AGES AND DISTANCES OF STAR CLUSTERS

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OBJECTIVES

After completing this exercise the student will be able to:

1. estimate the distance to a cluster using main sequence fitting.
2. correct the distance for interstellar reddening and absorption.
3. estimate the age of a cluster from the main sequence turn-off point.

STUDENT MATERIALS

pencil
calculator

LAB MATERIALS

extra transparent overlays

STUDENT REQUIREMENTS

This lab is to be done individually, without lab partners. After completion, turn in data table and the answers to the questions.

INTRODUCTION

Much of our understanding of the characteristics of individual stars is resultant from an application of our knowledge about clusters of stars. While investigating various types of clusters, we make certain reasonable assumptions about the stars found in each specific cluster. For instance, if we assume all of the stars in a given cluster began to form at approximately the same time, and that a given cluster formed from the same cloud of gas and dust, we can assume that the composition of these component stars will be alike. Also, relative to the size of the cluster and its distance away from us, all of the stars within a cluster can be considered to be approximately the same distance from us. Thus, if interstellar reddening is present, all of the stars in a given cluster should be affected to the same degree. We can also determine the approximate evolutionary age of a star cluster, and further, we can compare clusters to final differences in their ages and compositions.

This lab exercise will be concerned with determining the approximate ages of various star clusters, determining the distances to them, and noting the effects that interstellar reddening has on the distance estimate made for each.

PROCEDURE

Example: The cluster M45 (Pleiades) has been plotted in **Fig. 1** as a color magnitude diagram, which is similar to an H-R diagram (except for the use of different scales). **V** represents the apparent magnitude of each star and **B – V** represents the color index of each star, and is equivalent to temperature of spectral class. The main sequence of this cluster should be evident from the plot.

The transparency overlay provided is a graph of absolute magnitude, **M**, versus the corrected color index (**B – V**). On it is plotted the theoretical Zero Age Main Sequence (ZAMS) line of unevolved stars, and also a series of isochrones (lines of equal time) with their respective age estimates. For instance, if a star cluster is approximately 20 million years old (2×10^7 yrs.), the upper main sequence stars in the cluster will appear to lie along this line evolving away from the main sequence and going toward the red giant region. The remaining stars in the cluster below this turn-off point will be on or near the main sequence. This is because the upper main sequence stars (more massive) evolve faster than the lower main sequence stars (less massive).

STEP 1: Alignment

Place the overlay (overlay is in packet at the back of this book) on top of the Pleiades plot, lining up the corrected color index (**B** – **V**) scale of the overlay with the corrected (**B** – **V**) scale printed along the top of the Pleiades diagram. Note that the 0.0 points at the bottom of the overlay and on the cluster diagram do not necessarily coincide. This will be discussed later.

The overlay can now be moved only in the ***vertical direction*** along the corrected 0.0 (**B** – **V**) line. In order to align the cluster main sequence stars with the ZAMS line, move the overlay along this 0.0 line until the ZAMS line falls approximatelyone-third of the way from the bottom side of the plotted main sequence stars of the cluster. In other words, slide the transparent overlay up or down until its ZAMS is running along the middle of the Pleiades main sequence; then lower the transparency's ZAMS until more main sequence is above than below it.

STEP 2: Distance Modulus and Distance

Now that the position of the overlay has been established it is possible to determine the difference in magnitude between the observed apparent magnitudes **V** of the cluster and their theoretical absolute magnitudes, **M**. Look at where the overlay's value of **M** = 0.0 crosses the **V** axis of the cluster diagram directly under it. This should be around 5.6 or so. Thus, the distance modulus to the Pleiades is **V** – **M** = 5.6 – 0.0 = 5.6, approximately. Look up the distance modulus value of 5.6 on the graph of distance vs. distance modulus in **Fig. 11** and estimate the distance to the Pleiades. Record both the distance modulus and the distance to the Pleiades in the data table.

STEP 3: Cluster Age Estimate

With the ZAMS still aligned with the cluster's main sequence, find where the stars in the cluster's main sequence appear to be turning away from the ZAMS. Where they turn off is an indication that they are completing their main sequence lifetime. If we assume that all the stars formed at the same time then an estimate of the lifetimes of these massive stars gives an age estimate for the cluster as a whole. Follow the cluster's main sequence until it starts following one of the age isochrones to the right. Read off the age estimate for this isochrone. Selected ages have been given, so a cluster will not necessarily fall exactly on one of these isochrones. Estimate the cluster age using the selected isochrones as a guideline only. Record your answer in the table.

STEP 4: Interstellar Reddening

On some of the cluster graphs it is apparent that the (**B** – **V**) corrected color index scale on top and the (**B** – **V**) uncorrected color index scale on the bottom do not coincide with each other. The overlay zero point will either be aligned or shifted to the right on the bottom scale. You are to determine how much, if any, the scales have been shifted with respect to each other (a positive decimal number). The shift in the two scales is called the ***color excess*** (CE), or difference between the observed and actual color index of the star in the cluster. Record this number in your table.

The interstellar absorption factor **A** (the number of magnitudes absorbed by dust) is simply three times the color excess, which you have just recorded. Find the interstellar absorption factor **A** = (3 × CE) and record this in the table. If interstellar absorption is present, **A** will be some positive number; if not, **A** will be zero. If there is interstellar absorption, the distance to the cluster will have to be corrected. This is very easily done by subtracting the value **A** from the distance modulus previously found and written in column one of the data table. In other words,

$$\textbf{corrected distance modulus} = (\mathbf{V} - \mathbf{M_V}) - \mathbf{A}$$

Record the corrected distance modulus in your table; refer again to the graph of distance vs. distance modulus and find the corrected distance to the cluster. Record this new distance in your table for the cluster. Repeat steps 1 - 4 for the remaining clusters, recording your answers as you go along on the accompanying answer sheet.

