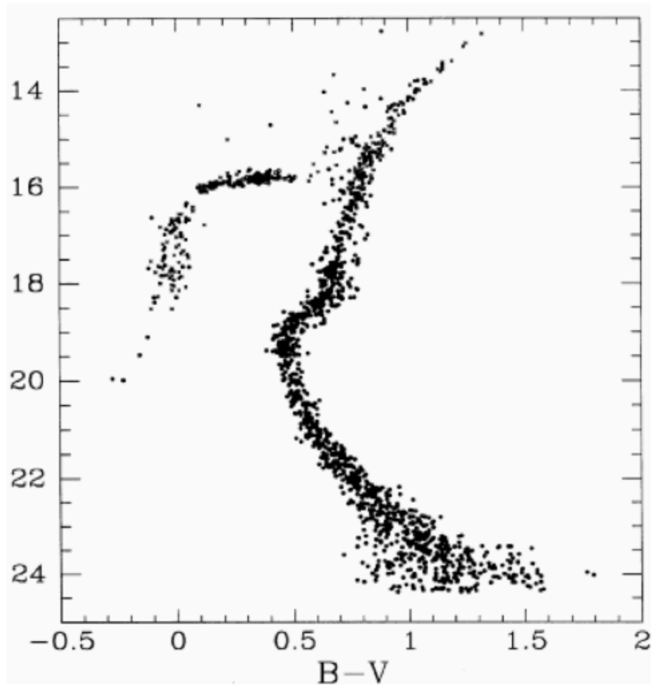
Physics 310/610 – Cosmology

Homework Set G

1. **[6] At right is the HR-diagram for a globular cluster showing color/temperature on the horizontal axis, and apparent magnitude *m* on the vertical axis. Identify approximately the apparent magnitude of the stars on the tip of the red giant branch, and from this, deduce the distance to this cluster. (Comment: because the vertical axis is not labelled on my source, I do not know if the magnitudes are infrared, which they should be for the TRGB method, and the answer is really not that reliable).**

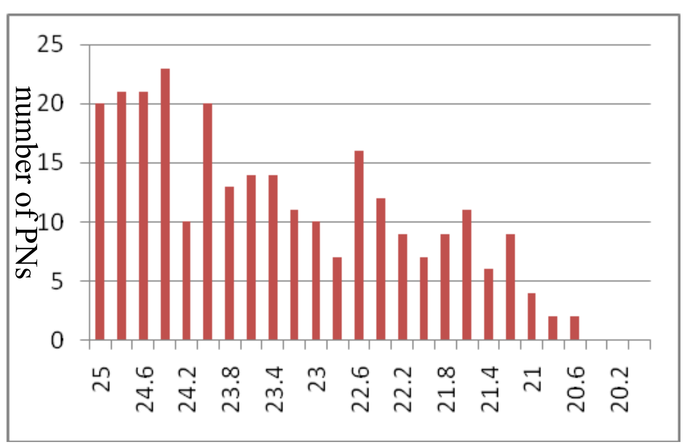


This method relies on the stars at the extreme upper right of the red giant branch, whose magnitude should be measured in infrared. We are not told what measure is being used, but let's assume it's infrared. Keeping in mind that magnitudes decrease as you go up, the tip of the red giant branch appears to be right around $m = 12.7$. Since the limiting absolute magnitude is around $M = -4.1$. Substituting this in the distance formula, we have

$$d = 10^{1+\frac{m-M}{5}} = 10^{1+\frac{12.7+4.10}{5}} = 2.29\times10^{4}\text{ pc} = 22.9\text{ kpc}$$

This is actually an H-R diagram for globular cluster M15, whose distance is around 10.9 kpc, so something is clearly a bit off about our estimate.

