Chapter -11: Astrophysics

Ques. ▶ 1 A Galaxy (X) is receding from our Galaxy Milkyway with velocity 1000 km^{-1}. There is a black hole with a mass of 5 M_o. [Hubble's constant, $H = 2.3 \times 10^{-18} s^{-1}$, $M_o = 1.99 \times 10^{30}$kg, $C = 3 \times 10^8 ms^{-1}$, 1 light year = 9.46×10^{12} km.]

[All Board 18]

a. Define dark matter. 1

b. Differentiate white dwarf and Nemeses mar in time of Chandrasekhar hast. 2

c. Determine the distance at X Galaxy in term of light year. 3

d. Verify whether any light ray can pass 12km far from black hole. 4

Answer to the question no. 1

a In the universe there are so many invisible masses which supplied very very strong gravitational energy to revolve the stars of the Galaxy. This huge amount of invisible masses is called dark matter.

b If the mass of the star during the onset of death is more than $1.4M_0$, then this star can never become a white dwarf. This limit of mass of 1.4 M_0 is called the Chandrasekhar limit.

During the onset of death cycle if the mass of the star is less than 1.4 M_0, they will transform into white dwarf. Due to expansion of the red giant it reaches to a stage when its outer envelope splits into fragments. The resideue that is left is called white dwarf.

The star whose original mass is in between 2 and 5 solar masses, after the explosion the remainder of core of the star contracts. It finally gives rise to a neutron star. A neutron star has a mass equal to 2 solar masses and radius 10^{-4}m (when radius reduces from 7×10^8m to 3×10^3m, then Black Holes will produce). When a star having mass is more than 5 solar masses and density is sufficiently high is called a Black Hole. At this stage light cannot reach to us from those stars even they attract photons towards them. This is why they are called Black Holes.

c Here,

Velocity of receding Galaxy X, $v = 1000\ km.s^{-1}$

$= 10^3\ km.s^{-1}$

Hubble constant, $H = 2.3 \times 10^{-18}\ s^{-1}$

∴ If the distance between our Galaxy to Galaxy X is 'd' then,

$v = Hd$

or, $d = \frac{v}{H}$

$= \frac{10^3}{2.3 \times 10^{-18}}$ km

$= 4.347 \times 10^{20}$ km

$= 4.6 \times 10^7$ kg **(Ans.)**

d Here,

Mass of black hole, $M = 5M_0$

$M_0 = 1.99 \times 10^{30}$ kg

∴ Schwarchild radius,

$R_S = \frac{2GM}{c^2}$

$= \frac{2 \times 6.67 \times 10^{-11} \times 5 \times 1.99 \times 10^{30}}{(3 \times 10^8)^2}$ m

$= 14.754$ km

$r = 12\ km < R_S$. So, no light ray can pass at this distance from that black hole.

Ques. ▶ 2 Another Glaxy E is away from the our milk way Glaxy with velocity 1000 kms^{-1}. X Galaxy has a blackhole of mass 5 M_0.

Huble constant $H = 2.3 \times 10^{-18}\ s^{-1}$, Solar mass $Mo_0 = 1.99 \times 10^{30}$ kg, Speed of light $C = 3 \times 10^8\ ms^{-1}$. One light year = 9.46×10^{12} km. *[BAF Shaheen College, Dhaka]*

a. Define Quark. 1

b. What do you mean by limit of Chandra Sekhor. 2

c. What is distance of X-Galaxy from our position by light year calculate mathematically. 3

4. Any light ray could be pass or travel at distance 12 km from the black hole is it possible or not? Verify the statement.

Answer to the question no. 2

a Quark is the fundamental particle of matter. Matter is composed of quark.

b If mass of any star is greater than 1.45 M_0 it will not be white dwarf. Again if it is less than $1.4M_0$ it can be white dwarf. This limit of mass $1.5M_0$ is called "Limit of Chandra Sekhor".

c See Q. No. 1(c)

d See Q. No. 1(d)

Ques. ▶ 3 From the analysis of Astronomy it is observed that, the radius of event horizon of two stars are 5.93km and 14.83km respectively. Mass of the Sun = 2×10^{30} Kg and Radius of the Sun = 7×10^{8}m. *[Sylhet Cadet College, Sylhet]*

a. What is Schwarzschild radius? 1

b. "Seeing is believing" is not applicable in Astro Physics. Explain. 2

c. Calculate the average density of the Sun. 3

d. Will the two stars be black holes? Give your opinion by mathematical analysis. 4

