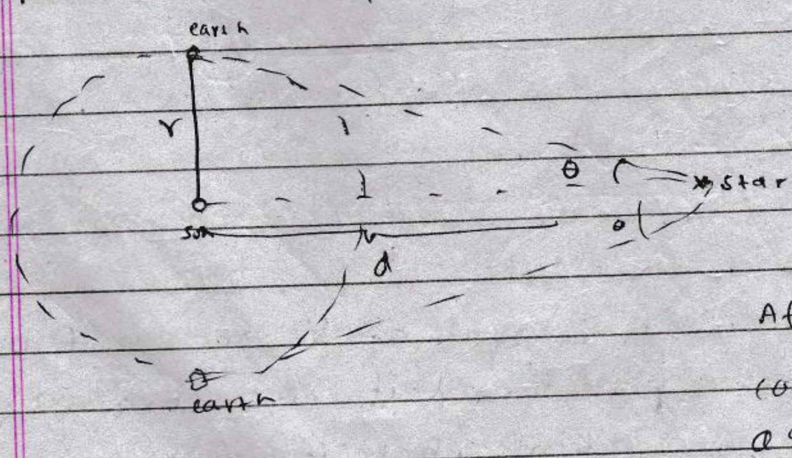
ASTRONOMY AND COSMOLOGY

- Astronomy is the branch of science which deals with celestial objects, space, and physical universe as a whole.
- Cosmology deals with the origin and development of universe which is mostly dominated by the big bang theory.

Units of distances

- Astronomical unit (AU) – The avg. distance betn. the sun and earth. (1.50×10^{11} m)
- Light year (ly) – Distance travelled by light in vacuum in one year. (9.46×10^{15} m)
- Parsec (pc) – one pc corresponds to distance at which the mean radius of earth's orbit subtends an angle of one second of arc. Equal to 3.26 ly. 1 degree = 3600 seconds.

Parsec comes from parallax method.



d is one parsec when θ is 1 second. r is one AU.

After 6 months when earth comes on other side θ is again measured.

Date
Page

Stellar parallax method : Useful to measure distance of close stars (<100 parsec) ; as farther stars subtend smaller angles whose degree of accuracy and precision slowly decrease.

Cepheid variable stars - A cepheid variable is a type of star that pulsates radially, varying in both diameter and temperature and producing changes in brightness with a well defined stable period and amplitude.

Intensity = $\frac{\text{Luminosity}}{\text{Area}}$ $I = \frac{L}{4\pi r^2}$

In ~~B~~ stellar ~~pars~~ parallax method

$\tan\theta = \frac{1 AU}{d}$ As θ is small, $\tan\theta \approx \theta$

$\therefore \theta = \frac{1 AU}{d}$

when star is distant, θ is very small

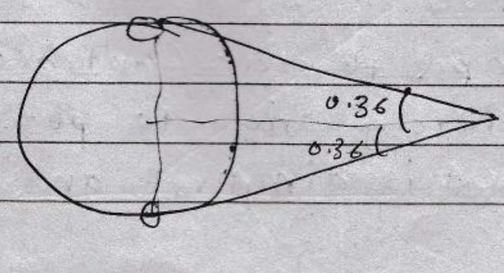
Star travels angular distance of 0.72 arcsec from Jan to July in the sky.

$p = \frac{\pi}{180 \times 3600} \times 0.36$

$1^\circ = \pi/180^c$

$3600'' = \pi/180^c \cancel{\times 3600}$

$1'' = \frac{\pi}{180 \times 3600}^c$



$p = 0.36''$

Luminosity of a star (L) is defined as the total radiant (electromagnetic energy) emitted per unit time. This is total power emitted by a star.
It is measured in watt or Js^{-1}.
Solar luminosity, Ls is about 3.83×10^{26} W. This much amount of energy is emitted per second from the earth's surface.

Observed intensity is known as radiant flux intensity, F. This is defined as the radiant power passing normally through a surface per unit area.

$$\text{radiant flux intensity} = \frac{\text{power of star}}{\text{surface area of sphere}}$$

Cepheid variable stars are brightest when diameter is max i.e. density is min. and dimmest (bluish) when diameter is min. i.e. density is max.

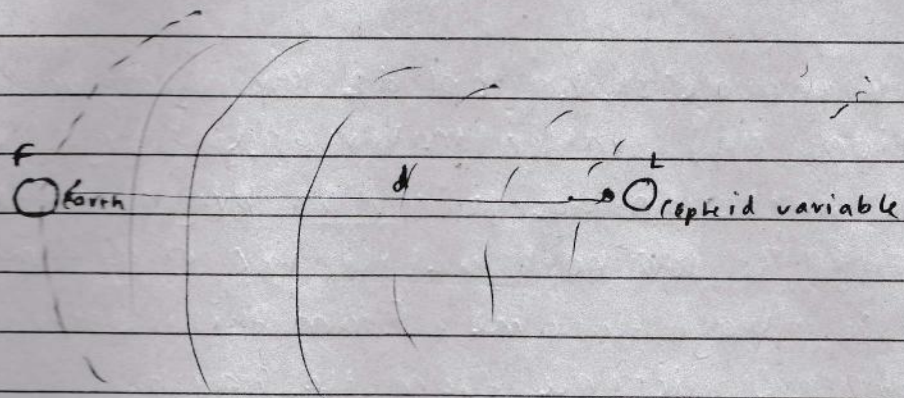
We can know the true luminosity of a Cepheid by observing its pulsation period. F - radiant flux intensity

$$F = \frac{L}{4\pi d^2}$$

we can measure 'F' from earth's surface and determine 'd' using ~~pa~~ stellar parallax method.

