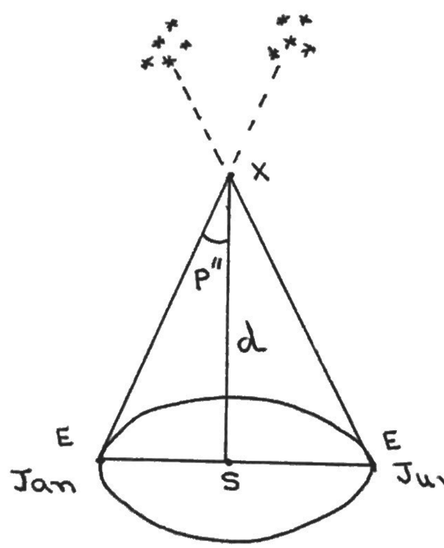
Stellar Distances

- In the solar system the unit of distance is the astronomical unit (1 A.U. = $1.5\text{x}10^{13}$ cm).
- 1 light year ≡ distance light travels in 1 year = $9.46\text{x}10^{17}$ cm
- Parallax : the apparent change in motion or direction of an object due to the motion of the observer.
- A star is at a distance of 1 parsec from the sun if its parallax angle is 1" of arc.

1 parsec = 3.26 light year = 206265 A.U. = $3.09\text{x}10^{18}$ cm
1 kpc = 1000 pc; 1 Mpc = 106 pc
d (pc) = 1 / p"   or, p" = 1 / d(pc)



- To measure distances by the method of trigonometric parallax. Take photographs of a star field six months apart. From photographs determine the parallax angle p". Use d(pc) = 1 / p" to obtain distance from the sun.
- The smallest parallax angle that can be reliably measured is 0.01" of arc. This corresponds to a distance of 100 pc.

Stellar Luminosity

- The apparent luminosity (l) or brightness is the amount of energy received on earth per unit area per unit time.
- Apparent luminosity easily measured with a photometer.
- The absolute luminosity (L) or brightness is the actual amount of energy emitted per unit time.

- <u>Inverse square law</u> for the propagation of light

$$l = L / (4 \pi d^2)$$

where d ≡ distance of the light emitting object

- Stefan - Boltzmann's law : The amount of energy emitted by a black body per unit area is proportional to the fourth power of the temperature.

$E \propto T^4$ or, $E = \sigma T^4$

$E \equiv$ energy emitted / unit area

$\sigma \equiv$ Stefan - Boltzmann's constant

$T \equiv$ Temperature in °k.

- Consider a star to be radiating like a black body. If it has a radius R, then its surface area is $4\pi R^2$. The total amount of energy it is radiating (absolute luminosity) is

$L = (4 \pi R^2) \sigma T^4 = (4 \pi \sigma) R^2 T^4$

$L \propto R^2 T^4$

Stellar Magnitudes

- Magnitude system invented by Hipparchus.

  Brightest star to the unaided eye ≡ 1st magnitude

  Faintest star to the unaided eye ≡ 6th magnitude

- A difference of 5 magnitudes is a factor of 100 in luminosity (brightness).

- A magnitude difference of 1 is a factor of 2.5 in luminosity
$m = -2.5 \log l$
- Absolute magnitude (M) is the apparent magnitude of a star at distance of 10 parsec.
- Distance modulus : (m - M)
$m - M = 5 \log d - 5$

Stellar Colors

- Johnson's U, B, V filters

Filter	Central Wavelength
U (ultraviolet)	3590Å
B (blue)	4370Å
V (visual, yellow)	5445Å

- Measure the magnitude of a star in each of three filters U, B, V
- Color Index : (B-V), (U-B)
(B-V) is negative → blue star
(B-V) is positive → red star
- Color Index is directly related to temperature

Stellar Motion

- The wavelength a source of light emits is called λ_{emit} or the rest wavelength.
- If both the source of light and the observer are stationary then the wavelength that the observer receives is the same wavelength as is emitted by the source.
- If the source of light is approaching the observer (or the observer is approaching the source of light) then the wavelength received will be less than the emitted wavelength. This is called a blue shift.

