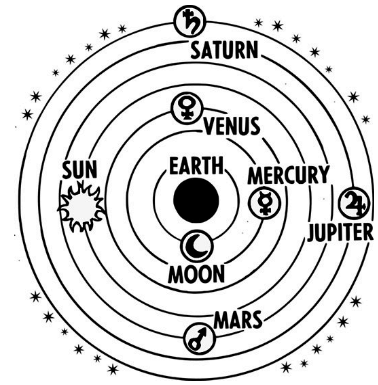
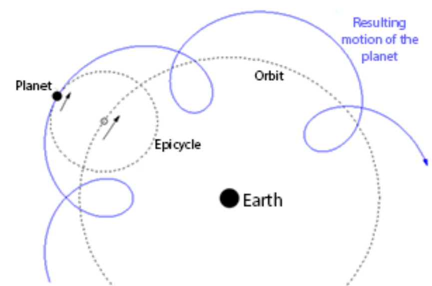
Unit 1 - Sky Observation & Measurement

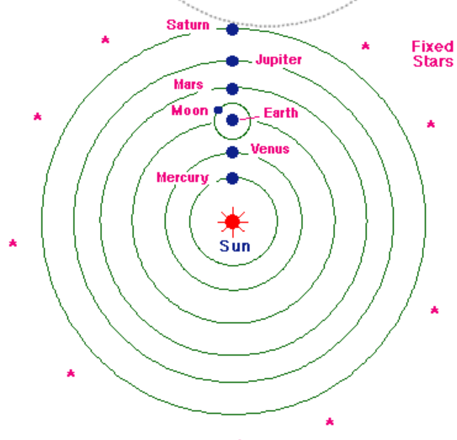
1. History
    a. Plato/Aristotle (384-322 BCE, ancient Greece) - Greek *philosophers*



        i. Geocentrism - Earth was center of universe, planets (wanderers) and stars revolved around in circles.
        ii. Uniform circular motion - Circles are "perfect," and the heavens must be perfect, therefore they must move in circles.
    b. Hipparchus (190-120 BC, ancient Greece) - "Father of astronomy" & inventor of trigonometry.
        i. First star catalog - Oldest existing record of actual measurements of movements of celestial bodies.
        ii. First mathematical models of Sun/Earth/Moon system - Worked out motions & distances of these allowing prediction/explanation of eclipses, solstices/equinoxes, etc.
            1. [Sextant](#)/[Astrolabe](#)/[Armillary sphere](#) - Used (possibly invented?) these devices to record positions & motions of the heavens.
            2. [Parallax](#) - Observations from different locations can be used in combination with trig to determine distances. Founder of trigonometry.
    c. Claudius Ptolemy (100-170, Greco-Roman Egypt) -



        i. [Retrograde motion](#) - The planets appear to change direction during certain times of the year and begin to move backward. Difficult to explain using geocentric model.
        ii. [Epicycles](#) - "Circles on circles." In order to maintain uniform circular motion, he uses multiple circles on circles to approximate motion of planets.
        iii. [Ptolemaic Model](#) -
    d. Nicolaus Copernicus (1473-1543, Prussia)



        i. Heliocentrism - Borrowing ideas from those like Aristarchus & Al-Tusi, postulates that apparent motion of the heavens is actually due to Earth's rotation & revolution around Sun
        ii. [Retrograde motion revisited](#) - "Backward" motion of planets is only apparent. It is due to an inferior planet passing a superior planet in orbit.
    e. Tycho Brahe (1546-1601, Denmark) -
        i. Built a giant observatory ([Uraniborg](#)) where he corrected/refined much of the earlier celestial data (often predicted events were off by days.)
        ii. [Tychonic model](#) & Epicycles on epicycles - All planets were in orbit around the sun, but the sun still orbited around earth. [Animated tychonic model.](#)
    f. Johannes Kepler (1571-1630, Germany) - Tycho Brahe's student in his later years, inherited his work.
        i. Laws of planetary motion - More to come on these in unit 2
            1. Law of Ellipses - Planets orbited not in perfect circles, but in [elliptical](#) shapes.
            2. Law of Areas - Describes the relative velocity of planets during different parts of orbit.
            3. Law of Harmonies - Describes orbital periods of planets at different distances
    g. Galileo Galilei (1565-1642, Italy) -
        i. Telescope - Improved upon telescope design and pointed it skyward, making several discoveries
            1. [Jupiter's moons](#) - Four moons of Jupiter (Galilean) were visible, looking very much like a mini solar system. Showed that there could be more than one center of motion in universe.