2. **[6] A nearby galaxy is studied. The planetary nebulae with *m* < 25 are measured, and the resulting apparent magnitudes are histogrammed. The result is sketched at right. What is the approximate limiting apparent magnitude of the planetary nebulae? What is the distance to this galaxy?**



Ideally, we should do this by fitting the number of observed planetary nebulas to a prediction of the shape of the histogram. The poor man's equivalent is to simply estimate the cutoff, the magnitude of the brightest planetary nebula. This is clearly somewhere around $m^* = 20.4$. According to the lecture notes, the cutoff is approximately $M^* = -4.47$, so we estimate the distance as

$$d = 10^{1+\frac{m-M}{5}} = 10^{1+\frac{20.4+4.47}{5}} = 9.4\times10^5 \text{ pc} = 940 \text{ kpc}$$

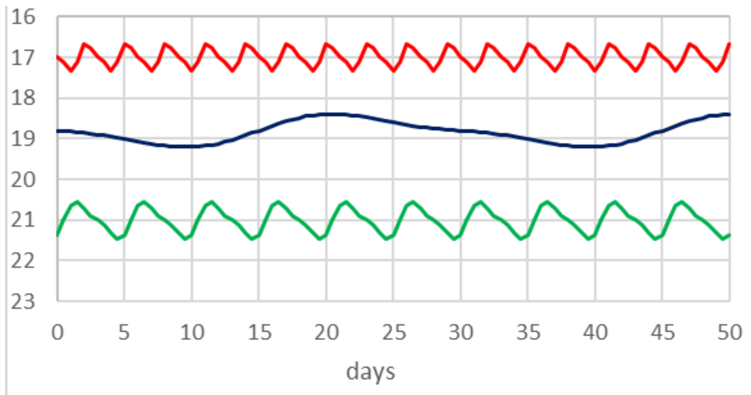
Since I made up the data in this case, I don't know what the actual distance is.

3. [18] Three Cepheid variable stars all in the direction of a nearby galaxy have their apparent magnitude *m* plotted as a function of time.

(a) Find the period and absolute magnitude for each of the three stars. Recall that this is the *average* absolute magnitude *M*.

The period for the three stars is just the time between peaks, which looks like it is approximately:

$$P_r = 3.0 \text{ d}, \quad P_b = 30. \text{ d}, \quad P_g = 5.0 \text{ d}.$$



We then use the period-luminosity relationship to get the absolute magnitudes, which are

$$M_r = -2.43\log(3) - 1.62 = -2.78,$$
$$M_b = -2.43\log(30) - 1.62 = -5.21,$$
$$M_g = -2.43\log(5) - 1.62 = -3.32.$$

(b) Find the distance to each of the three stars.

We first find the apparent magnitude, which is approximately the central value of each of the three curves. By eyeball, we estimate these as

$$m_r = 17.0, \quad m_b = 18.8, \quad m_g = 21.0.$$

We then simply substitute these into the distance-magnitude equation to find

$$d_r = 10^{1+\frac{m_r-M_r}{5}} \text{ pc} = 10^{1+\frac{17.0+2.78}{5}} \text{ pc} = 90,400 \text{ pc} = 90.4 \text{ kpc},$$
$$d_b = 10^{1+\frac{m_b-M_b}{5}} \text{ pc} = 10^{1+\frac{18.8+5.21}{5}} \text{ pc} = 634,000 \text{ pc} = 634 \text{ kpc},$$
$$d_g = 10^{1+\frac{m_g-M_g}{5}} \text{ pc} = 10^{1+\frac{21.0+3.32}{5}} \text{ pc} = 731,000 \text{ pc} = 731 \text{ kpc}.$$

(c) In fact, two of the stars are in the galaxy, and one is just coincidentally in the same direction. Which one is not in the galaxy?

Two of them have such similar distances that it is easy to believe they belong to the same galaxy. The difference is probably due to a combination of rounding/measurement error, and your professor not doing a good job to make sure they came out the same. The red one, however, is clearly too close to be in the same galaxy, since it is a factor of seven closer.