SPECTROPHOTOMETRIC STUDIES OF Am STARS

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Abstract. The relationships among the various physical parameters – namely, the effective temperatures, radii and bolometric magnitudes, determined on the basis of the energy distribution curves of 25 Am stars – have been studied. Their effective temperatures are in the range of 7200 K to 9700 K; the radii, 1.5 $R_\odot$ to 2.5 $R_\odot$; the bolometric magnitudes, 0.75 mag. to 2.25 mag.; and the masses, 1.5 $M_\odot$ to 2.25 $M_\odot$. The Am stars in general, appear redder than their normal counterparts, the blanketing in the blue and UV regions being the major cause. For the relatively cooler stars, the $(B - V)$ colours are found to be less affected by blanketing. They are located in the neighbourhood of the upper edge of the zero-age Main Sequence band and show a fairly wide range in the evolutionary status among themselves. The bolometric corrections which are independent of the uncertainties in the parallax measurements, follow the same trend as that of the Ap stars, with reference to the temperature.

1. Introduction

The effective temperatures, radii, bolometric magnitudes and bolometric corrections for twenty-five Am stars from a homogeneous data of the continuum energy distribution curves are given in our earlier paper (Babu and Shylaja, 1981; hereafter referred to as Paper I). From the results of that paper, it is found that the effective temperatures of Am stars are in the range of 7200 K to 9700 K, while their radii are from 1.5 $R_\odot$ to 2.5 $R_\odot$. On the other hand, their bolometric magnitudes are generally found to be between 0.75 and 2.25 mag. with a few exceptions.

The relationships among these physical parameters as compared to the normal ones, have been studied in detail here.

2. Relationship between Colour and Temperature

Taking the values of $(B - V)$ and θ_e from Paper I, we have plotted Figure 1, in which the temperature scale for the main sequence stars given by Code *et al.* (1976) has also been included. As can be seen from this figure, all the Am stars are on the right-hand side of the Main-Sequence temperature-scale. Thus for any given temperature they appear to be redder than their normal counterparts. This may be attributed to the blanketing in the blue and UV regions, caused by the strong metallic lines, which is true for all Am stars. As may be noted from the results of Am stars in Paper I, such blanketing appreciably influences their B magnitudes, while it does not affect the V magnitudes. Gerbaldi and Morguleff (1975) and Wolff (1967) also have shown that in the longer wavelength regions the blanketing effects are relatively negligible. Thus their $(B - V)$ colours look redder than what they could have been under normal conditions.

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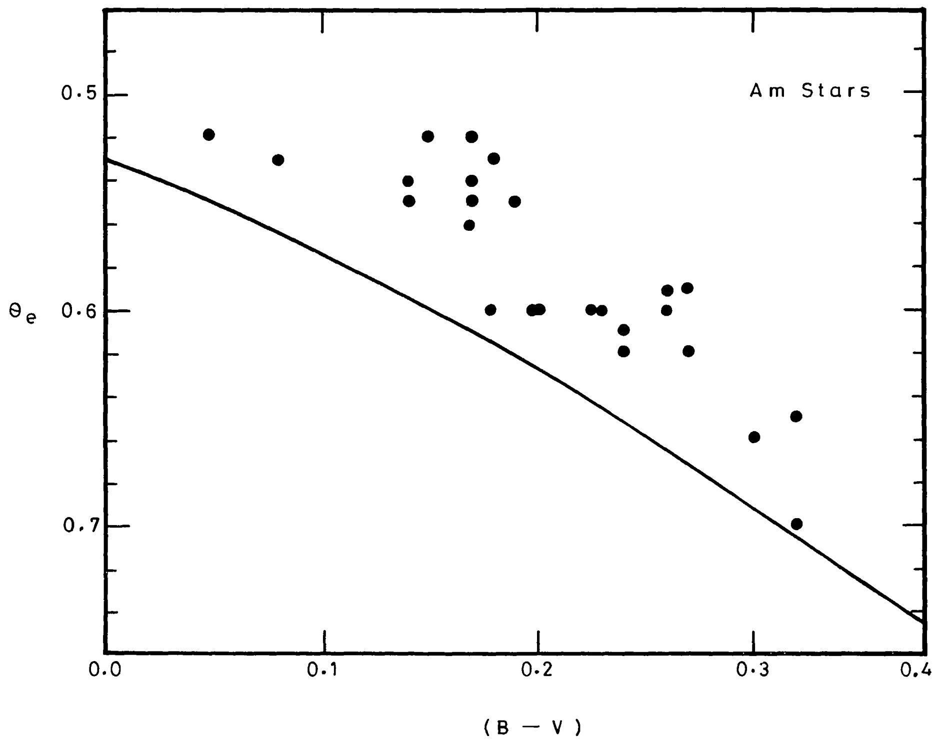