2. Phases of venus - Venus goes through phases very similarly to those of the moon. Geocentric model struggled to explain the observed phases. Geocentric vs heliocentric venusian phases.

ii. Heliocentrism returns - These two discoveries convinced him that the sun-centered model was correct. Published a book supporting the Copernican view (somewhat censured), was later tried for heresy by the inquisition and put on quasi house arrest.

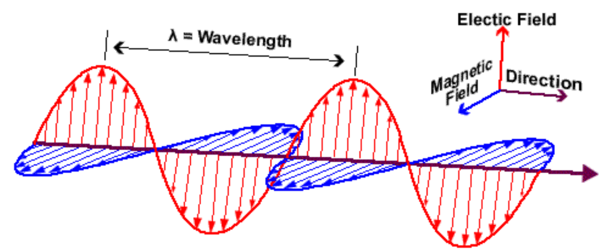
h. Isaac Newton (1642-1726, England) - Previous explanations of celestial motion focus on how objects move, not why they move in this way.

i. Universal law of gravity - Any two objects with mass experience an attractive force as expressed by the following equation: $F_G = Gm_1m_2/d^2$

2. Astronomy tools/technology

a. Behavior of waves and light

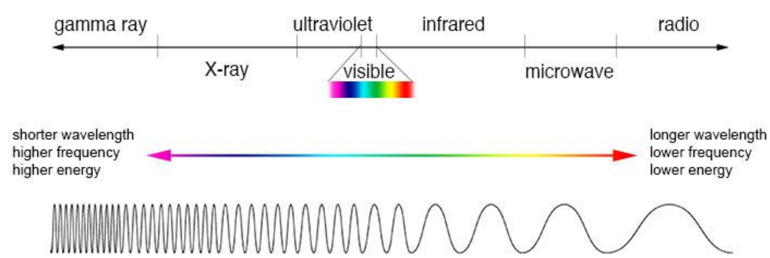
i. Structure of EM waves - Consist of an electric wave and magnetic wave propagating at right angles to one another.