AGES AND DISTANCES OF STAR CLUSTERS

NAME: ______________________

SECTION: ______________________

CLUSTER	distance modulus $V - M_v$	estimated age (years)	distance d(pcs)	color excess CE	absorption factor $A = 3\times CE$	corrected distance modulus $(V - M_v) - A$	corrected distance d(pcs)
M45 Pleiades							
NGC 6791							
NGC 6705							
NGC 2632 M-44 Praesepe							
NGC 2682 M67							
NGC 457							
IC 4725 M25							
NGC 752							
Mel 20 α Per							
Orion OB-1							

M45 (Pleiades)

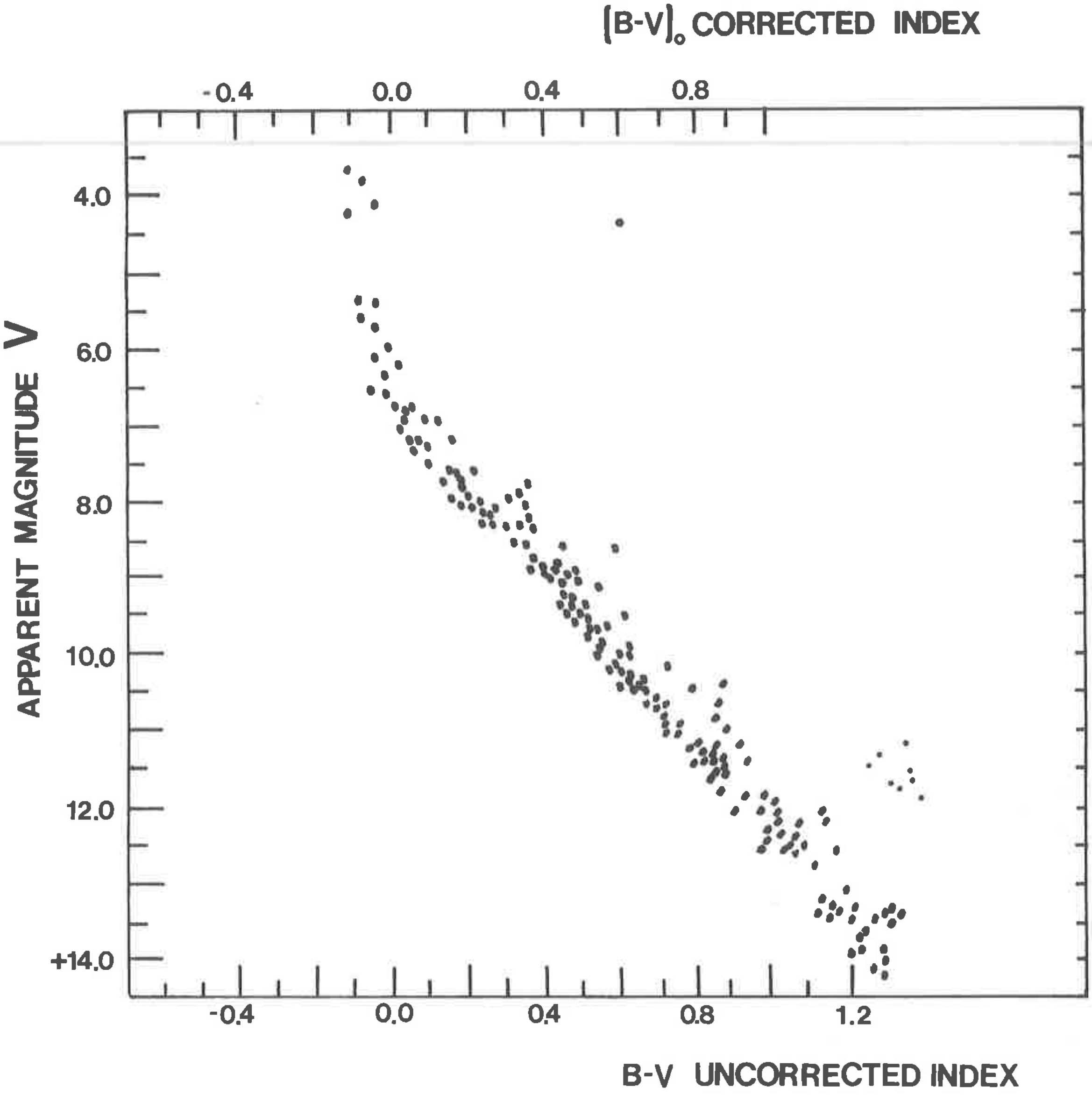

Fig. 1: H-R diagram for the Pleiades.

