VISUAL BINARIES AND THE CALIBRATION OF THE MAIN SEQUENCE

Karl D. Rakos

Institute for Astronomy Vienna

ABSTRACT. 147 of the best known visual binary stars have been used for an independent calibration of the main sequence in the interval $-0^{m}.15 < B-V < 0^{m}.80$. The ($M_V$, B-V) diagram is found to be equal to the composite open cluster diagram for the age group between 8.35 and 8.43 x 10^8 years - very hot stars excepted. The cosmic scatter of the main sequence is discussed. It appears that only a small number of visual binaries in our sample are simple binary systems.

1. INTRODUCTION

In the past there were a number of calibrations of the absolute magnitudes of the main sequence stars. The use of visual binaries provides an independent method for calibration. Usually the components of a binary system have different spectral types, but the difference in their apparent magnitudes mostly reflects the difference in their luminosities. In this way the absolute magnitudes of primaries can be found from the luminosities of the secondaries and vice versa. Starting with the best known calibration of the lower part of the main sequence, the shape of the sequence can be improved independently of the parallax of the binary system used. The systematic error along the main sequence will be minimized.

2. CALCULATION PROCEDURE

However, the best known binary systems were not used for the investigations until now. The components are too close together and therefore not suitable for classical photoelectric photometry. In particular the complete lack of B-V colors for components closer than 5 arc sec prevents the use of this group of stars - usually provided with reasonable orbits and distances - for the calibration. For the past few years it has been possible, by means of the area scanner technique, to measure the difference in brightness for binaries as

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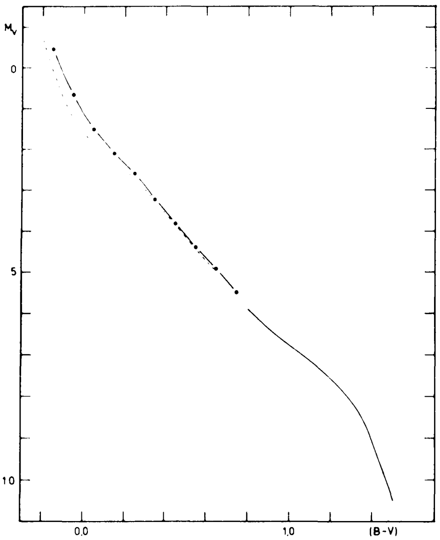

Fig. 1. (See text).

THE MAIN SEQUENCE

B-V	M_V
$-0^m\!.15$	$-0^m\!.44$
-0.05	0.66
0.05	1.51
0.15	2.10
0.25	2.58
0.35	3.23
0.45	3.82
0.55	4.40
0.65	4.92
0.75	5.50

close as 0.5 sec of arc with a high degree of accuracy. Observations of this type for a total of 215 double stars, published by Rakos et al. (1982), have been considered. An additional 28 visual binaries with larger separations measured by Lutz (1971) at KPNO and 153 binaries observed by Hurly and Warner (1982) at Cape Town have been added for analysis. In general the standard deviation for a typical B-V value does not exceed 0.05 magnitudes. The same is true for the difference of the V magnitudes of the components. The accuracy is more than an order of magnitude higher than the cosmic scatter in the main sequence. The quality of the calibration therefore depends on the good statistical sample used in the analysis and not on the accuracy of the individual observations. 147 systems with components on the main sequence have been selected for analysis.

For this reason we start from the main sequence for red stars found by Gliese (1982) from his catalogue of nearby stars. Because the main sequence lifetimes of these late type stars are greater than the age of the galaxy, this sample is free from evolutionary effects. In the HR diagram, see Figure 1, this sequence is a solid line for colors between $1^m\!.60>B\text{-}V>0^m\!.80$. We start with the assumption that the absolute magnitude of a secondary component of a binary system is exactly the tabular value for that B-V. The difference in the magnitudes of the components is then subtracted from this absolute magnitude yielding the absolute magnitude of the primary component. This procedure was applied to those binaries with secondaries in the interval $0^m\!.80<B\text{-}V<1^m\!.60$. The first components of these binaries define a continuation of the main sequence toward higher temperatures. We continued the procedure using the secondaries with higher and higher temperatures. The dots in Fig. 1, connected by the solid line, are this new mean sequence. As a check the ZAMS calibration of Mermilliod (1981) was used, and is shown as the broken line in Fig. 1. The complete new mean main sequence is also given in the Table. Comparing the results with the comparative studies of young clusters by Mermilliod (1981b), we find the composite diagram of an age group between 8.35 and 8.43×10^8 years will be most similar to our sequence, very hot stars excepted.