Gravitational force tries to collapse the star (contract) it while the thermonuclear reaction's energy tries to ~~pu~~ expand the star. When it has ρ_{max}, it is dimmest and at ρ_{min} it is brightest.

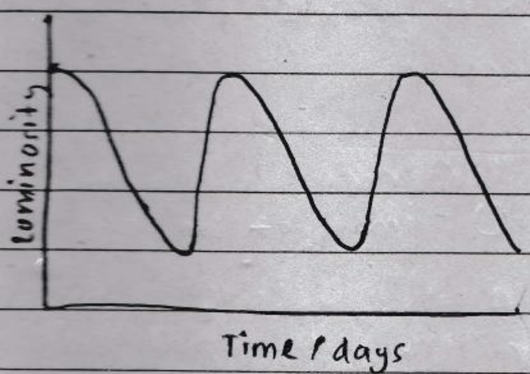
Luminosity is the total radiant power of a star.



$$F = \frac{L}{4\pi d^2}$$

$$d = \sqrt{\frac{L}{4\pi F}}$$

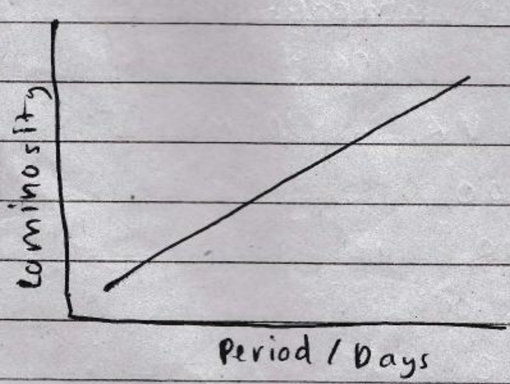
L and F both are known and d can be determined



This is not a trignometric function, the time to lose luminosity is more but time to rise back to max. luminosity is rapid.

When star is ρ_{max}, less light from the core can come out, so star is dimmer.

Experimentally, it is known that stars with larger time period have a higher luminosity.

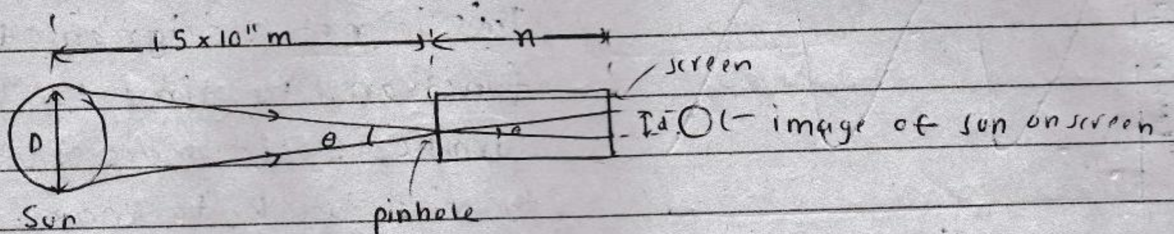


$L_{sun} = 3.85 \times 10^{26}$ W

Type 1A supernovae

Type 1A supernovae stars implode rapidly towards the end of their lives and scatter matter and energy out into space. This implosion event can be brighter than the galaxy itself. The luminosity of the star at the time of implosion is always the same. From this, astronomers can estimate the star's distance from the Earth.

The diameter of the sun.



As θ is small,

$$\tan\theta \approx \frac{d}{n} = \frac{D}{1.5\times10^{11}}$$

$$\therefore D = \frac{1.5\times10^{11}\times d}{n}$$

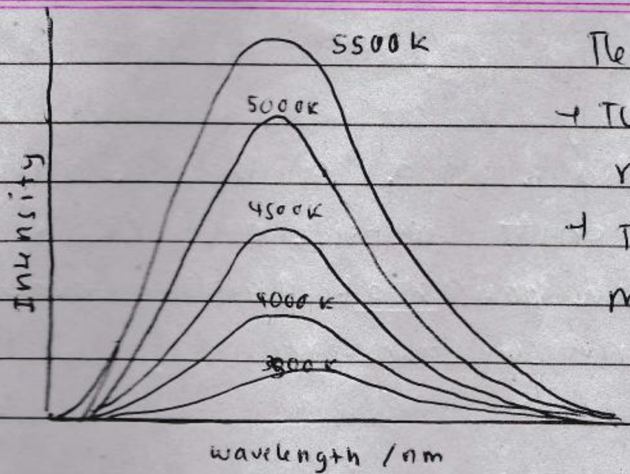
Or $\theta = l/r$

$$\theta = \frac{D}{1.5\times10^{11}} = \frac{d}{n}$$

$$\therefore D = \frac{1.5\times10^{11}\times d}{n}$$

Color of radiation depends on its temperature

Color of star	Surface temp /K
blue	> ~~300~~ 33000
blue - blue white	10000 - 30000
white	7500 - 10000
yellowish white	6000 - 7500
yellow	5200 - 6000
orange	3700 - 5200
red	< 3700