Fig. 1. Relationship between $(B - V)$ colour and θ_e $(= 5040/T_e)$ of Am stars. The temperature scale for the Main-Sequence stars (Code *et al.*, 1976) is shown by the solid line.

Since the temperatures of these stars have been estimated from the energy distributions in the longer wavelength regions only, the deviations in the values of $(B - V)$ from the Main-Sequence temperature-scale in Figure 1 can be treated as a measure of the reddening caused mainly by line blanketing in the shorter wavelength regions. We have termed these deviations as corrections in $(B - V)$ and we have plotted them against θ_e in Figure 2. Though a correlation between the two parameters seems to be apparent, we have not attempted any curve fitting for want of sufficient data. The two stars which do not fit into the trend (denoted by open circles) are given as Am stars of luminosity class IV. However, it may possibly be inferred on the basis of this figure that the abnormal strength of metallic lines in the Am stars which are causing the blanketing in the blue region is perhaps related to the temperature of the given star.

But the quantitative measurements of blanketing, for example from their respective spectra as done by Wolff (1967), may be necessary to confirm the dependence of such reddening on the temperature. Nevertheless, it may not be possible to standardise these measurements, since each star exhibits individuality as far as blanketing is concerned. This may be noticed from the results of Paper I and the Figure 1(b) of Babu and Rautela (1978). In addition, the chemical composition of these stars may introduce further complications.

The interstellar extinction has not been taken into account because of the proximity of the stars to the Sun.

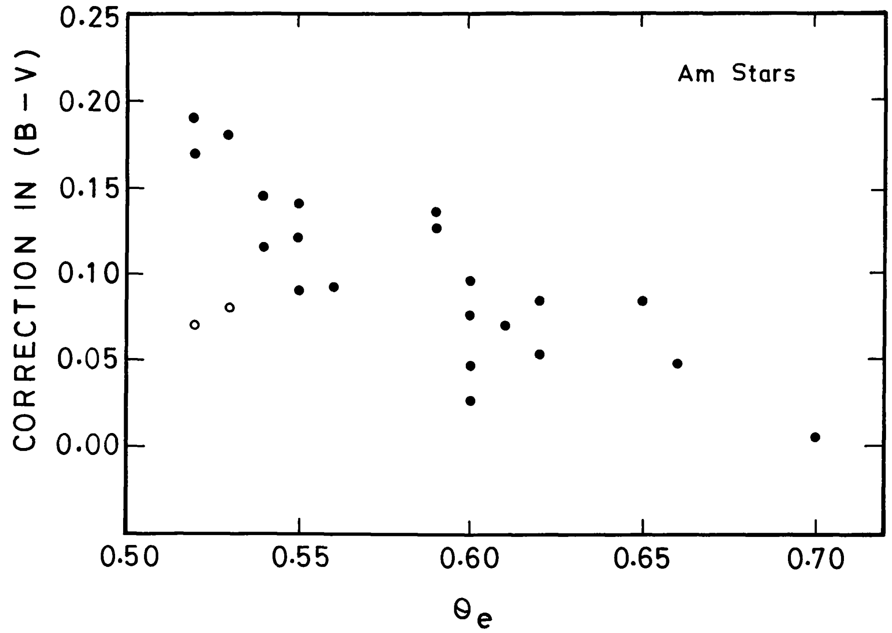

Fig. 2. Relationship between θ_e and corrections in $(B - V)$ for Am stars. The open circles represent Am stars of luminosity class IV.

