PHOTOMETRIC INVESTIGATION OF VISUAL BINARIES WITH A COMPONENT ABOVE THE MAIN SEQUENCE

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Abstract. Visual binaries containing a component above the main sequence in combination with a main-sequence star provide an excellent opportunity for determining absolute magnitudes of evolved stars. Some aspects of this technique are discussed, and preliminary results are presented.

1. INTRODUCTION

Studies of the photometric and spectroscopic properties of visual binaries containing a non-main-sequence star in combination with a main-sequence component have long provided a useful method for determining the luminosities of evolved stars. Well-known examples of such investigations include the pioneering work by Leonard (1921, 1923) and the more recent studies by Bidelman (1958), Eggen (1956, 1965), Slettebak (1963), Stephenson (1960), and Stephenson and Sanwal (1969), the latter representing a comprehensive investigation of the masses of stars above the main sequence.

One difficulty usually encountered by these investigators was the lack of accurate magnitudes or magnitude differences for the components of visual binaries. Good magnitudes of the individual components of double stars available through the work of Johnson (1953) and Eggen (1963) generally remained limited to pairs of angular separation greater than 10 arcsec.

For some closer pairs, magnitude differences measured by visual or photographic techniques were available and were generally taken from the catalog of Wallenquist (1954). In many instances, however, the only magnitude information in existence consisted of the visual estimates listed in the "Aitken Catalog" (1932) and in the *Index Catalogue of Visual Double Stars* (Jeffers *et al.*, 1963). In the case of small magnitude differences, the absence of accurate values should have had little effect on the resulting luminosity determinations of non-main-sequence stars. Large magnitude differences, however, whether estimated or determined by visual techniques, could have errors large enough to have

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caused serious errors in the absolute magnitudes obtained for evolved stars by main-sequence fitting of their dwarf companions. When planning a program of double-star photometry by photoelectric area-scanning, I therefore included in the observing program a representative sample of pairs of this type in order to examine this problem and to provide improved photometric data for its partial solution.

2. THE OBSERVATIONS

While a prototype area scanner developed by Rakos (1965) was used for initial exploratory observations (Franz, 1966), the observational program itself was carried out with an area scanner designed and constructed at the Lowell Observatory. This instrument and the associated data acquisition system in its original configuration have been described in some detail elsewhere (Franz, 1970).

The observing program, started in 1969, contains about 350 objects of which nearly 300 either have been completed or have at least some observations. Among these are more than 100 pairs either previously known or suspected on the basis of the new photometry to contain at least one non-main-sequence component. Some are newly detected variables or variable suspects found as a result of an effort made throughout the program to observe each object on several nights during several observing seasons.

3. RESULTS AND DISCUSSION

For 15 of the pairs previously known and studied as above-the-main sequence objects and sufficiently observed in this investigation, MK classifications given by Stephenson (1960) or Stephenson and Sanwal (1969) show that each pair consists of an evolved star and a main-sequence companion. By fitting their dwarf companions to a standard main sequence according to their MK types, absolute magnitudes and colors for the evolved stars are readily obtained from the observed UBV magnitude differences. Figure 1 shows the Hertzsprung-Russell diagram obtained in this manner for the 15 pairs with the use of the standard main sequence according to Allen (1973). Solid dots denote MK classifications by Stephenson (1960) or Stephenson and Sanwal (1969), while crosses indicate classifications adopted by them from the work of others. Also shown for each evolved star is its assigned luminosity class. The marked lines represent schematically the standard branches of luminosity classes Ib through IV according to Allen (1973). Inspection of Figure 1 shows at once that stars of luminosity class III according to Stephenson (1960) or Stephenson and Sanwal (1969), while forming a well-defined giant branch, *all* lie on the average nearly one magnitude below the standard sequence of luminosity class III giants. Before further examining this discrepancy attention is drawn also to the pairs containing a component of luminosity class IV whose absolute magnitudes are in satisfactory agreement with the mean sequence according to Allen (1973). Also shown in Figure 1 is the position of the Ba-star component of ADS 8448 according to the MK classification and photometry by Culver *et al.* (1977) and that of two M-type supergiants. One of them, namely ADS 10074A (Antares), has recently been classified by White (1981) as M1Iab.

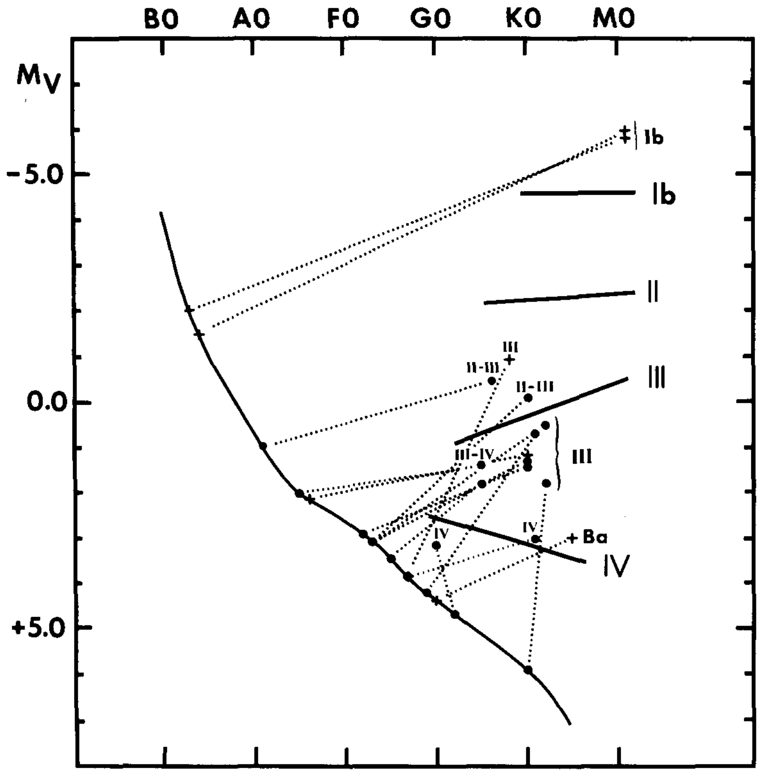

Figure 1. Hertzsprung-Russell diagram of 16 visual binaries consisting of a main-sequence star and an evolved component.

