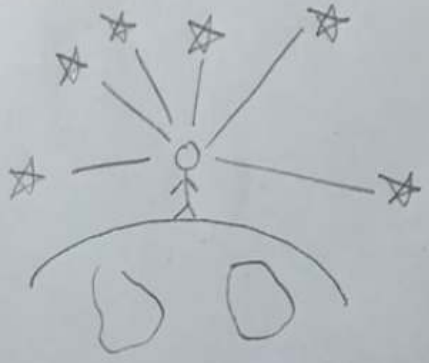
Why isn't the Sky white at night ?

In 1687, Newton publishes his work on Law of Universal Gravitation based on a cosmological model in which the universe was infinite, homogenous, isotropic and static. This model gave rise to Olbers' Paradox.

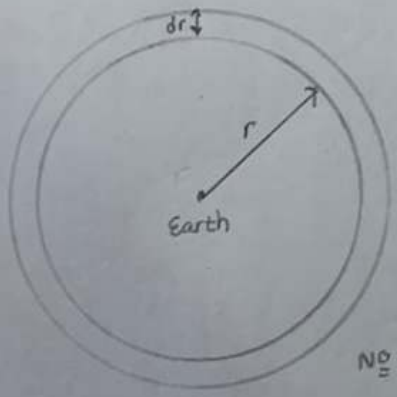
homogenous → Same property at any point

isotropic → Same when looking in any direction.

- As we look up the sky at night in the universe described above, each line of sight should meet with a star since there is an infinite amount of them and as a consequence the sky should be white.



- However, we might say that light from stars very far away arrive at very low intensities to Earth and are hence barely visible.



- Consider a thin shell of thickness dr at a distance r from Earth.

$\Rightarrow$ Volume of shell, $dV \approx 4\pi r^2 dr$

$dN_{stars} \approx 4\pi r^2 n\, dr$ where n is the no. of stars per unit volume of space.

↑ No. of stars in the shell.

Let the radiant flux of each star be γ

(J/s) ← $\therefore$ Radiant flux of shell, $d\varphi \approx 4\pi r^2 n \gamma\, dr$

Also Intensity = $\frac{\text{Power}}{\text{Area}}$

$\therefore$ Intensity of shell $dI \approx \frac{4\pi r^2 n \gamma\, dr}{4\pi r^2} = n\gamma\, dr$ ←

thickness of Shell.

We can see that Intensity of light coming from a shell is independent of the distance r of the shell from Earth.

- As we sum up the infinite number of shells in our infinite universe :

$$I_{\substack{\text{total} \\ \text{(reaching Earth)}}} = \int_{r_0}^{\infty} n\gamma \, dr \quad \text{where } r_0 \text{ is radius of Earth.}$$

$$= \infty$$

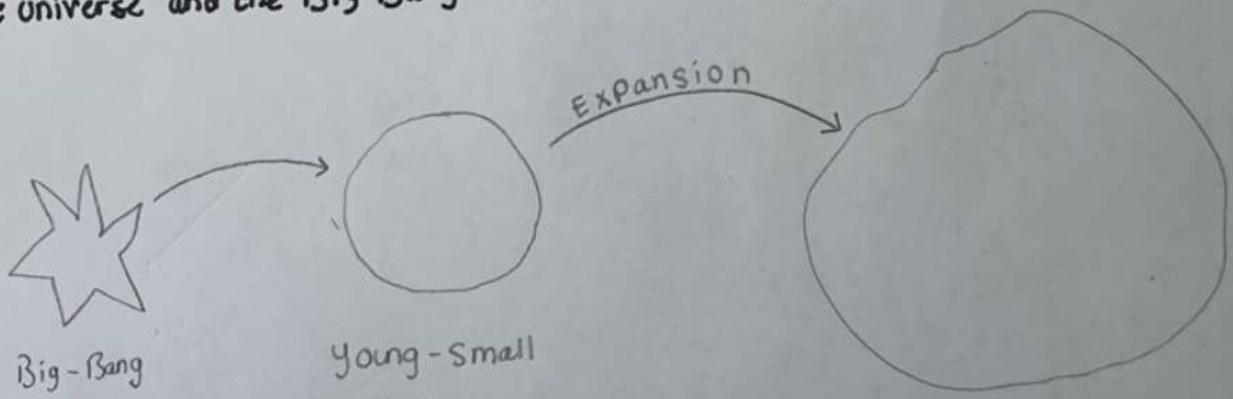
We can see that not only the stars from the entire universe would cause the sky to be white at night but also burn up Earth.

- We know that this is not the case.

The problem comes from the assumption that i) either the universe is infinite in ^ or
ii) the universe is static.

i) Even if the universe would be finite, it would still be very large and the brightness of the sky at night would be much higher than it actually is.

ii) The most widely accepted solution to Olbers' Paradox revolves around the Expansion of the universe ^ and the Big Bang model. (non-static.)



- If Earth was theoretically present at that time our sky would be white at night!

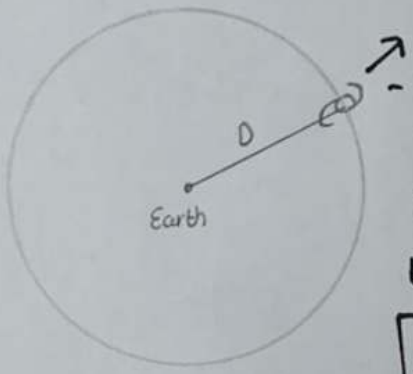
- As the universe expanded, the visible ~~EM waves~~ electromag. waves present got red-shifted to the microwave region which are invisible. This forms the CMBR (Cosmic Microware Background Radiation.)

- In 1929, Hubble published his observations on the ~~velocity of~~ recession velocity of galaxies:

$$v = H_0 D$$

v: Recession velocity of galaxy; H_0: Hubble Parameter Today; D: distance of galaxy from Earth.

Conclusion: Galaxies more distant from us move away at higher velocities.



- If D is very large then V is also very large. This causes a change in wavelength (red-shift) according to the Doppler shift equation:

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

Such that the EM waves reaching us from that galaxy are never in the visible region of the EM spectrum.

NOTE: For even larger values for D the recession velocity of the galaxies can be higher than the speed of light causing EM waves from those galaxies to never even reach us.

In Conclusion, although there is an infinite number of stars, only the few ones which are "close" to us are visible, the rest ~~are red shifted into the~~ have their light red-shifted into the invisible part of the EM spectrum when reaching us and those even farther away cannot even have their light reach us. These effects are due to the expansion of the universe and cause the sky to appear dark at night.