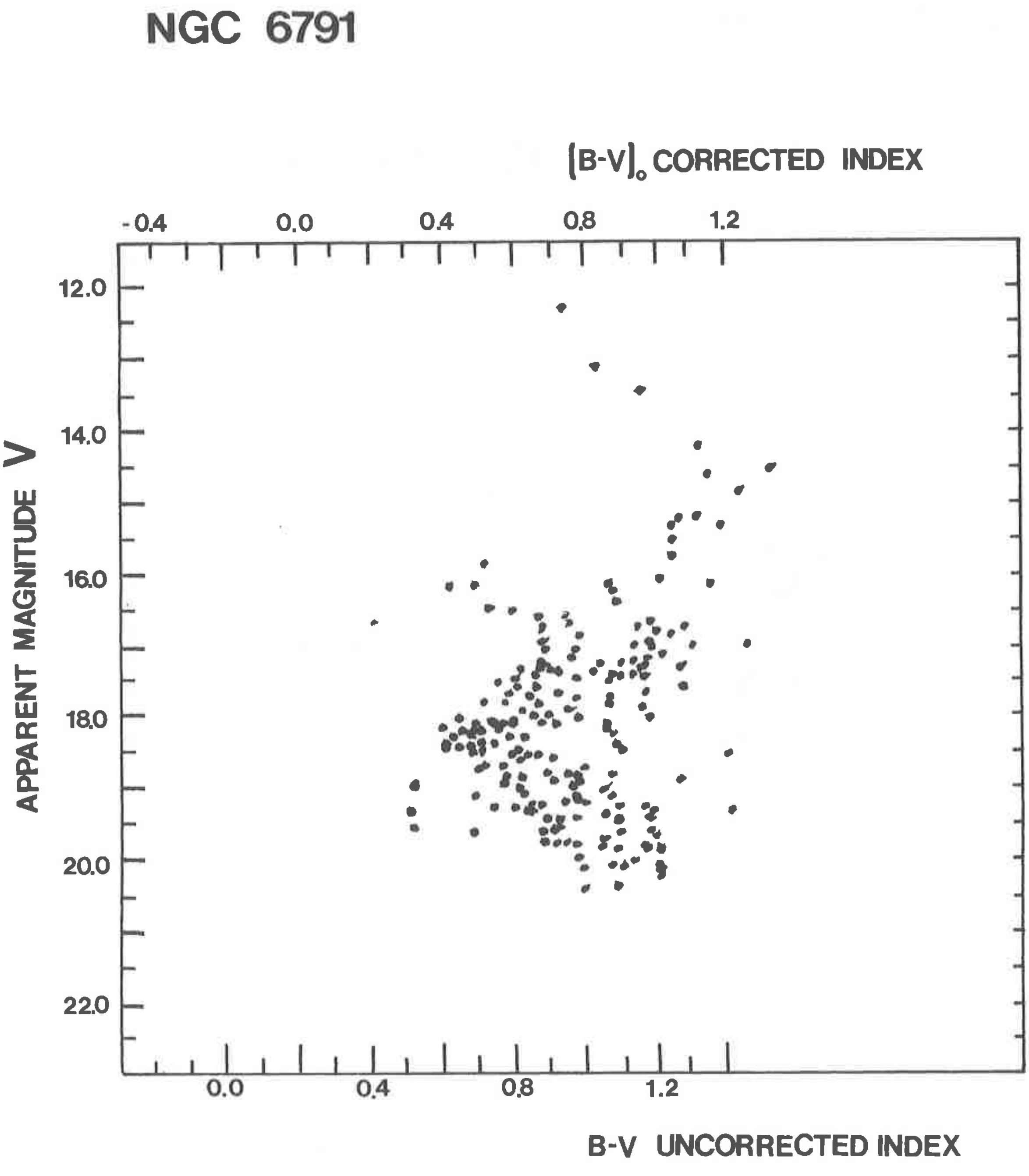

Fig. 2: H-R diagram for NGC 6791.

NGC 6705 (M 11)

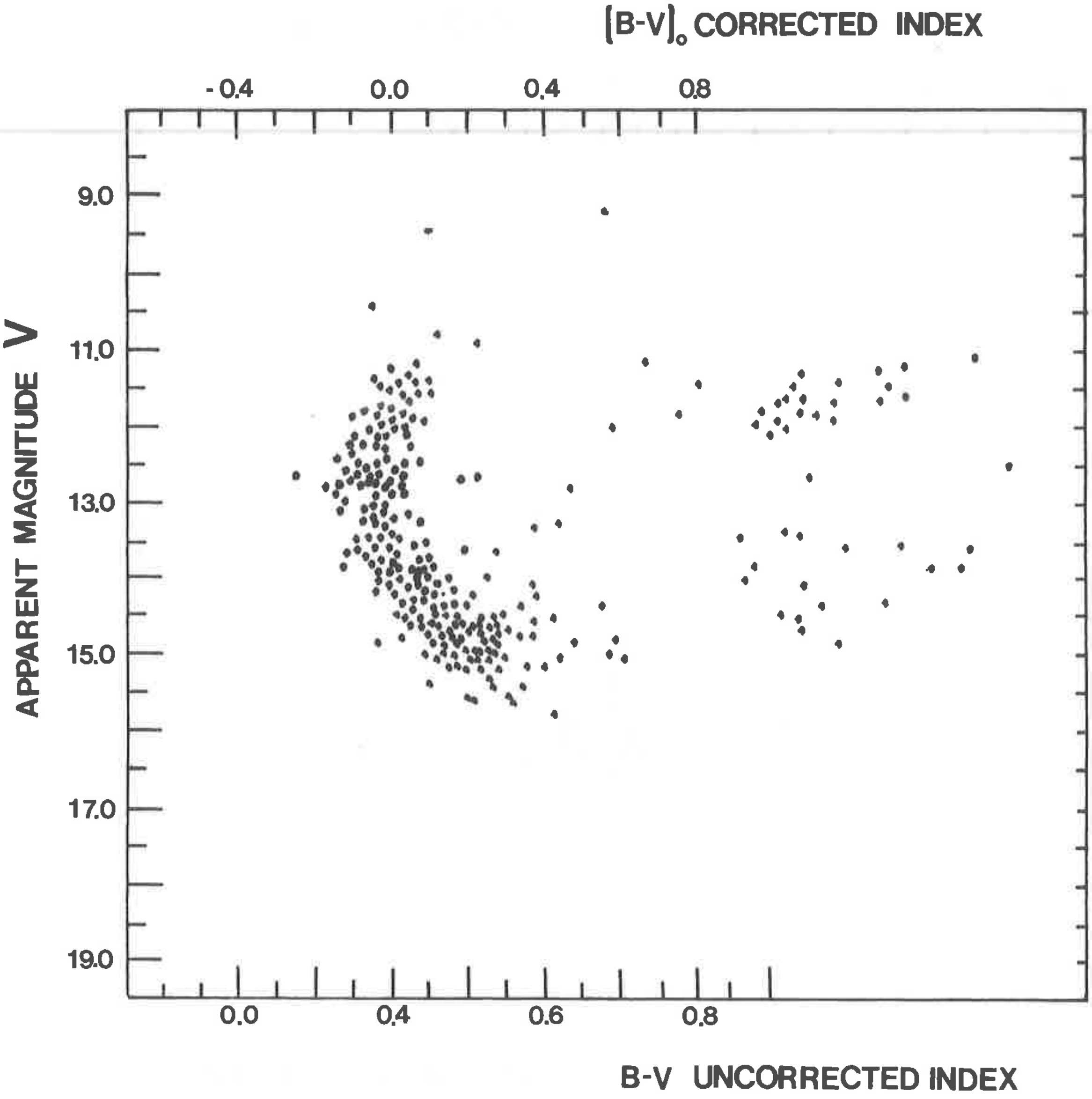

Fig. 3: H-R diagram for NGC 6705.

