Astrophysics and Cosmology

⇒ **Star formation** - The life and evolution of a star

→ it begins with a cloud of interstellar dust

→ this dust consists mostly of hydrogen

→ this dust (hydrogen) undergoes gravitational collapse, drawn together to the center of gravity

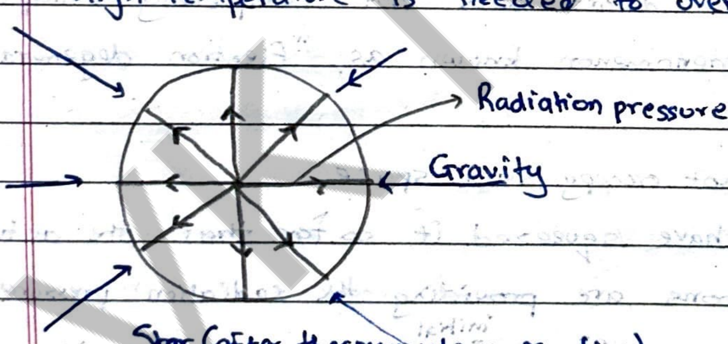
→ The gravitational potential energy is converted to kinetic and thermal energy.

$$E_k = \frac{3}{2} kT \quad \Big| \quad E_k \propto T$$

∴ as the interstellar dust experiences gravitational collapse its temperature is rising.

→ As the temperature touches 10^7 K, the hydrogen nuclei have enough energy to fuse and form Helium. This is called a Thermonuclear Reaction

→ High temperature is needed to overcome the repulsion of nuclei.



we achieve a balance where the gravity is trying to squash the star, while radiation pressure formed due to thermonuclear reactions, keeping the star in balance.

⇒ **Evolution of a star (similar to our sun)**

→ it constantly fuses hydrogen to helium

→ after a point it needs to fuse heavier elements

→ it requires more E_k and higher temperatures.

→ so the star converts more gravitational potential energy into thermal

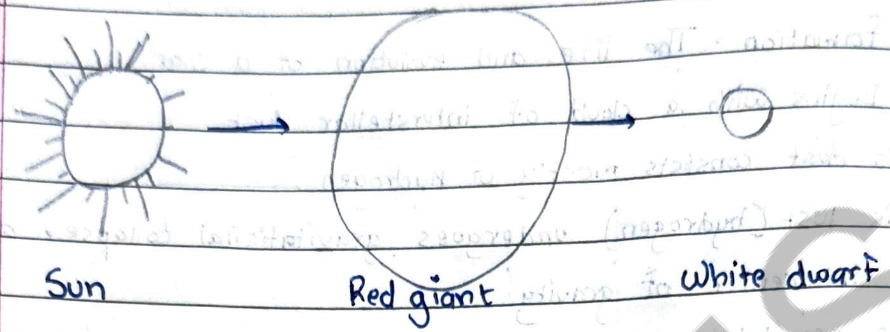
→ temperature in the core increases, allowing the star to fuse heavier elements.

→ this causes the outer layers to cool down and expand

→ this expansion turns the star into a red giant

→ Continued.

⇒ Evolution of a star (similar to Sun)



→ after the red giant stage is complete, the star will eventually collapse, gravity will win over radiation pressure (as ~~no~~ more fusion) forming a white dwarf.

→ In every star the radiation pressure is provided by different method. Ex. in a main sequence star it is provided by fusing hydrogen to helium.

Ex. in a red giant it is provided by fusing heavier elements into heavier elements

Ex. The white dwarf does not completely collapse because of a phenomenon known as, "Electron degeneracy Pressure"

⇒ Electron degeneracy

→ 2 electrons cannot occupy same space

→ This means we have squeezed it so far that the actual individual electrons are providing the radiation pressure

→ This will only work if the initial mass of the star is less than the Chandrashekhar limit.