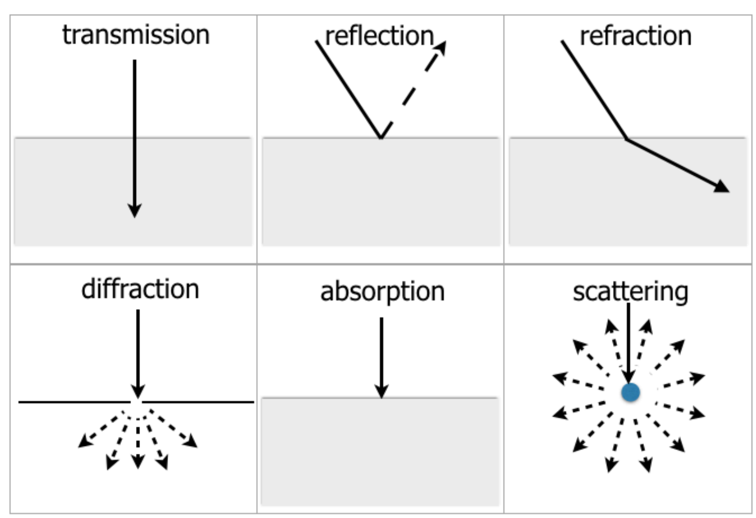
ii. Light variable relationships

1. Wavelength/frequency relationship $c = \lambda * \nu$
   - $c = 3.00 \times 10^8$ m/s (speed of light)
   - λ = wavelength (meters)
   - ν = frequency (1/s or Hertz)
   - Example:
2. Energy/frequency relationship $E = h * \nu$
   - E = energy of a photon (Joules)
   - h = Planck's constant (6.626×10^{-34} J*s)
   - ν = frequency (1/s or Hertz)
   - Example:

iii. EM spectrum - Various types of electromagnetic waves of different wavelengths fit into the categories pictured at right.



iv. Behavior of waves

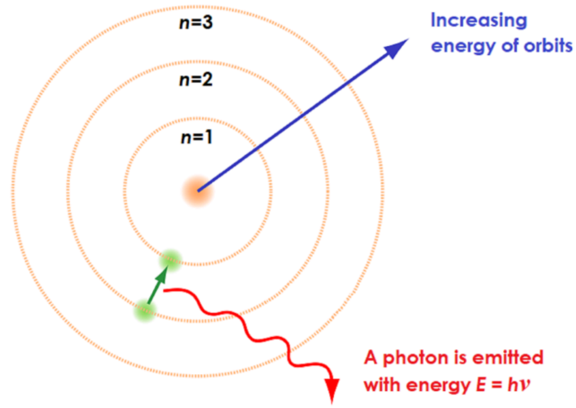


1. Transmission - Light passes straight through an object (glass)
2. Reflection - Light bounces off an object at the same angle it came in (mirror)
3. Refraction - Light bends as it changes mediums. Short wavelengths bend more than long wavelengths as in a prism
4. Diffraction - Light bends around corners & through small slits
5. Absorption - Light strikes atoms in a substance and causes them to vibrate, becomes thermal energy
6. Scattering - Light bounces off objects in random directions. This is why the sky appears blue.

b. Atomic spectra & spectroscopy

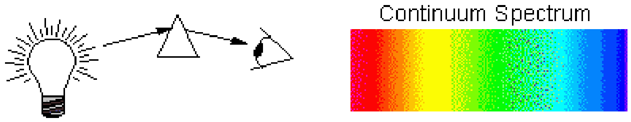
i. The Bohr Atom - As electrons move between energy levels in an atom, they gain or lose energy. Electrons can absorb a photon of light to move up, or release a photon and fall down.

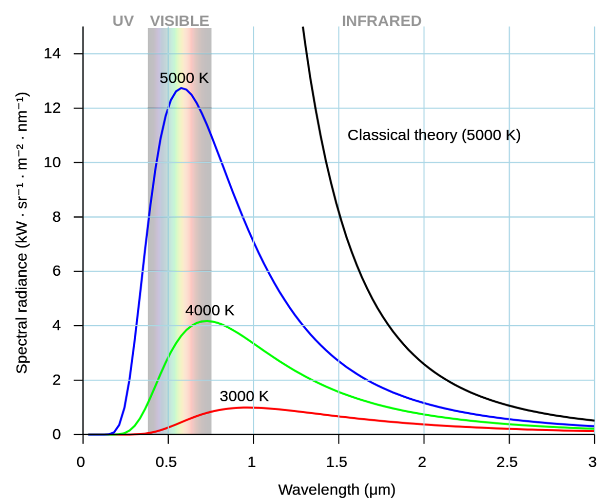
1. Every atom has a different configuration of protons & electrons, so the light each releases is unique (fingerprint).
2. The specific wavelengths/colors of light released by an atom is known as its "spectrum."
3. Chemical compounds (such as water, carbon dioxide, etc) release their own unique spectra as well.



