GALACTIC CLUSTERS

Objective

Determine the distance and age of a cluster of stars in the Milky Way galaxy.

50 cent word:

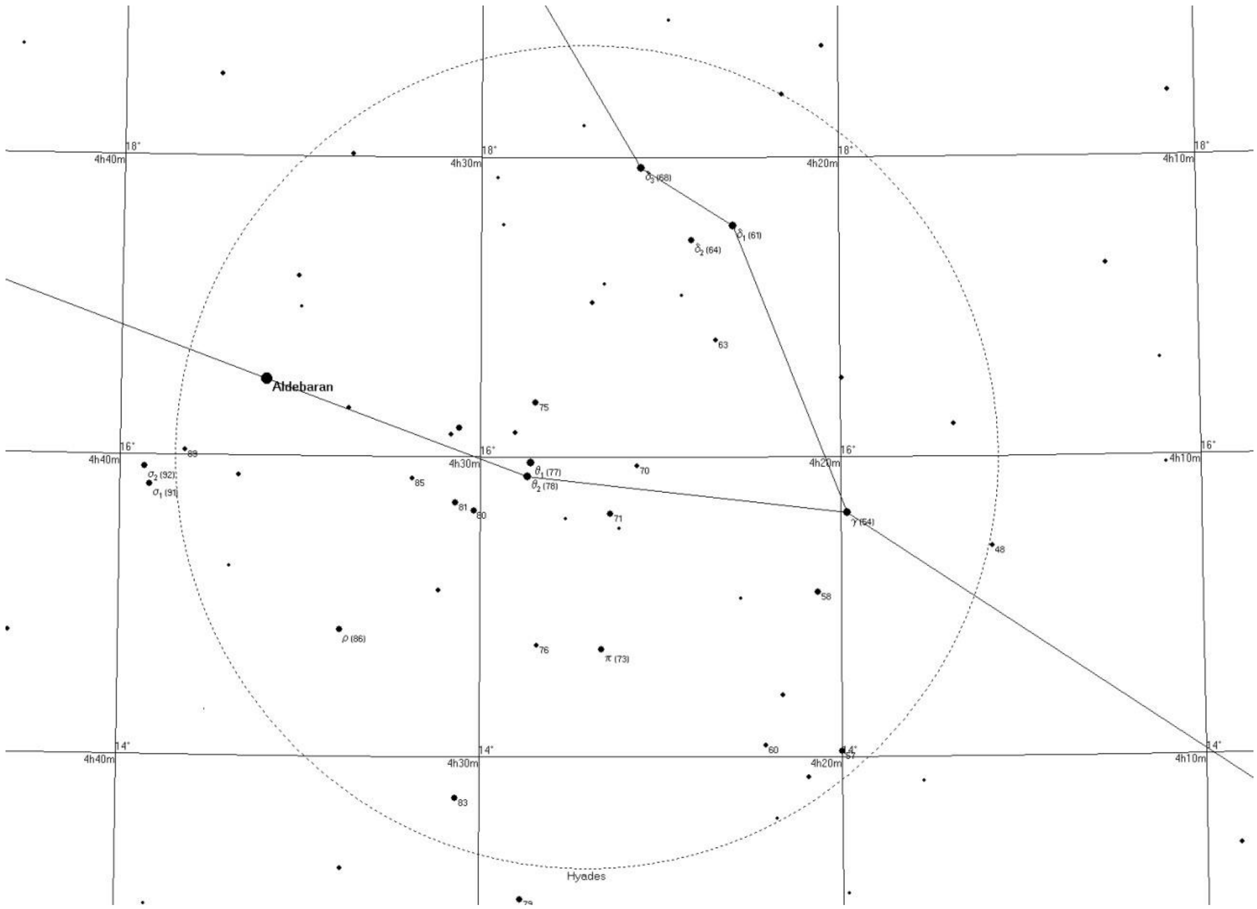
Isochrone (same time)

This is the locus of points on the Hertzprung-Russell diagram of stars all having the same age, calculated theoretically. Note that this is not the same word as isochron, coined by geochronologists.