Answer to the question no. 3

a It is a physical parameter that shows up in the Schwarzschild solution to Einstein's field equations, corresponding to the radius defining the event horizon of a Schwarzschild black hole.

b We know about black hole by Astro physics. But there is no outflow of light on black hole so we can't see black hole. But we can realize it. So, 'seeing is believing' is not applicable in Astro physics.

c If the average density is ρ, then,

$$\rho = \frac{M}{V} = \frac{m}{\frac{4}{3}\pi R^3} = \frac{2\times10^{30}}{\frac{4}{3}\pi(7\times10^8)^3} = 1392.03\ \text{kgm}^{-3}$$

Here,
Mass of sun, $M = 2\times10^{30}$ kg
Radius of sun, $R = 7\times10^{8}$m

d They will be black holes if their mass is more than 3 times of mass of sun. Now, if the mass of 1st star is M_1 and mass of Sun is M, then,

$$\frac{M_1}{M} = \frac{\frac{R_{s_1}C^2}{2g}}{M} = \frac{R_{s_1}C^2}{2GM} = \frac{5.93\times10^3\,(3\times10^8)^2}{2\times6.673\times10^{-11}\times2\times10^{30}} = 2$$

$\therefore M_1 = 2M$

Here,
Mass of Sun,
$M = 2\times10^{30}$ kg
Velocity of light,
$C = 3\times10^{8}$m
Radius of event horizon,
$R_{s_1} = 5.93$ km
$= 5.93\times10^{3}$m

So, it can't possible to be black holes.

Ques. ▶ 4 Recent studies have proved that some starts take the form of black holes due to their own gravity. To do so, its mass must be twice the mass of the Sun. This starts are situated 10^{13} height years away from our galaxies.(Hubble's constant is $67\text{kms}^{-1}/M_{pc}$) *[Barishal Cadet College, Barishal]*

a. What is dark energy? 1

b. Why we can't see black holes? 2

c. Calculate the frequency of the light that comes to the starts. 3

d. Discuss the nature of the radius of the starts that given in the stem. Give your opinion. 4

Answer to the question no. 4

a Dark energy is an unknown form of energy which is hypothesized to permeate all of space, tending to accelerate the expansion of the universe.

b A black is a region in space where the pulling force of gravity is so severe that the electromagnetic waves such as light can not pass through. As no light is coming back from black holes. So we can't see black holes.

c Given that,

Hubble's constant, $H = 67\ \text{kms}^{-1}/\text{Mpc}$

$$= \frac{67\times10^3\ \text{ms}^{-1}}{10^6\times3.2616\ \text{ly}} = \frac{67\times10^3\ \text{ms}^{-1}}{10^6\times3.2616\times9.46\times10^{15}\ \text{m}} = 2.17\times10^{-18}\ \text{sec}^{-1}$$

Distance from our galaxy to that stars,

$$r = 10^{13}\ ly = 10^{13}\times9.46\times10^{15}\ \text{m} = 9.46\times10^{28}\ \text{m}$$

∴ Vetocity of stars,

$$v = Hr = 2.17\times10^{-18}\ \text{sec}^{-1}\times9.46\times10^{28}\ \text{m} = 2.053\times10^{11}\ \text{ms}^{-1}$$

It is more than light velocity. So it is outside from our observable universe. So, it can't possible to see the light from that stars. So the determinable frequency is 0 Hz.

d Calculations show that the Schwarzschild radius of Earth is 0.00887 m. So if the world could be compressed to the extent that its radius is 0.00887 m, its escape velocity will be equal to the speed of light. The Schwarzschild radius of the sun is 2965.78 m.

The radius of a black hole may be equal to its Schwarzschild radius or smaller. No light can escape from a black hole, so an observer cannot know what happens inside it. That's why a sphere of Schwarzschild radius with a black hole as a center is called event horizon. Also, Schwarzschild radius is also called event horizon radius.

Scientists assumed that nothing could escape from a black hole. But English physicist Stephen Hawking proved that, the event horizon of a black hole will radiate a minuscule amount. This radiation is called Hawking Radiation. During Hawking Radiation, some photons, neutrons and other particles get emitted. Due to this radiation, black hole will continuously lose its mass. This process will continue till the black hole is depleted.