PHOTOELECTRIC MEASURES OF Hα, Hβ AND Hγ IN EARLY-TYPE STARS

A. FEINSTEIN

Observatorio Astrónomico, Universidad Nacional de La Plata, Argentina

Abstract. The results of over 200 stars measured with interference filters in Hα, Hβ and Hγ are given here. 113 Be stars from the northern and southern hemispheres were included. The comparison of 60 of them, in common with the observations made by Mendoza about 15 years ago, shows that nearly half of them have differences larger than 0^m030 in Hβ (Crawford system). On the other hand the comparison with the observations made recently by Crawford indicate variations in a short time for some active Be stars.

During 1970 the Hα, Hβ and Hγ lines in over 200 stars in both hemispheres were measured with interference filters. These observations made at the Kitt Peak National Observatory and at the Cerro Tololo Inter-American Observatory were carried out using the photomultiplier 1P21 and with a combination of a narrow and a wide interference filter, both centered at each line. Thus, the same procedure was employed that Crawford and associates do for their measures of the Hβ line.

The β index related to the measures of the Hβ line is in the system established by Crawford and Mander (1966), since their standard stars were measured. For the Hα and Hγ lines all the observations were reduced to a standard system defined by these same stars, which give the α and γ indices.

The data included observations of 81 standard stars (Crawford and Mander, 1966; Crawford *et al.*, 1970), 118 Be stars (Mendoza, 1958; Feinstein, 1968), 7 helium-weak stars (Jaschek *et al.*, 1969), 6 metallic-line stars, one peculiar star (α Circinis), and the cepheid *l* Carinae.

For all observed stars, the Figures 1, 2 and 3 show the relation between the three indices: α, β and γ. A clear separation between the standard and the Be stars results from these three diagrams, as smaller numbers mean that the line is in emission. However, some stars classified as Be are contained in the same part of the diagrams as the standards, which suggests that at the epoch they were measured, the hydrogen lines had no emission.

From these three diagrams we can obtain the condition which an early-type star must satisfy in order to be an emission-line star. Nearly all the Be stars have smaller values of the indices: α, β and γ, in comparison with normal B stars. Then, from (α, β) and (α, γ) diagrams we may conclude that any star with $\alpha < 1.44$ is a Be star. This condition includes nearly all the observed Be stars, as only very few stars with larger α values also have emission. There is also a condition for the Hβ line, since from the (α, β) and (β, γ) diagrams we see that any star with an index $\alpha < 2.50$ is a Be star, as was already pointed out by Haug (1970). However, this is not fulfilled by approximately half of the Be stars. For the γ index it does not seem possible to establish a

https://doi.org/10.1017/S0074180900099289 Published online by Cambridge University Press

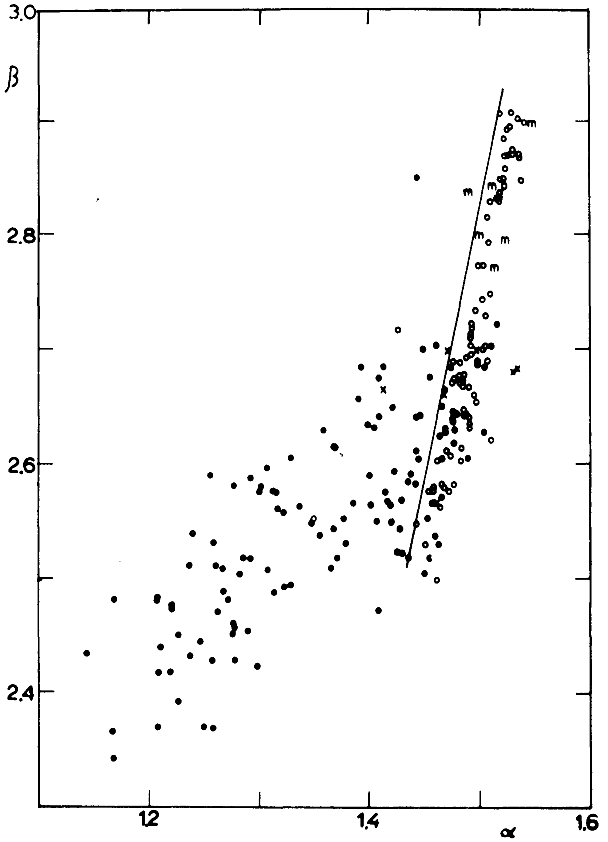

Fig. 1. The (α,β) diagram for all the observed stars. Open circles denote standard stars, dots Be stars, crosses helium-weak stars, *m* metallic-line stars, *p* the peculiar star α Circinis, and *c* the cepheid *l* Carinae.

condition, as the emission in this line is always small, much smaller than in Hα and in Hβ.