Introduction

Stars are not distributed in the sky at random. Many stars are found in clusters, identified by being (mostly) in the same part of the sky. They move as a group, and are evidently of the same age, suggesting a common origin in time and space. Most of what we know about stellar evolution comes from the study of clusters of different ages.

The closest galactic cluster is the Hyades in Taurus, and contains over 200 stars at last count, including a couple of brown dwarfs. It is very well studied because it is used as the first rung on the distance scale for the universe. The figure below shows the brighter stars of the central part of the Hyades. The brightest star in the field, Aldebaran, is not a member of the Hyades. It is a foreground star.



Actually, a cluster that is even closer is the one that we are in the middle of. Cluster members include Sirius, five stars in the Big Dipper and several other stars. The Sun itself is not a member of the group; it is just passing through.

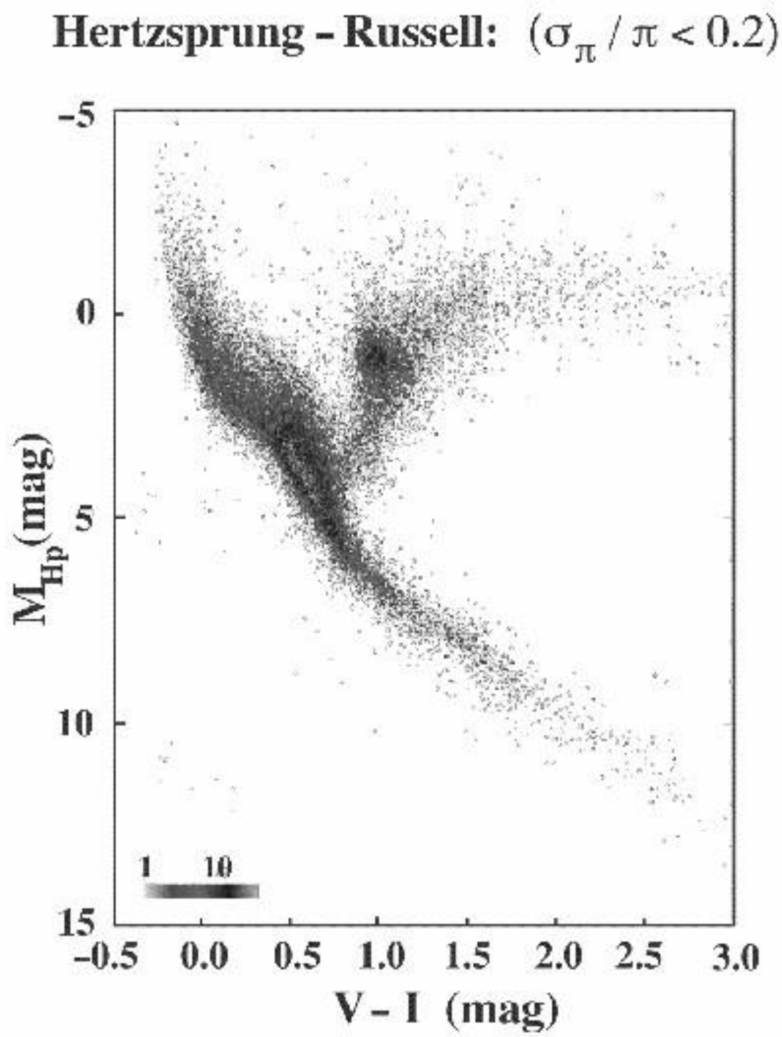
The youngest known cluster is in the Orion Nebula. The most massive stars have already moved off of the main sequence, while the least massive stars have not yet reached the main sequence. The age is estimated at two million years.

The oldest known clusters are the globular clusters which orbit the galaxy and are massive enough to retain their identity over an age of over ten billion years, which is comparable to the age of the galaxy itself.

Next, we examine the Hertsprung-Russell diagram. Typically, the vertical axis is the luminosity in units of the luminosity of the Sun, increasing upwards, while the horizontal axis is given as surface temperature, increasing towards the left. More generally, some brightness unit is represented on the vertical axis, while some measure of color is represented on the horizontal axis.