NGC 2632 (M44-Praesepe)

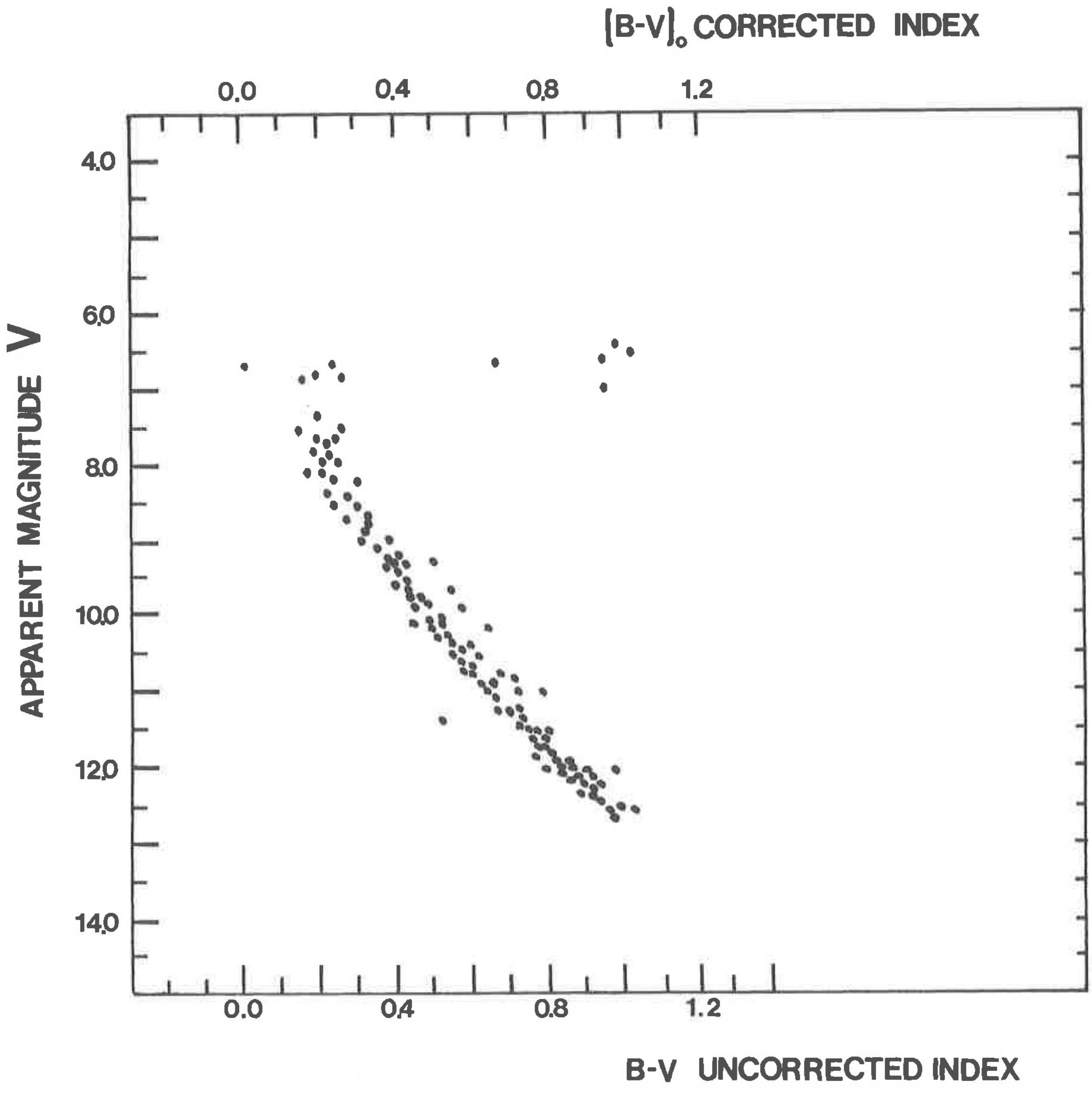

Fig. 4: H-R diagram for the Praesepe.

