FAR-ULTRAVIOLET COLORS OF B STARS WITH AND WITHOUT EMISSION LINES

J. ZOREC[1], D. BRIOT[2], L. DIVAN[3]
[1]Laboratoire d'Astrophysique Théorique, Collège de France ; [2]Observatoire de Paris, France ; [3]Institut d'Astrophysique, Paris, France

ABSTRACT. A method free of interstellar reddening of comparing the energy distributions in the far-UV of Be/Shell stars to those of normal B stars is presented. The deviations of Be/Shell stars from the sequences of normal stars are correlated with other physical parameters observed in these stars. The largest UV color differences to the sequences of normal stars are found for those Be/Shell stars having the largest IR color excesses.

I. INTRODUCTION

A big problem to be solved in analysing the energy distribution of Be/Shell stars in any wavelength is the separation of the effects due to the ISM and the circumstellar envelope. In the far-UV, this is illustrated by the disagreement between the results obtained by Briot (1978) and Beeckmans and Hubert-Delplace (1980) using different methods of interstellar dereddening.

When the UV fluxes of Be/Shell stars are compared to those of normal B stars, they have to be normalized to a similar photospheric flux. However as probably no spectral region in Be/Shell stars is produced only by a photosphere, it does not seem possible to determine if a flux excess or deficiency exists as compared to normal B stars. We are then limited to only compare slopes of flux distributions or colors.

Due to the irregular variations of the radiation of Be/shell stars it is necessary to define colors only from simultaneously observed fluxes. With this in mind, the method proposed here avoids : a) the determination of the ISM extinction and b) the scatter due to the non-simultaneity of the observations in the different wavelength ranges.

II. THE METHOD

We have defined a color index which is independent of a mean ISM extinction and strongly sensitive to colour differences due to the spectral type in the UV spectral range covered by the low resolution S2/68 observations made with the TD-1 satellite (Jamar et al.,1976 ;

M. Jaschek and H.-G. Groth (eds.), Be Stars, 419–422.

Macau-Hercot et al., 1978). This index is in fact independent of all extinctions with the same absorption law than the mean one for the ISM adopted here (Savage and Mathis, 1979). The color index which characterize the UV behavior is defined as follows :

$G = \Delta_{13} - K . \Delta_{12}$

where $\Delta_{13} = m_{1460} - m_{2740}$; $\Delta_{12} = m_{1460} - m_{2350}$ and K is the ratio of the colour excesses $E(\Delta_{13})/E(\Delta_{12}) = -11.21$. The m_λ values are magnitudes and the wavelengths are chosen to be as free as possible from strong line absorption, as seen from the high-dispersion IUE spectra.

It was noted by Divan (1979) that neither the value of the first Balmer discontinuity D_o attributed to the stellar photosphere nor the value of the parameter λ_1 characterizing the luminosity class change during the variations of Be/Shell stars. These parameters are then used to classify the Be/Shell stars (BCD system of classification), which is in good agreement with the MK spectral classification. Chalonge and Divan (1977) have shown that the type given by (λ_1 ,D_o) may be also characterized by a single parameter S_{70} free of the luminosity class.

Using MK standard stars with BCD classification, we have obtained two well defined sequences (G vs.S_{70}), one for the luminosity classes IV and V and the other for the luminosity class III. As the dispersion of the G values around each mean sequence is not higher than σ=0.6, this procedure may be used to classify normal B stars from the continuous energy distribution in the far-UV.

It is interesting to note that the ßCMa stars are placed in this diagram between both sequences (they are normally considered to be of luminosity class IV and are known to have the UV colours of normal stars of the same spectral type (Beeckmans and Burger, 1977), but σSco which has a different ISM absorption law (Snow and York, 1976), has such a different value of G that it does not fit into our scheme. So our method immediately indicates special absorption laws.

Using the parameter S_{70}, which represents a non-variable spectral type of the Be/Shell stars (or just their MK spectral type when BCD classification were not available),we have compared the G values of these stars to the sequence of normal B stars of the same luminosity class. The differences ΔG=G(Be/Shell)-G(B) were then correlated to other physical quantities.

III. RESULTS AND DISCUSSION

The Be/Shell stars plotted in the (G,S_{70}) diagram have a higher dispersion than the dispersion due to the method itself around the main sequence of normal stars of the same luminosity class. The majority of the Be stars show redder colors in the far-UV than the normal B stars, i.e. $\Delta G > 0$, while a smaller number of them show bluer colours, i.e. $\Delta G < 0$. These results are compatible with those obtained by Beeckmans and Hubert-Delplace (1980, fig.7) for the ultraviolet colors of Be and Shell stars. The mean ΔG for each spectral type seems to decrease towards later types. On the other hand, among the Be and Shell stars with $\Delta G < 0$, some like χOph have even bluer colors than those of the bluest normal stars (around spectral type BO). Such a very blue color may be due to a different interstellar absorption law absorbing less in the short wavelengths than the mean law used here, as for σSco. But this cannot explain cases like 59 Cyg varying from ΔG=+1.3, during a Be phase (1972), to ΔG=-5.5 during a strong shell event (1973) (these two points are connected in fig.1).The UV observations are taken from Beeckmans (1976).This UV color change has been noticed in Beeckmans and Hubert-Delplace (1980). Very blue colours, like those of some well developed shell stars (e.g. 48 Lib) might be explained by a strong circumstellar absorption with a λ^3-like law. But this is not the case for χOph for which an explanation might be given assuming a different interstellar law. In any case,we can note that as the number of stars with ΔG<0 is rather low, it is possible to think that the time the stars spend during such events (when they have them) must generally be short.

