ASTRONOMY AND COSMOLOGY

Star: A cloud of hot gas, mainly comprising of Hydrogen. Hydrogen undergoes fusion reaction to produce Helium and releases large amount of energy.

Galaxy: A collection of stars.

Luminosity: It is the total power of radiation emitted from the surface of star.

- SI Unit: Watt (W)

Luminosity of a star depends upon the surface area of the star and the temperature of the surface.
(Luminosity of any star can be calculated using Stephan-Boltzmann Law)

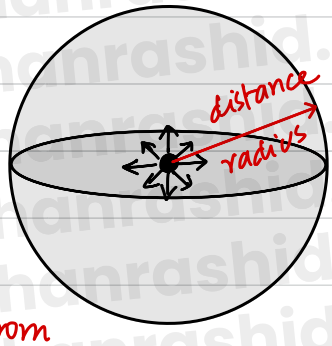
Radiant Flux Intensity: The total power of radiation incident per unit surface area

$$\text{Intensity} = \frac{\text{Luminosity}}{\text{Surface Area}}$$

$$\text{Intensity} = \frac{L}{A} = \frac{L}{4\pi r^2} \text{ or } \frac{L}{4\pi d^2}$$

r → radius

d → distance from the center to star to any point X



→ S.A of a sphere "$4\pi r^2$"

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

SI Unit: Wm^{-2}

(It can be referred as Luminous Intensity)

Standard Candles: "These are bodies of known Luminosity in the outer space." Examples include Cepheid Variables and Type I-A SuperNova.

These bodies are used as reference to calculate the Luminosity of a distant body in outer space.

Black Body : A body that is a perfect absorber and a perfect emitter of all electromagnetic radiations.

- Black body is not necessarily black
- Ice is a black body for light and heat as
  - → it emits all colors → it is a good absorber of heat
- Stars are assumed to be black bodies as they radiate out energy equally in all directions.

1. Black body is a perfect absorber
2. Black body is a perfect emitter
3. Black body is a diffused emitter (emits energy equally in all directions)

Radiations emitted off from a Black Body are called Black Body radiations.

Laws that can be applied on a Black body are
1. Stephan-Boltzmann Law
2. Wein's Displacement Law

Stephan-Boltzman Law

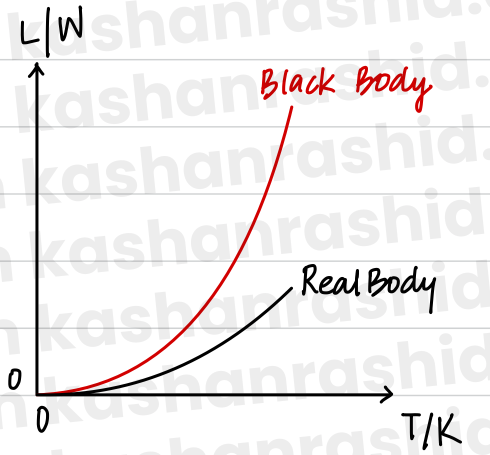
"The total power of radiation emitted from the surface of a star is directly proportional to its surface area and to thermodynamic temperature of the surface powered four."

$L \propto A$
$L \propto T^4$

$L \propto AT^4 \rightarrow \boxed{L = \sigma AT^4}$

It is used to calculate the max power of radiation that can be emitted at a temp T.

A: surface area of the star
T: surface temperature
L: Luminosity
σ: Stephan-Boltzman constant ($\sigma = 5.67 \times 10^{-8}$)



- Real body emits less radiations per unit time than an ideal body.

For two stars of same Luminosity

$L = \sigma A T^4$

$\frac{L}{\sigma} = A T^4$

if constant

$A \propto \frac{1}{T^4}$

$$A_1 T_1^4 = A_2 T_2^4$$

as $A = 4\pi r^2$ or $A = \pi d^2$ so

$\sqrt{d_1^2 T_1^4} = \sqrt{d_2^2 T_2^4}$

$$d_1 T_1^2 = d_2 T_2^2$$

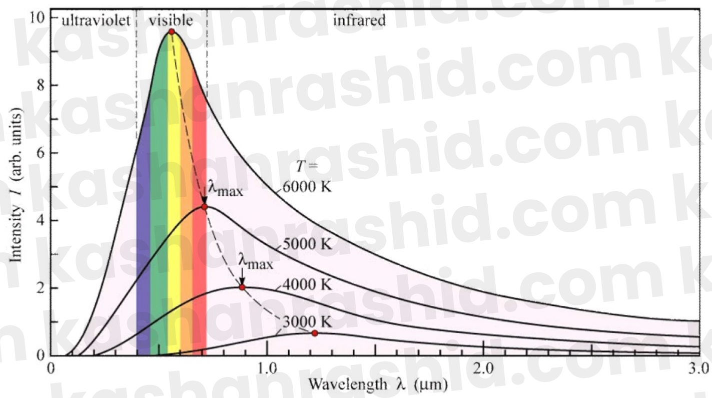
For same Luminosity

→ Smaller sized star will be hotter !

