UNIT 17 - SPECTROSCOPIC PARALLAX

Introduction

For stars which are too far away for their distances to be measured using stellar parallax, estimation techniques must be used instead. Many of these techniques rely on the relationship between:

- The relative magnitude of the star - a measure of the amount of light from the star which is received at the Earth's surface. (Also called apparent magnitude.)
- The absolute magnitude of a star - a measure of how much light a star is actually radiating into space, or luminosity.
- The star's distance from us.

Figure 1 Relationship between absolute magnitude, relative magnitude, and distance

In principle, if the first two of these quantities are known, then the distance can be calculated. The first is usually easy to measure, all that is needed is to equip a telescope with a calibrated light detector. The absolute magnitude is harder to obtain, since we cannot travel to the correct distance from the star (defined as 10 pc) in order to measure it. Instead, we must rely on other measurable properties of the star to obtain an estimate of its absolute magnitude.
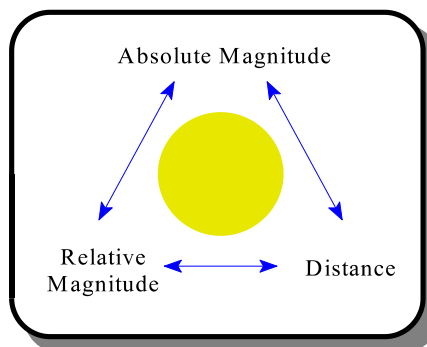
One such method relies on the use of the Hertzsprung-Russell (H-R) diagram. If the surface temperature of a main sequence star can be measured using the color distribution of the light which it emits, then its absolute magnitude can be determined. This is the method of Spectroscopic Parallax.

The Experiment

Select *Spectroscopic Parallax* from the *Start Lab* menu. You are given a view of a portion of the sky containing a collection of 50 main sequence stars. By selecting *Number of Stars* from the overhead menu, you may change the number of stars appearing in the field of view. The stars are shown in black and white, as you might observe them through a telescope. By selecting *Color* from the overhead menu, the stars are shown in color, as they might appear in a color photograph. This will give you a qualitative idea of the temperature of the stars. Remember that the blue stars are the hottest, and the red stars the coolest.

In order to determine the distance of each star you will need to measure its relative magnitude and its surface temperature. You should make these measurements for as many stars as possible within the time available for this exercise.

MEASURING THE RELATIVE MAGNITUDE

To the right of the field of view is a window which contains a gauge to indicate the amount of light from a star falling onto a detector. This gauge is directly calibrated in terms of the relative magnitude. By positioning the cursor directly over a star, the gauge will read its relative magnitude. This display will also show an identification number for the star. Make a note of both the

identification number and the relative magnitude.

MEASURING THE SURFACE TEMPERATURE

Click on a star in order to view that star's distribution of light amongst the different visible wavelengths. The wavelength at which this curve reaches a maximum is an indication of the surface temperature of the star. Measure the wavelength at which the peak light intensity occurs. To assist you in reading the plot, the display at the bottom of the screen shows the wavelength (in nm) at the position of the cursor. (Click anywhere in the window in order to be returned to the view of the stars.)

Once you have the peak wavelength, it's a simple procedure to obtain the surface temperature using Wien's Law:

$$\text{Surface Temperature} = 2.898 \times 10^6 / \text{Peak Wavelength}$$

where the peak wavelength is measured in nanometers (nm), and the temperature in Kelvin (K).

DETERMINING THE ABSOLUTE MAGNITUDE

You can now determine the absolute magnitudes of these stars using the H-R diagram. To see an H-R diagram for the stars in the field of view, click on the *Help* menu, and then select *Show H-R Diagram for these Stars.* Any star for which you have measured the surface temperature shows up on the H-R diagram as a flashing dot to aid in identifying it. You can further identify individual stars from the surface temperature which you determined earlier, this quantity is plotted along the horizontal axis[1]. Once you have identified a star, read off its absolute magnitude from the vertical axis. A grid is available from the overhead menu to help you make this reading.

Determining the Distance - Graphical Method

The distance can be readily determined once the absolute and relative magnitudes have been determined. The graph to the right shows the relationship between the distance to a star and the difference between its absolute and relative magnitudes. First compute this difference for each of the stars whose properties you have measured. Locate this value on the vertical axis, then read the corresponding distance on the horizontal axis in parsecs (pc). To convert to light years (lyr), remember that 1 pc is equal to 3.26 lyr.

Magnitude vs Distance

Figure 2
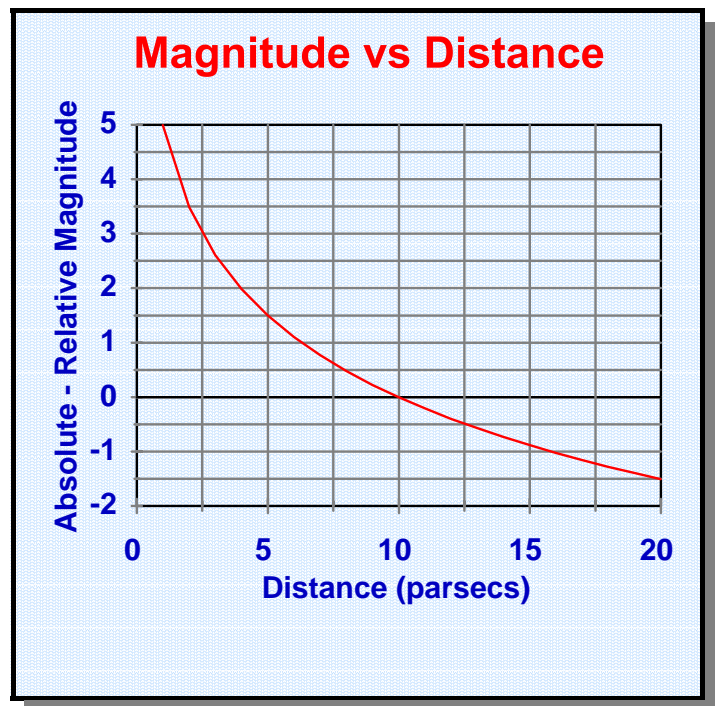
[1] Remember that in the H-R diagram, the temperature scales from hot to cool.

Determining the Distance - Algebraic Method
If you wish to use an algebraic method to determine the distance, we can make use of the relationship that the intensity of light from a star decreases with distance according to the inverse square law. If

$$\frac{\text{Intensity of light at the Earth}}{\text{Intensity of light emitted by the star}} = \left(\frac{10}{\text{distance}}\right)^2$$

we also remember that the absolute magnitude is defined as the relative magnitude at a distance of 10 parsecs, then:

where the distance is measured in parsecs.

$$\frac{100^{\frac{\text{Relative Magnitude}}{5}}}{100^{\frac{\text{Absolute Magnitude}}{5}}} = \left(\frac{10}{\textbf{distance}}\right)^2$$

The magnitude scale is a logarithmic one, in which five orders of magnitude correspond to a change in the intensity of the light by a factor of 100. This allows us to re-write equation (2) in the form: Taking logarithms of both sides yields the final result:

$$\text{Relative Magnitude - Absolute Magnitude} = 5 \log_{10}(\text{distance}) - 5$$

CHECKING YOUR RESULTS
Select *Check Your Answers* from the overhead menu. Enter the star's identification number, the absolute and relative magnitudes, and the distance. By identifying each star in turn, you may check your results for as many stars as you like. Correct results will be indicated with a check mark.