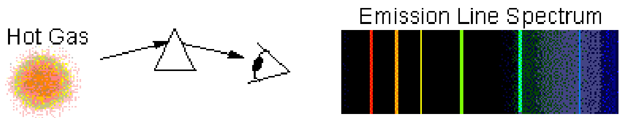
ii. Spectroscopy - Uses diffraction/refraction to split light apart into constituent parts called a spectrum. The spectra are each unique to a particular element/compound.

1. Continuous spectrum - All objects with a temperature release EMR in some part of the spectrum. Also known as "[blackbody radiation]"

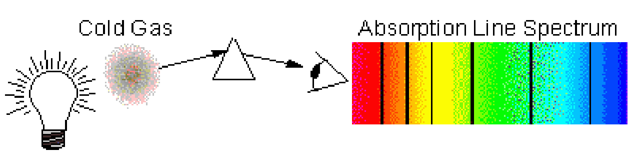




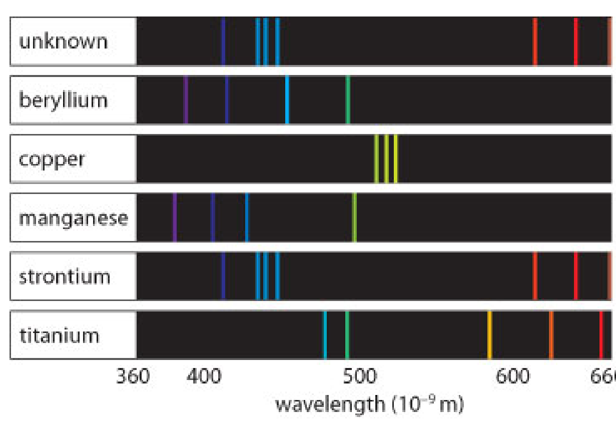
2. Emission spectrum - When heated, electrons bouncing between energy levels release specific wavelengths of light



3. Absorption spectrum - If a continuous spectrum of light passes through a cloud of gas, atoms absorb the same specific wavelengths as they would in an emission spectrum

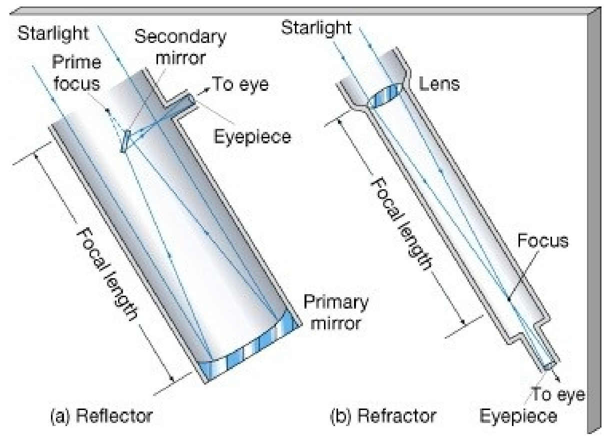


Atomic spectra act as "fingerprints" of elements and compounds. What is the identity of the unknown compound pictured at right?



c. Sextant/Astrolabe/Armillary sphere - Possibly? invented by Hipparchus around 200 BCE, has been used by many cultures for various reasons. Used to:
   - Find stars and other celestial objects in the night sky
   - Determine the time without the sun
   - Determine location/directions for navigation
   - Predict sunrise/sunset times

