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VISIBLE AND ULTRAVIOLET FLUXES OF Be STARS IN TERMS OF THE EMISSION IN THE BALMER LINES

J. Zorec

Institut d'Astrophysique, París

and

D. Briot

Observatoire de París

RESUMEN. En el presente trabajo se estudian los flujos visible y ultravioleta lejano de las estrellas Be, comparándolos a los flujos respectivos correspondientes a fases sin emisión y en función de la intensidad de emisión en las líneas de Balmer Hα y Hβ. Se ha encontrado una correlación entre las intensidades de las líneas de emisión y el flujo visible, pero ninguna correlación parece existir con el flujo ultravioleta. Sin embargo, algunas estrellas Be con espectro *shell*, presentan deficiencias en el flujo ultravioleta lejano.

ABSTRACT. The variation of the visible and ultraviolet fluxes of Be stars, as compared with their values during a non-emission phase of the star, is studied as a function of the emission intensity in the Hα and Hβ lines. A correlation is found between the line emission intensities and the continuum flux in the visible range, but it seems that this correlation does not exist with the ultraviolet flux. However, some Be stars with a shell spectrum show a deficiency in the ultraviolet flux.

I. INTRODUCTION

The correlation between the excess of the infrared radiation of Be stars as compared with normal B stars, and the Hα line emission is well established by several authors (Feinstein and Marraco 1981, Damineli and Pacheco 1982, Dachs and Wamsteker 1982). So, it is interesting to search whether there exists in Be stars a similar correlation between the continuum in the visible and ultraviolet range and the emission in the first Balmer lines.

When the interstellar reddening of Be stars is determined from the 2200 Å bump of the interstellar absorption curve, these stars show a deficiency in the ultraviolet flux normalized to the visible flux, when compared with B stars without emission. This deficiency seems, on the average, to be stronger for Be stars with a strong emission (Beeckmans and Hubert-Delplace 1980), the amount of emission being eye estimates. It is then important to search if there exists a correlation between the intensities of the Hα and Hβ Balmer emission lines and the difference between the ultraviolet flux normalized to the visible flux of Be stars and that for normal B stars. This is the aim of section II in this paper.

Nevertheless, we know that the flux emitted by a Be star in the V band is, at least in certain cases, stronger than that emitted by a B star without emission. So, the difference of the ultraviolet flux normalized to the visible flux of Be stars as compared with normal B stars, corresponds to a color difference between Be and B stars and not necessarily to a deficiency of the absolute ultraviolet flux of Be stars as compared with that of normal B stars. Absolute fluxes of Be stars as compared with those of B stars will be estimated, on one hand, in the ultraviolet range and, on the other hand, in the visible range. Absolute fluxes in terms of the emission intensities in the Hα and Hβ lines will then be studied. This is the object of section III.

II. ULTRAVIOLET FLUX OF Be STARS NORMALIZED TO THE VISIBLE FLUX, COMPARED WITH THAT OF B STARS, IN TERMS OF THE EMISSION INTENSITY OF THE Hα AND Hβ LINES.

Our study concerns the *classical* Be stars. For comparison purposes we also study normal B stars which have never been reported as having any emission.

We used the spectrophotometric data obtained in the ultraviolet by the S2/68 experiment on board the TD-1 satellite and published in two catalogues (Jamar *et al.* 1976, Macau-Hercot *et al.* 1978). The V magnitudes of normal B stars were taken from Johnson *et al.* (1976) or from Blanco *et al.*'s (1968) compilation catalogue. Due to the strong and irregular variability of Be stars, it is essential that observations of a given star in the various wavelength ranges be as simultaneous as possible. For the V magnitude of Be stars we used Feinstein's (1975) and Rufener's (1981) photometric observations, which were made for a given star as simultaneously as possible to the TD-1 satellite measurements. The reddening due to the interstellar absorption was determined from the 2200 Å bump (Malaise *et al.* 1974) and the mean interstellar absorption curve of Savage and Mathis (1979).

For normal B stars, the interstellar absorption was also determined from the E(B-V) color excess, the $(B-V)_0$ being those of FitzGerald (1970).

For each B and Be star studied we defined an index

$$I = m_{1460} - V \qquad (1)$$

where m_{1460} is the flux at $\lambda = 1460$ Å expressed in magnitudes.

To compare the ultraviolet flux of a Be star with that of a normal B star having the same spectral type and luminosity class, we defined

$$\Delta I = I(Be) - I(B) \qquad (2)$$

We used the Hα and Hβ emission line intensities determined in Zorec *et al.* (1983), which correspond to observations made as simultaneously as possible to those in the ultraviolet.