→ Chandrashekhar limit = 1.4 solar mass

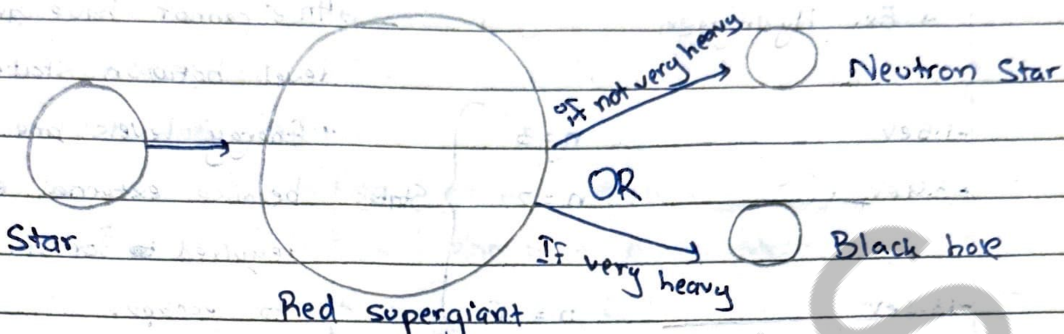
→ if the initial mass of a star is greater than 1.4 solar mass then it becomes a red supergiant.

* White dwarf - Very high density, Small volume

* Neutron Star - Very high density, Small volume, strong gravitation field

* Black hole - Infinite density, extremely strong gravitational field

⇒ Evolution of a star (mass > 1.4 solar mass)



⇒ Neutron Star

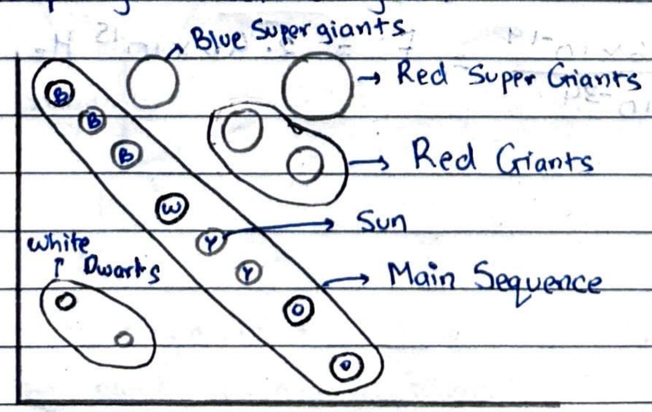
- The red supergiant undergoes a process called supernova
- it forms a neutron star only if it is not very large compared to the Chandrashekhar limit.
- again 2 neutrons cannot occupy same space ∴ the produce the Neutron degeneracy pressure.

⇒ Blackhole

- The red supergiant undergoes a process called supernova
- it forms a black hole, if it is very large compared to the Chandrashekhar limit.
- In this case the gravity wins eventually.
- The mass of a gigantic star collapses into a singularity forming a black hole.

⇒ Hertzsprung - Russel diagram

Luminosity
↓
measure of total power radiated



← Temperature

Luminosity

$L \propto M^{3.5}$ → Mass

Temperature inc towards left.

Red stars have lower surface temperature

Blue stars have higher surface temperature.

$E = \frac{hc}{\lambda}$, $E \propto \frac{1}{\lambda}$

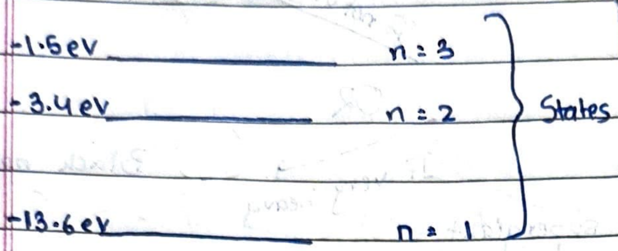
λ of red is very long

∴ E is very small

and $E \propto T$, so T is also less

⇒ Energy levels in atoms

→ Ex. Hydroggen



→ An e^- cannot have an energy level between states.

→ Energy levels are negative because external energy is required ~~to~~ for an electron to escape.

→ The lowest (most negative) energy level is called ground state.

→ if electron drops from $n=2$ to $n=1$ then a photon is released

→ if electron gains from $n=1$ to $n=2$ then a photon is absorbed.