3. Relationship between Temperature and Bolometric Magnitude

In Figure 3, we have plotted log T_e against the bolometric magnitudes taken from Paper I. The Main-Sequence band from Novotny (1973) has also been included in this figure. The values of bolometric magnitudes are expected to be free from blanketing effects

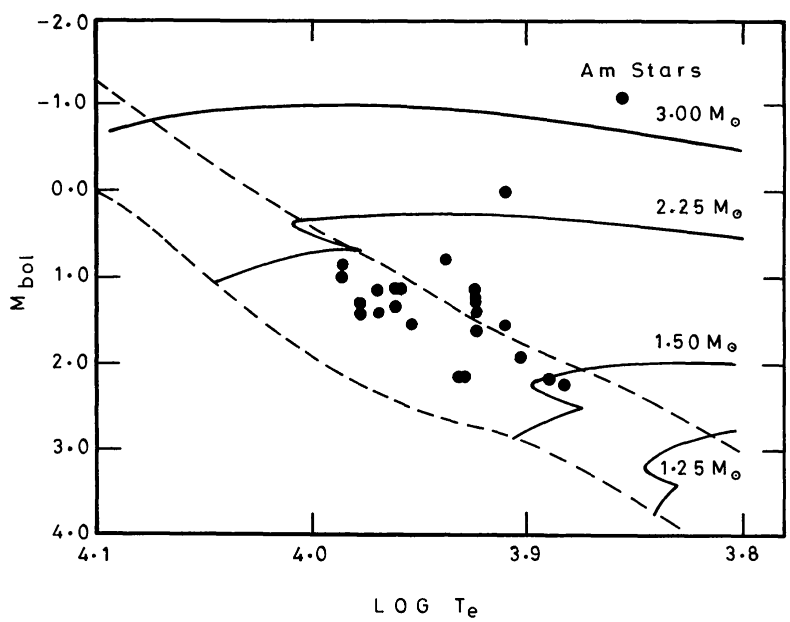

Fig. 3. Relationship between bolometric magnitudes and temperatures of Am stars. The evolutionary tracks are from Iben (1967a, b) and the Main-Sequence band shown in broken lines is from Novotny (1973).

because of the usage of such effective temperature values, which in turn, are free from those effects. Thus the positions of the stars in this diagram may safely be considered as real. They are seen to be occupying a domain in the neighbourhood of the upper edge of the main sequence band. The evolutionary tracks given by Iben (1967a, b) have been adopted in the figure for comparison purposes. Based on these tracks, there seems to be a possibility of identifying those Am stars which are almost in the final stages of hydrogen burning in the core as well as those which are already in the hydrogen shell burning stage to a fair approximation. On the other hand, the rest of them which are sandwiched between the above mentioned two cases might in all likelihood be either in the overall contraction phase or at the phase where the hydrogen burning in the shell has just about commenced. There are two stars (HR 2291 and HR 7928) which are apparently among the most evolved Am stars. Thus, it appears that there is a fairly wide range in the evolutionary status of the Am stars.

However, in a severely blanketed star, the consequent back-warming would raise the continuum in the longer wavelength region, altering its slope. Thus, there is a possibility that the value of θ_e ($= 5040/T_e$) obtained on the basis of such a slope can only be an upper limit for that star. This, in turn, would alter the value of its bolometric magnitude. In such a case, if both θ_e and M_{bol} are corrected for these inherent factors, the resultant shift would still be almost parallel to the Main-Sequence band; and, hence, the star continues to occupy the similar transitional phase, the corresponding evolutionary tracks being slightly different.