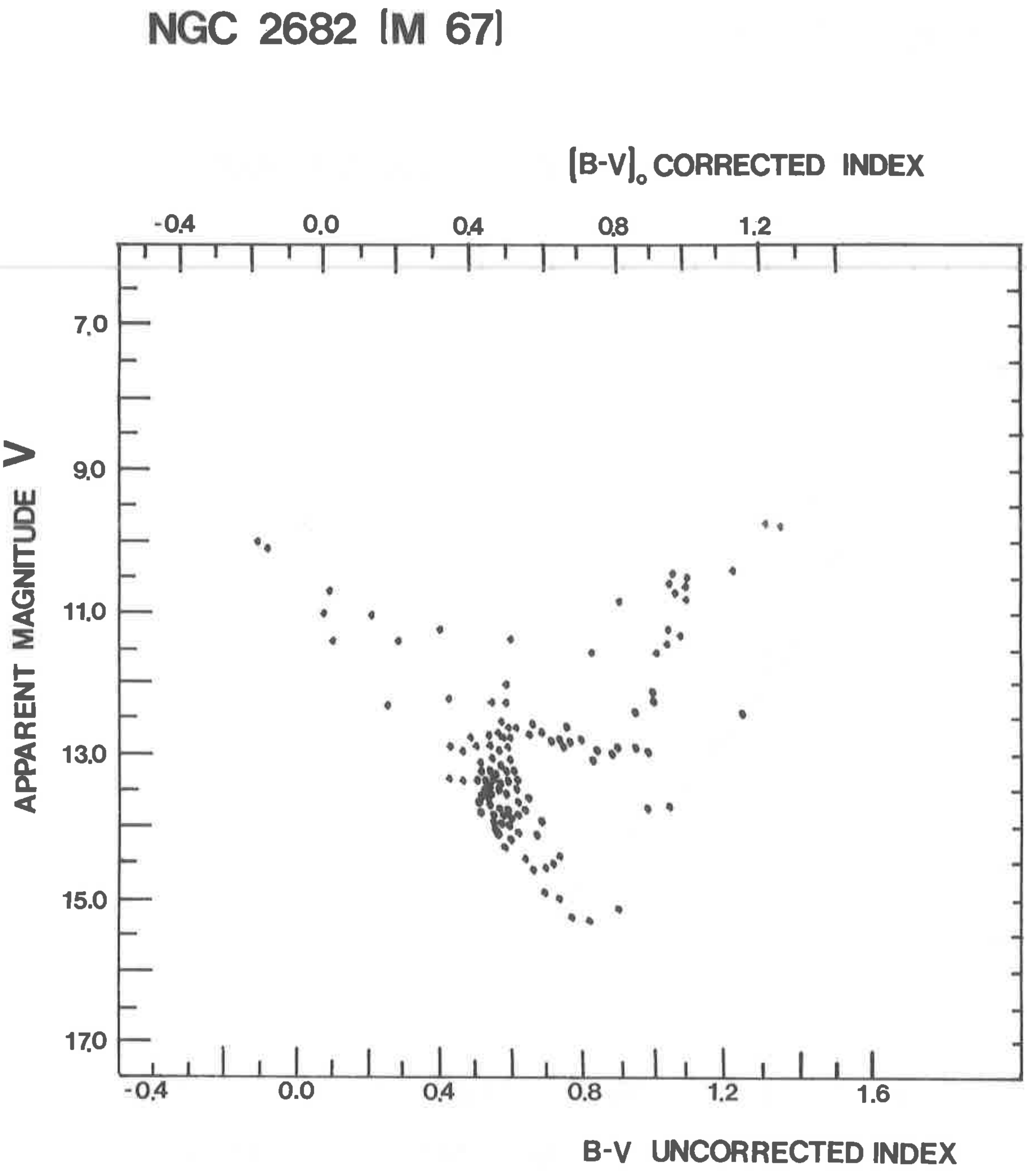

Fig. 5: H-R diagram for M67.

NGC 457

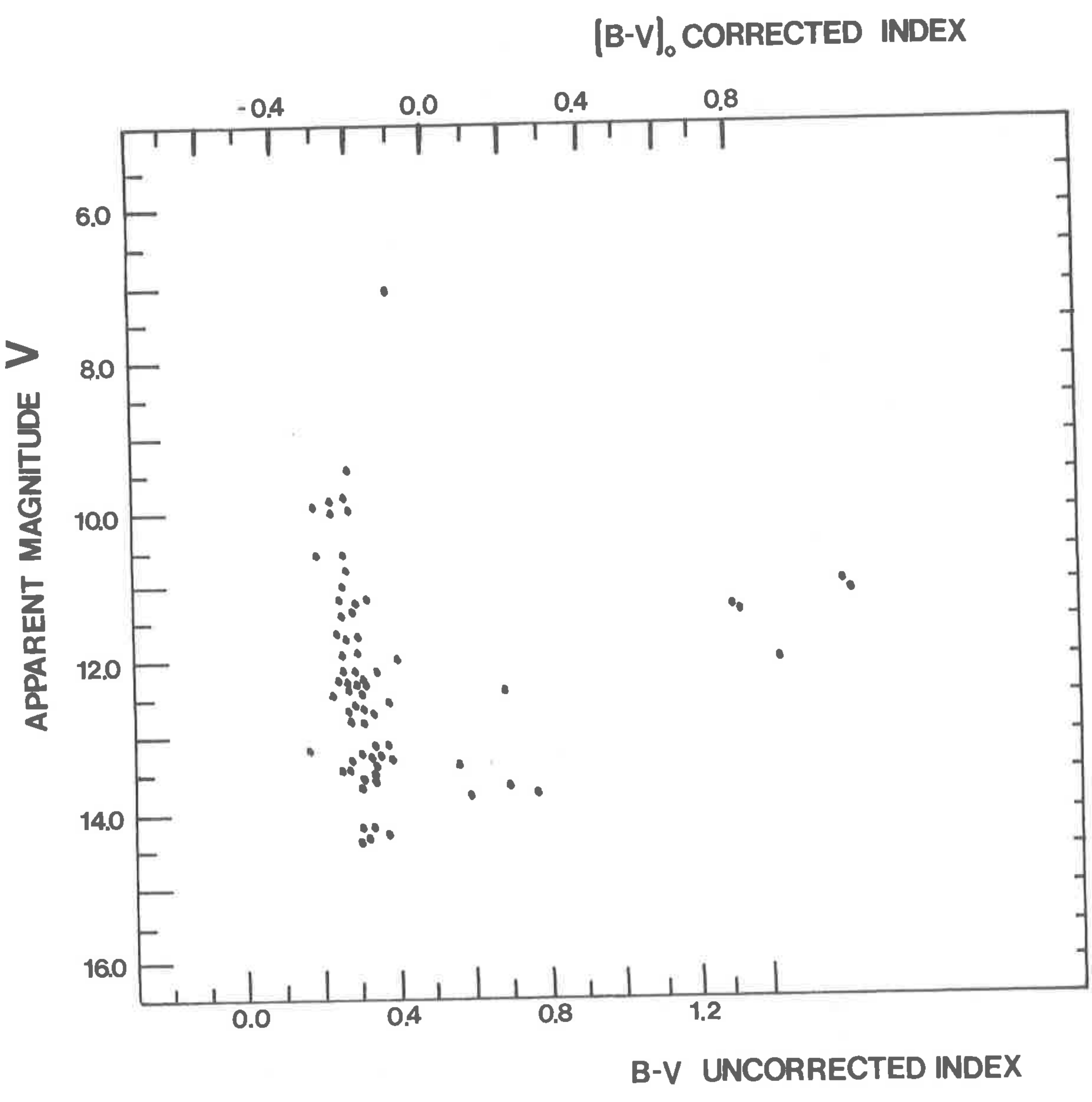

Fig. 6: H-R diagram for NGC 457.

IC 4725 (M 25)

