Dr. Bob's Notes for Week 9

1.1 The Standard Candle Method (again)

In some of our previous work we used the parallax method to find the distance to stars. Unfortunately, the parallax method only works for stars less than 500 pc away. Another method that will work is the Standard Candle Method. The idea is as follows: if you know the luminosity L of an object, and measure the apparent brightness B of the object, you can calculate the distance using the formula below.

$$\begin{aligned} B &= \frac{L}{4\pi d^2} \\ d^2 &= \frac{L}{4\pi B} \\ d &= \sqrt{\frac{L}{4\pi B}} \end{aligned}$$

The key to being able to use this method is having access to both the luminosity and brightness of the object in question.

In the next section we will see how the standard candle method can be used to find the distance to variable stars.

1.2 Variable Stars and Distance

Variable stars are stars whose brightness varies over time. The brightness of some types of variable stars vary in a regular pattern that repeats over time. We will discuss two types of variable stars: RR Lyrae stars, and Cepheids (please check your text for full details).

The key to finding the distance to these types of variable stars is the fact that the peak luminosity is related to the period of time between peak brightness'. In other words, if the period of a variable star can be measured, then its luminosity can be determined. Check the "Luminosity vs Period" chart found in the *ASTR 100 Formula Sheet* (look under the Dr. Bob's Notes Link). This chart allows the luminosity of RR Lyrae and Cepheid variables to be determined.

Example
Find the distance to a Type I Cepheid star if its Period is 30 days and its apparent brightness is measured to be 1.230 x 10^{-38} L_{Sun}/m^2.

Determine the Luminosity: 9000 L_{Sun} (from the chart)

Calculate the Distance

$$d = \sqrt{\frac{L}{4\pi B}} = \sqrt{\frac{9000\, L_{Sun}}{4\pi\,(1.230\,\mathrm{x}\,10^{-38})\, L_{Sun}}} = 2.413\,\mathrm{x}\,10^{20}\,\mathrm{m} \; = 25,506\,\mathrm{Ly}$$

Great! So the distance to variable stars can be determined. Why is this such a big deal? Globular clusters are tightly packed clusters of stars that orbit at great distances in the halo component of our galaxy. Cepheids are found in these globular clusters - thus finding the distance to a Cepheid in a cluster allows us to determine the distance to that cluster (and allows us to determine how these clusters are arranged around our galaxy). Cepheids can also be detected in other galaxies - this allows the distance to other galaxies to be determined.

1.3 Hubble Law

In the 1920's Edwin Hubble discovered a relationship between the distance to a galaxy and how fast a galaxy is moving away from our galaxy. This relationship is called the Hubble Law and is written below.

$$V_r = H\,d$$

Where V_r is the velocity at which a galaxy is receding from us (this velocity can be calculated using the Doppler formula). H is known as the "Hubble Constant" (the current value is 72 km/s/Mpc). The distance d is in millions of parsecs (Mpc).

Example

Find the distance to a galaxy if it is moving away from our galaxy at a speed of 21,240 km/s.

$$\begin{aligned} V_r &= H\,d \\ d &= \frac{V_r}{H} \\ d &= \frac{21,240}{72} \\ d &= 295\,\mathrm{Mpc} \\ d &= 295,000,000\,\mathrm{pc} \\ d &= 961,700,000\,\mathrm{Ly} \end{aligned}$$

Note that in this example you were given the velocity - you may not be this lucky in homework or on an exam! Be sure to review how to use the Doppler formula in case you need to calculate velocity!