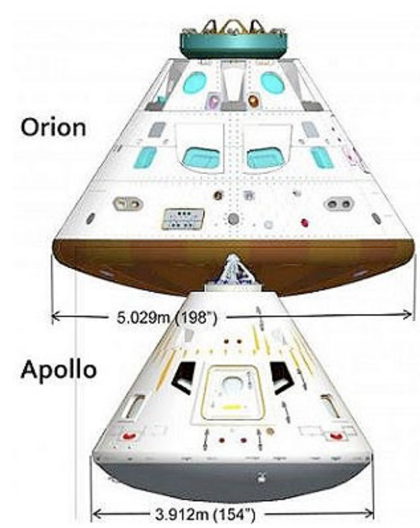
d. Telescopes
   i. Land vs space telescopes
      1. Land - Larger, cheaper, easier to maintain. Image is blurred by atmosphere. Adaptive optics can help this. See example here
      2. Space - Smaller, expensive, difficult to maintain. No atmospheric interference leads to very high quality images.
   ii. Reflector vs refractor
      1. Refractor - Uses a combination of convex lenses to focus light on your eye or a detector
      2. Reflector - Uses a concave mirror to focus light on a secondary flat mirror, then your eyes. These scale up



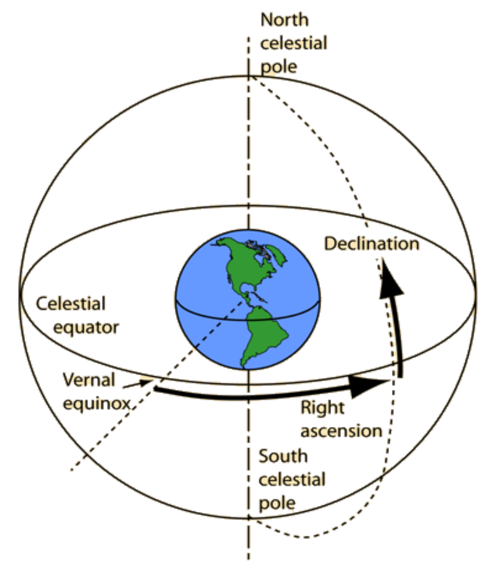
   iii. Various wavelengths - Astronomers use telescopes that can see in all different portions of the EM spectrum. Certain substances are transparent to certain wavelengths of EMR but opaque to others.

e. Space probes - Sent to other parts of the solar system to gather data and send it back to us.
   i. Voyagers 1 & 2 - Sent to outer solar system during the 1970's, visited several planets for the first time. Currently the furthest two human made objects from earth.
   ii. Cassini/Huygens - Sent to study Saturn & Titan in the 1990's in more detail. Mission ended in 2017 when NASA purposefully burned it up in Saturn's atmosphere
   iii. New Horizons - Launched in 2006 to study Pluto. Reached Pluto in 2015, then made a flyby of Ultima Thule in 2019
   iv. Juno - Launched in 2011 to study Jupiter in more detail. Arrived in 2016.
   v. Parker - Sent to study the sun in more detail.
   vi. Mars rovers - Sojourner, Spirit/Opportunity, Curiosity, Perseverance

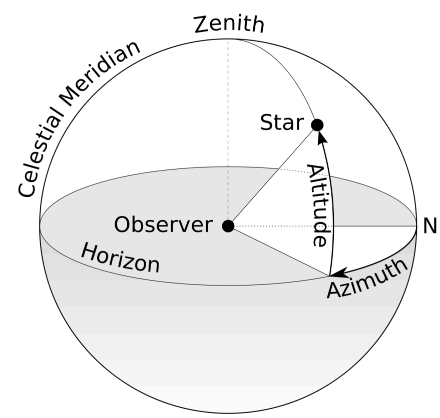
f. Crewed spacecraft
   i. Mercury/Gemini/Apollo Missions - Only missions which have put humans on another celestial body (the moon) to date.
   ii. Mars - SpaceX? NASA?
      1. Artemis program - NASA returning to moon, stopover for Mars
      2. SpaceX - Dragon capsule, falcon heavy, starship. Straight to Mars?
      3. Other private companies, other government agencies



3. Motions of the Sky
    a. The celestial sphere - Imaginary sphere surrounding earth upon which the celestial objects lie. UNL astro sim.
        i. North & South Celestial Pole, Celestial Equator - Extensions of the same objects on earth, projected upon celestial sphere
        ii. Celestial Coordinates
            1. Declination - Equivalent of latitude. Runs -90° (SCP) to 0° (CE) to +90° (NCP). Subdivided into arcminutes and arcseconds.
            2. Right Ascension - Equivalent of longitude. Runs from 0h to 24h, subdivided into minutes and seconds.