- If the source of light is receding from the observer (or the observer is receding from the source of light) then the wavelength received will be greater than the emitted wavelength. This is called a red shift.

- Doppler Formula

$\Delta\lambda$ = change in wavelength = $\lambda_{obs} - \lambda_{emit}$

$\Delta\lambda / \lambda_{emit} = v_r / c$

$c \equiv$ velocity of light

$v_r \equiv$ radial velocity, velocity of approach or recession along the line of sight

line of sight = line joining the source of light and the observer

- Space Velocity

$v_s \equiv$ space velocity

$v_r \equiv$ radial velocity along the line of sight

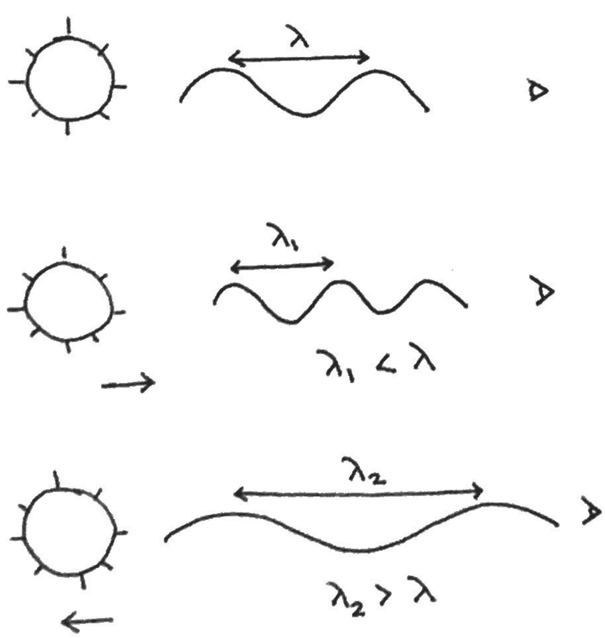
$v_t \equiv$ tangential (transverse) velocity perpendicular to line of sight

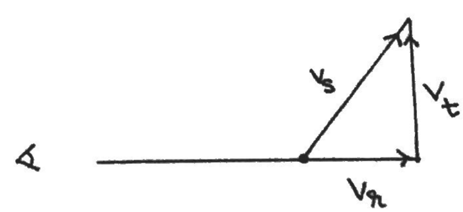
$$v_s^2 = v_r^2 + v_t^2$$

- Proper motion : μ'' (mu) : The angular distance measured in seconds of arc a star moves in a year perpendicular to the line of sight.

$\mu'' \propto v_t / d$ where d is the distance of the star

v_t (km/s) / d (pc) = 4.74 μ''/yr





Information from Stellar Spectra

- Temperature
- Chemical Composition
- Radial velocity (from Doppler formula)
- Rotational velocity (from rotational broadening)
- Pressure (from pressure broadening)
  High pressure → broad lines
  Low pressure → thin lines
- Magnetic field (from Zeeman splitting)

- Stellar Energy Source
- What is the source of energy for stars?
  - Chemical? [from combustion; e.g. burning natural gas]
  A star would last only a few thousand years.
  - Gravitational Potential Energy?
  Kelvin-Helmholtz Contraction ("hypothesis") : A star could be slowly contracting. It will lose potential energy which would be converted to heat. A star like the sun would last only 10^7 years.
  - Nuclear Energy?
  Yes, by nuclear fusion of hydrogen into helium.
- Proton - Proton Chain

$$^1H_1 + {}^1H_1 \rightarrow {}^2H_1 + e^+(\text{positron}) + \upsilon(\text{neutrino})$$

$$^2H_1 + {}^1H_1 \rightarrow {}^3He_2 + \gamma \text{ ray}$$

$$^3He_2 + {}^3He_2 \rightarrow {}^4He_2 + {}^1H_1 + {}^1H_1$$

Net result $4\,({}^1H_1) \rightarrow {}^4He_2$

But the mass of $4({}^1H_1)$ > mass of ${}^4He_2$. Some mass is lost in the fusion process. This lost mass is converted to energy by the formula $E = mc^2$. For every 1 gram of Hydrogen fused to Helium 0.007 gram is converted to energy.