Less Area ⟶ more Temperature

Wein's Displacement Law

"Wavelength of max intensity emitted from the surface of a star is inversly proportional to the thermodynamic temperature of the surface."



→ At higher temperatures, shorter wavelengths are emitted more often.

$\lambda_{max} \propto \frac{1}{T}$ ⟶ $\lambda_{max} T = \text{constant}$ $\quad$ $\lambda_1 T_1 = \lambda_2 T_2$

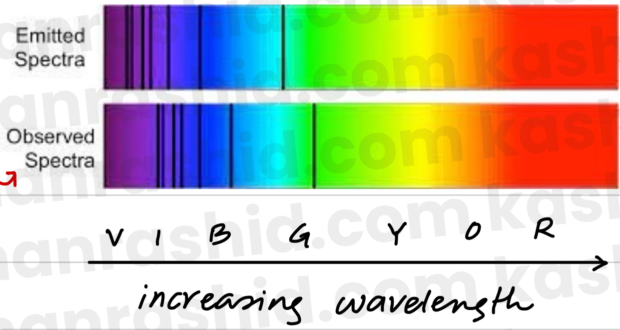
↓

Wavelength with max intensity

Red Shift:

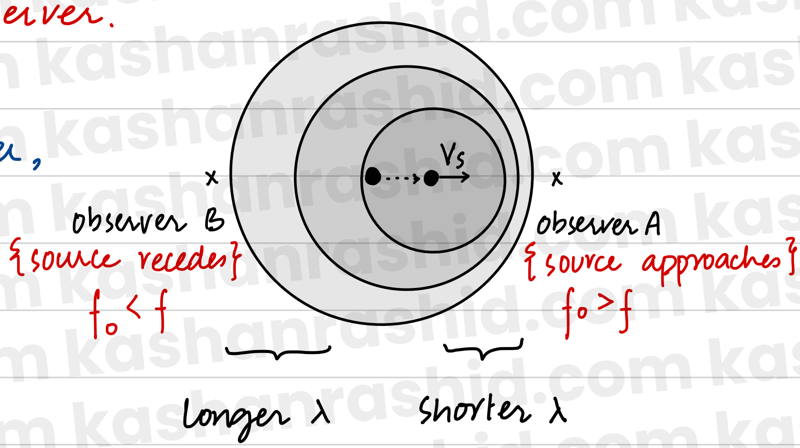
Results from same Temp body in lab →

Results from light coming from a distant star →



"It is increase in observed wavelength of light as star moves away from observer."

→ When star moves away from observer, the observed λ is longer than actual and observed f is lesser than actual. (Red Shift)



→ When star moves towards the observer, the observed λ is shorter than actual and observed f is greater than actual. (Blue Shift)

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

↑ $v \propto \Delta\lambda$ ↑

Δλ: change in wavelength
λ: actual wavelength
*v: speed of source/star
c: speed of light

Similarly

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

The spectrum of the light coming from a distant star is compared with that of a stationary body in lab of the same temperature. The difference is λ is used to determine its relative speed of moving away.

→ Red Shift proves that universe is expanding! Its because stars and galaxies are moving away from one another.

Hubble's Law:

The relative speed of a star moving away from the observer is directly proportional to the distance of that star from observer.

• star/galaxy •

$v \propto d$

$v = H_0 d$

v: relative speed

d: distance

H_0: Hubble's constant $2.2 \times 10^{-18}\ s^{-1}$

* find v using Red Shift
* use v to find distance of that galaxy.

- The more distant the galaxy is from us, the faster it is moving away from us.
- All galaxies are moving away from us and from one another.

→ This proves the universe is expanding.

- It means they must have been closer at one point in time
- The existance of an outward velocity proves that Big Bang should have occured.

Cosmic Microwave Background Radiations

→ Universe is filled Microwaves everywhere

→ These radiations were of shorter wavelengths when formed but the expansion of universe would have increased their wavelength.

→ The abundance in their quantity also proves that a huge explosion would have caused them as no body is large enough to fill the universe this way.

→ Hence CMBR also prove the Big Bang Theory.