The higher the temperature
+ The greater the intensity of em radiation.
+ The shorter the wavelength at maximum intensity.

λ_{max} indicates λ for max. intensity not max λ.

λ_{max} gradually decreases as temp. is increased.
Experimentally, it is determined: $\lambda_{max} \propto 1/T$
where T is in kelvin
$\lambda_{max} . T$ = constant
This relation is called Wien's displacement law.

Wein's displacement law states that the wavelength of radiation (corresponding to a max. intensity) emitted by a blackbody is inversely proportional to its absolute temperature.

$$\lambda_{max} \propto \frac{1}{T}$$

$\therefore$ $\lambda_{max} T$ = constant
Experimental value of constant is 2.9×10^{-3} mK.

Incandescent bulb - As filament's temp. drops, wavelengths lengthen, making filament redder.

Stefan - Boltzmann law

States that the power radiated by a hot body (black body) across all wavelength per unit surface area (P) is directly proportional to the fourth power of absolute temp. of the body. P = Power per unit surface area

$P \propto T^4$

$\therefore P = \sigma T^4$

where σ is Stefan-Boltzmann constant equal to ~~$5.67 \times 10^{-8}\ wm^{-2}k^{-4}$~~

$5.67 \times 10^{-8}\ wm^{-2}K^{-4}$.

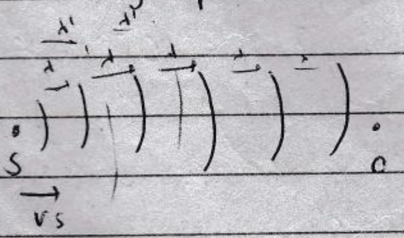
Product of P and A gives ~~to~~ luminosity of star.

$L = P \times A = 4\pi r^2 \sigma T^4$

Hence, luminosity depends on its surface thermodynamic temperature T and radius r.

$L \propto r^2$, $L \propto T^4$

In lab, an emission spectral line is observed of 656.4 nm. The same spectrum from a galaxy has wavelength 663.1 nm. Calculate the receding speed v of galaxy.



$$\frac{663.1 - 656.4}{656.4} = \frac{v_s}{3 \times 10^8}$$

$\therefore v_s = 3.1 \times 10^6\ ms^{-1}$

$\lambda' = \lambda + v_s . T$

$\therefore \lambda' - \lambda = v_s / f$

$\therefore \Delta\lambda = \frac{v_s}{c} . \lambda$ $\quad \therefore \frac{\Delta\lambda}{\lambda} = \frac{v_s}{c}$

The Big Bang Theory

This is a model of evolution of the universe from extremely hot and dense state of mass about 14 mil. yrs ago. The mass was in a point size (smaller than atom) which banged in the a fraction of a second.
No science laws are applicable before Big Bang. The univerce is expanding and is cooling continuously.

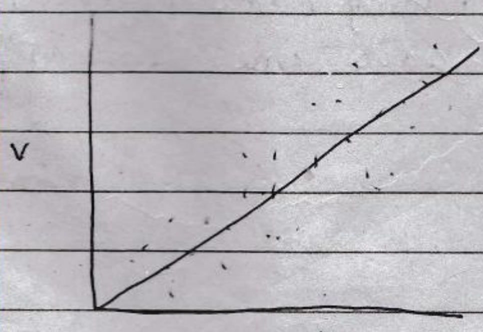
It was observed that more the distance of the galaxy, the faster it moves. The receeding speeds of different stars are different.

Hubble's law states that the recession speed (v) of galaxy/stars is directly proportional to its distance (d) from earth.

$v \propto d$

$v = H_0 d$

where H_0 is hubble's constant, $H_0 = 2.4 \times 10^{-18}\ s^{-1}$ or,
$72\ kms^{-1} Mpc^{-1}$ where Mpc is megaparsec
$1\ Mpc = 10^6\ pc = 3.084 \times 10^{22}\ m.$ (3.26 ly)



There is a considerable uncertainity in the observations.

$$\frac{c}{\lambda_o} = \frac{c}{c+v_s} \times \frac{c}{\lambda_s}$$

$$\frac{1}{\lambda_o} = \frac{c}{\lambda_s(c+v_s)}$$

$$c+v_s = \frac{\lambda_o c}{\lambda_s}$$