When stars are plotted on a Hertzprung-Russell diagram, we find that about 90% of stars fall along a stripe, the main sequence. These are the stars that are burning hydrogen to helium in their cores. The brighter stars are the more massive stars, which burn (and burn out) faster. While on the main sequence stars don't change much in their appearance. The remaining stars are doing something else, like burning helium in their cores (giants) or just cooling off (white dwarfs).

The most accurate Hertzprung-Russell diagram is made from the Hipparcos star catalog, currently the best source of stellar distances. The distances are required to obtain absolute magnitudes. It is shown below. Super giants and red dwarfs are missing for lack of accurate data, but the main sequence, giants and a few white dwarfs are apparent.



In order to make the Hertzprung-Russell diagram on the preceding page, the following steps were undertaken:

1) Select those stars in the Hipparcos catalog whose parallaxes are known to an accuracy of 20% or better.

2) Find the distance to each star in step 1).

$$d = \text{distance in parsecs} = \frac{1}{\text{parallax in seconds of arc}}$$

3) Find the distance modulus, (m-M) using the definition

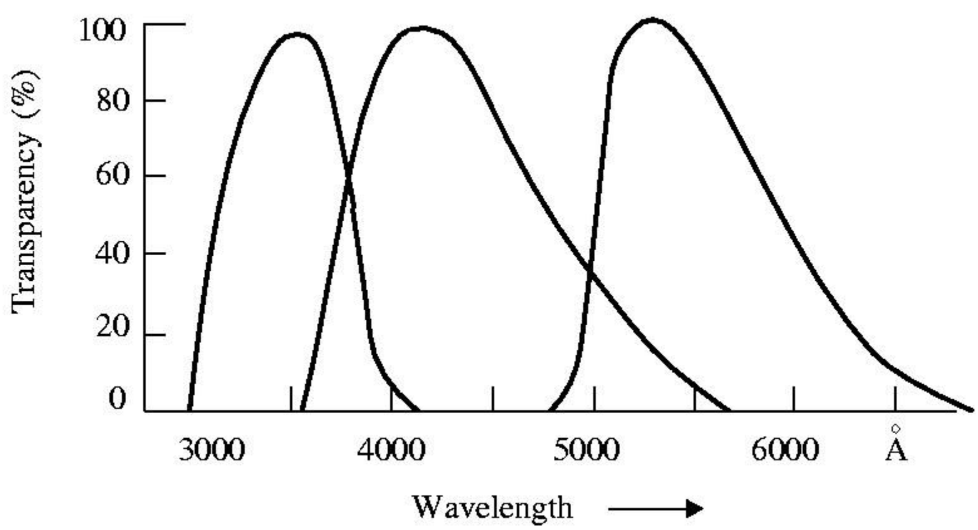
$$m - M = 5 \log d$$

4) Calculate M from the observed magnitude and the relationship

$$M = m - (m - M)$$

5) Find a color index from the list of observed magnitudes. The choice here is m_I-m_V.

Plot the points. There are about 100,000 of them. Color indices are found from observed magnitudes in different wave length bands. The bands are actually rather broad, and reflect the response to light of certain photographic emulsions.



An accurate set of curves (U, B, V) is shown above.

In this experiment, we will reverse the calculation shown on the previous page.

1) Select a part of the sky containing a galactic cluster. Select the data m_V, m_B and the proper motion for each star in the area from the TYCHO-2 catalog (the best source of this data)

2) Edit the star list, retaining only those stars that have the correct proper motion.

3) Prepare a Hertzprung-Russell diagram with m_V as the vertical axis and m_B-m_V as the horizontal axis. Plot each star.

4) Superimpose an Hertzprung-Russell diagram containing an isochrone with M_V as the vertical axis and M_B-M_V = m_B-m_V as the horizontal axis.

5) Shift the Hertzprung-Russ ell diagrams from steps 3) and 4) vertically so as to obtain a match with the main sequence.

