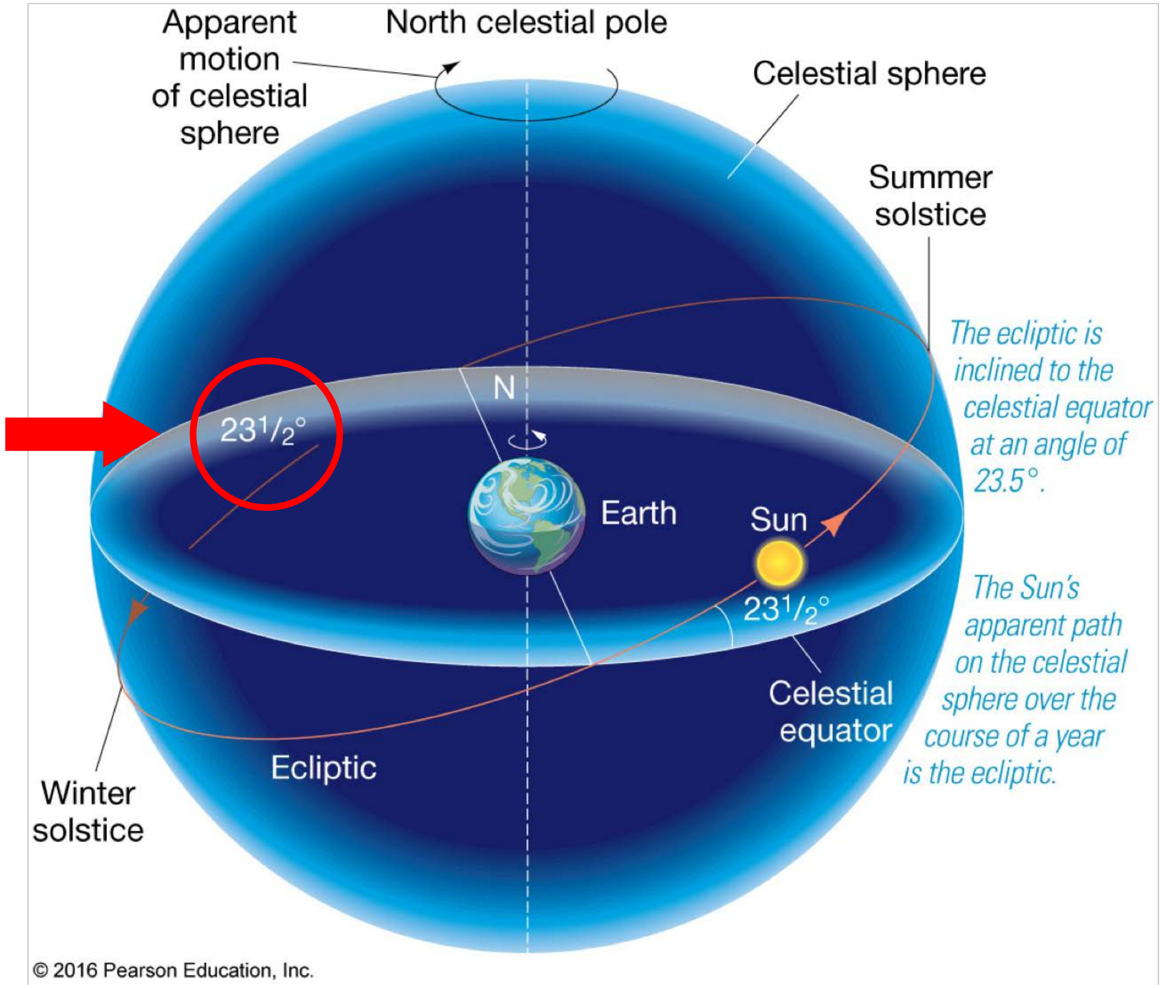
Scientific Method



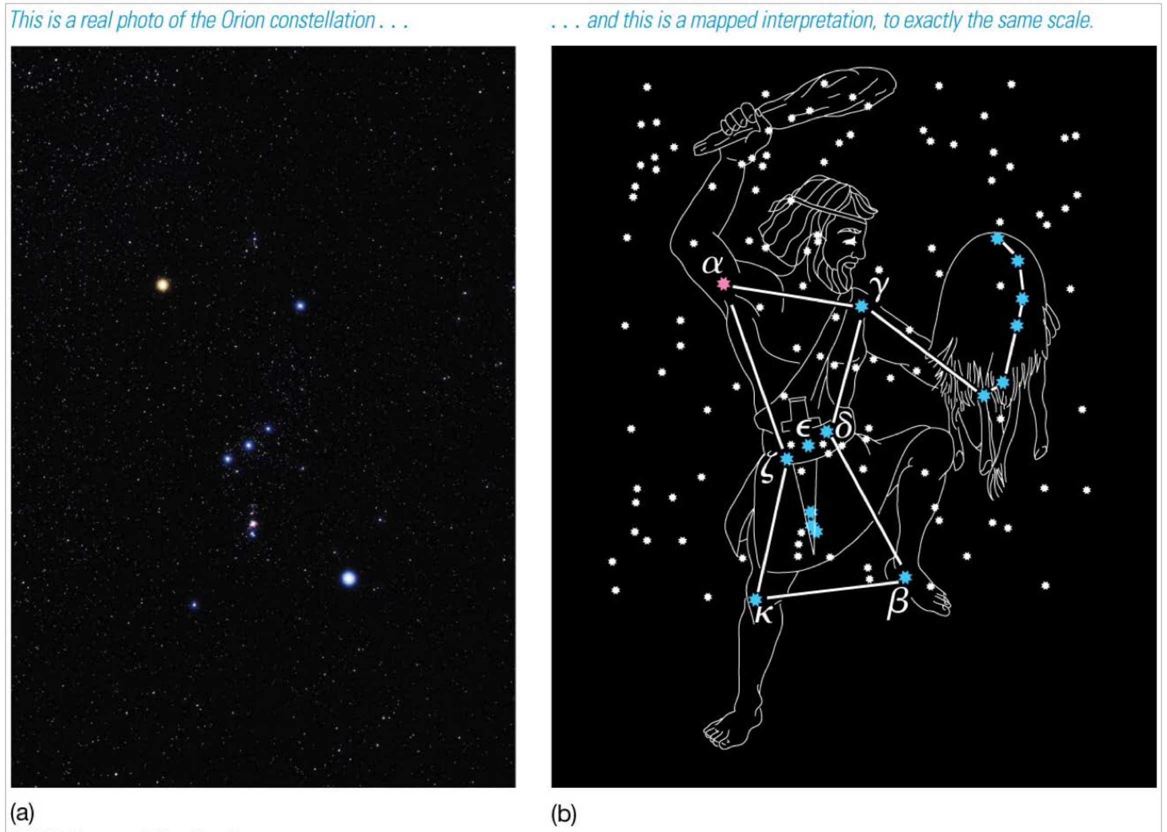


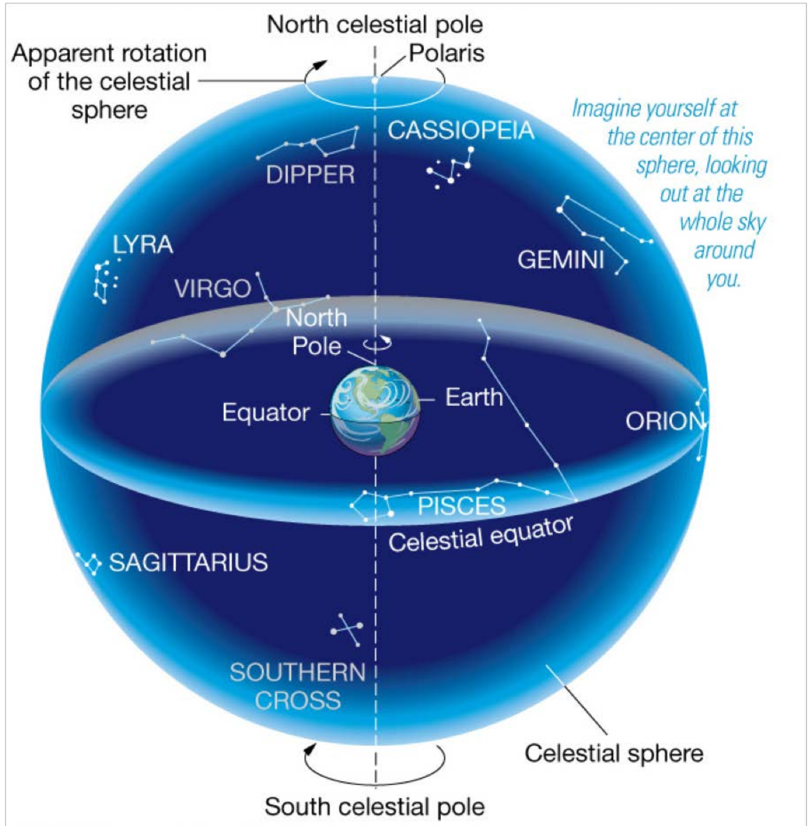
Geocentric View

Same as orbital tilt
in heliocentric view.

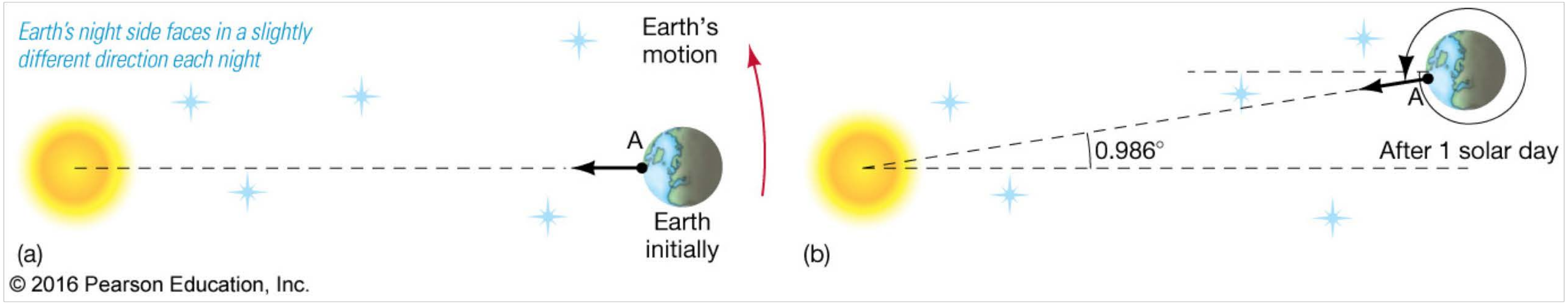


Constellations



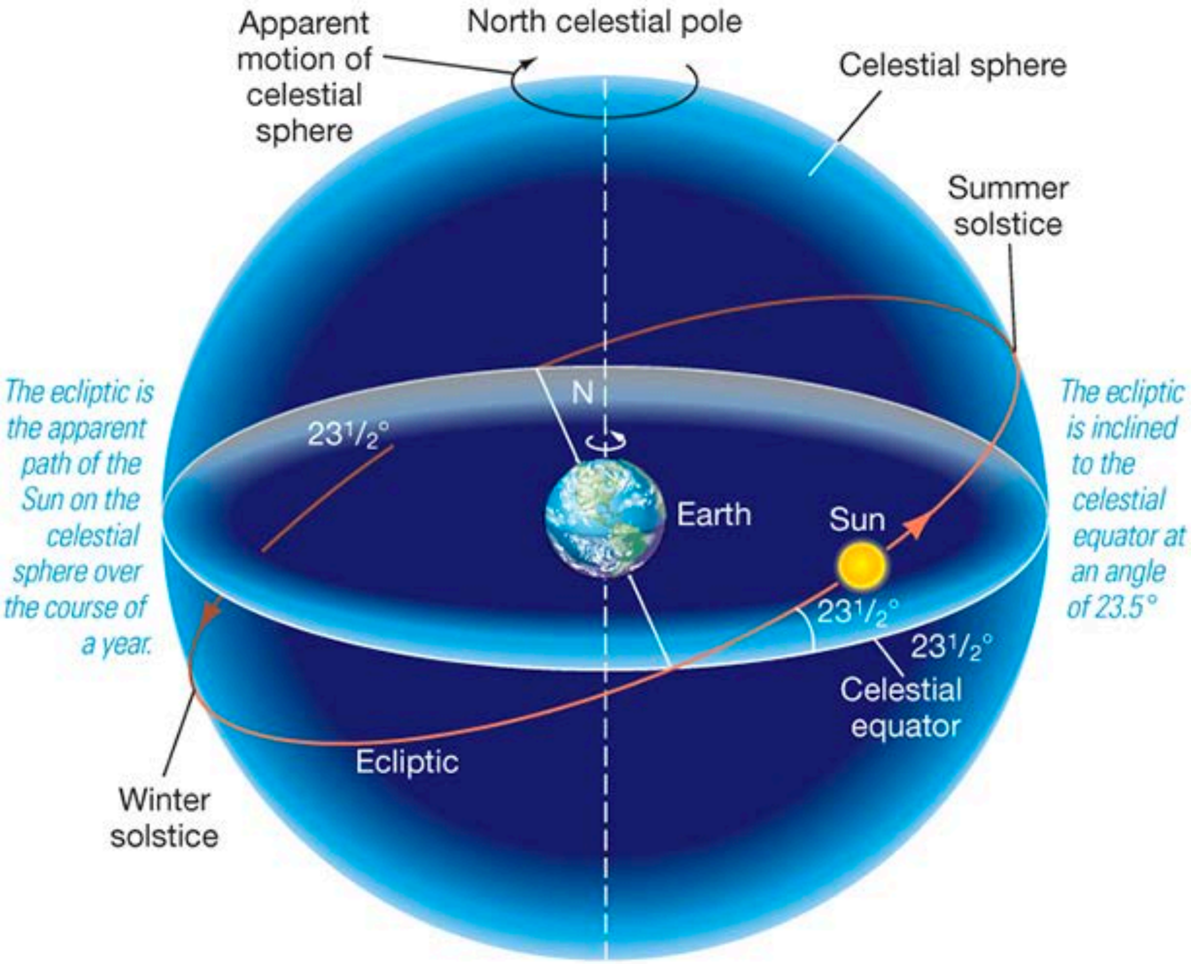


Sidereal vs. Solar Time



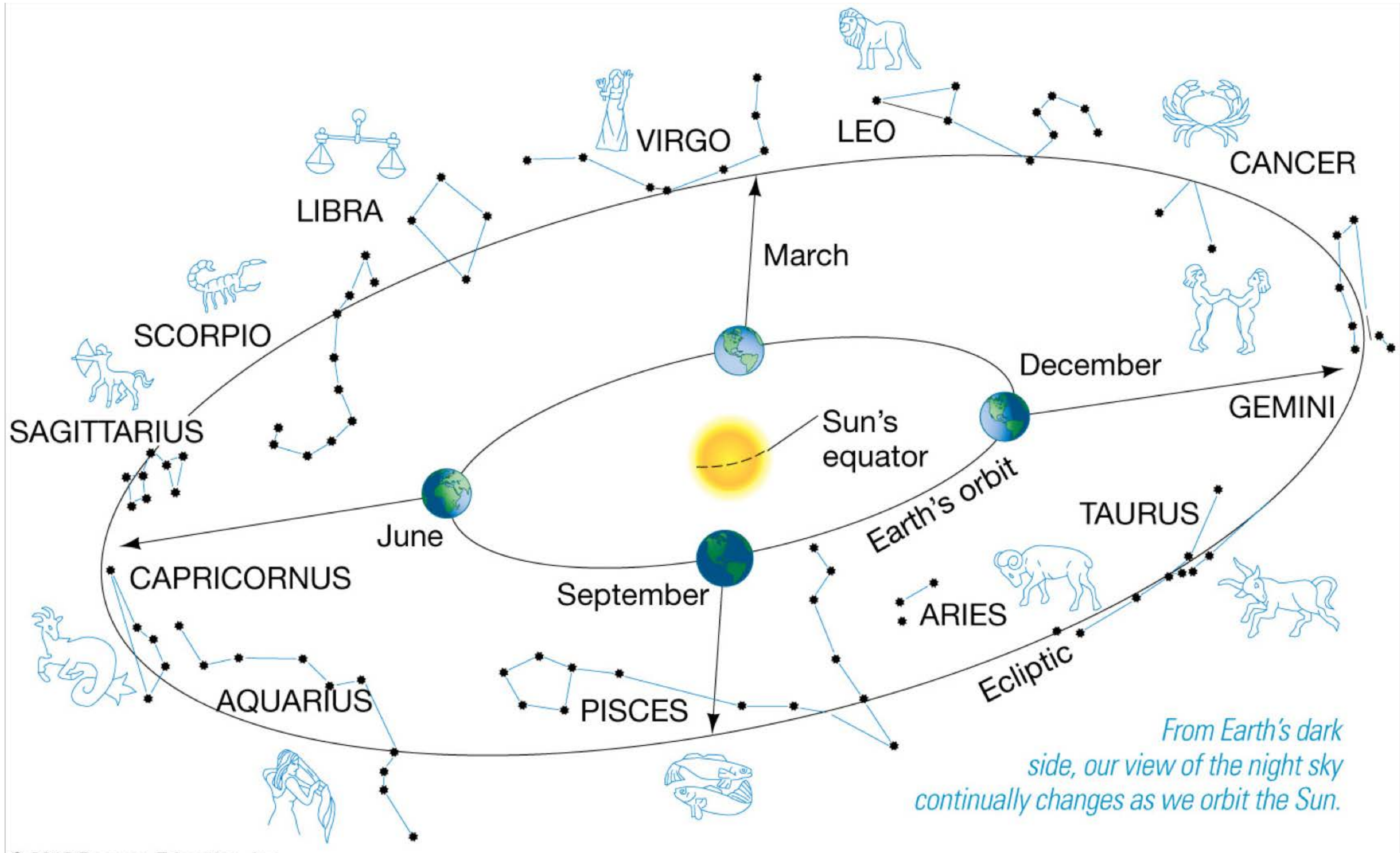
24 solar hours = 23 h 56 min sidereal time