Figure 4 presents the diagram (α, β–γ) for the observed stars, which also shows very clearly the condition for the Be stars, that is $\alpha < 1.44$.

The comparison of the Hβ measures of the Be stars with observations obtained by Mendoza before 1958 (private communication) shows that of 63 stars in common, 25 of them display differences larger than $0^m.03$ (Table I). It seems to be no systematic differences as there are nearly equal number of positive and negative values. The data indicates that about 40% of the Be stars have variable emission in the Hβ line in a time interval of around 13 yr.

A similar comparison with the measures for southern Be stars obtained between 1963 and 1969 (Crawford *et al.*, 1970) is plotted in Figure 5. It indicates that of 21 stars in common, 6 have differences larger than $0^m.03$, but although in this case the time interval is shorter, the percentage is nearly the same.

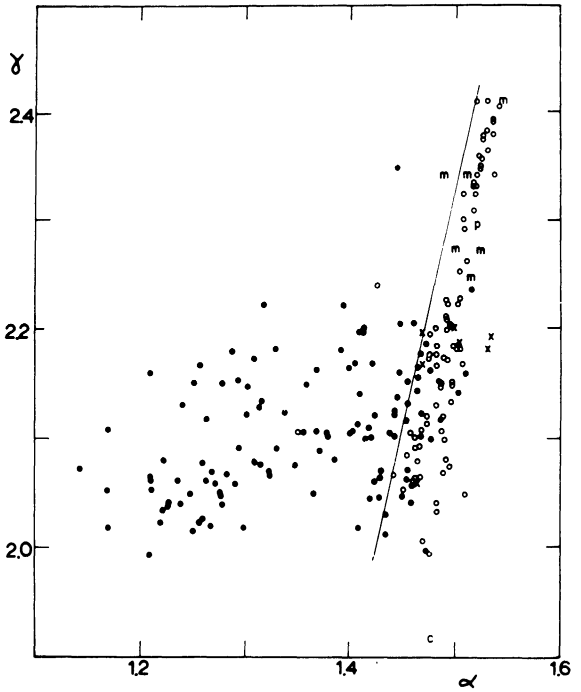

Fig. 2. The (α,γ) diagram for all the observed stars.

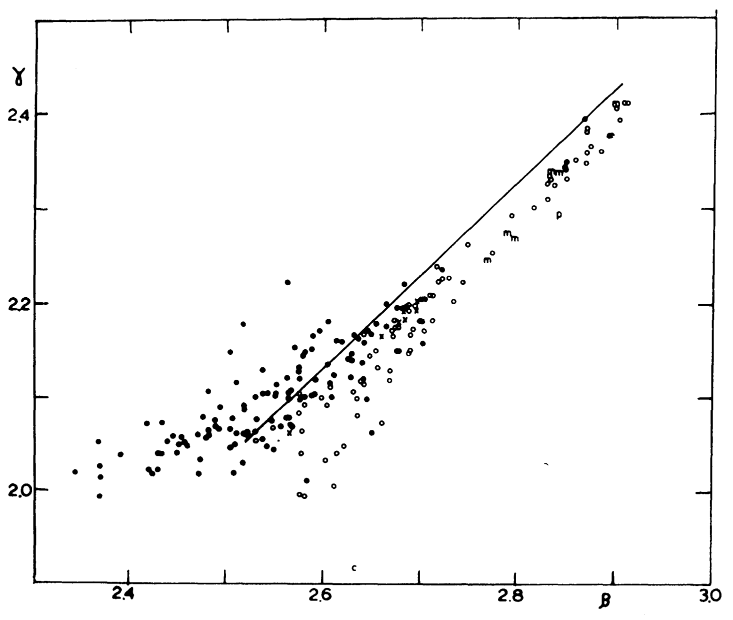

Fig. 3. The (β,γ) diagram for all the observed stars.