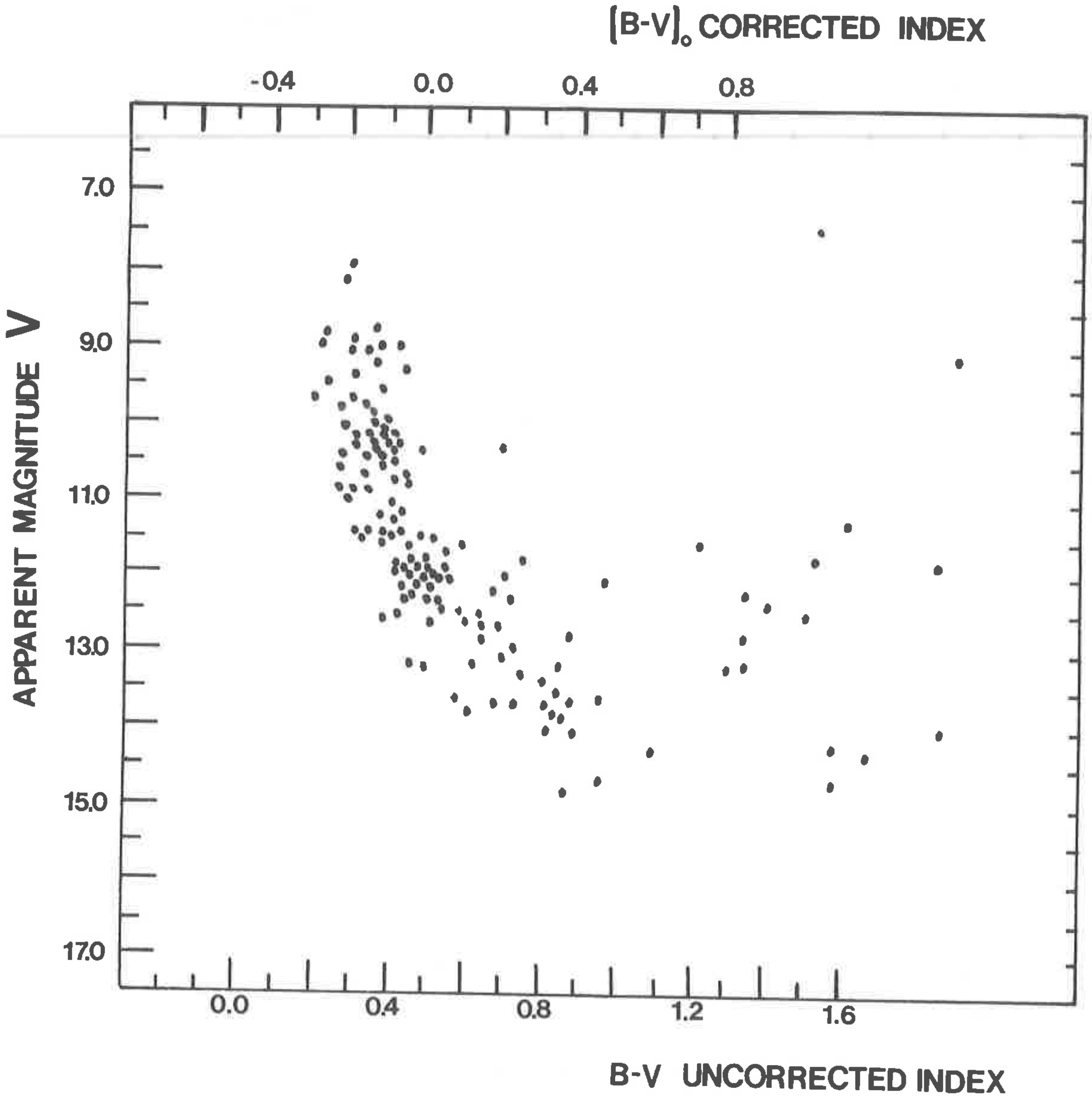

Fig 7: H-R diagram for M25.

NGC 752

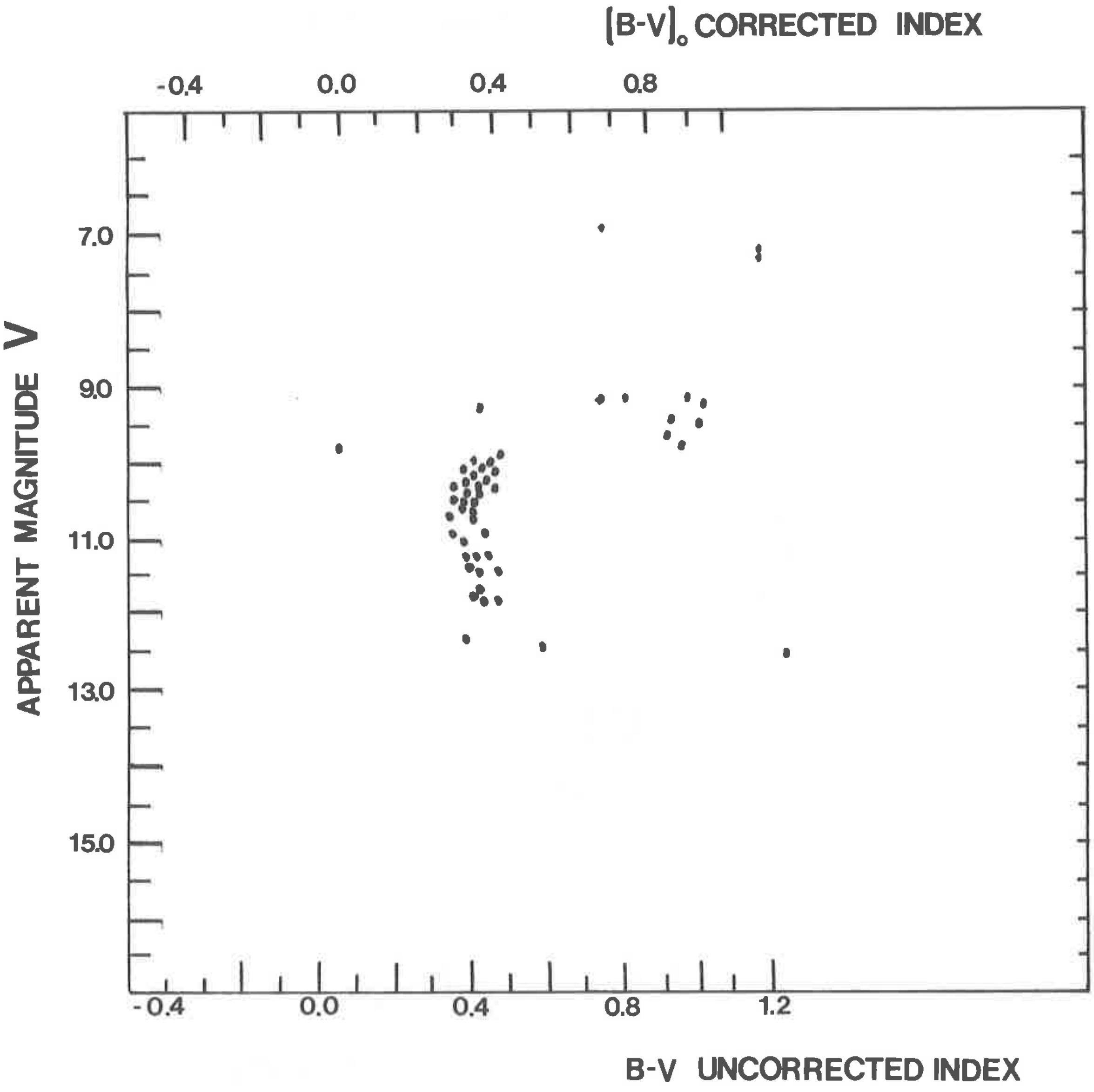

Fig 8: H-R diagram for NGC 752.