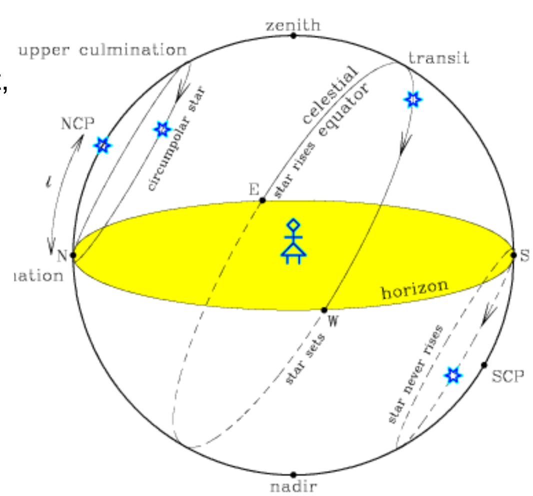


    b. Navigating your sky (Horizon view)
        i. Reference points in your sky
            1. Zenith - The point directly above your head
            2. Meridian - An imaginary line which runs from N to S over your head through the zenith
            3. Horizon - Zero degrees altitude around you in all directions
        ii. Coordinates in your sky
            1. Altitude - Degrees above the horizon in your sky, from 0° (horizon) to 90° (zenith)
            2. Azimuth - Degrees clockwise from North, 0° - North, 90° - East, 180° - South, 270° - West
            3. Estimating angles using your hand

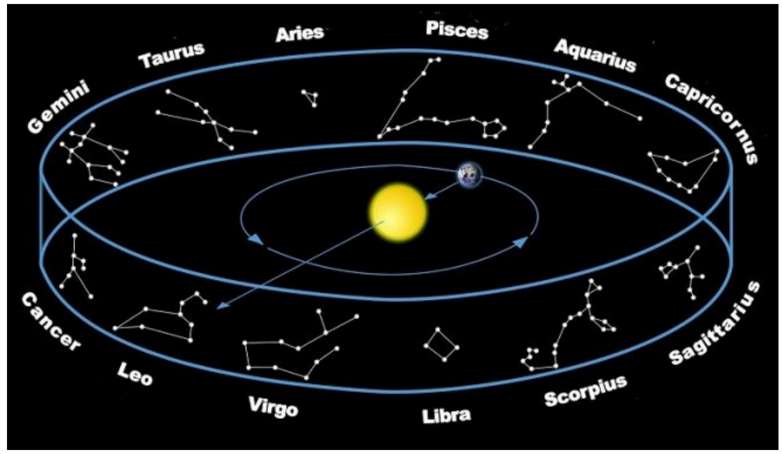


        iii. Patterns in the sky
            1. Constellations - Many ancient civilizations recognized star patterns, but these varied from place to place. Were later standardized into 88 internationally recognized portions of the sky.
            2. Asterisms - Commonly recognized patterns which are not one of the 88 (ex big dipper)

    c. Celestial motion
        i. Daily cycle
            1. Altitude of NCP is the same as your latitude
            2. All objects rotate around the NCP/SCP, from east to west, making one full revolution in roughly 24 hours (<u>not quite</u>)
            3. Circumpolar, never rise, and rise/set stars
                ○ Circumpolar - Never set below horizon. Declination > 90-latitude
                ○ Never rise - Never rise above horizon. Declination Inverse of circumpolar
                ○ Rise/set - Spend part of time above, part of time below horizon. Declination range is all those between the above two.
            4. Polaris & southern cross
                ○ Polaris - Star currently nearest to the NCP, our “North Star”
                ○ Southern cross - There is no “South Star,” but the Southern cross points toward the SCP



ii. Yearly cycle - As the year progresses, the sun appears to move through the zodiac constellations.
    1. The portion of the celestial sphere visible at night changes from month to month.
    2. Other than never-rise stars, all parts of the sky "rise" at some point, but may not be visible if this is during the middle of the day.