3. COSMIC SCATTER OF THE MAIN SEQUENCE

Double stars are also very suitable for deriving the intrinsic scatter in the luminosities along the main sequence. Several binary systems are composed of components of the same colors. These stars provide direct information on the cosmic scatter. The modern theory of star formation predicts that multiplicity should be the natural configuration in which stars are found. The observed binary frequency along the main sequence is one of the interesting parameters useful in obtaining the luminosity distribution function for multiple star systems. This function is very poorly known, and the results of several investigations - due to extreme selection effects - are still controversial, but it is one of the most important touchstones for the theory of star formation.

In our sample 46 binaries have components of the same B-V colors, that is, the difference in the colors is less than or equal to $0\overset{m}{.}03$. From the distribution of ΔV as a function of B-V for these stars it appears that the scatter is homogenous for all values of B-V between A0 and K7. The color versus brightness difference, Fig. 2, and the histogram, Fig. 3, show three different groups of stars. Stars with $\Delta V > 0\overset{m}{.}80$ are hot and evolved from the main sequence. The group around $\Delta V = 0\overset{m}{.}70$ are visual binaries and one of the binary components has a close companion of the type A, B-C, all three components are of equal colors. In the third group the stars with $\Delta V < 0\overset{m}{.}1$ are simple binaries and the deviation in the brightness is introduced by the observing errors, or of intrinsic origin. For $\Delta V > 0.1$ with the peak about $0\overset{m}{.}15$ we have triple systems but the contribution of the small companion to the color of the unresolved system does not exceed $0\overset{m}{.}03$. This third group has the same structure of the histogram for hot and cool stars and is not influenced by the evolutionary effects. It seems that we are able to attribute the observed scatter to the presence of a large number of triple systems among the so called binary stars. Only 6 of the total sample of 46 are probably simple binary systems.

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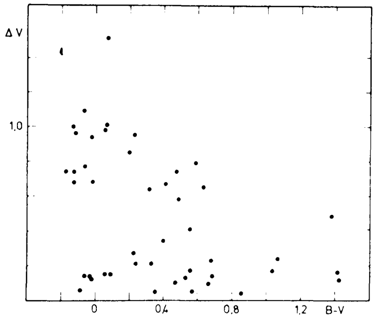

Fig. 2. (see text)

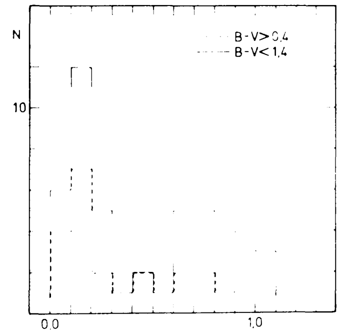

Fig. 3. (see text)

DISCUSSION

GARRISON: I have a question and a comment. The comment is to emphasize the importance of what Corbally has called the "gold zone", that is, binaries with separations of 1 - 5 seconds. These stars are true physical systems, since they are so close, yet they are not so close that there are interactions. Therefore, they are an ideal group for calibration of fundamental quantities.

The question concerns the overlap between your work and that of Hurly. There are only a few stars in the overlap, if I remember correctly, but there is a larger than expected difference in the magnitudes and colors. Can you give us your opinion on the reason for the difference?

RAKOS: The difference can be at least partly attributed to the instrumental effect of the area scanner used by Hurly. When scanning the stars by means of a slit aperture, attention should be paid to the telescope entrance pupil; that is, it must be projected on the same place on the photocathode of the photomultiplier during the scanning cycles. This is possible only by moving the slit aperture in the focal plane of the telescope. Hurly's area scanner violates this principle. I would like to continue my observations in the future. At the moment I am looking for a suitable telescope and the necessary financial support.