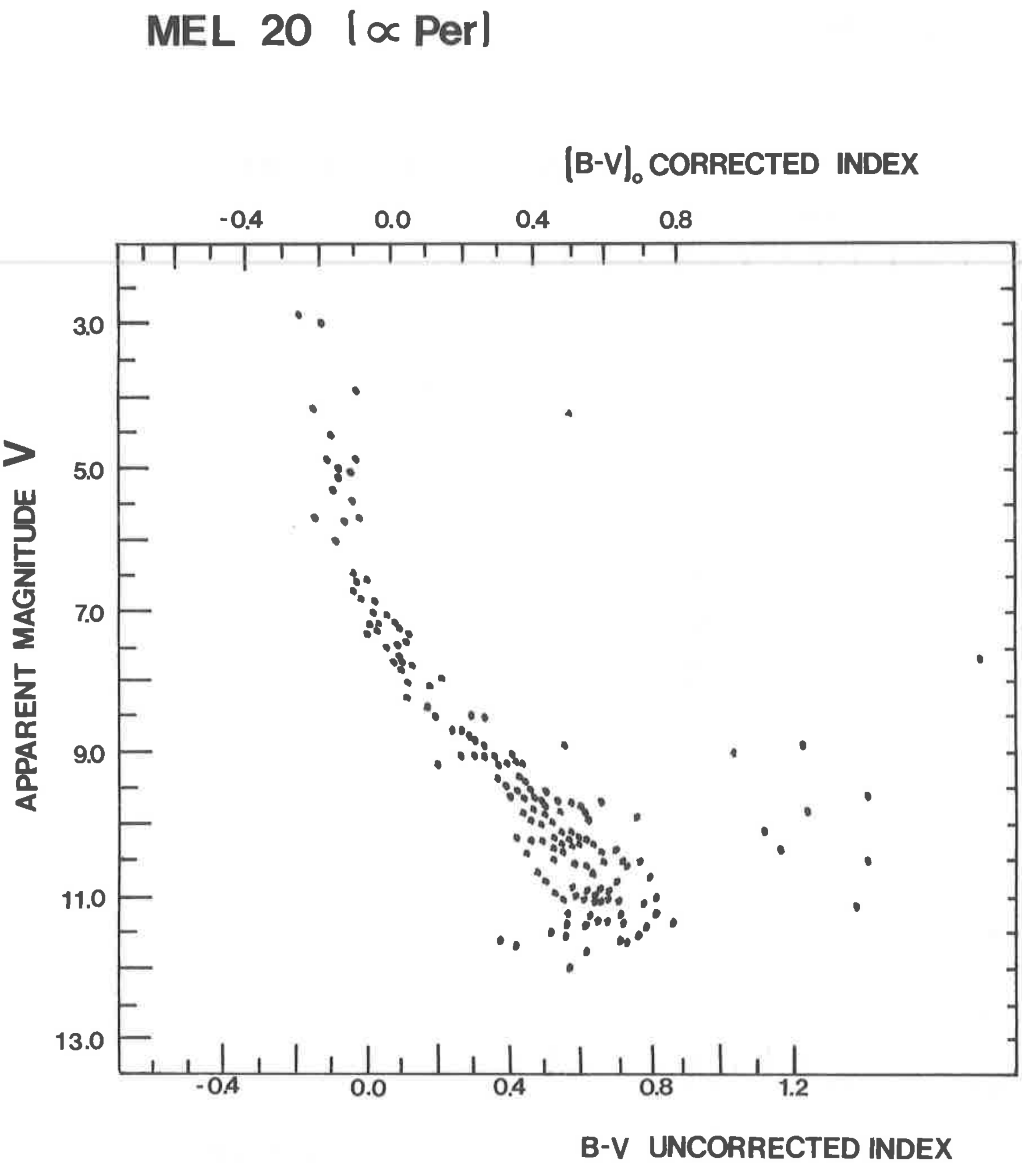

Fig 9: H-R diagram for α Persei.