We have studied the UV color index G of Be/Shell stars according to their IR color exceses using Allen (1973) and Jaschek et al. (1980). The Be/Shell stars classified F in Allen (1973) (stars with an infrared color excess attributed to free-free radiation) correspond

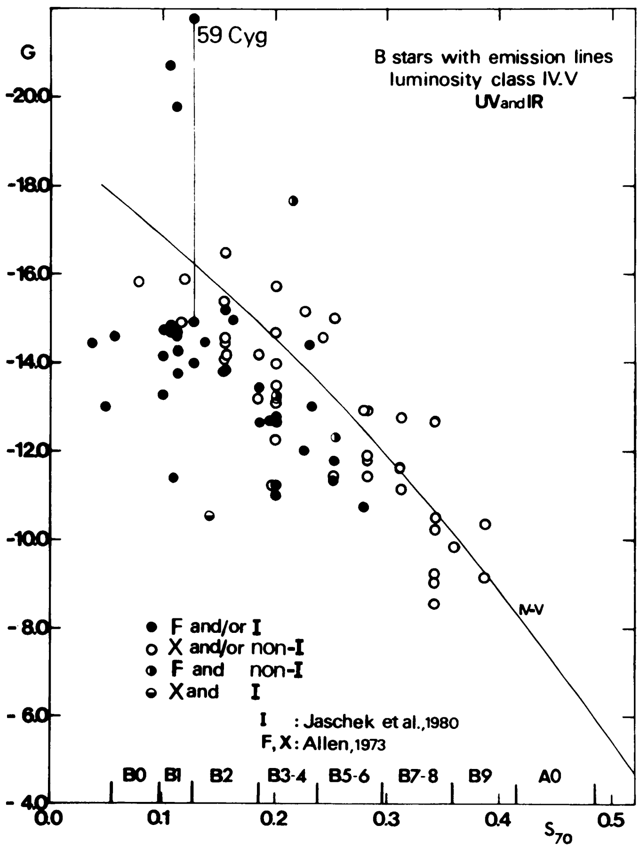

Fig. 1.

https://doi.org/10.1017/S0074180900038146 Published online by Cambridge University Press

almost entirely to the stars classified I in Jaschek et al. (1980) while the stars classified X in Allen (1973) (stars with little or no IR color excess) correspond to the stars not classified I in Jaschek et al. (1980) with a few exceptions. In figure 1 the Be/Shell stars of luminosity class IV and V as classified above and the mean sequence of normal stars of these luminosity classes are plotted. Even though the observations in the IR are not strictly simultaneous with the UV, we can see that there exists a quite different distribution of stars according to their IR color excesses : the stars classified X and/or non-I have UV colors close to those of normal B stars (small values of $|\Delta G|$)and those classified F and/or I have very different UV colors compared to normal B stars (large values of $|\Delta G|$). This indicates that some connection may exist among the processes or the regions which produce such IR and UV color behaviors.

The differences ΔG were also compared to the strength of emission lines using the photometric index in the Balmer lines observed during February 1972 (quasi-simultaneously with the UV observations) by Feinstein (1974). A general tendency was found of high values of ΔG corresponding to strong line emission. However a complete lack of correlation is seen between ΔG and vsini, indicating that there is little probability of detecting some rotational darkening in the far-UV.

It appears that with the very simple method described here, it is possible to clearly relate the UV colors of Be/Shell stars to their physical properties in other wavelength ranges.

REFERENCES

Allen, D.A.:1973,Monthly Notices Roy. Astron. Soc.161,145

Beeckmans, F.: 1976, Astron. Astrophys. 52,465

Beeckmans, F., Burger,M., 1977, Astron. Astrophys.61,815

Beeckmans, F., Hubert-Delplace, A.M.: 1980, Astron. Astrophys. 86,72

Briot, D.: 1978, Astron. Astrophys. 66, 197

Chalonge, D., Divan, L.: 1977, Astron. Astrophys. 55, 121

Divan, L.: 1979, IAU Coll. 47, Ed. G.V. Coyne, M.F. McCarthy, A.G.D. Philip, p.247

Feinstein, A.: 1974, Monthly Notices Roy. Astron. Soc. 169, 171

Jamar, C., Macau-Hercot, D., Monfils, A., Thompson, G.I, Houziaux, L., Wilson, R.: 1976, Ultraviolet Bright-Star Spectrophotometric Catalogue, ESA SR-27

Jaschek, M., Hubert-Delplace, A.M., Hubert, H., Jaschek, C. : 1980, Astron. Astrophys. Suppl. Ser., 42, 103

Macau-Hercot, D., Jamar, A., Monfils, A., Thompson,G.I, Houziaux, L., Wilson, R. : 1976, Ultraviolet Bright-Star Spectrophotometric Catalogue, ESA SR-28

Savage, B.D, Mathis, J.S.: 1979, Ann. Rev. Astron. Astrophys. 17,73

Snow, T.P., York, D.G: 1976, Astrophys. Space Sci.55,19

https://doi.org/10.1017/S0074180900038146 Published online by Cambridge University Press