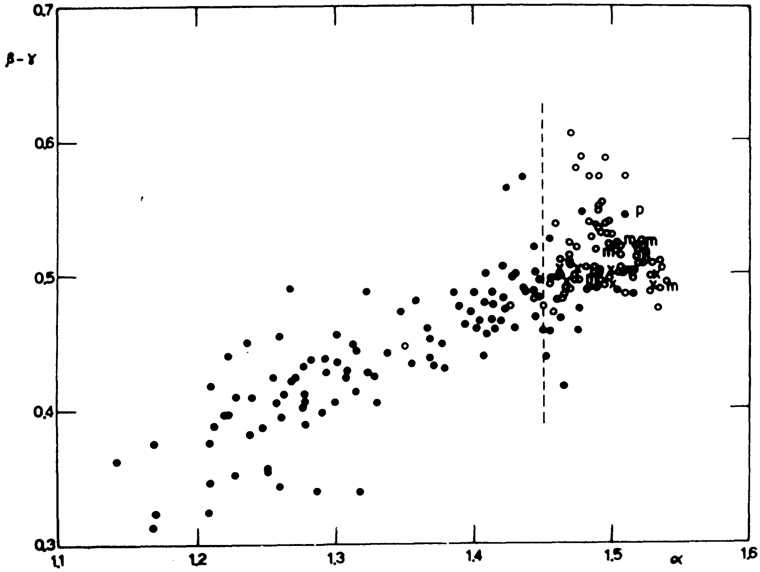

Fig. 4. The (α,β-γ) diagram for all the observed stars. The vertical line at $\alpha = 1.44$ separates the Be from the normal stars.

TABLE I

Comparison of β indices from measures made by Feinstein and Mendoza

HD	β_F	β_M	$\beta_F - \beta_M$
5394	2.370	2.484	−0.114
11606	2.850	2.508	+0.342
19243	2.429	2.509	−0.080
20336	2.604	2.566	+0.038
21650	2.589	2.627	−0.038
22780	2.665	2.749	−0.084
23480	2.614	2.660	−0.046
28497	2.458	2.572	−0.114
32343	2.504	2.560	−0.056
33604	2.489	2.523	−0.034
41117	2.543	2.415	+0.128
43285	2.684	2.630	+0.054
45910	2.432	2.400	+0.032
58050	2.493	2.434	+0.059
60855	2.606	2.538	+0.068
83953	2.580	2.483	+0.097
184279	2.576	2.609	−0.033
187567	2.518	2.606	−0.088
187811	2.646	2.565	+0.081
189687	2.629	2.539	+0.090
191610	2.538	2.623	−0.085
200120	2.531	2.494	+0.038
206773	2.369	2.400	−0.031
212571	2.391	2.460	−0.069
217891	2.605	2.666	−0.061

Another interesting point to investigate is the Balmer decrement of the normal stars. Figure 6 shows the relation of the α vs the $(\alpha-\beta)$ indices for the standard stars, with the spectral type for each star given. Beginning with the star with earlier spectrum, around O9, it is found that the $(\alpha-\beta)$ values decrease with later spectral types whereas the α index increases slightly until around A0. At this point the relation takes the reverse direction, that is the $(\alpha-\beta)$ values increase with later spectral types. The two sequences are not superposed, as there is small difference between the α values. But a very noticeable fact is presented around spectral types F0 in one way, and B9 in the other. In this position there is a large gap with a few stars. This gap of $0\overset{m}{.}06$ wide in $(\alpha-\beta)$ is occupied by: 3 metallic-line stars, one δ Scuti star (HD 211336, F0IV), and just one normal star: HD 196867, B9V. Nearly the same gap is also presented in Figure 7, where the relation between the α and the $(\alpha-\gamma)$ indices is given.