Ecliptic

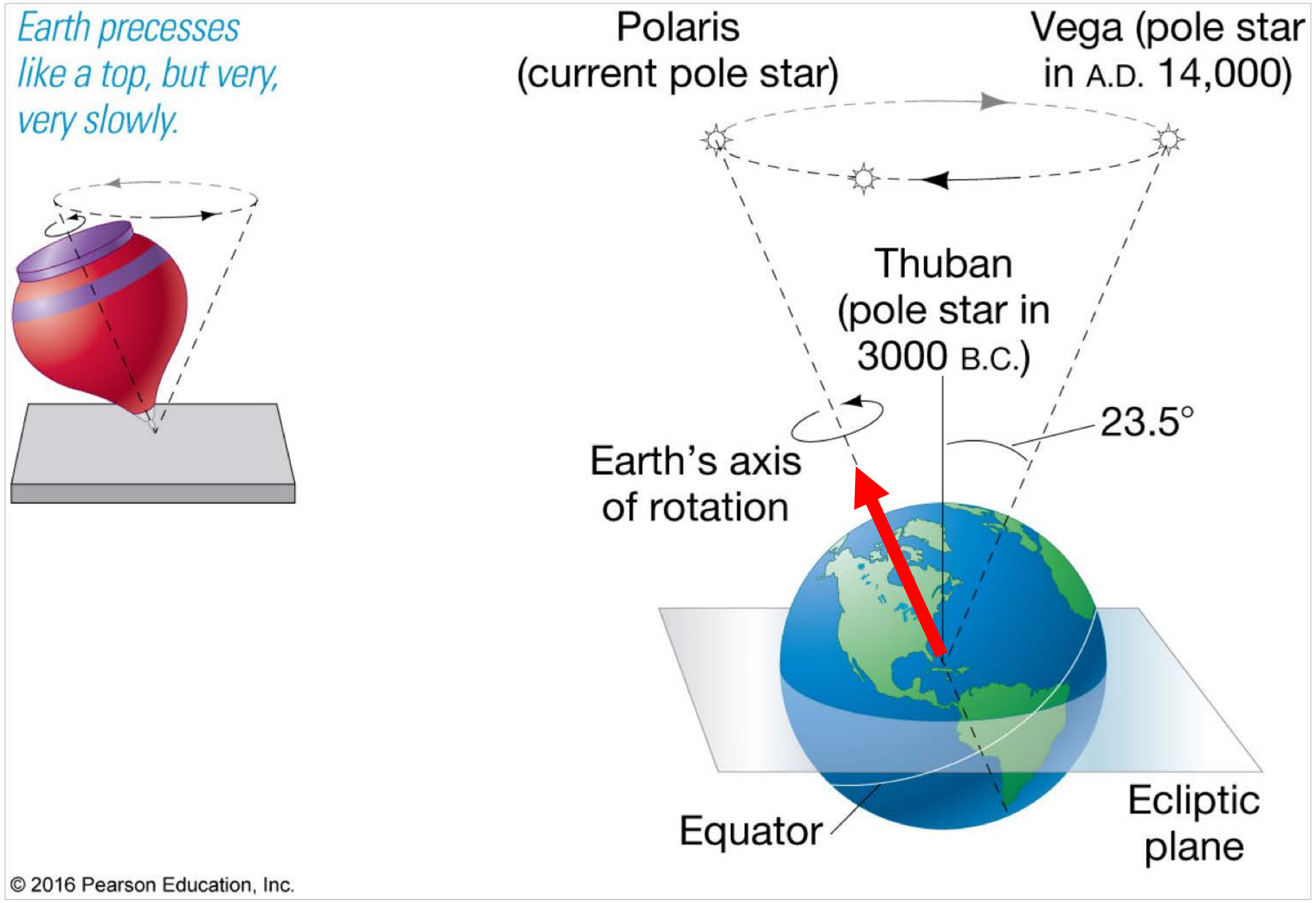


Apparent motion of celestial sphere
North celestial pole
Celestial sphere
Summer solstice
The ecliptic is the apparent path of the Sun on the celestial sphere over the course of a year.
N
23 1/2°
Earth
Sun
23 1/2°
23 1/2°
Celestial equator
The ecliptic is inclined to the celestial equator at an angle of 23.5°
Ecliptic
Winter solstice

Seasons and the Night Sky

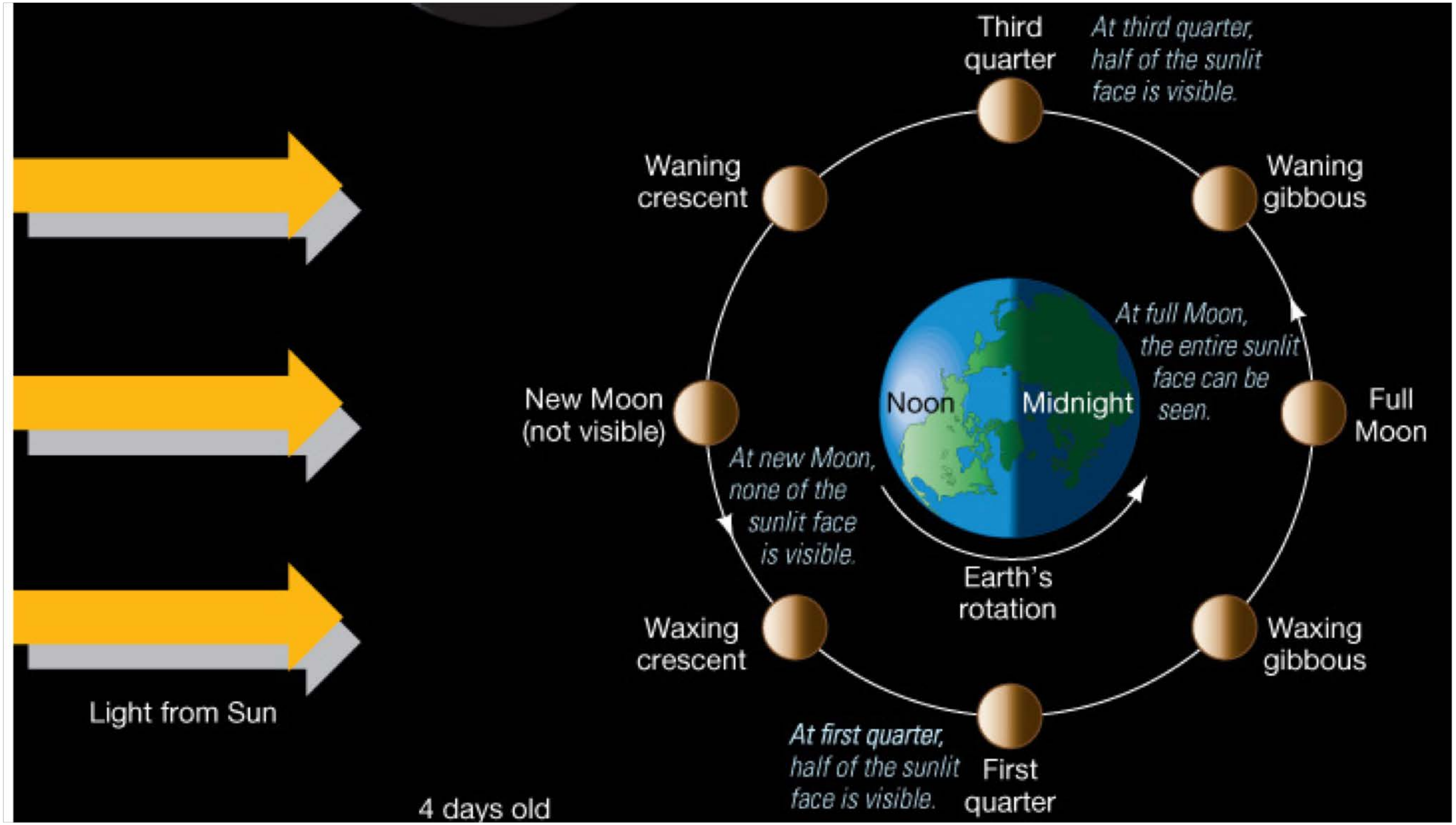


Orbital Procession



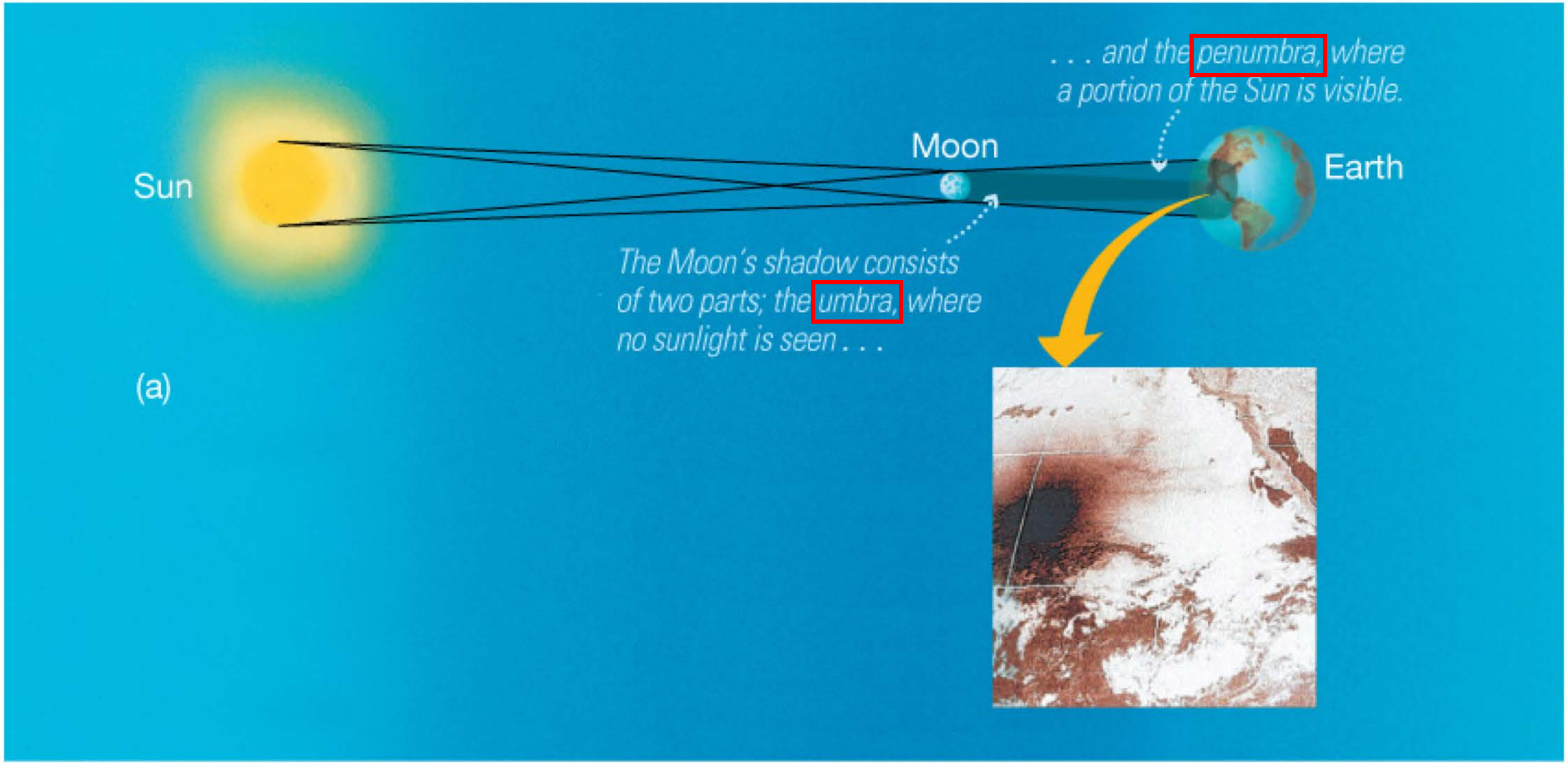
~26,000 years

Phases of the Moon

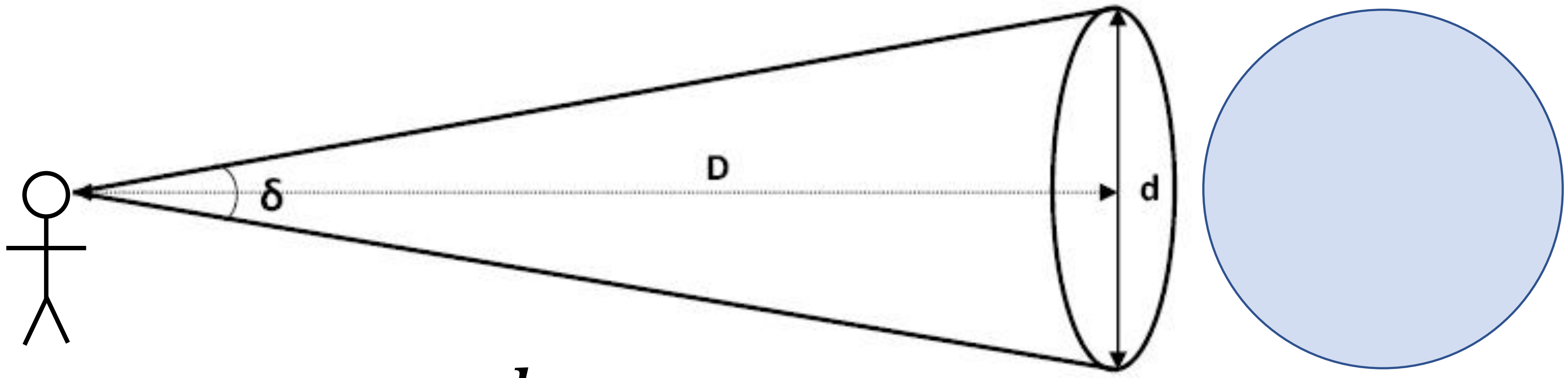


Phases of the Moon (cont'd)

