Homework 9 Solutions

Astronomy 1

Due December 6, 2019

1(a)
The K line of singly ionized calcium has a wavelength $\lambda_o = 393.3$ nm. Using the redshift equation we obtain:

$$z = \frac{\lambda - \lambda_0}{\lambda_o} = \frac{403.2 - 393.3}{393.3} = .025$$

1(b)
For redshift values less than .1, we can use the low redshift relationship between speed and redshift which states that

$$v = z \times c = .025 \times 3 \times 10^5 \frac{\text{km}}{\text{s}} = 7552 \frac{\text{km}}{\text{s}}$$

Hubble's law gives the distance to a galaxy as

$$d = \frac{v}{H_0} = \frac{7552}{73} = 103 \text{ Mpc}$$

2(a)
We know that a solar mass is 1.99×10^{30} kg and that a single hydrogen atom has a mass of 1.67×10^{-27} kg. Therefore, assuming the Coma Cluster is made entirely of hydrogen atoms, if we take the entire mass of the object and divide by the mass of a single hydrogen atom we will get the number of hydrogen atoms.

$$N_{\text{H}} = \frac{M_{\text{object}}}{M_{\text{H}}} = \frac{10^{13} \times 1.99 \times 10^{30}}{1.67 \times 10^{-27}} = 1.19 \times 10^{70} \text{ Hydrogen atoms}$$

2(b)
First we will convert the radius into centimeters since the question wants density in cubic centimeters. 1 parsec is 3.09×10^{18} cm. So the radius of the object is 9.27×10^{24} cm. The equation for the volume of a sphere is

$$V = \frac{4\pi R^3}{3} = \frac{4\pi(9.27 \times 10^{24})^3}{3} = 3.34 \times 10^{75} \text{cubic centimeters}$$

The density is the number of molecules divided by the volume

$$D = \frac{N_{\text{H}}}{V} = \frac{1.19 \times 10^{70}}{3.34 \times 10^{75}} = 3.57 \times 10^{-6} \text{ molecules per cubic centimeter}$$

2(c)
To compare we will take ratios of densities. For Earth, the ratio is

$$\frac{3.57 \times 10^{-6}}{3^{19}} = 3.07 \times 10^{-15}$$

So the cluster is 3.07×10^{-15} times less dense than Earth's atmosphere
For a gas cloud

$$\frac{3.57 \times 10^{-6}}{100} = 3.57 \times 10^{-8}$$

So the cluster is 3.57×10^{-8} times less dense than a typical gas cloud
For the Sun's corona

$$\frac{3.57 \times 10^{-6}}{10^5} = 3.57 \times 10^{-11}$$

So the cluster is 3.57×10^{-11} times less dense than the Sun's corona

3)
From lecture, we know that spiral galaxies have younger stars and star forming regions in the spiral arms and older stars throughout the disc. An elliptical galaxy contains mostly older more mature stars.If we look at the image we see exactly this. In the center, where the elliptical galaxy is, we see areas lit by starlight, indicating more mature/older stars are present. In the outer edges, where the spiral arms are present, we see pink areas of star formation. So from these two facts we conclude that NGC 5128 can be explained from a merger of an elliptical and spiral galaxy.

4)
Using the graph, stars that are 20 kpc away have an orbital speed of about 300 km/s. Also note that 1 kpc is 3.086×10^{16} km. So the orbital period, which is the time it takes to go around the circumference of a circle, is:

$$T = \frac{2\pi R}{v} = \frac{2\pi \times (20 \times 3.086 \times 10^{16})}{300} = 1.94 \times 10^{16} \text{ seconds}$$

The mass inside an orbit is given by

$$M = \frac{r \times v^2}{G} = \frac{20 \times 3.086 \times 10^{19} \times (300 \times 10^3)^2}{6.67 \times 10^{-11}} = 8.33 \times 10^{41} \text{ kg} = 4.18 \times 10^{11} M_\odot$$