Peculiar Versus Normal Phenomena in A-Type and Related Stars
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THE COLORS OF Am STARS

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ABSTRACT The energy distribution of the Am stars are affected by the line blanketing, which appears as a deviation in the behaviour of color indices with reference to the normal stars. In this paper we study the various color indices along with the data from IRAS and try to identify a realistic representative of the effective temperature. An excess in the IR also becomes apparent in some cases.

INTRODUCTION It is well known that the flux distribution of the chemically peculiar stars are severly affected by the large number of metallic lines in their spectra. This aspect was discussed in our earlier investigations (Babu and Shylaja, 1981, Paper I; Babu and Shylaja, 1982, Paper II and Shylaja, Ashok and Babu, 1992, Paper III) with an emphasis on the effective temperature determinations. In this contribution, we study the various color indices and the relation and/or departure when compared to the Main Sequence normal stars.

DATA The colors of the Am stars have been obtained from the Bright Stars catalogue(1982), which gives (B-V), (U-B) and (R-I). For other cases the Mortet-Magnetat Catalogue has been used. The near infra red (IR) measurements of Bouchet et al. (1991), are used to derive the (V-K) color for normal stars. For the Am stars observations reportd in Paper III have been used.

The IRAS Point Source Catalogue was searched for Am stars and about 50 candidates were identified from the source list of Nicolet (1983). The corresponding (V-[12μ]) colors were derived for these stars.

DISCUSSION The basic problem in the spectral energy studies of Am stars is the model fit, which reflects in the determination of the effective temperature. Since, the blue and UV region appear severly deficient of flux, the Paschen continuum to the longward of λ5000 only was used in Paper I to determine the T_{eff}. This aspect was discussed in Paper II and shown that the (B-V) colors of Am stars appear redder than the normal stars of similar T_{eff}, the departure being more obvious for hotter Am stars.(cf. Fig 2 of Paper II).

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The method of determination of the T_{eff} was analysed more critically in Paper III and it was shown that the above method probably yields more realistic estimates of T_{eff}.

Whether this method is reliable or not may be judged from a comparision of the (R-I) color which is in a region less affected by the flux deficiency. This is depicted in Figure 1 where $\theta_e = (5040/T_{eff})$ is plotted against (R-I). The line represents the relation for the normal stars as derived from Johnson's data (1966). It is immediately apperent that the agreement is fairly good.

Thus it appears that (R-I) is a more reliable color index than (B-V) for comparing with the normal stars. Figure 2 shows the relation between these two indices for normal stars as well as Am stars. The shift in (B-V) needed for the Am stars, which was referred to earlier, shows its effect here also.

This comparison of the (B-V) and (R-I) colors can be used as a distinct characterstic to identify Am stars. This excercise was done for those stars in the list of Nicolet (1983) which have these indices determined and listed in the BS catalogue. Out of 102 Am stars thus selected, most of them fall into the domain determined by the Am stars in Figure 2. Therefore this can perhaps be taken as the indicator of the Am phenomenon itself. However, there are some exceptions, i.e., those which according to Figure 2 are probably Am, but not so otherwise. These are listed in Table I, along with the spectral classification of other sources like Rufner (1981), Cowley et al. (1969) and the BS catalogue (1982). It is worth monitoring these objects from the optical through IR for variability and spectral changes as well.

We may now compare the other color (V-K), which is also likely to be free of the flux deficiency. Figure 3 shows the (V-K) and (R-I) relation. A lateral shift from the normal stars relation becomes apparent in spite of the small sample. In Paper III the energy distribution from UV to IR was studied and it was shown that the flux redistibution starts in the near IR itself for a few stars. This can explain the departure of the (V-K) color. Here the effect is the opposite to that for (B-V) i.e. the K magnitude is brighter and (V-K) is bluer.

Thus both the colors (B-V) and (V-K) seem to represent the same phenomenon of the flux redistribution. We may compare these two indices themselves with the normal stars relation in order to judge the redistribution. From the Figure 4 it may be seen that the shifts from the MS is indicative of the red shift of (B-V) and the blue shift of (V-K). However, the two shifts may not be equal.