→ To work out the wavelength or frequency of photon being emitted or absorbed, we use:

$$\Delta E = hf \quad \text{or} \quad \Delta E = \frac{hc}{\lambda}$$

let's find the energy of photon absorbed when $n=1$ changes to $n=2$

$$\Delta E = -3.4 - (-13.6)$$
$$= 10.2\ eV$$

$$\Delta E = hf$$

$$10.2\ eV = 6.63 \times 10^{-34} \times F$$

$$10.2 \times 1.6 \times 10^{-19} = 6.63 \times 10^{-34} \times F$$

$$\frac{10.2 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = F = 2.46 \times 10^{15}\ Hz$$

⇒ Diffraction

→ spreading of a wave when it passes through a gap or around an object.

→ Diffraction Grating

→ it can be made, because all it consists of is multiple slits. Ex. it has 300 lines per mm which means 300 000 lines per m.

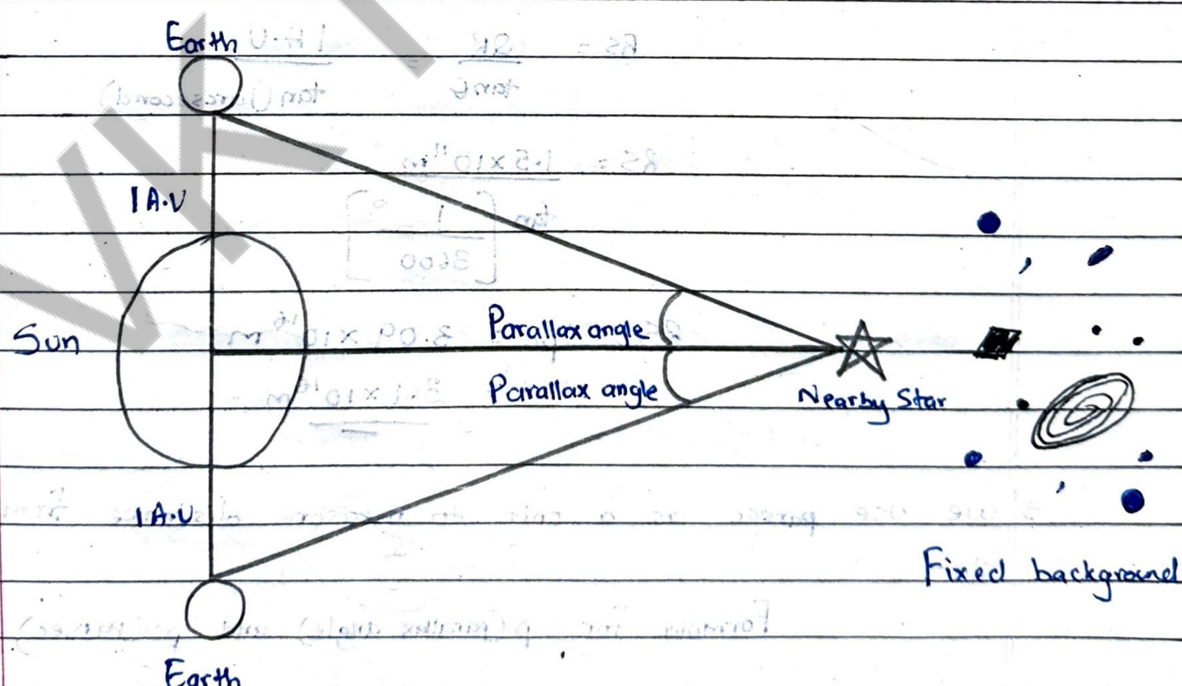
→ distance between 2 consecutive lines = $\frac{1}{N} = \frac{1}{300000}$

→ Formula → $d\sin\theta = n\lambda$

⇒ Parallax and Parsec

→ Average distance of Earth from the Sun = 1.5×10^{11} m = 1 A.U

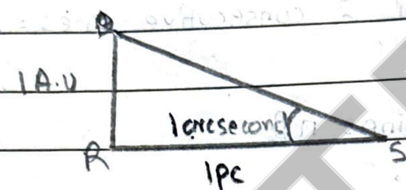
→ Parallax is a technique used to determine distances to nearby stars, by comparing the nearby star to a fixed background of much further away stars.