Solar Eclipses

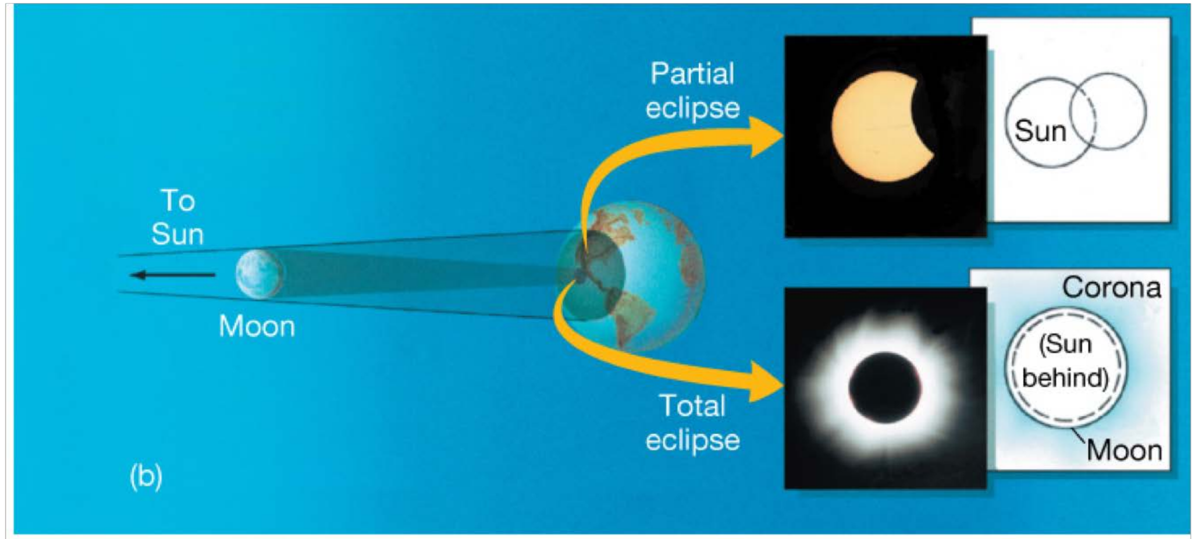


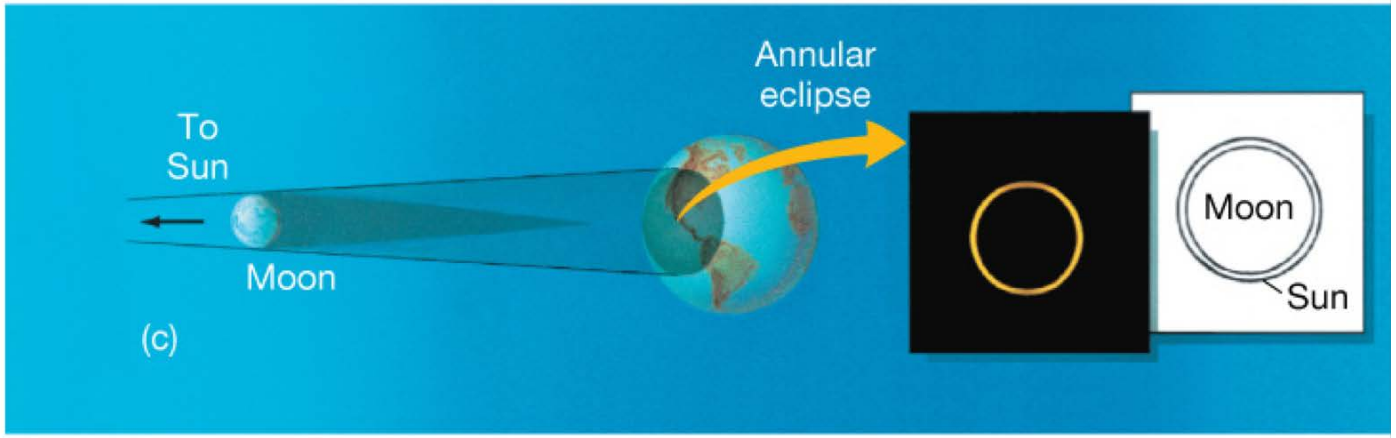
Angular Size



$$\delta \approx \frac{d}{D}$$

Total vs. Annular Solar Eclipses

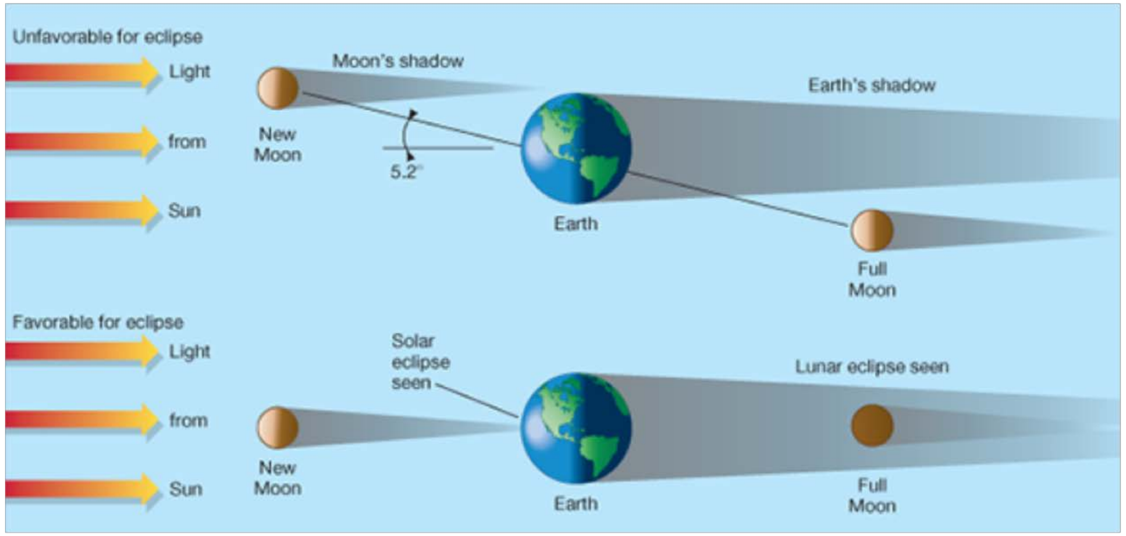


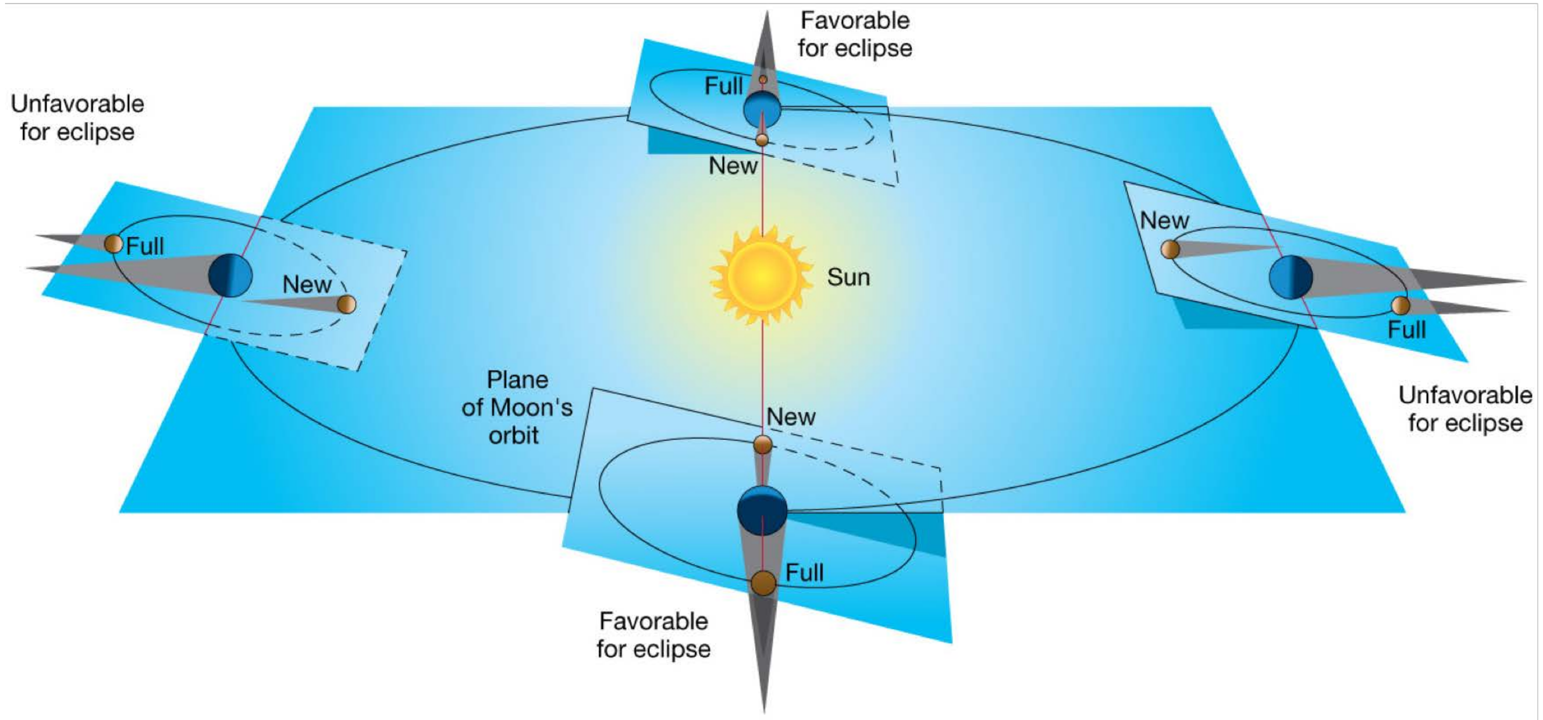


Eclipse Interactive Applet:

https://highered.mheducation.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/007299181x/220730/eclipse_interactive.swf::Eclipse%20Interactive

Conditions for Eclipse

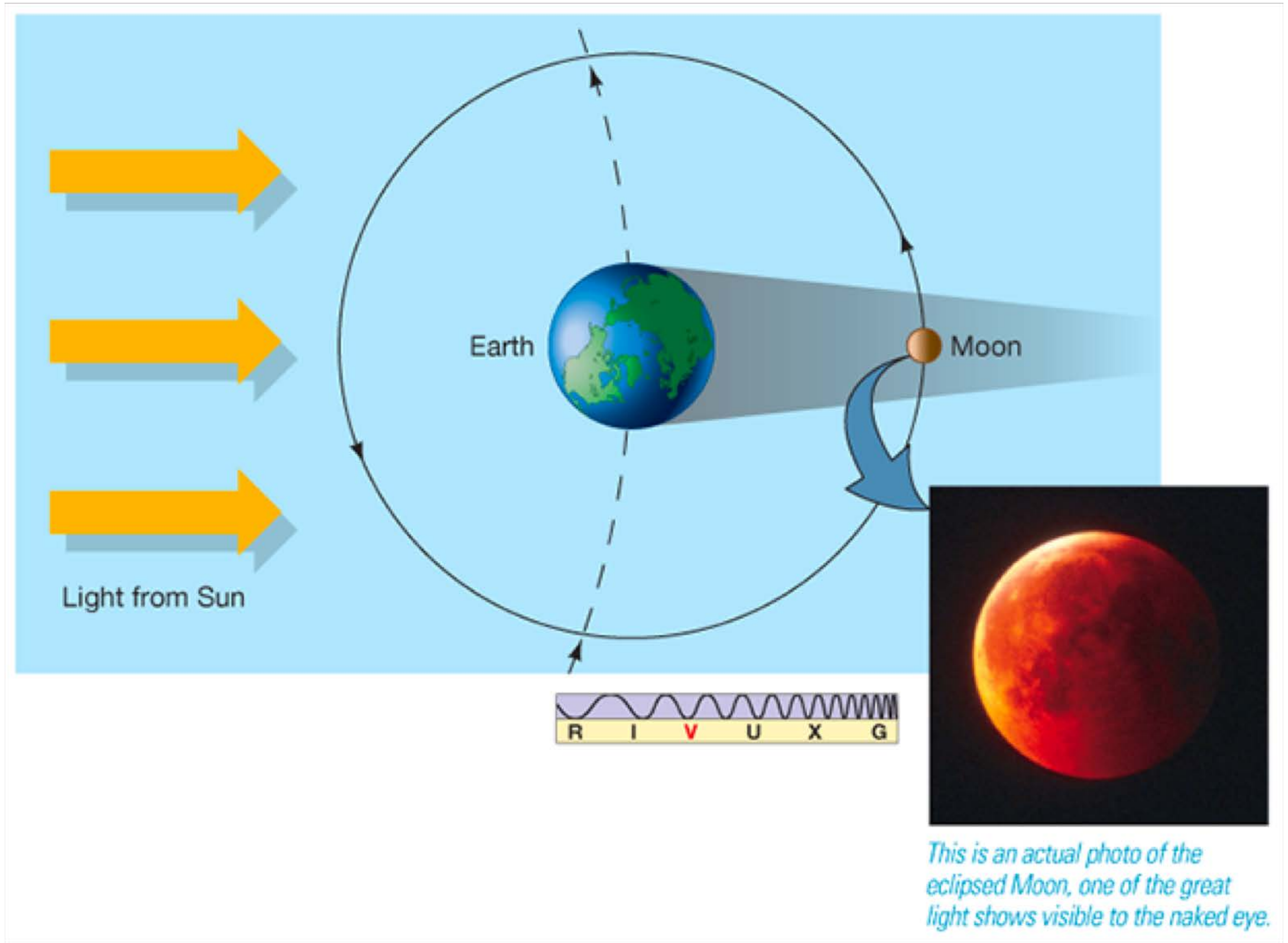




Frequencies of Eclipses

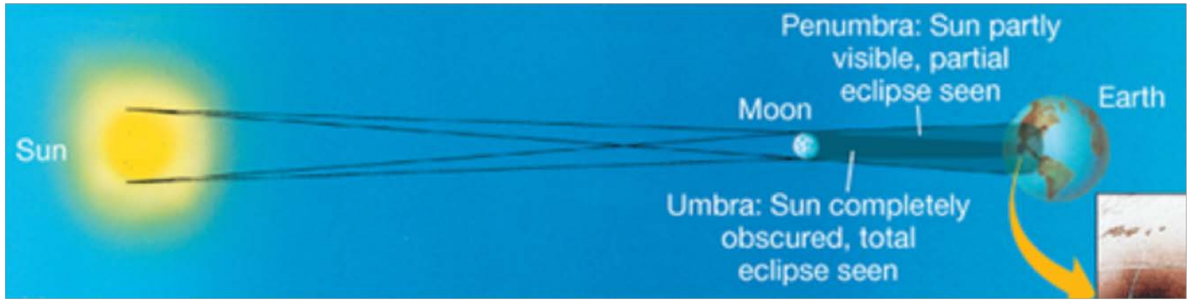
- 2 – 5 solar eclipses occur per year of various types.
  - ~240 per century.
- Total solar eclipses occur somewhere on Earth every ~18mo.
  - But only recur at a given location every ~400yr.
- The moon actually gets further from the Earth each year (3.8 cm/yr) and the sun gets brighter (grows in angular size), so between 650M – 1.4B yr from now, total eclipse will be impossible.