In conclusion: by means of measuring photoelectrically the α and β indices, and

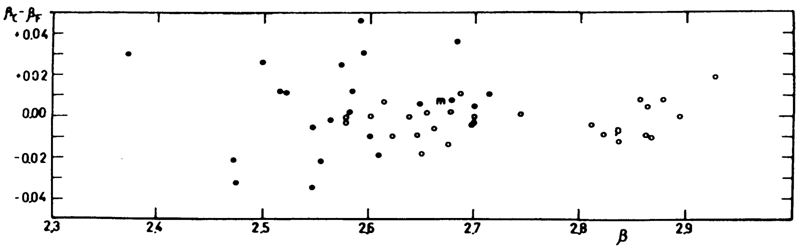

Fig. 5. The relation of the β index vs the difference $\beta_C - \beta_F$ for the stars in common with Crawford *et al.* (1970).

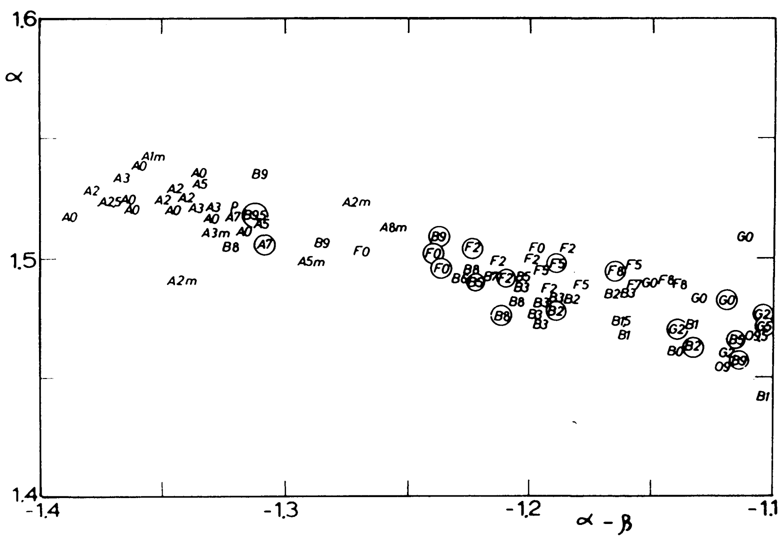

Fig. 6. The relation of the α vs the α-β indices for the standard stars. The position of each star is indicated by its spectral type. A circle around it means a supergiant or a giant.

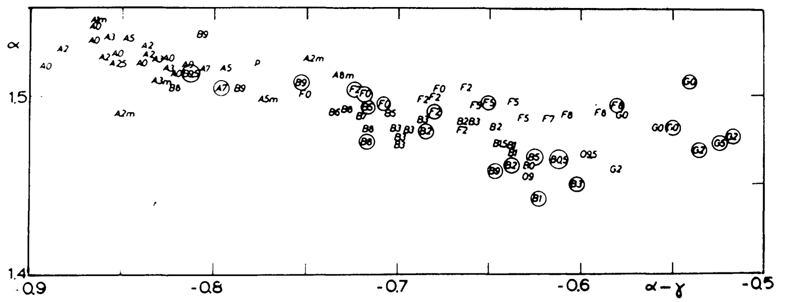

Fig. 7. The relation of the α vs the α–γ indices for the standard stars.

eventually the γ index, of the first three Balmer lines, it is feasible to detect easily the early-type stars which have hydrogen emission. Also, from the comparison of the Hβ measures with those of other authors, this method seems very useful in order to follow the variations of the emission-line strengths in the Be stars.

Acknowledgements

I would like to express my appreciation for the use of Kitt Peak and Cerro Tololo Observatory facilities. A large part of this work was done with a John Simon Guggenheim Memorial Fellowship.

References

Crawford, D. L. and Mander, J.: 1966, *Astron. J.* **71**, 114.
Crawford, D. L., Barnes, J. V., and Golson, J. C.: 1970, *Astron. J.* **75**, 624.
Feinstein, A.: 1968, *Z. Astrophys.* **68**, 29.
Haug, U.: 1970, *Astron. Astrophys.* **9**, 453.
Jaschek, M., Jaschek, C., and Arnal, M.: 1969, *Publ. Astron. Soc. Pacific* **81**, 650.
Mendoza, E. E.: 1958, *Astrophys. J.* **128**, 207.

https://doi.org/10.1017/S0074180900099289 Published online by Cambridge University Press