→ Parallax angle is the measure of the apparent displacement of the stars against a fixed background.

→ Parallax angle is measured in arcseconds
→ arcseconds is a fraction of a degree.
→ degree is divided into arc minutes, which is further divided into arcseconds.
we have 60 arc minutes max.
→ $1 \text{ arcsecond} = \frac{1}{3600}^{\circ}$

⇒ Parsec → distance which 1A.U will subtend an angle of 1arcsecond



QR = 1 A.U, if RS = 1 Parsec then ∠S = 1 arcsecond
OR
QR = 1A.U, if ∠S = 1arcsecond then RS = 1 Parsec (pc)

1 pc in m → $\tan\theta = \frac{QR}{RS}$

$$RS = \frac{QR}{\tan\theta} = \frac{1\,A.U}{\tan(1\,\text{arcsecond})}$$

$$RS = \frac{1.5\times10^{11}\,m}{\tan\left[\frac{1}{3600}^{\circ}\right]}$$

$$RS = 1pc = 3.09\times10^{16}\,m$$
$$= 3.1\times10^{16}\,m$$

→ we use parsec as a unit to measure distance from earth to star.

Formula for p (parallax angle) and pc (parsec)

$$d\,(pc) = \frac{1}{p\,(\text{arcsecond})}$$

distance
angle

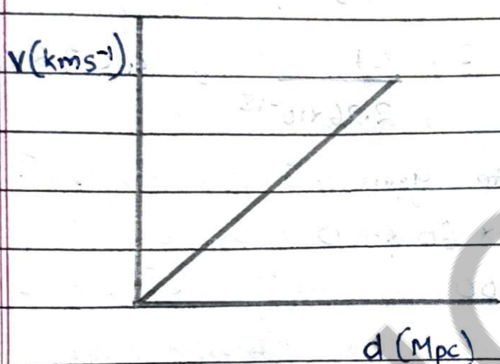
Q. A star has a parallax of 0.72 arcseconds, find the distance to star in parsecs and meters.

→ $d = \frac{1}{p}$

$d = \underline{1.39\ pc}$

1 pc — 3.1×10^{16} m
1.39 pc — $\underline{4.31 \times 10^{16}\ m}$

⇒ Hubble's law



$V = H_0 d$ — H_0: Hubble's constant

→ The recession speed of a galaxy is directly proportional to its distance from the Earth.

→ comparing $y = mx + c$ with $V = H_0 d$

$y = v, \quad m = H_0, \quad x = d, \quad c = 0$

→ $H_0 = \frac{v}{d}$ $\quad \left(v = \frac{d}{t}\right)$

$= \frac{d/t}{d} = \frac{1}{t} = H_0 =$ age of the universe

↳ S.I units = (s^{-1})

$$\boxed{Z = \frac{\lambda - \lambda_0}{\lambda_0}}$$ Red Shift

$Z = \frac{V}{C}, \quad V = H_0 d, \quad Z = \frac{H_0 d}{c}, \quad \frac{zc}{H_0} = d$

$$\boxed{d = \frac{zc}{H_0}}$$

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⇒ Converting H_0 in SI units

example : $70 \frac{km s^{-1}}{Mpc}$

$$\frac{70 \times 10^3}{10^6 \times 3.1 \times 10^{16}} = 2.26 \times 10^{-18} s^{-1}$$

$$H_0 = \frac{1}{t} = \frac{1}{H_0} = t$$

t → age of universe

$$= \frac{1}{2.26 \times 10^{-18}} = 4.43 \times 10^{17} s$$

Converting $4.43 \times 10^{17} s$ into years

1 year has = $360 \times 24 \times 60 \times 60$

= 31104000

$$\therefore \frac{4.43 \times 10^{17}}{31104000} = 1.4 \times 10^{10} \text{ years}$$

= 14 billion years

⇒ Absorption and emission spectra

→ Absorption Spectra - dark lines with a continuous spectrum (all colours) background

→ Emission Spectrum - specific colour lines on a dark background