Lunar Eclipses

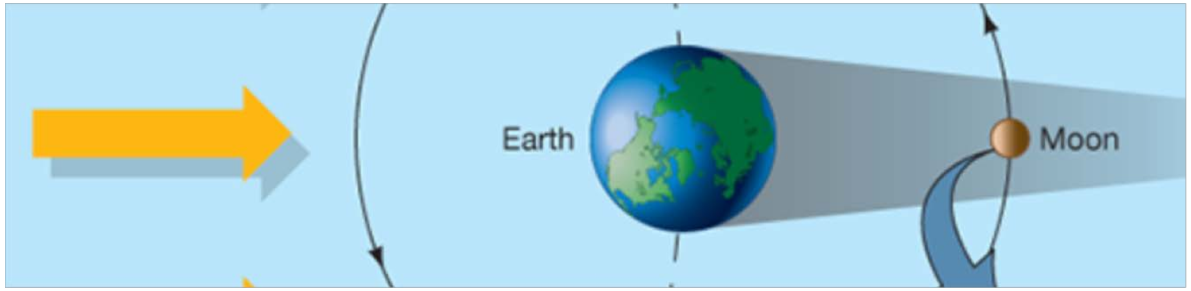


Solar vs. Lunar Eclipses

Solar Eclipse: Earth is in shadow of the Moon

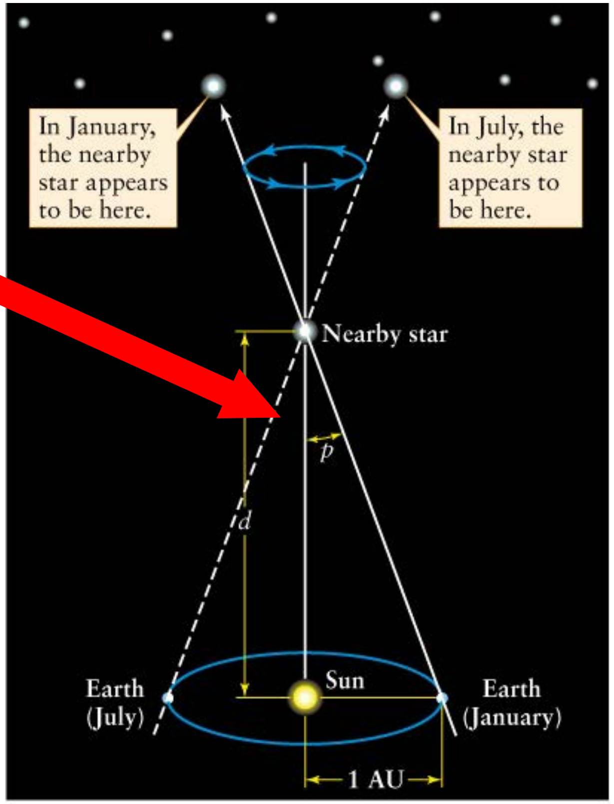


Lunar Eclipse: Moon is in shadow of the Earth

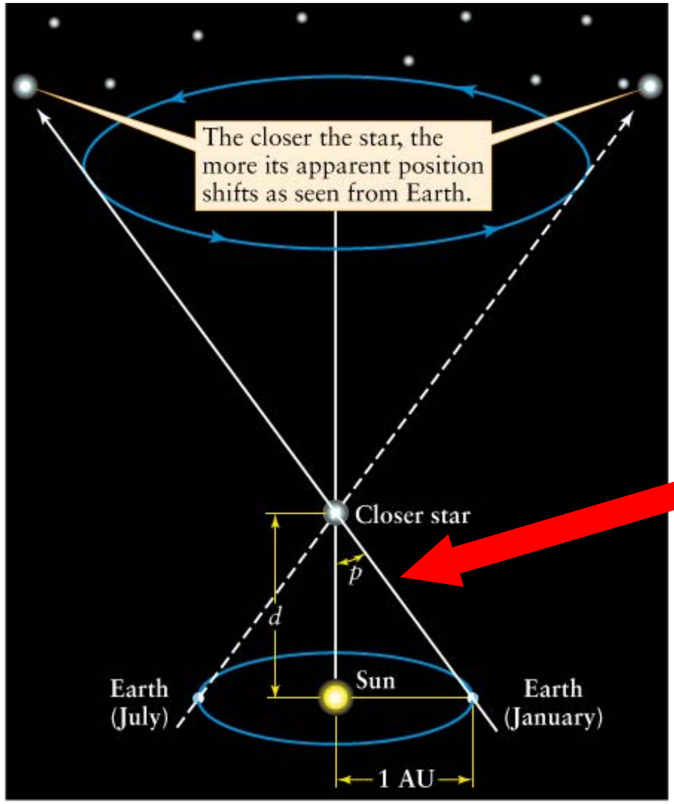


Parallax

Smaller parallax
→ larger distance



(a) Parallax of a nearby star



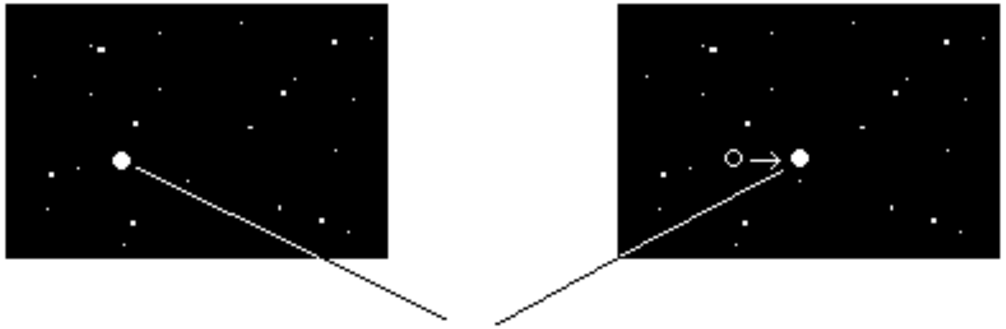
(b) Parallax of an even closer star

Larger parallax
→ smaller distance

Measuring Parallax

Spring

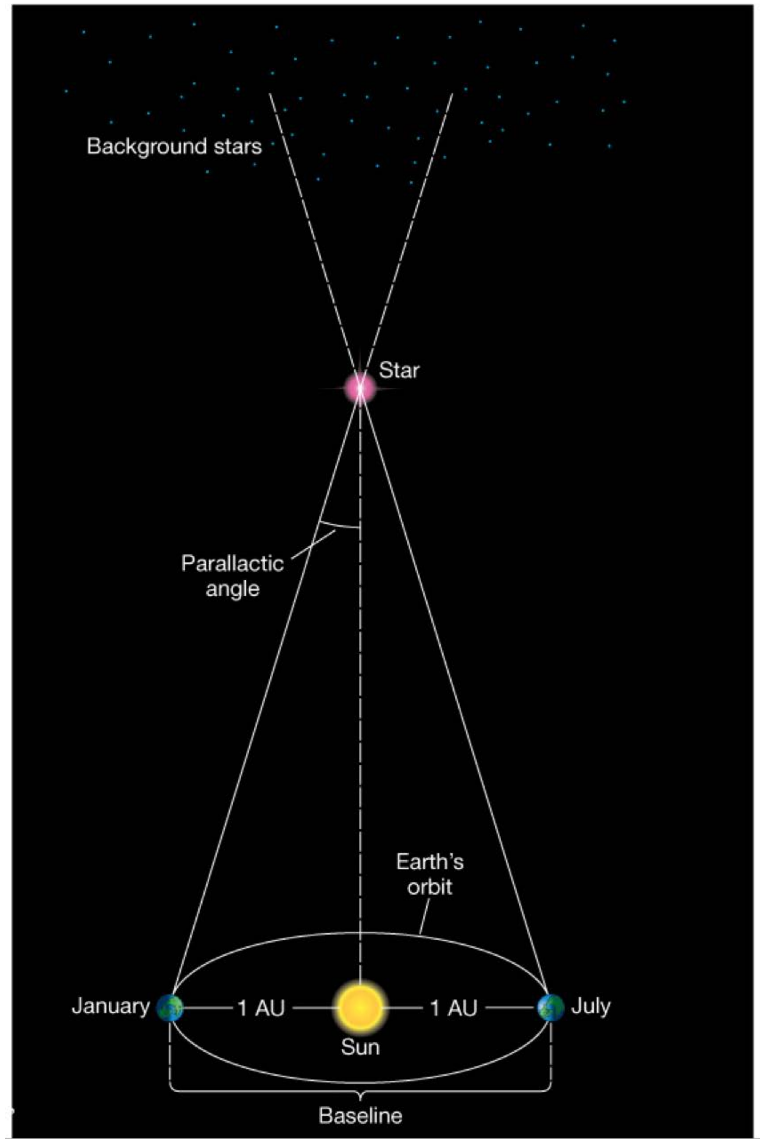
Fall



This star has moved 0.5 seconds of arc between photos.

$$d = \frac{1}{p} = \frac{1}{0.25''} = 4\text{pc}$$

parsec = “per arcsecond”

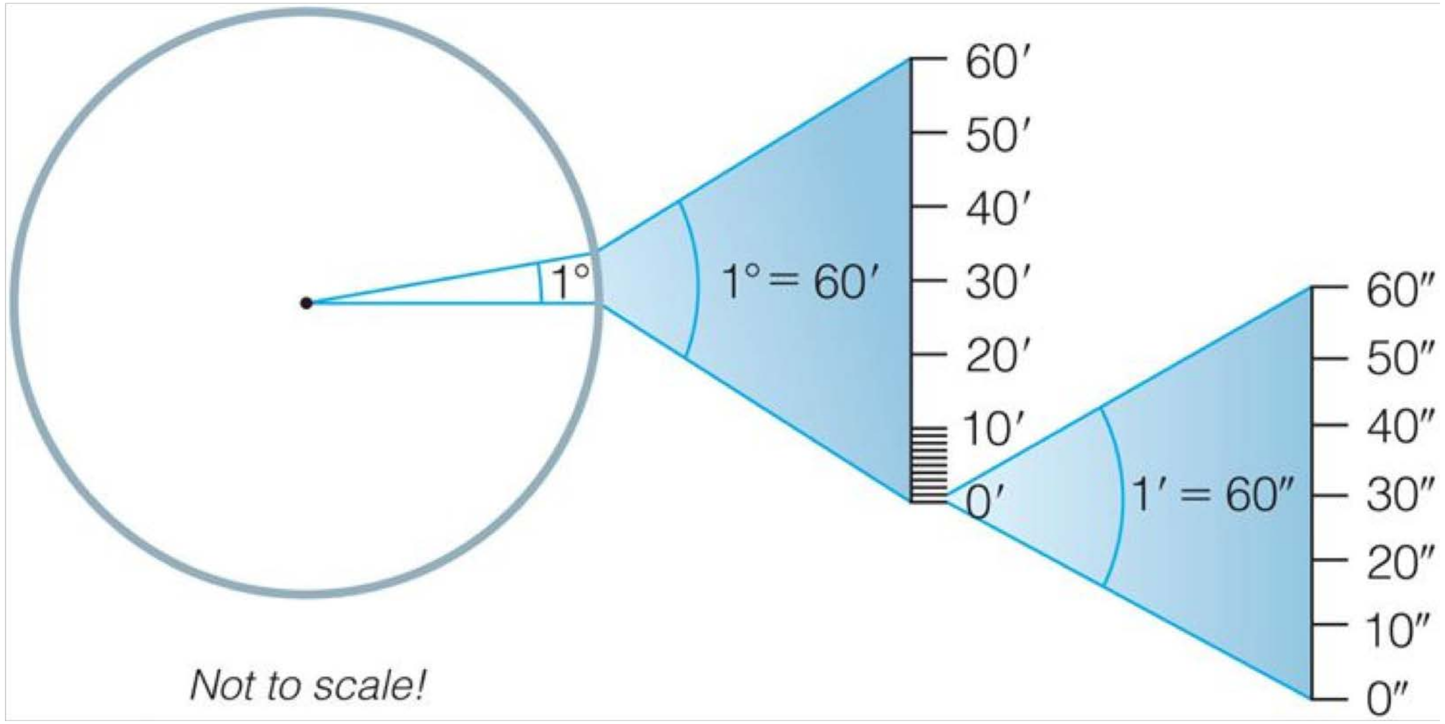


Arcminutes and Arcseconds

$$1 \text{ circle} = 360^o$$

$$1^o = 60'$$

$$1' = 60''$$



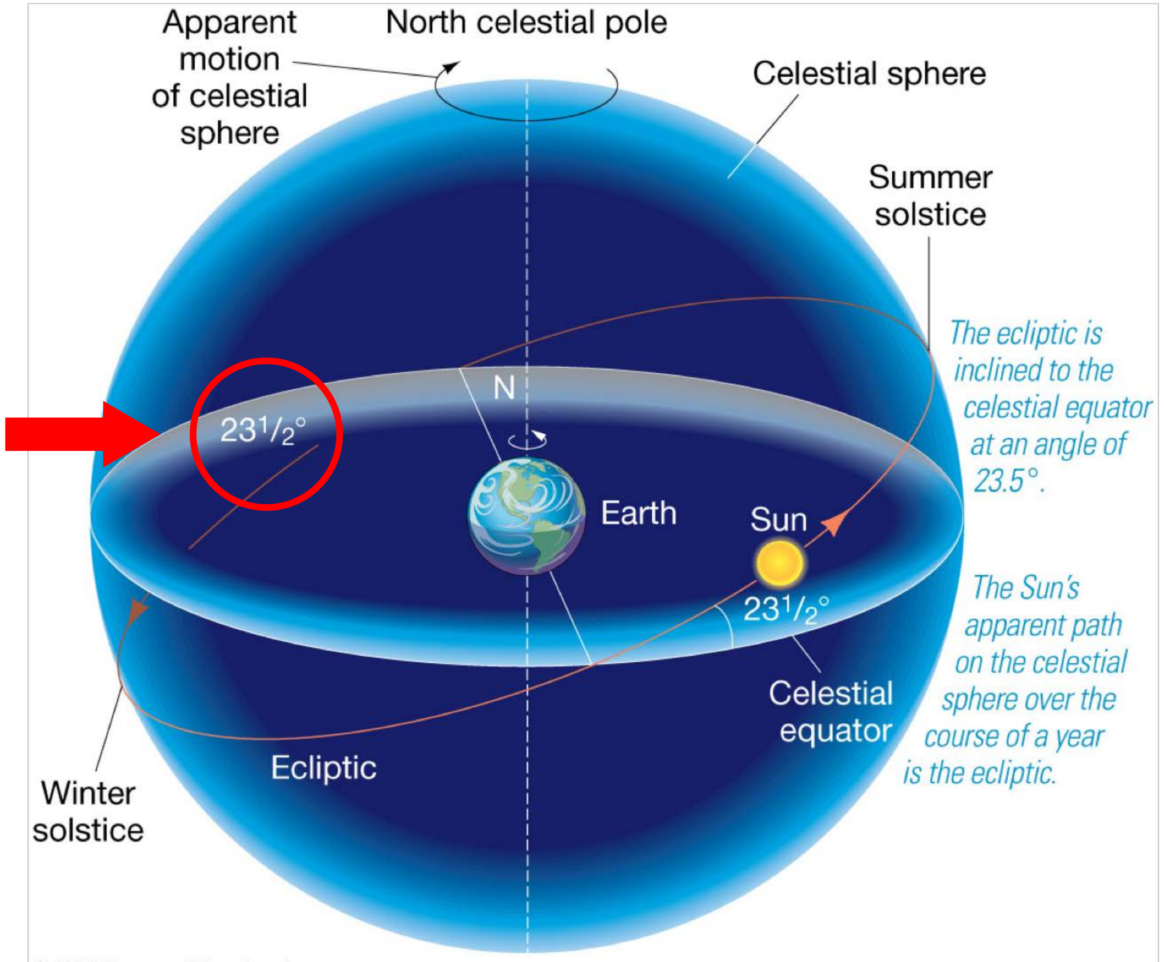
Chapter 2:
The Copernican Revolution

Prof. Douglas Laurence

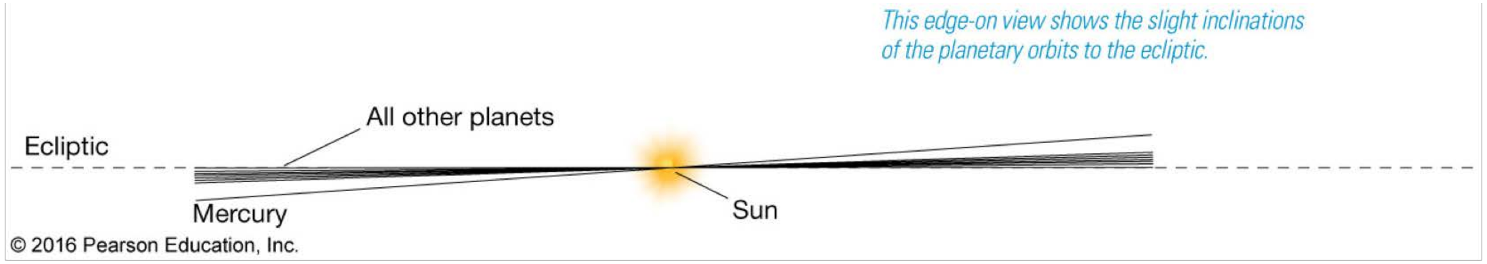
AST 1004

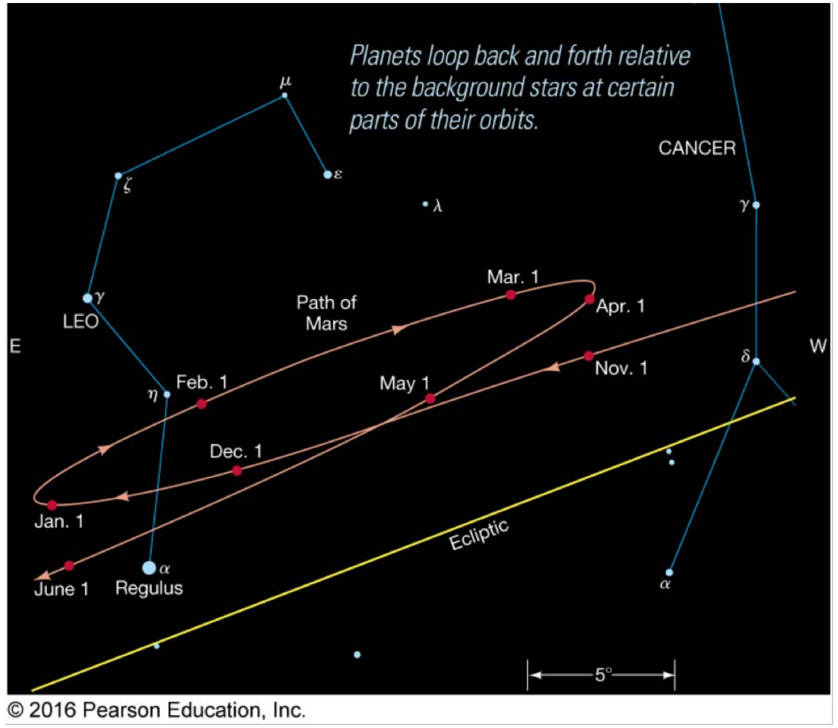
Geocentric View

Same as orbital tilt in heliocentric view.

