A STUDY OF Be STAR VARIABILITY

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ABSTRACT. Variations of Balmer emission line strength for Be stars are compared to simultaneously measured photometric light-curves in the visual and infrared regions of the spectrum. Three different types of correlations between photometric and spectrometric variations are described. Variable intensity of continuous recombination radiation from ionized hydrogen in the circumstellar envelope is shown to be a major source of light variations for Be stars.

Variability is a well established fact for many if not all Be stars (see, e.g., Feinstein and Marraco, 1979). Yet systematic investigations of light-curves and associated changes of emission-line strength are lacking, and the few known studies on correlations between photometric and spectrometric variations for Be stars (Sharov and Lyuty, 1976; Nordh and Olofson, 1977) lead to contradictory results.

Therefore new measurements were obtained in 1978 and 1979 for 35 bright southern and equatorial early-type Be stars, by means of the 61 cm and 1 m reflectors at the European Southern Observatory in Chile. For these stars, photoelectric UBV magnitudes (unpublished) were measured nearly simultaneously with Balmer emission line profiles (Dachs et al., 1981) and infrared JHKLM magnitudes (Dachs and Wamsteker, 1981). As far as possible, these data are compared to published observations of the same stars at other epochs, in particular from the lists of Allen (1973), Feinstein (1974, 1975) and Gehrz et al. (1974). For the study of spectrometric variations, the photometric α indices of Hα emission line strength determined by Feinstein (1974) are converted into equivalent widths of Hα emission by using the empirical transformation formula

$$W_e(\mathrm{H}\alpha) \;=\; 173\ \mathring{A}\ \ (\alpha_{\mathrm{Feinstein}} - 1.455) \qquad (1).$$

Evaluation of these data permits the following conclusions:
1. Amplitudes of light variations in the V photometric band exceed $0^{\mathrm{m}}\!.5$ for many well observed Be stars (μ Cen, κ CMa, χ Oph, 31 Peg).
2. If V brightness increases, Be stars generally become redder. The ratio

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of (B-V) colour index to V magnitude variations, $\Delta(B-V)/\Delta V$, ranges between about -0.1 and -0.3 for individual Be stars.
3. Photometric V band variations are accompanied by changes of Balmer emission line strengths and of infrared excess radiation from the circumstellar envelope. Infrared and V magnitude variations are always positively correlated.
4. Infrared excess radiation of early-type Be stars as measured, e.g., by the (J-M) colour index is strongly correlated to the equivalent width of the Hα emission line.
5. Photometric and spectrometric variations of large amplitude (exceeding $|\Delta V| = 0^m.1$ or $|\Delta W_e(H\alpha)/W_e(H\alpha)| = 0.2$) proceed rather slowly on time scales of more than about one month. For the study of large-amplitude variations of Be stars, measurements obtained within less than one month can therefore usually be considered to refer to the same epoch.

According to the sign of the correlation between photometric variations and changes of Balmer emission line strength three different types of Be star variations can be distinguished:

Type I - Positive correlation: Simultaneous increase or decrease in V brightness, near infrared brightness, and equivalent width of Balmer line emission. Type I variations are observed for Be stars showing weak to moderate emission-line strength, with equivalent widths of their Hα line emission of no more than about -30 Å. As an example, the variations for μ Cen from 1968 until 1979 are shown in Fig. 1; this star completely lost its Balmer line emission in 1978 when also its V and infrared brightnesses reached minimum values. For type I variations, the ratio of amplitudes in the L band (at wavelength 3.6 microns) to those in the V spectral range, $\Delta L/\Delta V$, is of the order of 10.

Type II - Hα emission saturation: The intensity of Balmer line emission from the circumstellar envelope remains constant while large amplitude changes occur in visual and infrared magnitudes. Variability of this type is observed for the extreme B2Ve star χ Oph in 1972 - 1979 (Fig. 2). The ratio of amplitudes for V and L infrared variations is of order unity.