We plotted ΔI as a function of the Hα and Hβ emission line intensities expressed in logarithms. For each of both lines, the highest values of ΔI have a tendency to correspond with the strongest line intensities, but none of the obtained correlations is well defined. Nevertheless, it must be pointed out that the error bar estimated for ΔI is rather large.

We have to specify then whether the trend obtained between ΔI and the Hα and Hβ emission line intensities corresponds either to a correlation between the line intensities with the flux of Be stars in the ultraviolet range or in the visible.

III. STUDY OF ABSOLUTE FLUXES OF Be STARS IN THE ULTRAVIOLET AND VISIBLE RANGES IN TERMS OF THE Hα AND Hβ EMISSION LINE INTENSITIES.

The determination of absolute fluxes of Be stars presents some difficulties and needs several hypotheses.

We first supposed that the total luminosity of Be stars remains constant during observed variations of the star, then that this total luminosity is the same than that of a B star without emission of same spectral type and luminosity class. Observational facts on which we base these hypotheses are detailed in a paper in this same issue (Zorec and Briot 1984) and will not be given again here.

To determine the total luminosity of Be stars, we studied their flux on a wavelength range as extended as possible. From shortest to longest wavelengths, the observations used are those of the TD-1 satellite between 1360 Å and 2740 Å (Jamar *et al.* 1976, Macau-Hercot *et al.* 1978) and the narrow band photometric observations of Johnson and Mitchell (1975) between 3300 Å and 11000 Å. For each of the stars studied we have then at our disposal the ultraviolet flux, the V magnitude that corresponds to the epoch of the ultraviolet observation and visible and near infrared fluxes observed at a different epoch. To determine the total luminosity of the star in a coherent way, in the various wavelengths, it is necessary to correct the photometric observations in the visible range of a possible variation between the epoch at which they were observed and the epoch where the ultraviolet data were observed. Now we know that when a Be star varies, the total Balmer discontinuity is linearly correlated, on one hand, with the V magnitude, and, on the other hand, with a color gradient which corresponds to an estimate of energy distribution in the visible (Divan 1979, Divan *et al.* 1982). We determined the relation between V and the energy distribution in the visible for each of the stars studied. From the V magnitude that corresponds to the epoch of TD-1 ultraviolet observations (Jamar *et al.* 1976, Macau-Hercot *et al.* 1978) and from the V magnitude obtained from photometric observations in the visible (Johnson and Mitchell 1975), we determined the energy distribution in the visible for each star at the epoch of TD-1 ultraviolet observations.

For wavelength ranges for which we have no observations, we completed the energy curves by interpolation with theoretical models. These theoretical models are those of Kurucz (1979).

By using the hypothesis that the total luminosity -that means, the flux integrated on all the wavelength ranges- is the same for Be stars and for normal B stars and eliminating the distance effect, we determine the difference of the V magnitude between the Be star and a B star of the same spectral type and luminosity class

$$\Delta V = V(Be) - V(B) \qquad (3)$$

By using this ΔV index and the ΔI index defined in section II, we can determine a similar index for the ultraviolet range

$$\Delta UV = m_{1460}\,(Be) - m_{1460}(B) \qquad (4)$$

The ΔV and ΔUV indices, respectively, represent the flux difference in the visible and in the ultraviolet of the Be stars between a phase with some emission and a phase without emission.

We plotted ΔV against the W_α and W_β intensities, expressed in logarithms, of the emission lines Hα and Hβ (Fig. 1, a and b). We can see that rather well defined correlations exist between the differences of the V magnitudes of B and Be stars and the emission intensity in the Hα and Hβ lines (Be stars being more luminous than B stars and even more luminous when the emission increases). This correlation between ΔV and $\log W_\beta$ is better than that between ΔV and $\log W_\alpha$.

On the same way we plotted ΔUV as a function of $\log W_\alpha$ and $\log W_\beta$ (Fig. 2, a and b). We can see that the values of ΔUV are located around zero, whatever the value of the emission intensity in the lines. Only two stars, which are shell Be stars, show a really smaller ΔUV.

From this set of results we can conclude that

When the emission of Be stars varies, the ultraviolet flux at λ = 1460 Å does not vary or varies only a little, but the flux in the visible increases when the emission increases, in such a way that the visual magnitude is approximately linearly correlated with the logarithm of the emission intensity in each of the first two Balmer lines. However, the ultraviolet flux of shell Be stars is smaller than the ultraviolet flux of normal B stars. This corresponds to the observed decrease of the ultraviolet flux of a Be star when a shell is appearing (Beeckmans 1976).