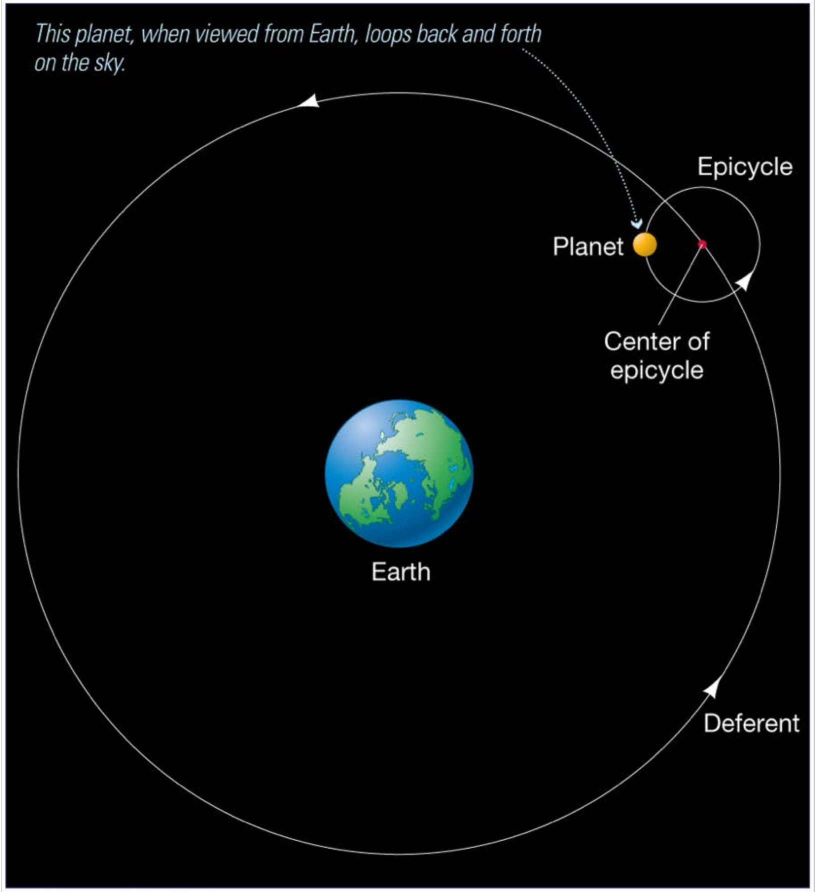


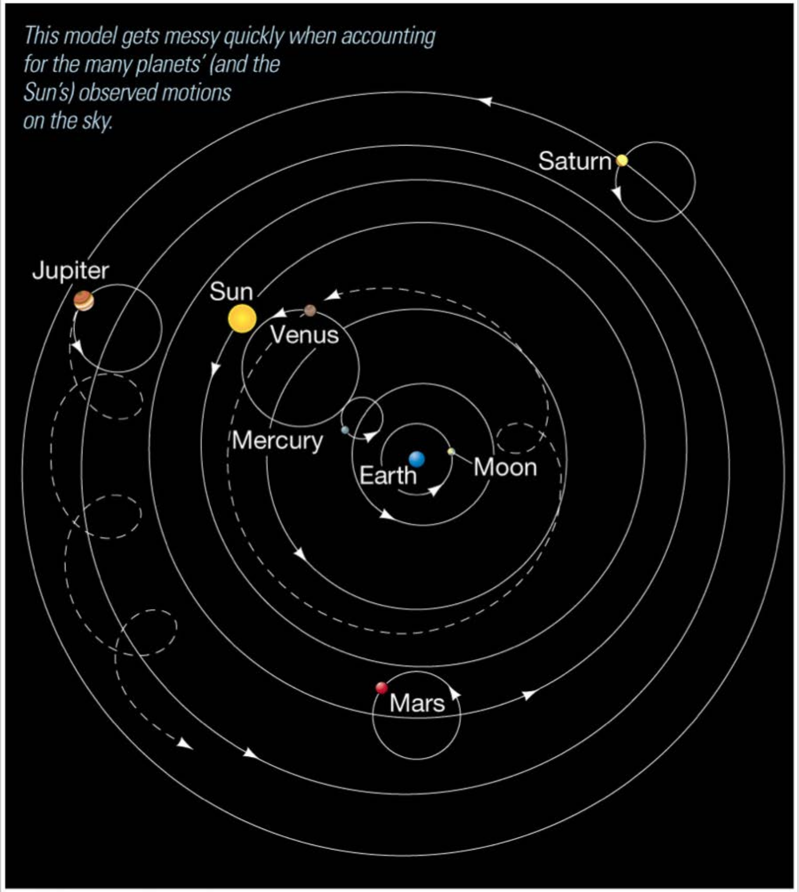
Features of Planets

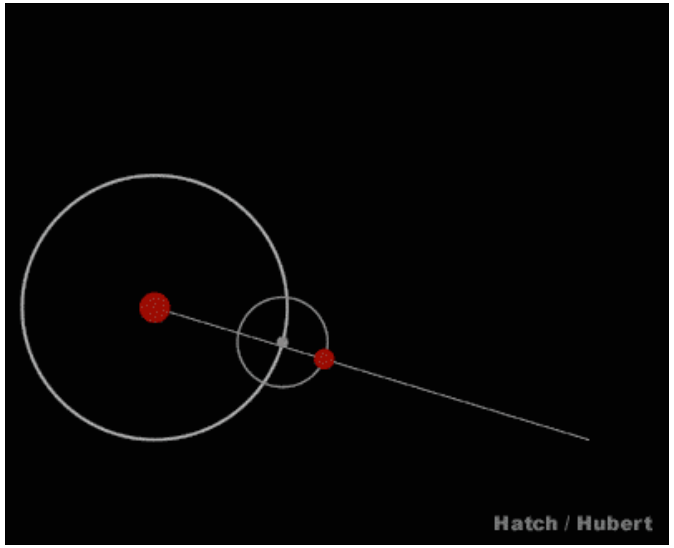




Ptolemaic Geocentrism

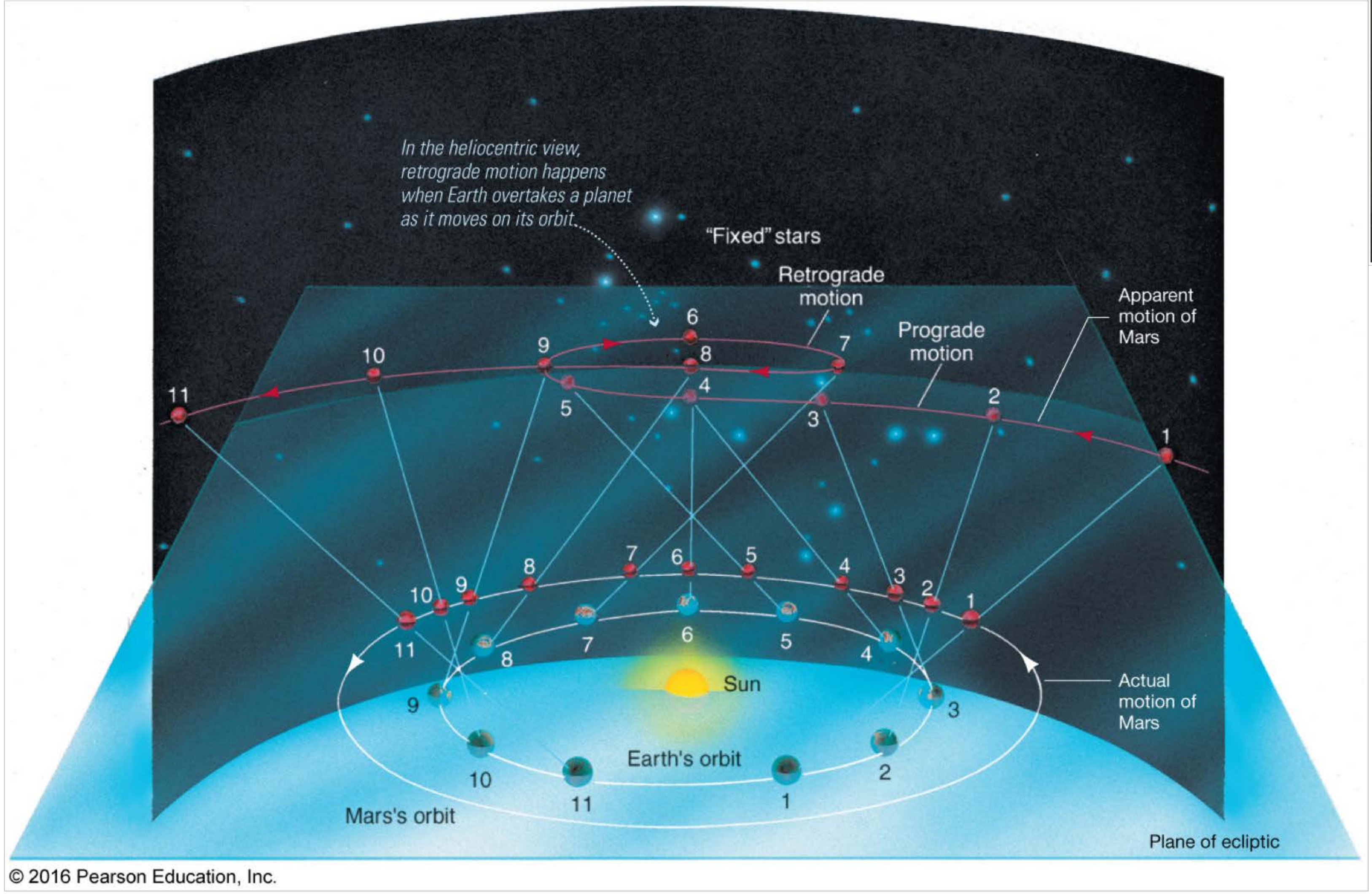


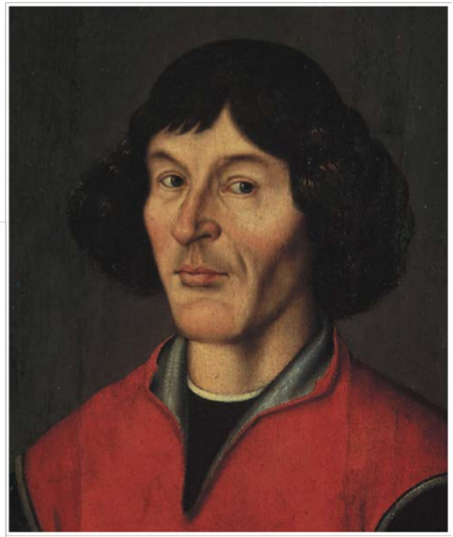




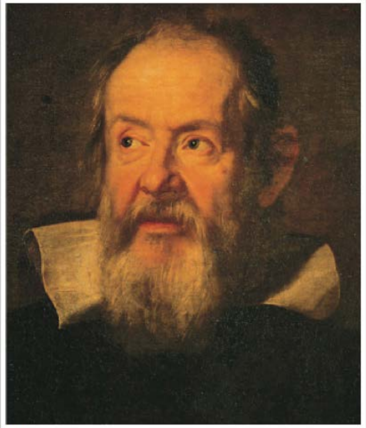
http://users.clas.ufl.edu/ufhatch/images/earthCenterRetrograde.gif

Heliocentrism (Copernicus)

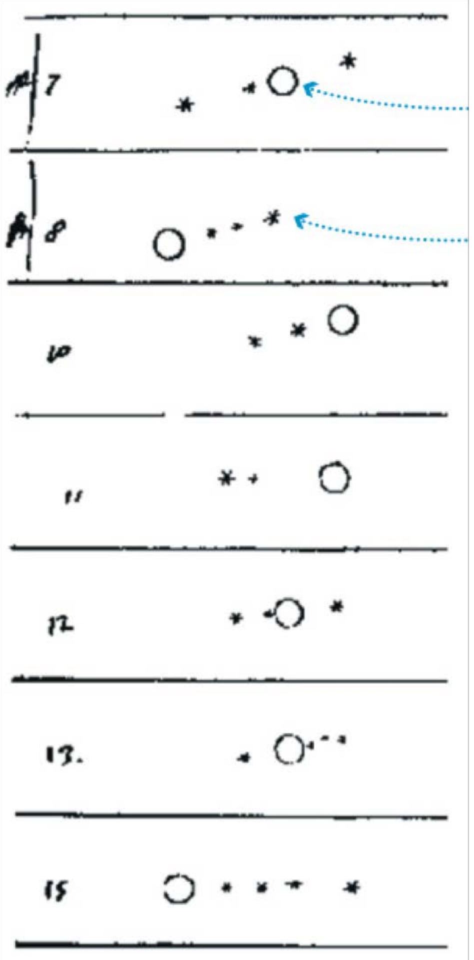




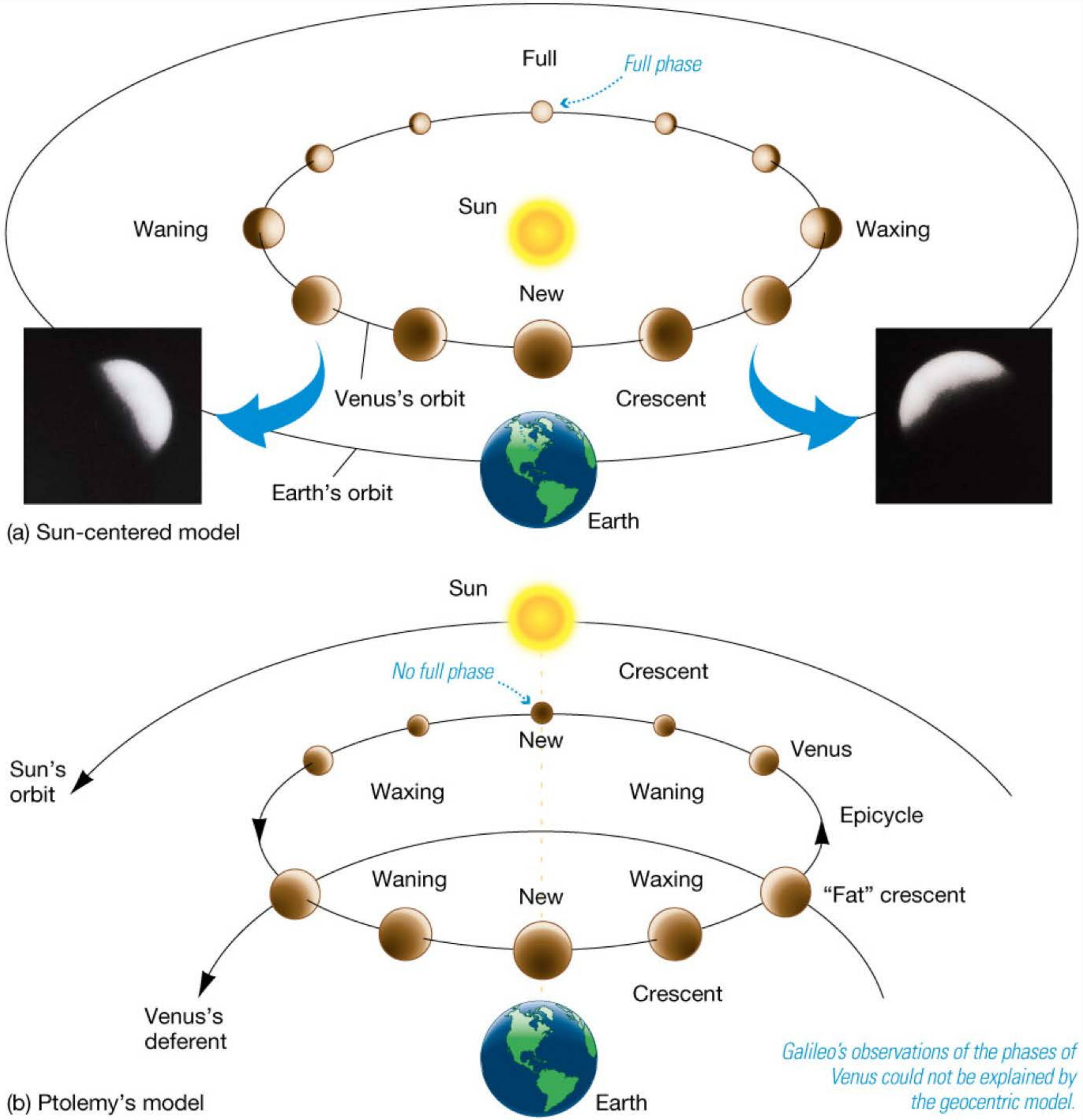
Heliocentrism (Galileo)



(a)



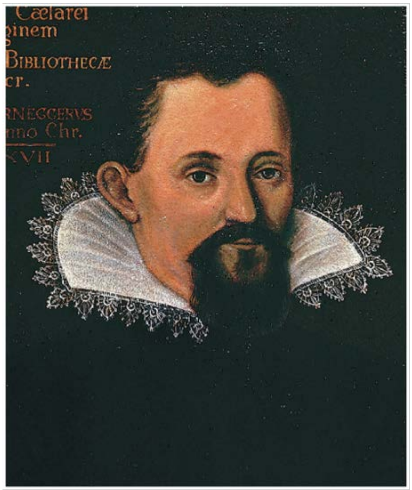
(c)