The limiting evolutionary tracks of Am stars, in general, appear to be the ones belonging to 1.5 $M_\odot$ and 2.25 $M_\odot$ which prompt us to set these as the range in masses for them.

4. Relationship between Temperature and Bolometric Correction

The relationship between temperature and bolometric correction (BC) has earlier been established as

$$BC = -12.98\,\theta_e^2 + 16.77\,\theta_e - 5.58 \tag{1}$$

by Babu and Rautela (1978) for Ap and some Am stars, where the independence of BC from the errors in parallax measurements has been pointed out. It is clear from Figure 4 (a plot between θ_e and BC) that the same relationship holds good for Am stars also even when they are taken as a separate class, the only difference being that they are located at the lower end of the curve. But the scatter is about ± 0.05 mag. which is a trifle larger than what one sees in the case of Ap stars (Babu and Shylaja, 1982). This is possibly due to the uncertainties in flux measurements arising from the back-warming effects, which are discussed in Section 2.

5. Conclusions

Generally, the Am stars are redder than their normal counterparts. This reddening decreases with temperature, giving rise to a possible inference that the abnormal strength of the metallic lines is perhaps related to the temperature of the given star.

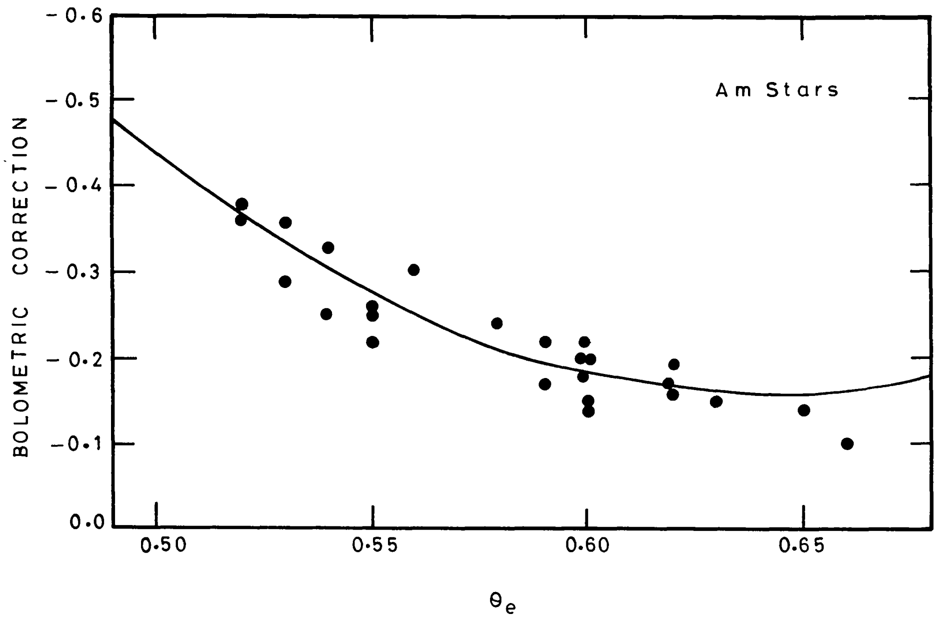

Fig. 4. Relationship between bolometric correction and θ_e of Am stars. The solid line represents the relation obtained earlier by Babu and Rautela (1978).

These stars are seen to be occupying a domain in the neighbourhood of the upper edge of the main sequence band, and their evolutionary status apparently extends from about the final stages of hydrogen burning in the core, through the overall contraction to the phase of the hydrogen burning in the shell. Their mass range may be set as 1.5 $M_\odot$ to 2.25 $M_\odot$.

The bolometric correction of Am stars follow the same trend as that of the Ap stars with respect to temperature. The backwarming effects probably alter these values to some extent resulting in a small scatter.

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