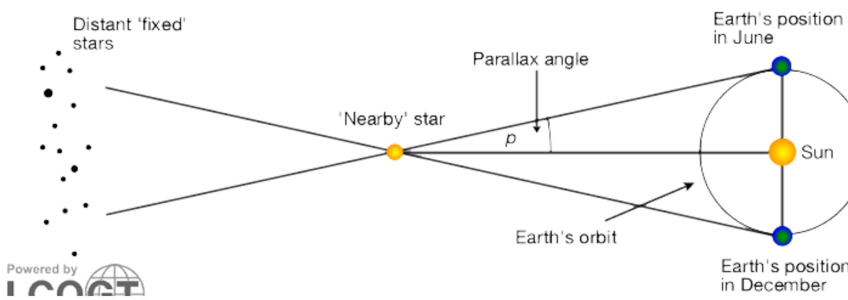


4. Astronomical units of measure
   a. Distances
      i. Kilometers/miles - Useful mostly for nearest planets/moons, low earth orbit
      ii. Astronomical Units (AU) - average distance from sun to earth, used within solar system
      iii. [Lightyears (ly)]() - Distance light travels in 1 year. Used for stars in our own galaxy
      iv. Parsecs (pc) - Distance of an object with a parallax angle of 1 arcsecond. Used for the most distant objects (other galaxies).
         1. Parallax - 1 parsec is defined as the distance to a star which demonstrates a parallax angle of 1 arcsecond.

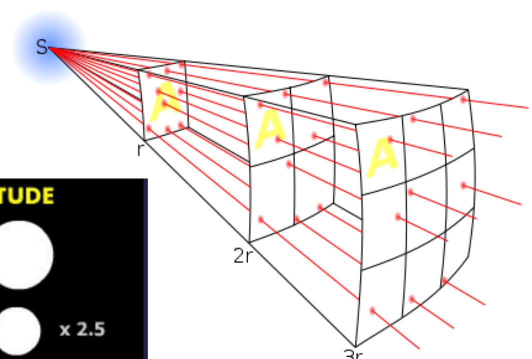
$$d = \frac{1}{p}$$

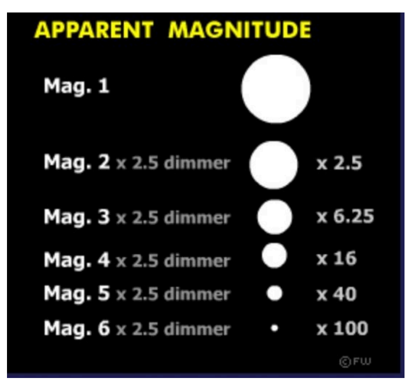
$d = distance\ to\ star\ in\ parsecs$

$p = parallax\ angle\ of\ star\ in\ arcseconds$



   b. Brightness & Magnitude
      i. Luminosity - Energy emitted per unit time. Joules/second (aka Watt)
      ii. Brightness - Depends upon distance. Watts/meter^2
         1. $b=L/4\pi d^2$
      iii. Magnitude
         1. [Apparent magnitude]() - A relative scale of brightness as seen by the naked eye. 1 is brightest, 6 is dimmest.
         2. Absolute magnitude - Magnitude as seen from a standard 10 parsecs.





   c. Temperature
      i. Fahrenheit - Water freezes at 32 degrees and boils at 212 degrees
      ii. Celsius - Based upon the freezing (0 degrees) and boiling points (100 degrees) of water
      iii. Kelvin - Based upon absolute zero which represents zero thermal energy
         1. $T_K = T_C + 273$