Orion OB-1

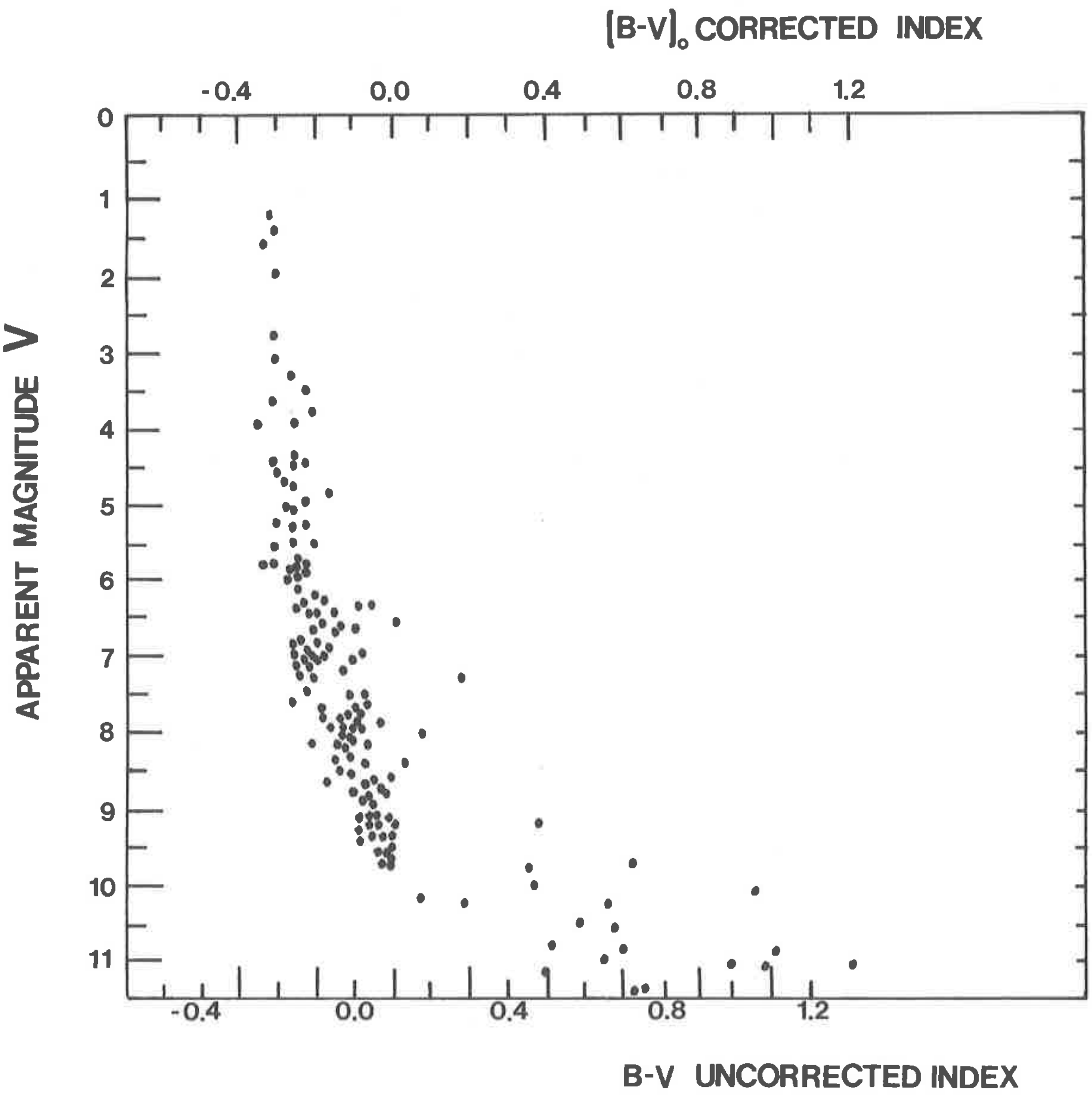

Fig 10: H-R diagram for Orion OB-1.

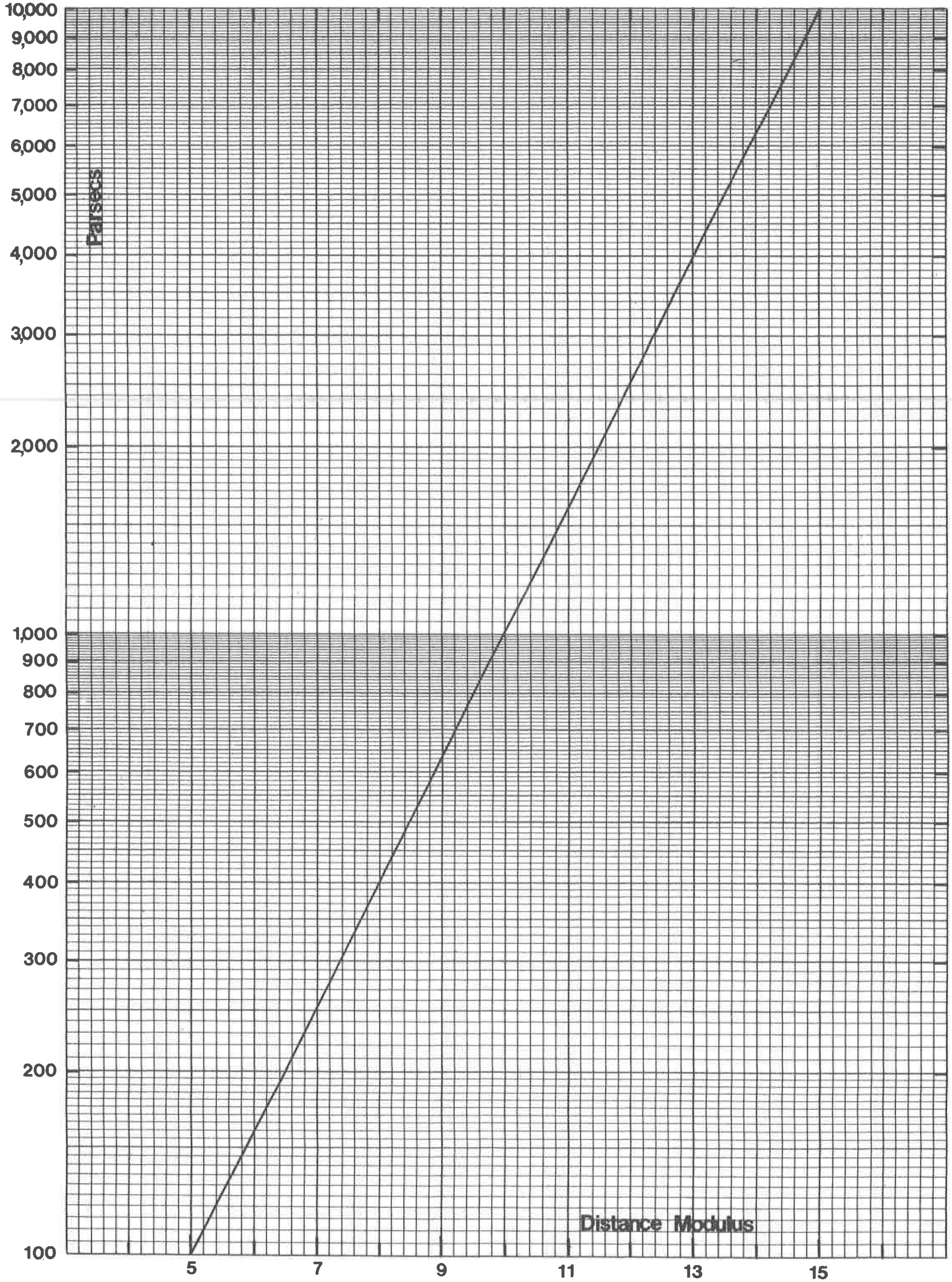

Fig. 11: A plot of parsecs vs. distance modulus.