Physics of Galaxies

ANSWERS: Exercise NUMBER 1

1. In the case of Shapley's observations, the answer is trivial – without inclusion of interstellar extinction, in the out-of-plane direction, stars appeared if they were twice as far away – hence the over-estimation of the size of the galaxy [1 mark] ([1]see movie below for fun). But with Kapteyn's observations the absorption in the plane of the galaxy (the avoidance zone) was so severe that he could not detect stars outside 10 kpc, despite the fact they *were* there – hence the under-estimation of the size of the galaxy. [3 marks]

([1]The above argument is somewhat similar to Father Ted: "Small, Far Away" episode, BUT "small" should be replaced by "dim" for the sake of an argument

https://www.youtube.com/watch?v=dS12p0Zqlt0)

The significance of measuring distance to andromeda of 500 kpc was in that this was larger than any inferred size of the galaxy (by Shapley or Kapteyn) that signalling resolution of the 1920 great debate, proving that there *are* objects outside our own galaxy [1 mark] [1+3+1 = **5 marks**]

2. Using $\lambda = c/f$ and $\lambda_0 = c/f_0$ we have

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{c}{f_0}\left(\sqrt{\frac{1+v/c}{1-v/c}} - 1\right)\frac{f_0}{c} \approx \left(1+\frac{1}{2}\frac{v}{c}\right)\left(1-\left(-\frac{1}{2}\right)\frac{v}{c}\right) - 1 = \left(1+\frac{1}{2}\frac{v}{c}\right)\left(1+\frac{1}{2}\frac{v}{c}\right) - 1 \approx \frac{v}{c}.$$

Note that here the Binomial expansion is used $(1+\alpha)^n \approx 1 + n\alpha$ where $\alpha = v/c << 1$. [**5 marks**]

3. After substitution of the value for the angle we have

$1 + z = \dfrac{1}{\sqrt{1 - v^2/c^2}}$. Square both sides and do the algebra

$1 = (1 - v^2/c^2)(1+z)^2 = (1+z)^2 - (1+z)^2 v^2/c^2;$

$\dfrac{v^2}{c^2} = \dfrac{(1+z)^2 - 1}{(1+z)^2} \Rightarrow \dfrac{v}{c} = \sqrt{1 - \dfrac{1}{(1+z)^2}}$. **[5 marks]**

Substitute the value $\dfrac{v}{c} = \sqrt{1 - \dfrac{1}{(1+9)^2}} = \sqrt{0.99} \approx 0.995$. **[2 marks]**

The gravitational pull of galaxies may cause them to collide causing the transverse motion away from each other. **[3 marks]**
see e.g. gravitational slingshot
https://en.wikipedia.org/wiki/Gravity_assist

[Total marks available 20]