(a) Sun-centered model

(b) Ptolemy's model

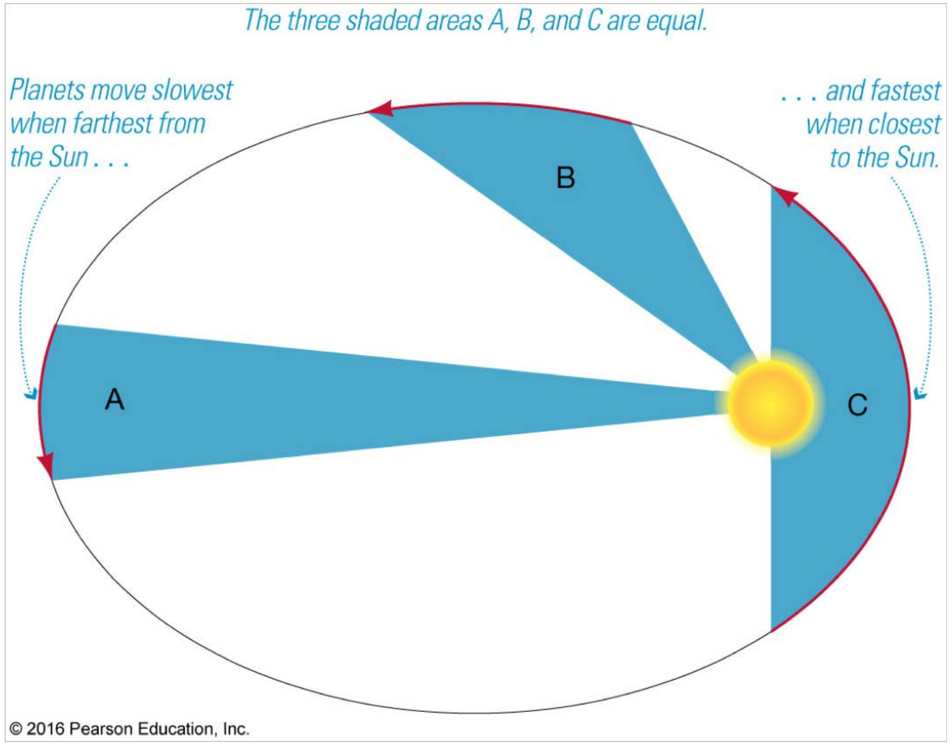
Kepler's Laws of Planetary Motion



I. Planetary orbits are ellipses

II. A planet covers equal areas in equal times around the ellipse

III. $P^2\ (\text{years}) = \dfrac{a^3\ (\text{AU})}{M\ (\text{solar masses})}$



Kepler’s First Law

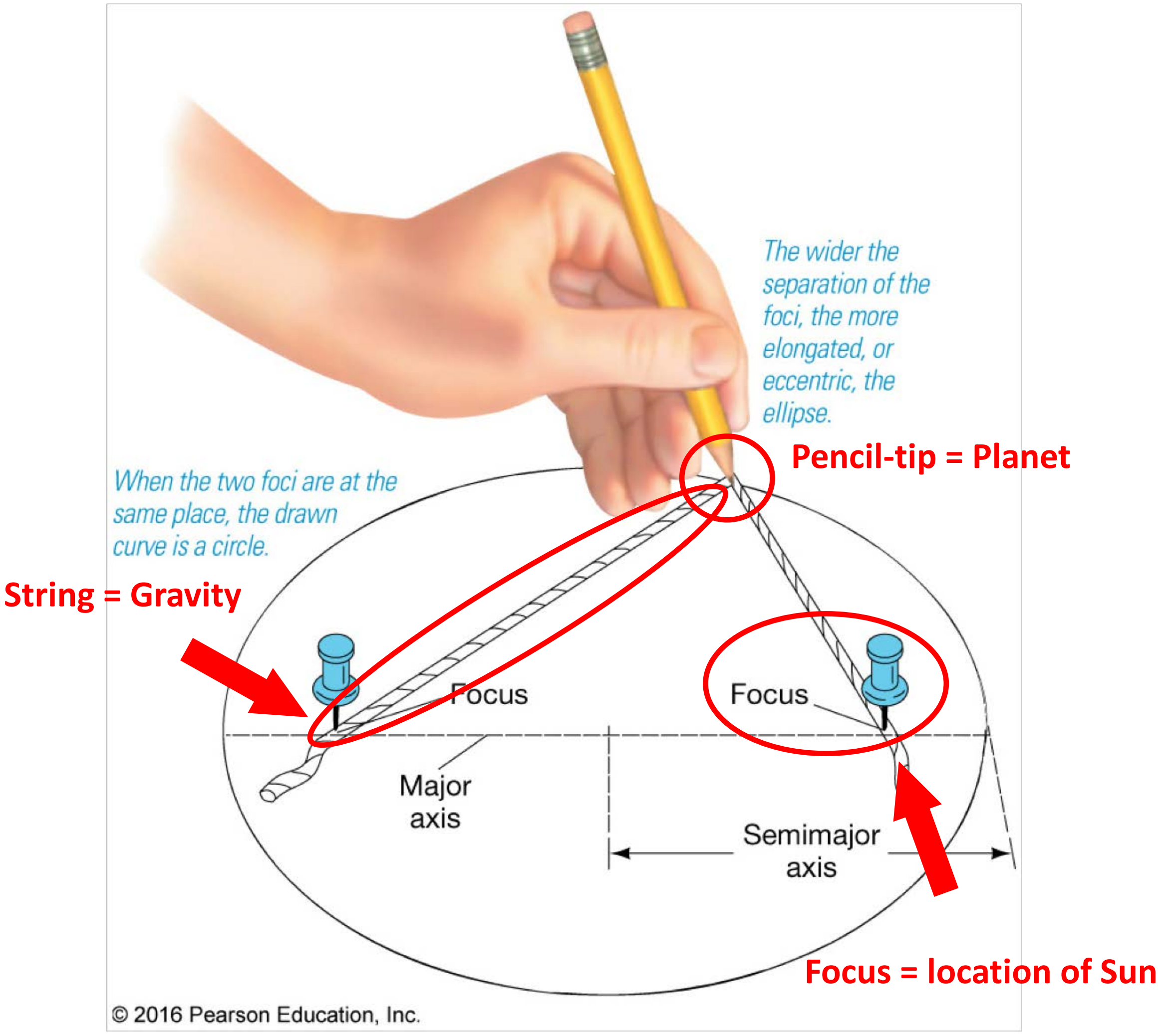
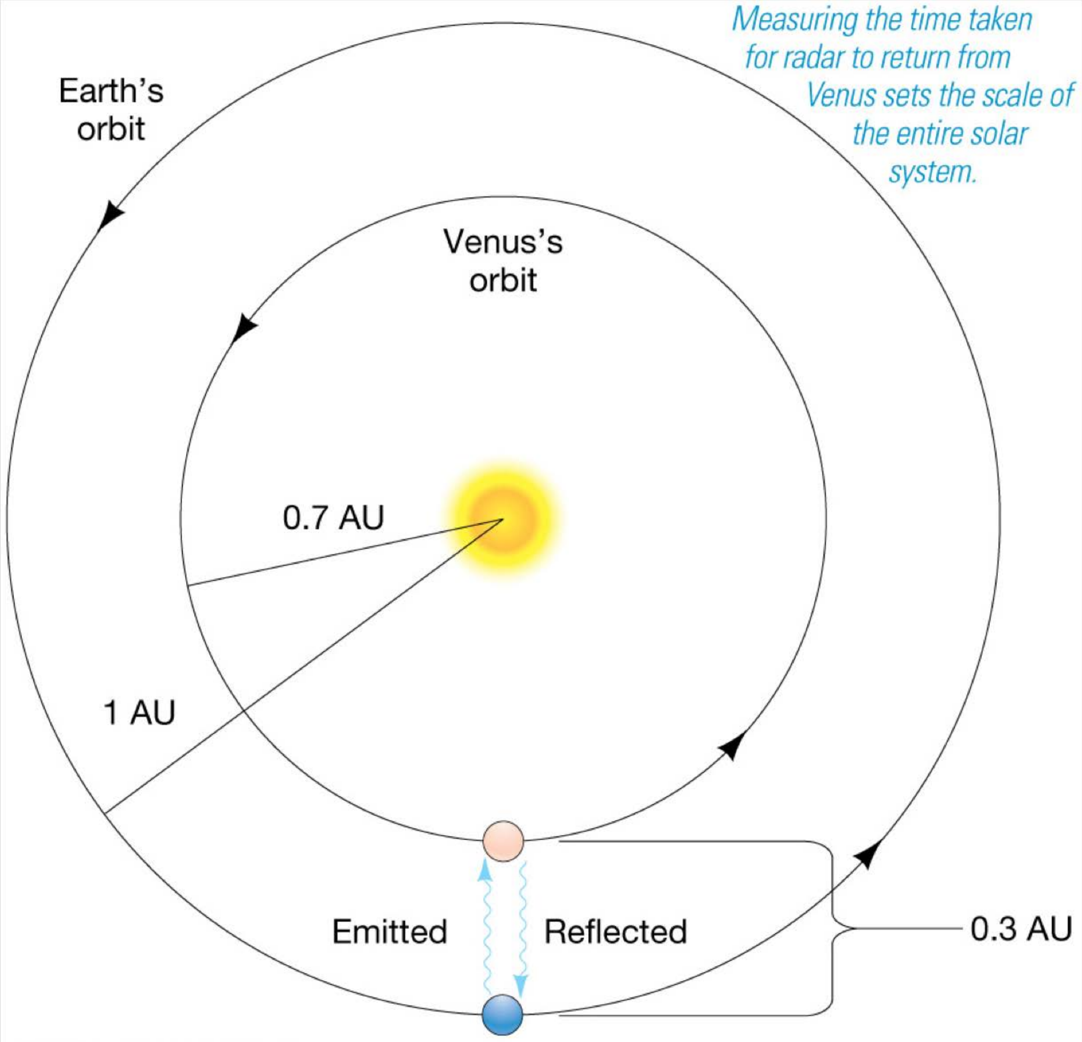


Table 3.1 Properties of Some Solar System Objects

Object	Orbital semimajor axis (AU)	Orbital period (Earth years)	Orbital eccentricity
Mercury	0.39	0.24	0.206
Venus	0.72	0.62	0.007
Earth	1.00	1.0	0.017
Mars	1.52	1.9	0.093
Jupiter	5.2	11.9	0.048
Saturn	9.5	29.4	0.054
Uranus	19.2	84	0.047
Neptune	30.1	164	0.009
Sun	—	—	—

$$e = \sqrt{1 - \frac{b^2}{a^2}}$$

Kepler’s Third Law

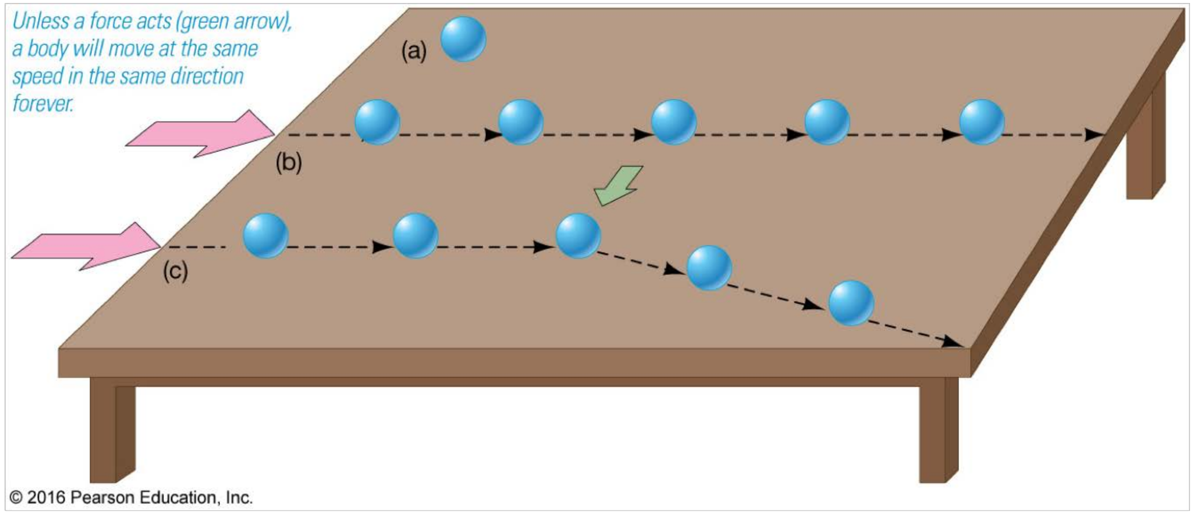


Newton’s Laws of Motion

I. An object at rest will remain at rest, and an object in motion will remain in motion, unless acted upon by a force.

II. $F = ma$

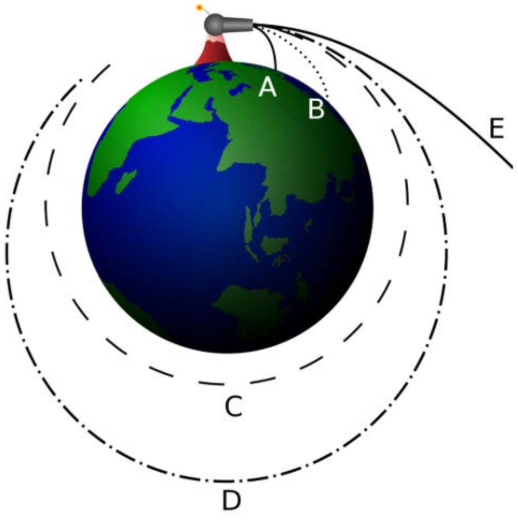
III. For every action, there is an equal and opposite reaction.

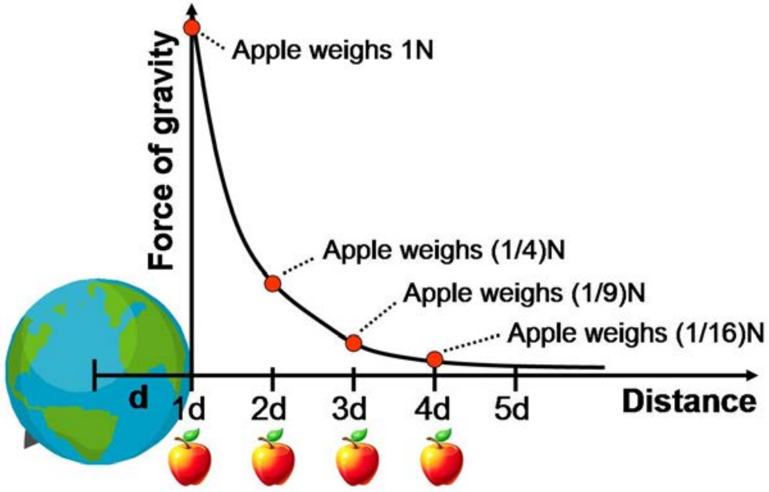


https://en.wikipedia.org/wiki/Newton%27s_cannonball

Newton’s Law of Universal Gravitation

- Newton explained Kepler’s laws by postulating that the force responsible for apples dropping on Earth and the force responsible for the motion of heavenly bodies are the same force: gravity.
- This is the concept of **universal gravitation**.
- Newton justified his postulate with his famous Cannonball Thought Experiment.
- To properly account for Kepler’s laws, the force of gravity must decrease with distance.



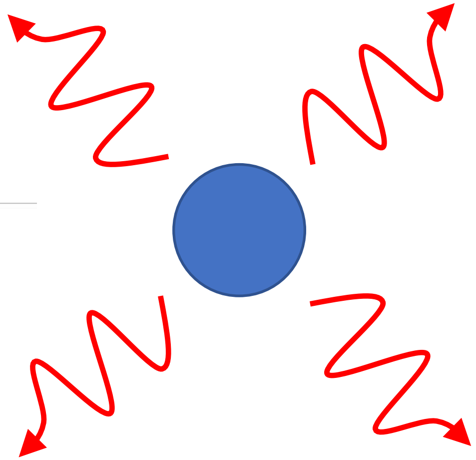


Chapter 3:
Radiation

Prof. Douglas Laurence

AST 1004

Radiation



ra·di·ate

verb

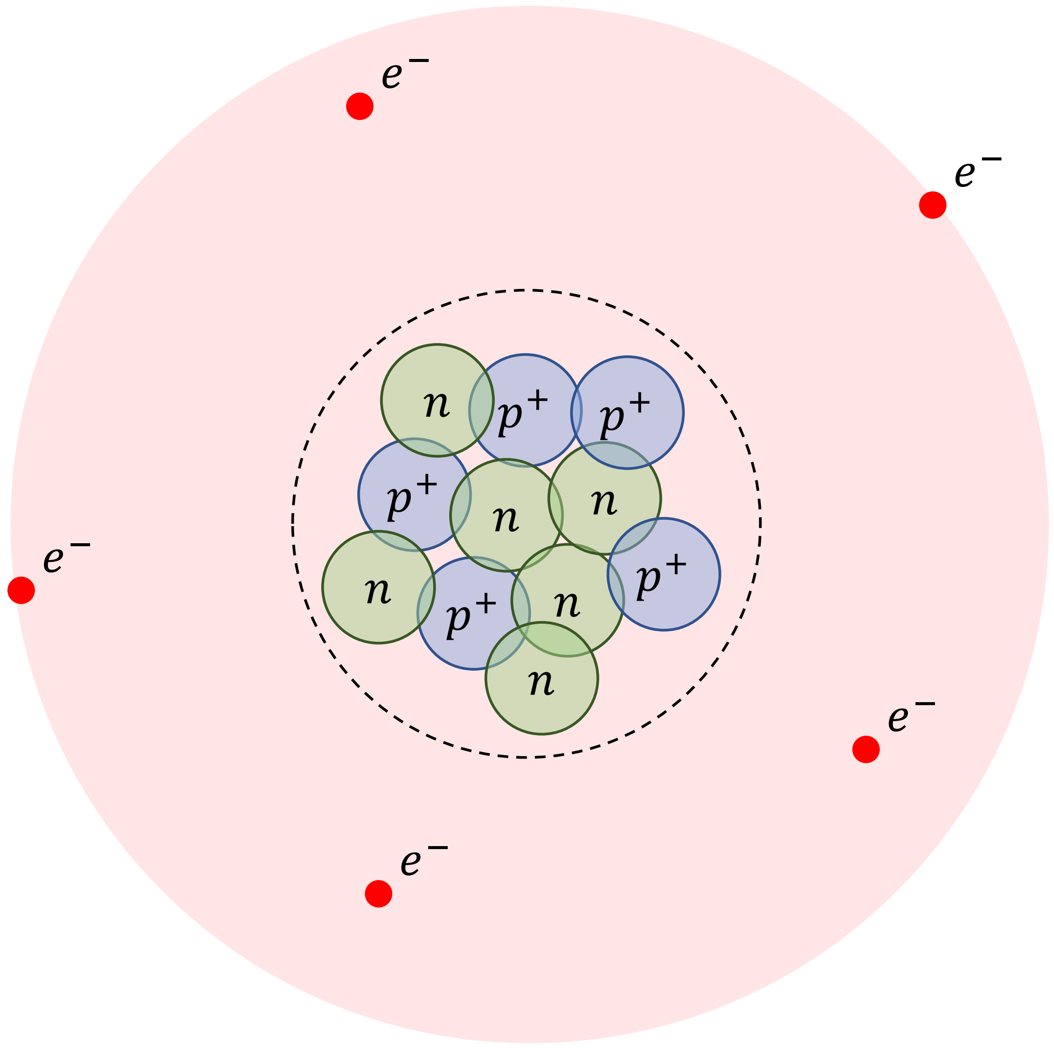
/ˈrādēˌāt/

1. emit (energy, especially light or heat) in the form of rays or waves.
   "the hot stars radiate energy"
   synonyms: emit, give off/out, send out/forth, discharge, scatter, diffuse; More
2. diverge or spread from or as if from a central point.
   "he ran down one of the passages that radiated from the room"
   synonyms: spread out, fan (out), ray (out), branch (out/off), diverge, extend, separate, split off, issue; More

