

Module 6: “The Message of Starlight

Assignment 9: Parallax, stellar distance and the Hertzsprung Russell diagram

You have now explored three methods of getting temperatures of stars. Without knowing anything about stars, you might suspect that if they have different temperatures, then their intrinsic brightness are different. By intrinsic brightness we mean how bright they are, independent of their distance. So let's see how we can determine this. We want to know if stars are all the same, or different, intrinsic brightness. But unless we know the distance of a star we can't say if its brightness depends on its distance or its intrinsic brightness. It's as if you saw a light at night: you can't know if it's a bright car headlight at a great distance or a dim flashlight just down the road. If we can compute the distance to a set of stars, we can convert their apparent brightness to their intrinsic brightness using the inverse square law of light. Then we can plot the temperature versus the intrinsic brightness for a sample of stars and see if there is a relationship. We call this plot the Hertzsprung Russel diagram, and since this relation is one of the Arizona state science standards, you might suspect that there IS a relationship!

To measure the distance to stars, we use a technique called parallax. Try the following to illustrate this: hold a pencil at arm's length. Close one eye and line the pencil up with a more distance object: say, the edge of a door. Now, without moving the pencil or your head, close your open eye and open your closed eye.

Comment on how the pencil appears to move with respect to a background object. Now, repeat this but with the pencil at a different distance from your face. How does the apparent shift of the pencil change? [Post your answer to this experiment in the blog.](#)

Now imagine that your right eye represents the earth in July, and your left eye the earth in January. The pencil is a nearby star, seen with respect to more distant stars. You can measure the angular shift, and using some nice high school geometry and simple trigonometry, compute the distance to the star (assuming you can measure the distance from the earth to the sun).

Parallax is illustrated: http://sci2.esa.int/interactive/media/FLASHES/2_1_1.htm

At this point there is no way to avoid the units that astronomers use: we have mentioned magnitude already, which is a brightness scale in which very bright stars are roughly magnitude 0, faint stars are magnitude 5, and really faint stars have larger and larger magnitudes. These are further divided into apparent magnitude: what we measure when we go out and look at the star, and absolute magnitude: how bright a star would be at a fixed distance from the sun. The unit of distance generally used in astronomy is called a parsec: one parsec is 3.26 light years. (A light year is how far light travels in a year.)

Now, if we know the distance to the star, we can convert its brightness, measured in magnitudes (mag), to the magnitude a star would have at a fixed distance which has been chosen to be 10 parsecs, or about 32.6 light years. The equation we need is called the “distance modulus equation” and is a nice example of using logs. (It’s also an equation that any inquisitive high school student could derive.) In words, it is:

$$\text{apparent mag.} - \text{absolute mag} = 5 \log_{10} (\text{distance in parsecs}) - 5$$

and expressed in more conventional algebra it is:

$$V - M_v = 5 \log_{10}(d) - 5$$

So for stars with known distance, we can compute their absolute magnitude, and we already know how to measure their temperature, from several methods. A plot of these quantities is known as the HR diagram.

Creating the HR (Hertzsprung_Russell) diagram

The excel file `Nearby_stars_data.xls` contains a list of stars near enough for us to compute their distance from their parallax, and from distance, their absolute magnitude. It also contains the color difference B-V, and their spectral type. (There is a column labeled “Lum” for luminosity: we aren’t using that). And the final column gives their distance in parsecs.

If you aren’t familiar with using excel, see Chris’ tutorial: `Excel Tutorial.ppt`

1. Open the file `Nearby_stars_data.xls` and make a plot of B-V versus M_v (absolute magnitude) for the stars in the file. To match the plots that astronomers make, please use M_v on the Y axis, with negative numbers increasing up (the magnitude scale is reversed: big numbers are fainter), and B-V on the X axis. **Send a screen shot or copy of this plot to Chris. Comment on your plot. Do you see a relationship? Compare it with a published HR diagram: for example, see Wikipedia, Hertzsprung-Russell Diagram.**

2. Sort the data by B-V. (Remember, this is a measure of temperature.) How does B-V compare with the spectral types in the table? Make a table to express the relation. Make a third column for temperature. **How does your table compare with the axes in the published HR diagram from Wikipedia?**

3. Finally, choose one of the stars you classified in assignment 8. Assume that its spectral type can be related to B-V as you just saw in step 2. From your plot of the HR diagram for near stars, find the absolute magnitude that a star of that spectral class should have. You have m (apparent magnitude) as V . Now use the distance modulus equation to derive the distance to this star. **What distance do you derive?**

Congratulations! You have just found, by indirect inference, the distance to a star too far away to measure its parallax. And you have plotted it in the “HR Diagram” which is the equivalent of the periodic table for astronomers. There is a whole lot more behind the HR diagram: it describes how stars evolve over their lifetimes, but that’s another story,