The extent of the phenomenon of flux redistribution can be qualitatively understood by the study of the 12μ flux. The previous investigators have noted that the 12μ flux is generally underpredicted for the A type stars (Waters et al., 1987) by the available models. To take care of this we may use the (V-[12μ]) relation for the normal stars. Waters et al. (1987) derived the relation for (B-V). This is shown in Figure 5. The distribution of Am stars in this diagram only give an idea of the complexity because of the uncertain amounts of shifts in the (B-V) values. Therefore we try to use the (R-I) colour, which is probably more realistic. Figure 6, which is a plot of (R-I) v/s (V-[12μ]) is thus better for comparison.

This figure shows that although the general trend is similar to that of normal stars, a small deviation for smaller values of (R-I) is present. This, if real, may be a consequence of possible circumstellar dust emission. The IRAS PSC data do not provide reliable estimates of the fluxes at 60 and 100μ to check this aspect. Even the 25μ data is available for a few cases only.

Considering that the trend is apparent for hotter Am stars the possibility of free free emission may be calculated. Since there is no information on the mass loss rates any such calculation represents only the limiting values. Further, the precise calculation requires a knowledge of γ, the ratio of the number of ions to the number of electrons, μ, the mean atomic weight, g, the gaunt factor, which inturn depends on the electron density in the wind. With some reasonable values like $T_{eff} \approx$ 9500K, v $\approx$ 100km/s, M $\approx 10^{-10} M_O$/yr, μ= g = Z= 1, $T_e = 10^4$,N_e=10^{12} a shift of about 0.2 units on the figure (units of magnitude) at 25μ may be explained, which fits the observations. But these asumptions are yet to be ascertained. Observations at longer wavelengths are essential for this.

CONCLUSIONS The study of various color indices of Am stars and comparison with normal A stars shows that,

1. The anamolous behaviour of the colors (B-V) and (V-K) is caused mainly by the flux redistribution.,

2. The color (R-I) appears to be a more realistic representative of the spectral type (T_{eff}).,

3. The color (V-[12μ]) differs from that of normal stars for the hotter stars only, implying other possible contributions like free free and circumstellar dust, which can be confirmed by further observatons in the region beyond 25μ.

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Table 1: Possible candidates for spectral reexamination

HR	HD	(B-V)	(R-I)	thiswork	Rufner	Cowley et al.	BS catalog
1689	33641	0.18	0.10	normal	A4m	normal	A4m
2172	42083	0.14	0.02	m	A5III	A5m	A5m SB 106d
4624	105509	0.24	0.11	m	A3III		A3m var 4.97d
4650	106251	0.27	0.11	m	A2m	A2V	A2m
5094	117661	0.18	0.07	m	(A4)	F0IV-V	Double
5359	125337	0.13	0.06	normal	A2m	A2m	SB 1.93d or 206.5d
8662	215545	0.30	0.16	m	F0III	A9IIIm	Double
8728	216956	0.09	0.02	m	A3V		A3V CPM with 8721

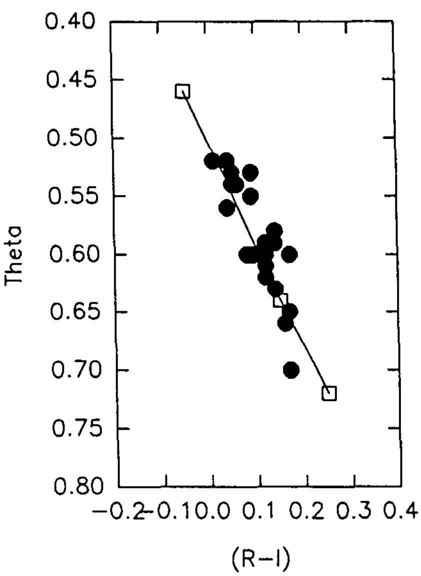

Fig 1. The relation between theta and color (R−I) for Am stars (filled circles) and normal A stars.