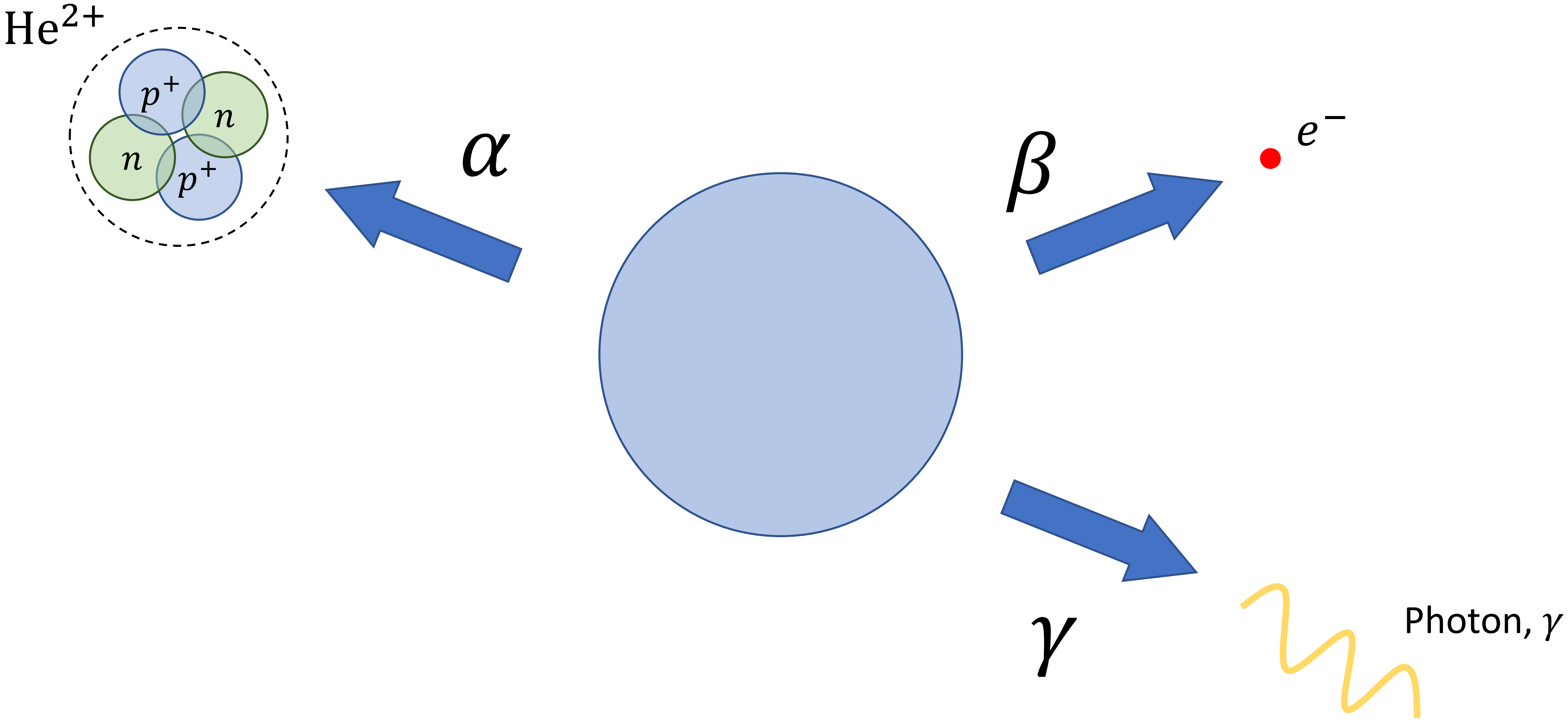
Types of Radiation

- Radiation comes in two types: **particle** radiation and **electromagnetic** radiation.
- 3 forms of **nuclear** radiation (originating in the nucleus):
  - α (alpha) radiation: a form of particle radiation
  - β (beta) radiation: a form of particle radiation
  - γ (gamma) radiation: a form of electromagnetic radiation
- Examples of **non-nuclear** radiation:
  - Blackbody radiation: a form of electromagnetic radiation
  - Electron-transition radiation: a form of electromagnetic radiation

Atoms



Nuclear Radiation



Mass-Energy Equivalence

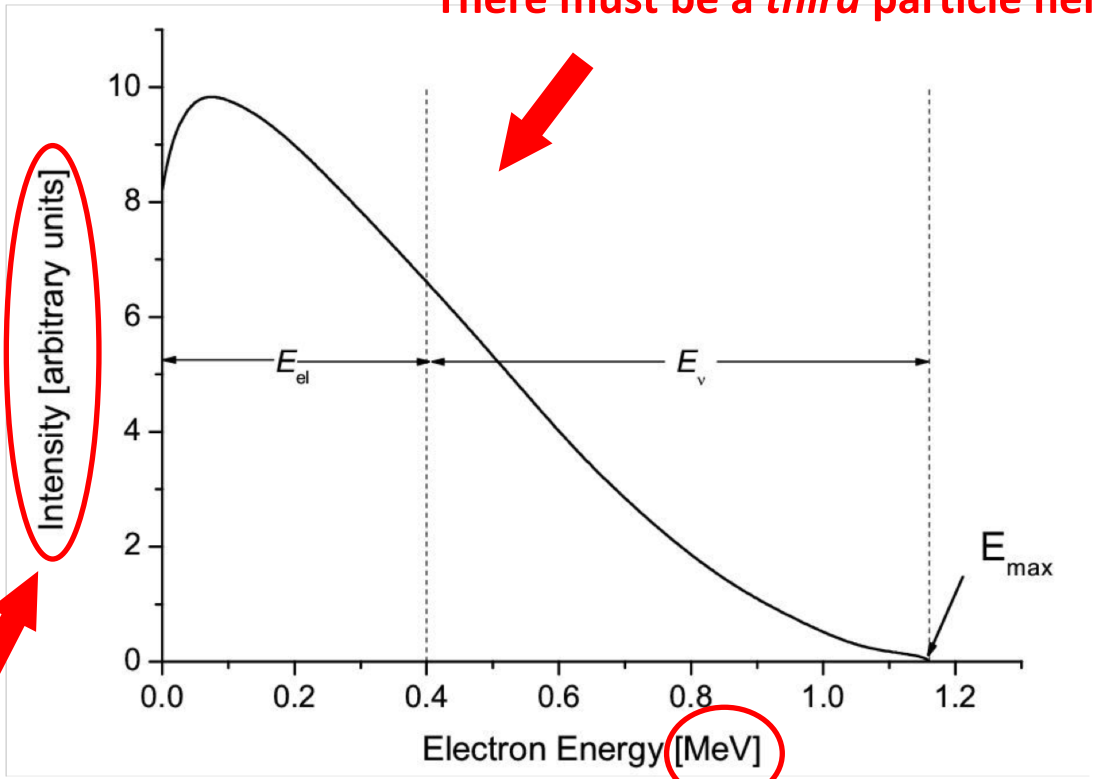
$$E = mc^2$$

β-Decay

$$n \rightarrow p^{+} + e^{-}$$

$$\Delta E = 1.252\times10^{-13}\ \text{J}$$

There must be a *third* particle here



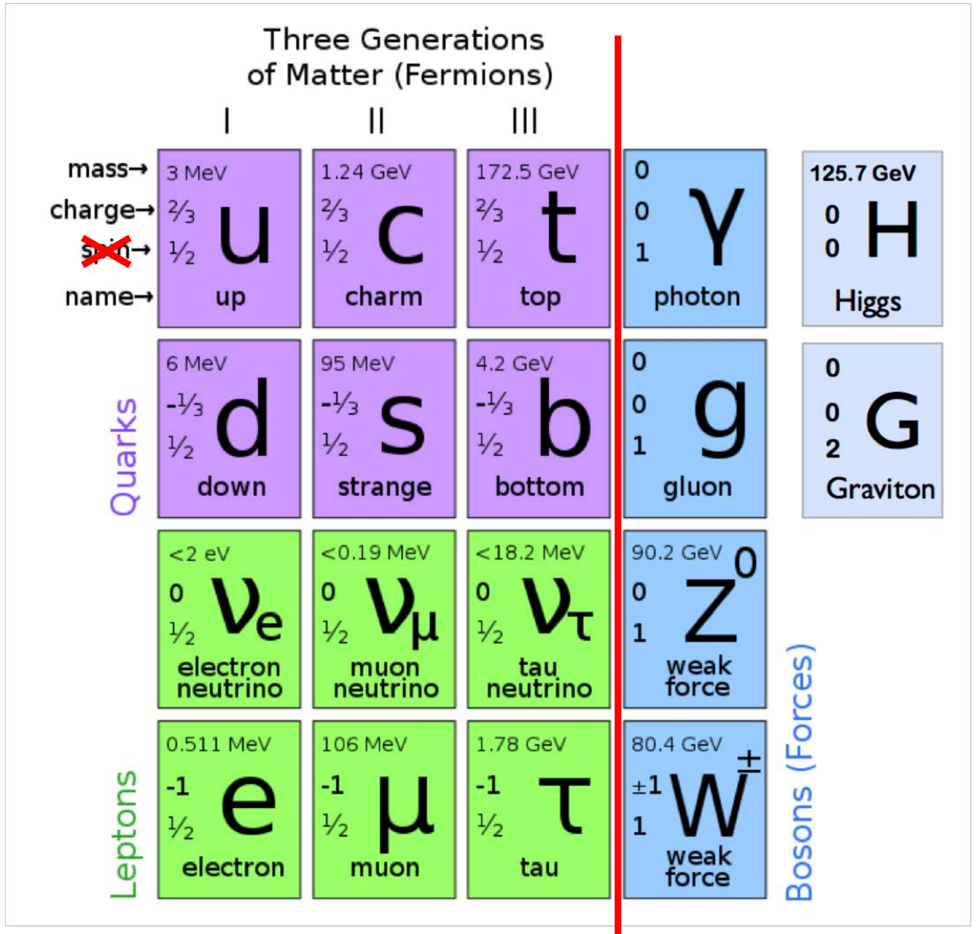
Number of electrons

Weird energy unit, $1\ \text{MeV} = 1.62\times10^{-19}$ J

Elementary Particles

2 Types of Matter:

- Quarks
- Leptons

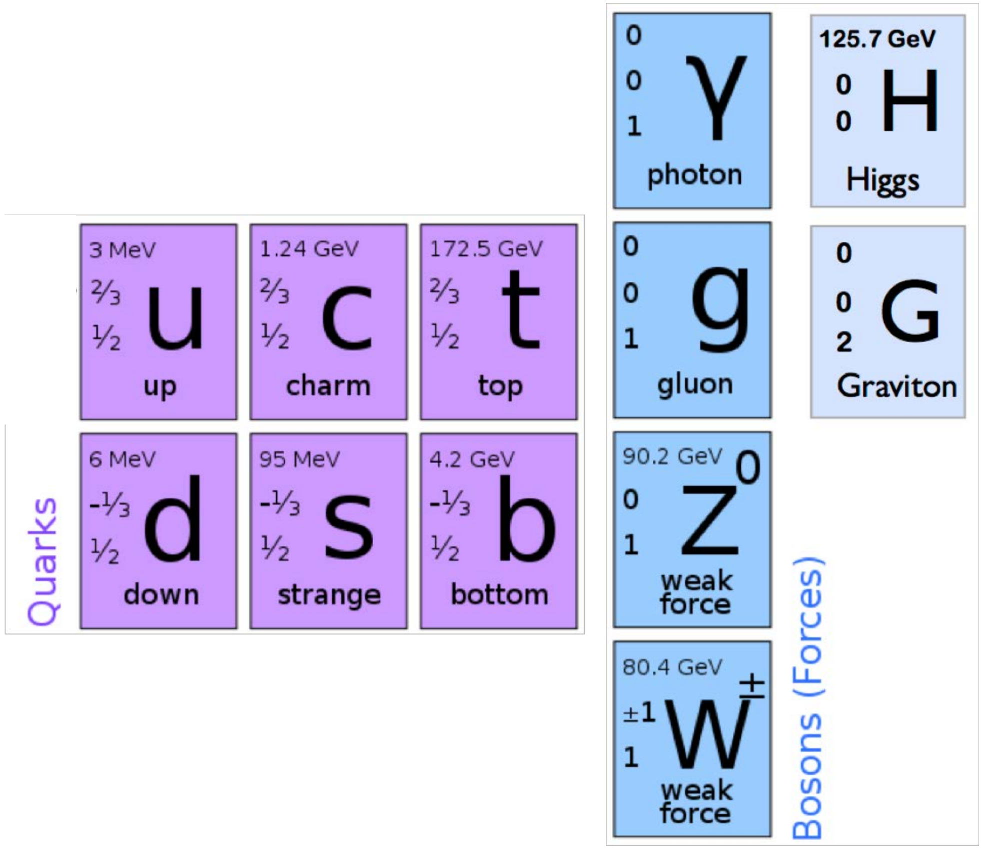


Matter **Forces**

4 Fundamental Forces:

- Strong Force
- Weak Force
- Electromagnetic Force
- Gravity

Quarks

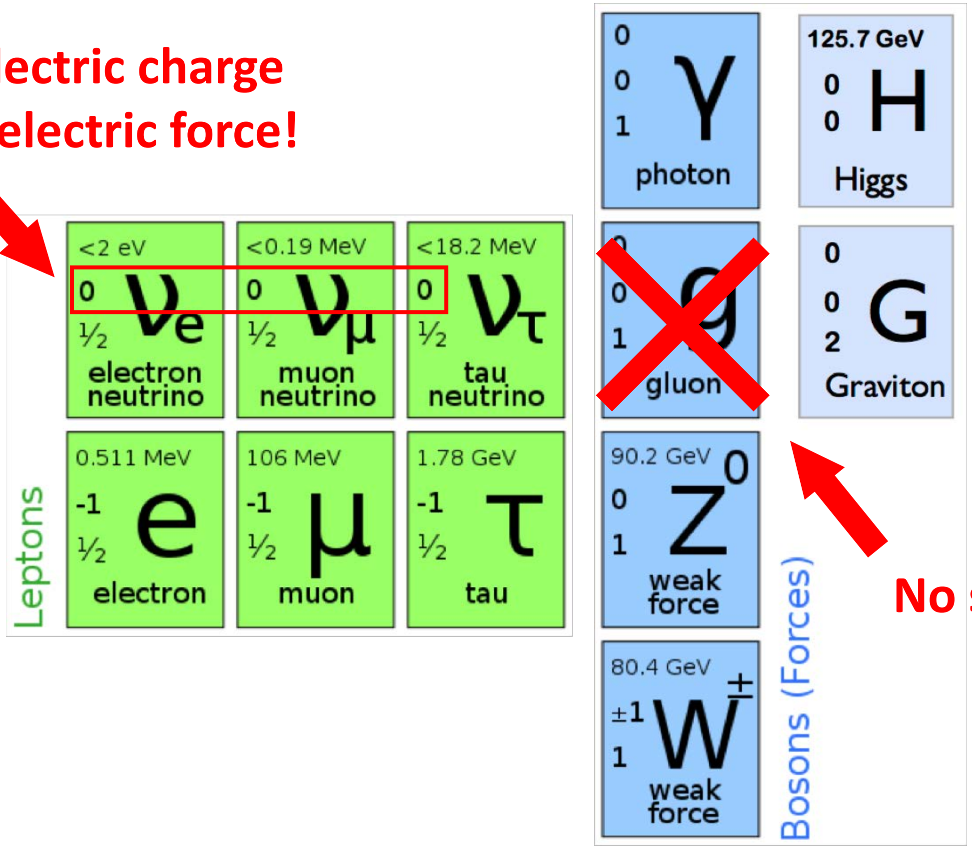


$$u + u + d + (\text{gluons}) \rightarrow p^{+}$$

$$u + d + d + (\text{gluons}) \rightarrow n$$

Leptons

No electric charge
= no electric force!