6) Record the distance modulus, m-M.

7) Find the distance to the cluster using the formula

$$d = 10 \ parsecs \times 10^{(m-M)/5}$$

8) The age can be found by choosing the isochrone that best matches the observed stars, in particular the turnoff point, where stars start leaving the main sequence to become giants.

This process is error prone, but has much improved in recent years. You will be using the best available theoretical isochrones and star catalogs for this kind of work, which is a hot topic in the current literature.

Computer Program

Step 1) Please enter your name(s) and click the OK button.

Step 2) Choose the Star Cluster for the experiment and click the OK but ton.

Step 3) Choose the cluster age Log (Age/Year) and click the OK but ton.

Step 4) Edit the star map. Use a left button mouse click to remove a star. Use a right button mouse click to restore the last star removed. If you make too many mistakes a right button mouse click with the Shift key pressed will restore all the stars. Remove stars that are not cluster members, as indicated by their proper motions.

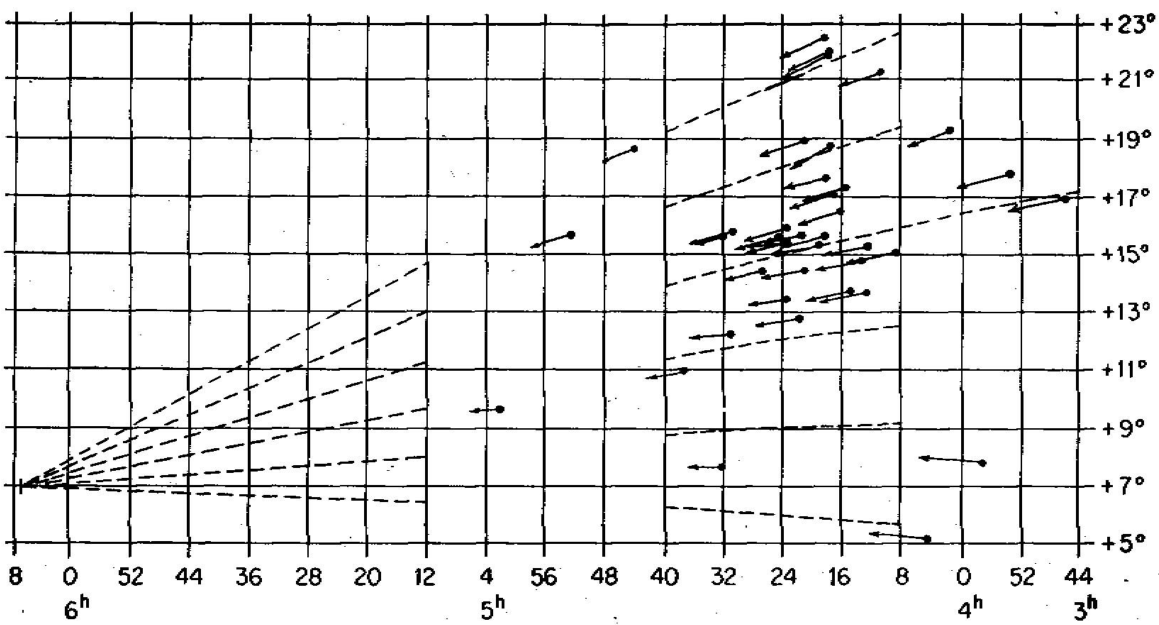
Step 5) Shift the distance modulus (m-M) by left button mouse drag on the slider to the far right to get the best match between the calculated values and the observed stars. Repeat steps 3) - 5) As needed.

Step 6) Click on the Print menu entry to print your results.

Questions

Name ______________________________ Section ___________ Date __________

1) A careful plot of the proper motions of the hyades (below) shows that the paths converge. What does this tell you about the mot ion of these stars in three dimensions?



2) What would be the effect of interstellar gas and dust on the placement of a star in the HR diagram?

3) What would be the effect of a star being an undiscovered double star on the placement of the system in an HR diagram?