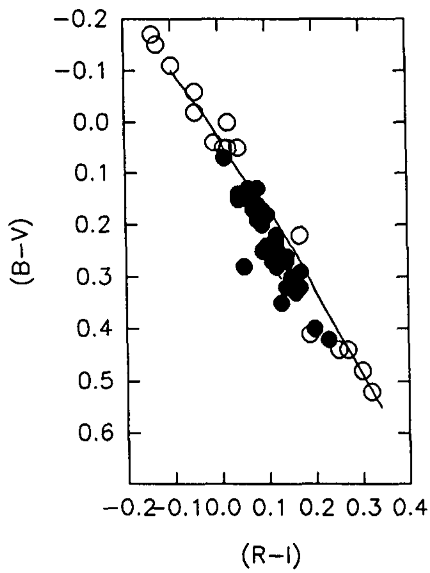

Fig 2. The relation between the colors (B−V) and (R−I) for Am stars (filled circles, in the other figures also) and normal stars (unfilled circles, in the other figures also).

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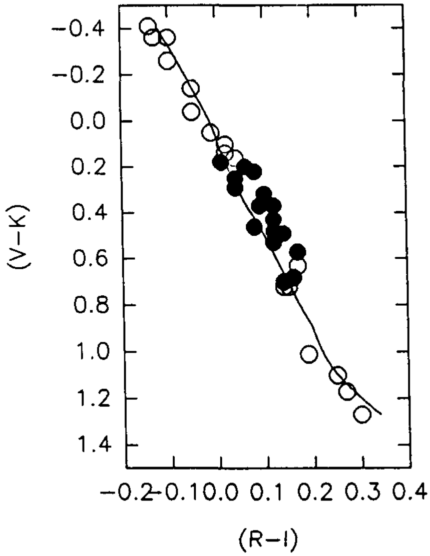

Fig.3 The relation between the (R−I) and (V−K) for Am . and normal stars.

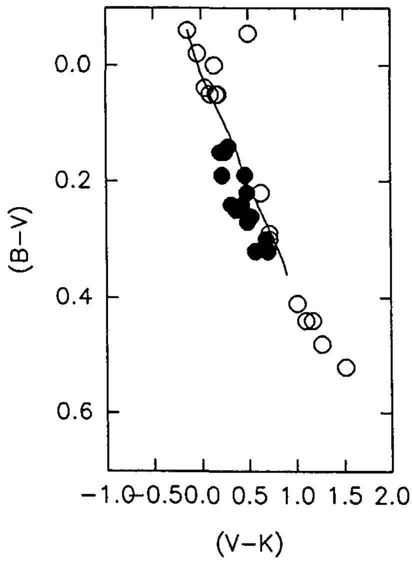

Fig 4. The relation between (B−V) and (V−K) for Am and normal stars.

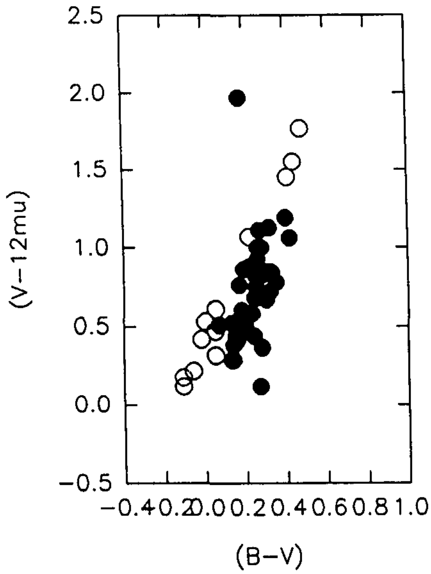

Fig 5. The relation between the colors (V−12) and (B−V) for normal and Am stars.

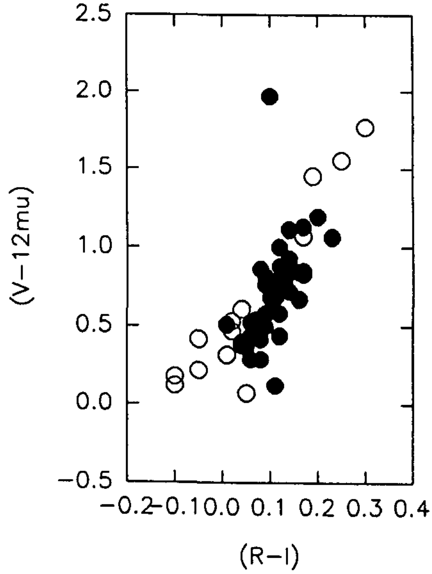

Fig 6. The relation between the colors (R−I) and (V−12) for normal and Am stars..

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