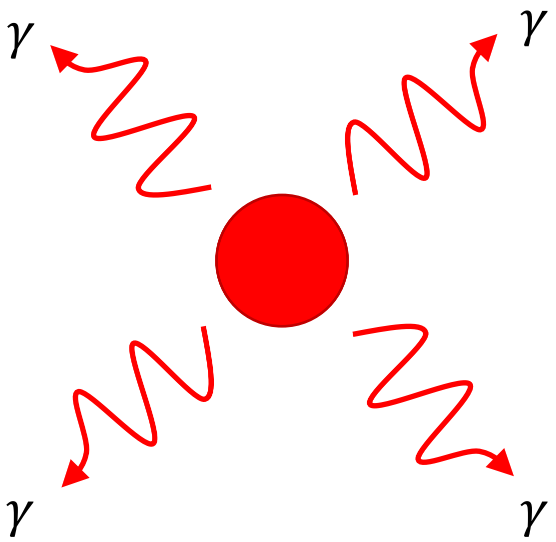
No strong force!

$$e^- + p^+ + (\text{photon}) \rightarrow \text{H}$$

$$n \rightarrow p^+ + e^- + \bar{\nu}_e$$

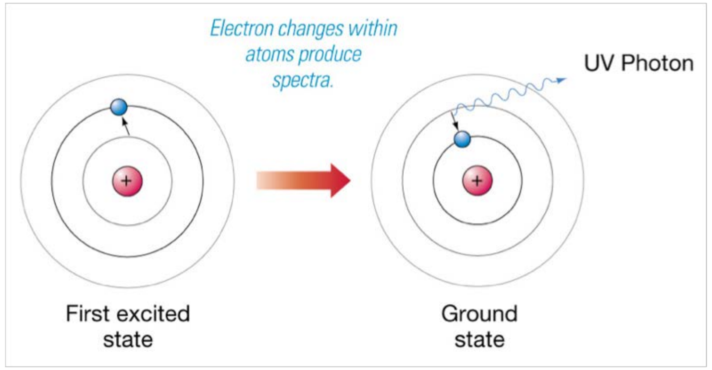
Non-nuclear Radiation

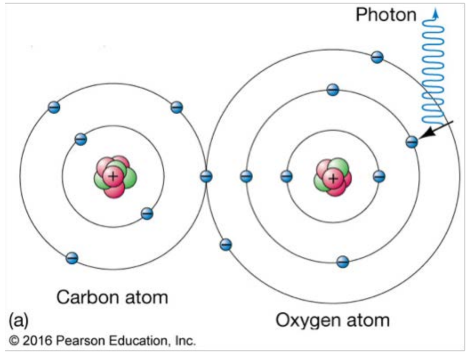
Blackbody Radiation



Hot objects glow

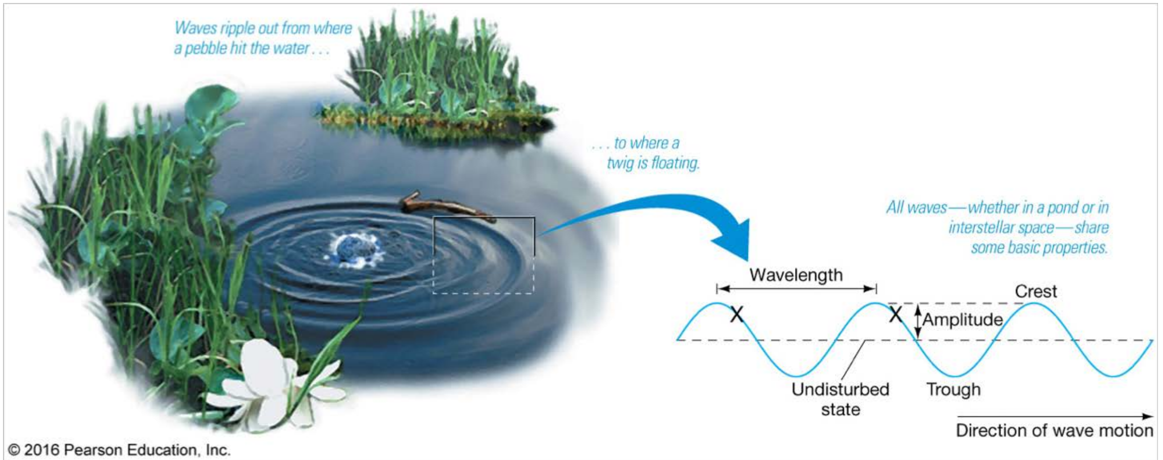
Electron-transition Radiation





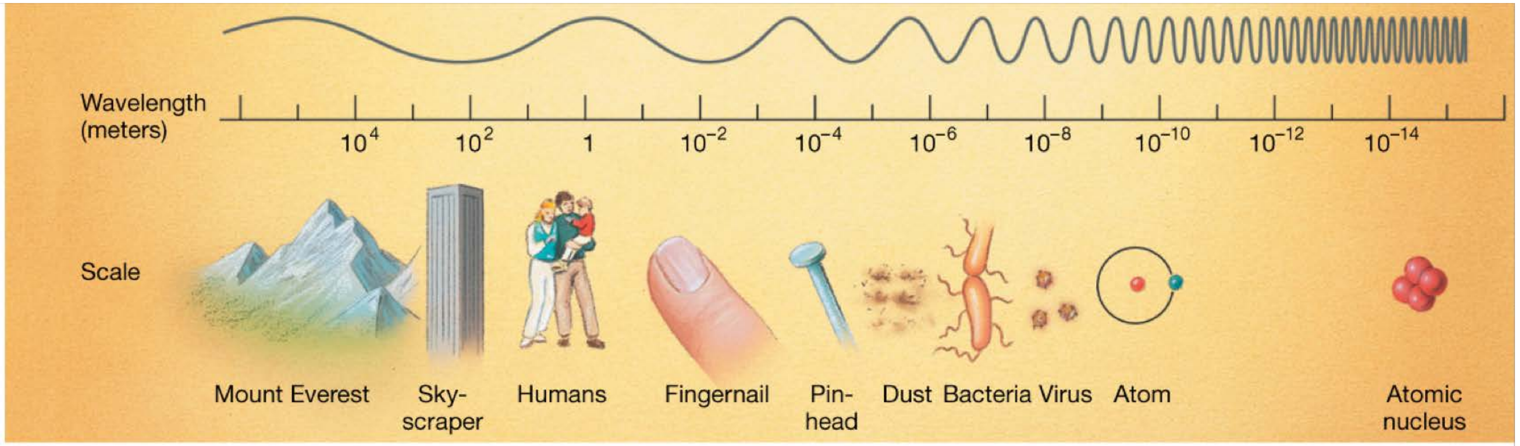
Electrons drop into lower energy states, releasing energy in the form of light (photons)

Electromagnetic Radiation

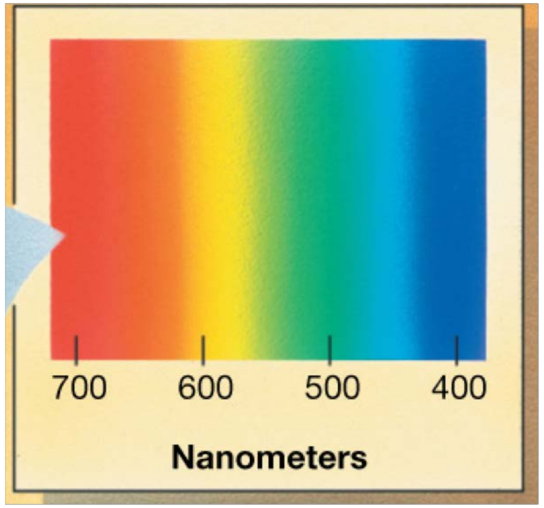


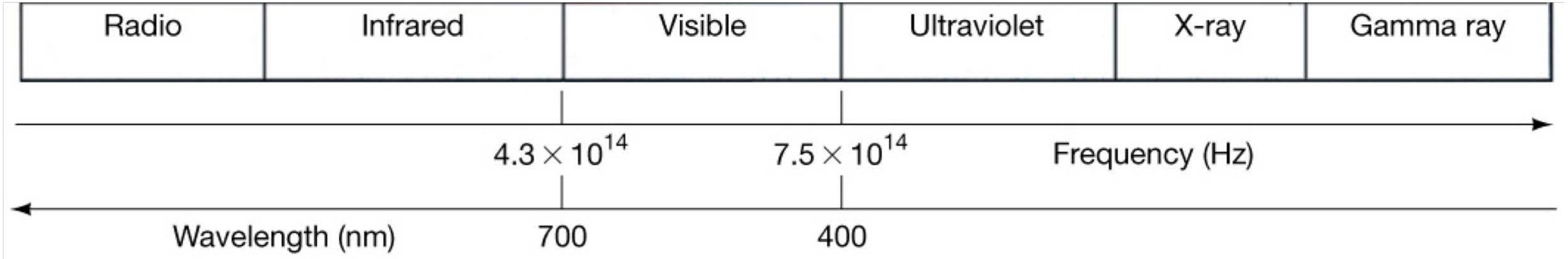
$$v = \lambda f$$

$$E = hf$$



Visible Light Spectrum





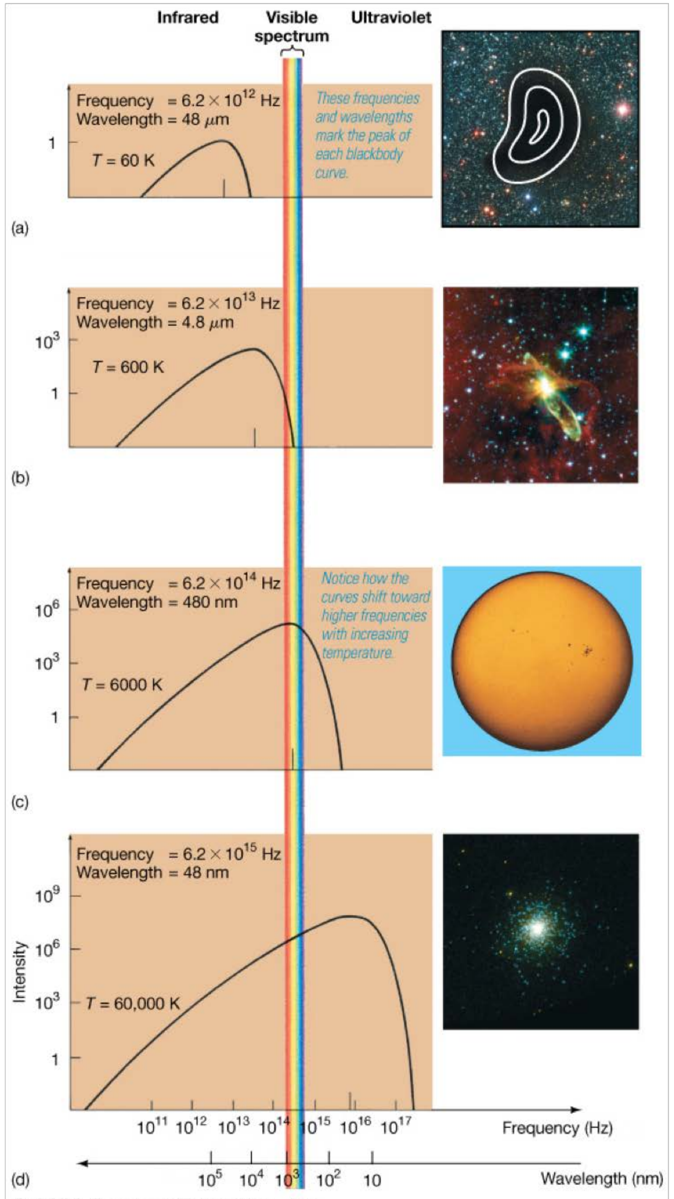
Blackbody Radiation

Stefan-Boltzmann Law:

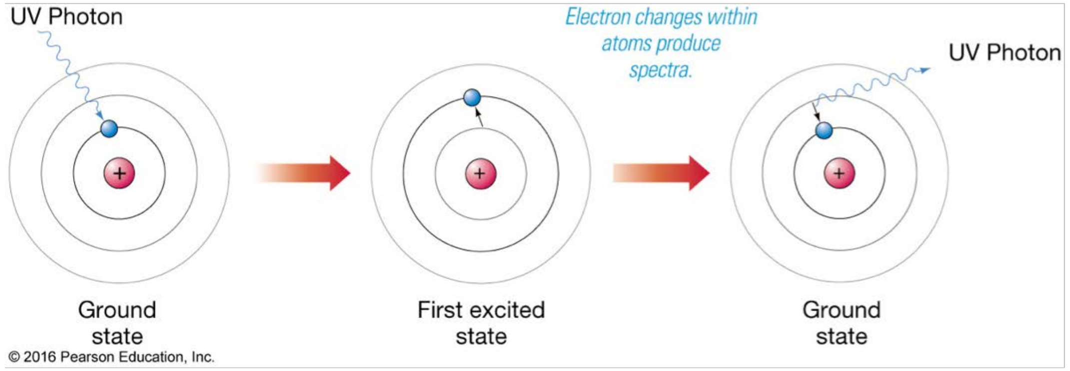
$$I = \sigma T^4$$

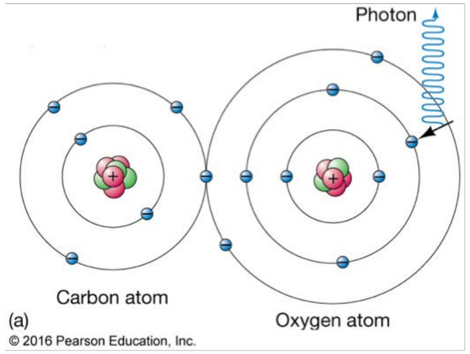
Wein's Law:

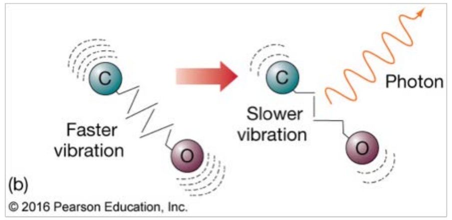
$$\lambda_{max} = \frac{b}{T}$$

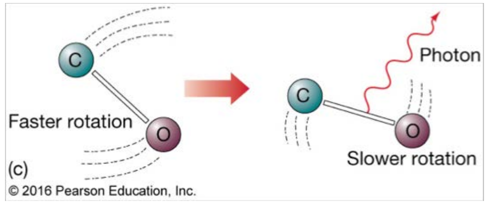


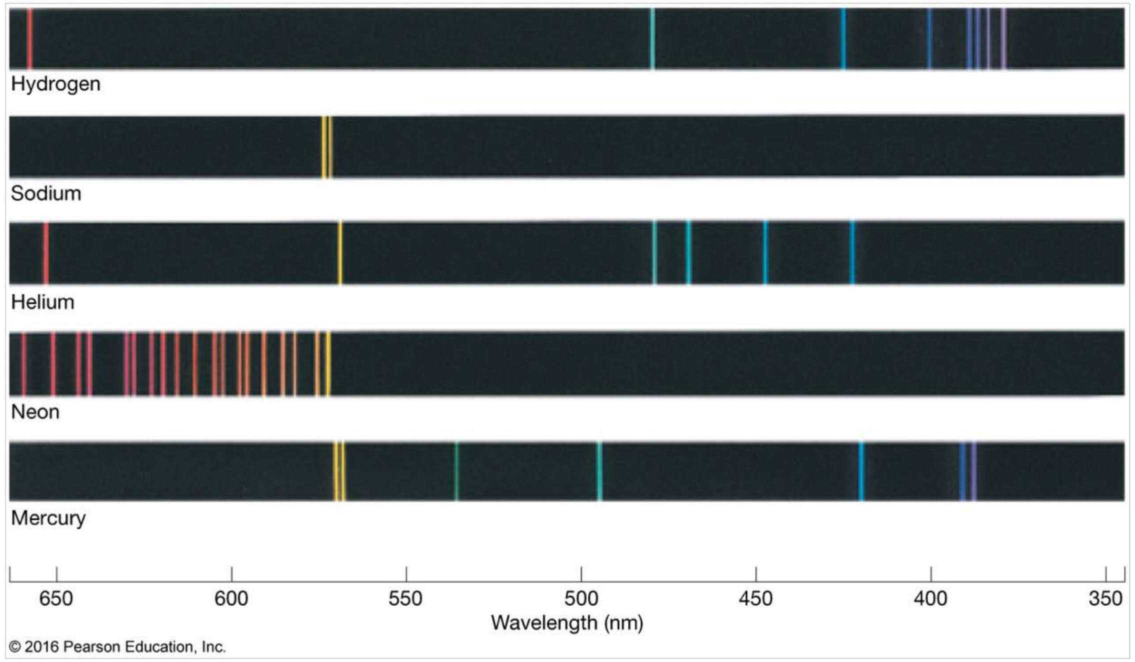
Emission and Absorption of Photons











Doppler Effect

$$\Delta f = \frac{-v}{c} f_0$$