IV. CONCLUSION

We studied the ultraviolet flux of Be stars in terms of the emission in the Hα and Hβ lines. We first studied the ultraviolet flux normalized to the visible flux. There exists a correlation between this normalized ultraviolet flux of Be stars and the emission intensity in the Hα and Hβ lines, but this correlation is not very well defined.

In order to specify this result, we determined the absolute fluxes of Be stars both in the ultraviolet and visible ranges, which were then correlated with the intensities of the emission in the Hα and Hβ lines. No correlation was found between the emission intensities in the Hα and Hβ and the ultraviolet flux, which seems to correspond approximately to a flux of a normal B star. Only two shell Be stars were detected as having a clear ultraviolet flux deficiency. However, the emission intensities in the Hα and Hβ lines are well correlated with the flux in the visible range, Be stars being more luminous in the visible when the emission is stronger.

We conclude that during the line emission variations of Be stars, the flux does vary in the visible range, but, in the ultraviolet, the variation is slight or none. However, for some shell stars, the ultraviolet flux is weaker. It seems, then, that the deficiency of the ultraviolet flux normalized to the visible flux sometimes found for Be stars (see, for example, Beeckmans and Hubert-Deplace 1980) corresponds, in fact, to an excess of flux in the visible.

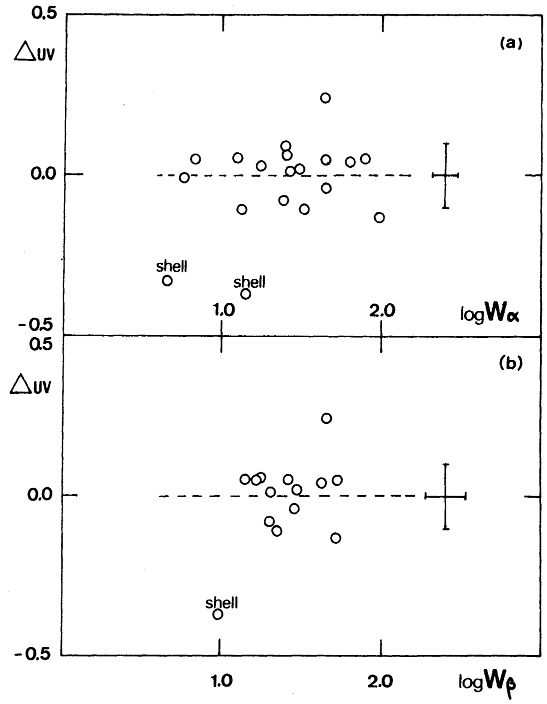

Fig. 1. Correlation of the flux excess in the V magnitude with (a) the Hα emission intensity and (b) the Hβ emission intensity. Mean error bars are indicated.

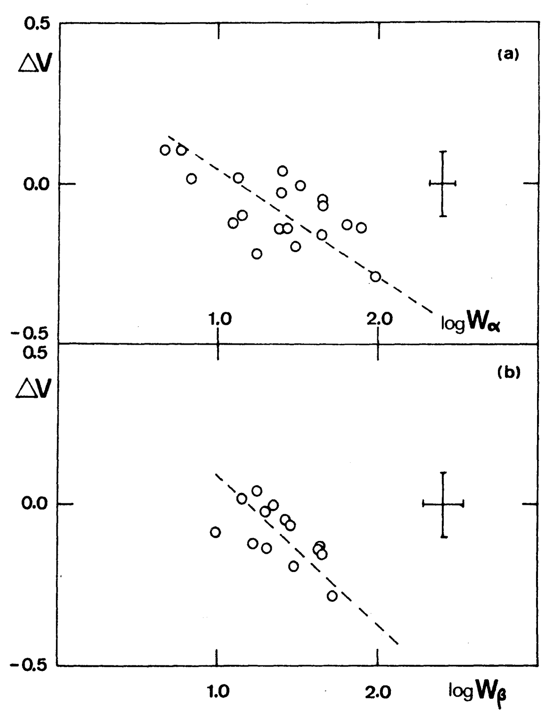

Fig. 2. Behavior of the far-ultraviolet fluxes as function of (a) the Hα emission intensity and (b) the Hβ emission intensity. Mean error bars are indicated.

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Juan Zorec: Institut d'Astrophysique, 98 bis Bd Arago, F-75014 Paris, Francia.
D. Briot: Observatoire de Paris: 61, Av. de l'Observatoire, F-75014 Paris, Francia.