A color (B-V) versus absolute magnitude (M_V) diagram is shown in Figure 2. Note that the supergiant ADS 14864A (HR 8164), whose classification is M1.1Ib according to White and Wing (1978), thus virtually the same as that of Antares A, is much bluer than the latter. This is probably due to the presence in its spectrum of a B-type component (Bidelman, 1954) which would have significant effect upon the (B-V) color but little on the V magnitude. The systematic difference between the newly determined absolute magnitudes of class III giants and the standard giant branch is again readily apparent.

While there could be numerous causes for this discrepancy, one most disturbing would be a difference resulting from the use of two principal calibration techniques, namely luminosity calibrations based upon trigonometric and statistical parallaxes on the one hand, and main-sequence fitting on the other. Fortunately, this problem has only most recently been resolved through the work of Abt (1981) on MK classifications of visual multiple stars. Since only two of the 15 pairs have new classifications by Abt (1981), a star-by-star comparison with previous classifications is not possible. However, in examining systematic and random classification errors, Abt (1981) finds that a comparison of his

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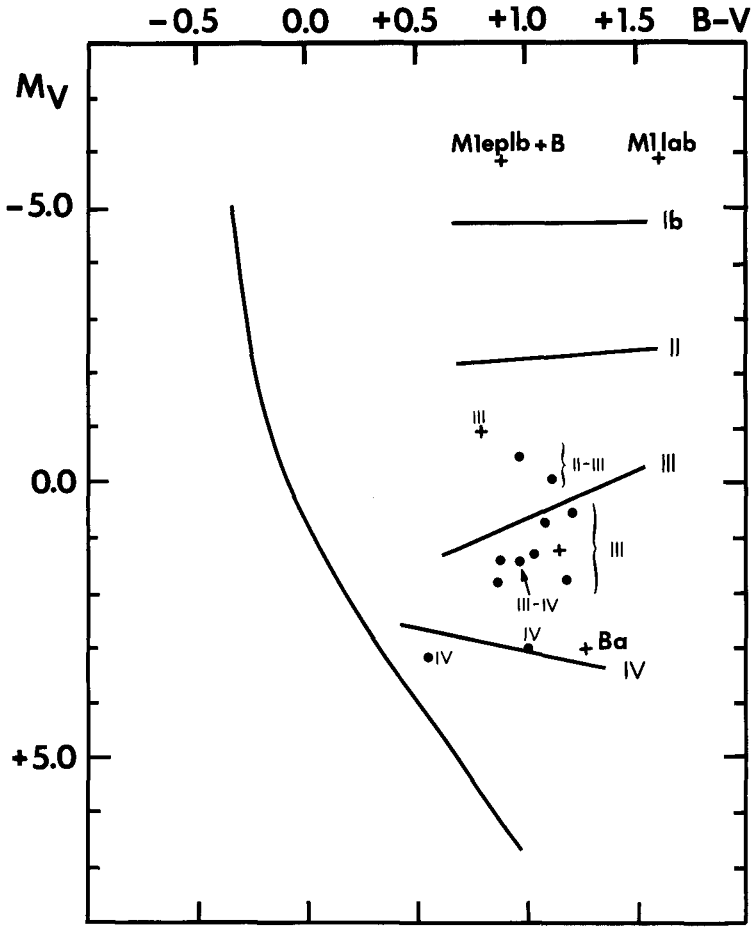

Figure 2. Color (B-V) versus absolute magnitude (M_V) for 16 visual pairs containing a main-sequence component and an evolved star.

classifications with those of Stephenson (1960) and Stephenson and Sanwal (1969) "shows the only fairly convincing systematic difference" in the sense that he assigns luminosity classes that are on the average 0.4 of a luminosity class lower than those obtained by the other investigators. For example, the 31 stars which are contained in both sets of classifications, have non-composite spectra, and have been assigned class III by Stephenson (1960) or Stephenson and Sanwal (1969), have been classified by Abt (1981) as shown in Table I. Clearly, there exists a systematic difference in classifications that can fully account for the discrepancies seen in Figures 1 and 2 between newly determined absolute magnitudes and the published standard sequence for class III giants.

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TABLE I.

LUMINOSITY CLASSES BY ABT (1981)
FOR 31 STARS PREVIOUSLY ASSIGNED L. C. III
BY STEPHENSON (1960) OR STEPHENSON AND SANWAL (1969)

No. of Stars	Abt L. C.
1	II
17	III
2	IIIb
1	III - IV
7	IV
3	V

One may therefore conclude that modern MK classifications made against current MK standards combined with accurate magnitude differences obtained by photoelectric area scanning will produce reliable absolute magnitudes for evolved stars that are members of visual binary systems. To this end, a program is now under way, in collaboration with R. B. Culver, to complete the photometry and to carry out MK classifications of 125 pairs known or suspected to contain a non-main-sequence component. Progress and ultimate completion of the work should add substantially to our knowledge of what has been so aptly chosen by its organizers as the subject of this colloquium.

Acknowledgements

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