Type III - Anticorrelation: Maximum strength of metallic shell absorption lines coincides with a minimum of V brightness as observed, e.g., for Pleione in late 1973 by Sharov and Lyuty (1976).

Variations of type I indicate that in this case broad-band magnitude variations are caused by variable amounts of continuous hydrogen recombination radiation emitted from a stellar envelope of variable density and dimension, as first suggested by Nordh and Olofson (1977) in order to explain the variations observed for π Aqr. Analysis of the slope for the correlation between photometric and Balmer emission line variations of type I shows that Be star envelopes are optically thick for Hα line radiation.

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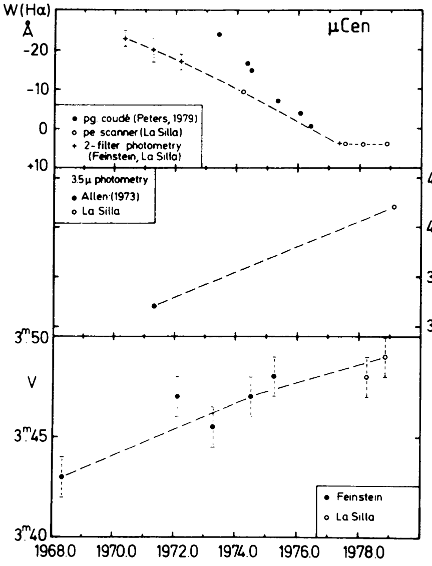

Figure 1. Variations of type I for μ Cen (B2IV-Ve).

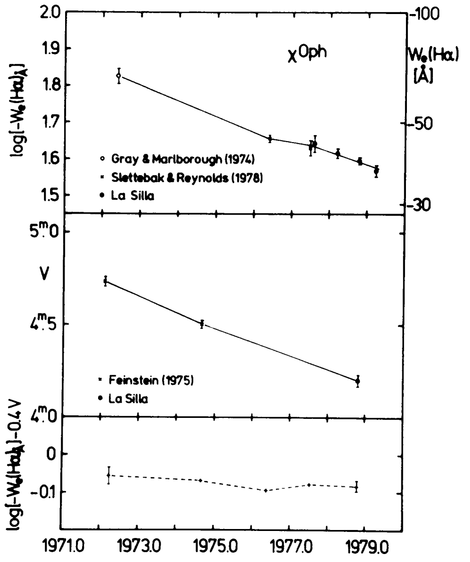

Figure 2. Variations of type II for χ Oph (B2Ve).

Variations of type II point to variable amounts of continuous light scattered by electrons in the circumstellar envelope at constant level of saturated Balmer line emission. Type III variations were attributed by Sharov and Lyuty (1976) to absorption of visual starlight in the ejected shell material.

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DISCUSSION

A.M.Hubert: I think it is difficult to determine with accuracy the equivalent widths of the emission lines in χ Oph, at some time, because of an effect of "veiling" temporary observed.

Dachs: For photometrically variable Be stars, one should try to determine the intensity of $H\alpha$ emission by simultaneously measuring the $H\alpha$ equivalent width and the actual brightness of the star in Johnson's R band.

Peters: Are you continuing to observe μ Cen? It is currently, once again, developing an emission line envelope.
The B-V colour for μ Cen appears to be anticorrelated with U-B just as you showed for χ Oph.

Dachs: I am continuing my observations.

Viotti: χ Per has a long term behaviour similar to that of your stars, being redder when brighter, with smaller variations in U-B, but larger IR variations. These results are a clue to a model of the atmospheric envelopes, but it is difficult for the moment to say if the variations are due to changes in the mass loss rates or in the envelope structure or both.

Snow: Have you looked for variations on shorter time scales than you have discussed in this presentation?

Dachs: I looked for night-to-night variations and found a few cases of photometric and spectroscopic variations within 24 hours.