10. TWO-DIMENSIONAL CLASSIFICATION SYSTEMS FOR O-TYPE STARS

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An observational programme of O and early B-type stars is being conducted at the Merate Observatory (**1**, **2**) with the grating spectrograph. The dispersion is 35 Å/mm and the spectral range λλ3300–4700. The purpose is to find criteria for a two-dimensional classification of O-type stars.

As is well known, all the quantities which are measurable in the spectra of the O-type stars are strongly dependent upon the temperature and very slightly or not at all upon the luminosity. The problem consists in finding two functions of L and T which differ sufficiently to allow a graphical solution of the system $f_1(L, T) = 0$; $f_2(L, T) = 0$ giving the two unknowns L and T. Attempts at a two-dimensional classification using small dispersion spectrograms like those employed by Chalonge (**3**) (criteria D and λ_1) or by Hack (**4**) (criteria $H\delta$ and D) were not successful. Because of the low sensibility to luminosity effects of the spectral features in the O-type stars it is necessary to use average dispersion spectrograms and quantitative measurement methods.

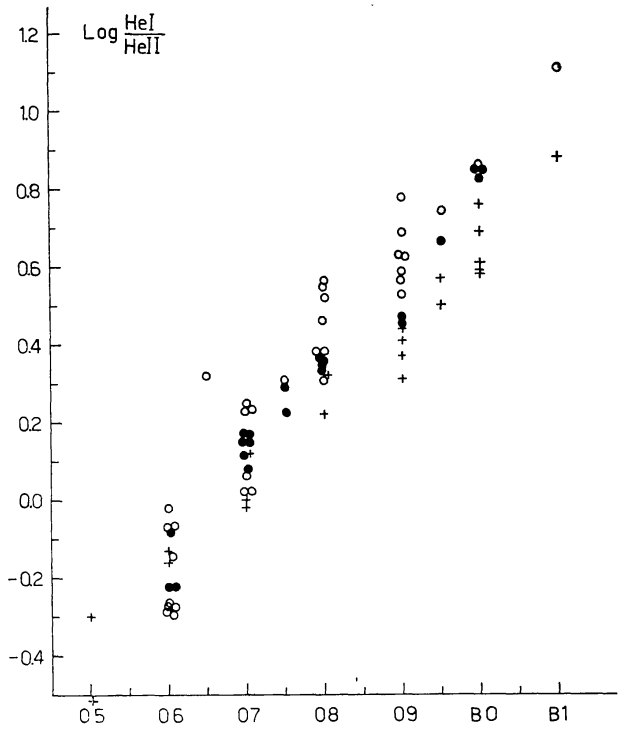

FIG. 1. *Open circles denote classes IV–V, filled circles class III, and crosses classes Ia, Ib, and II.*

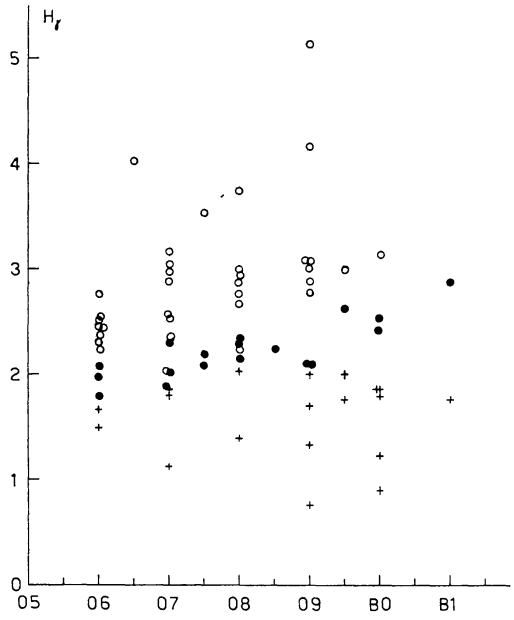

FIG. 2

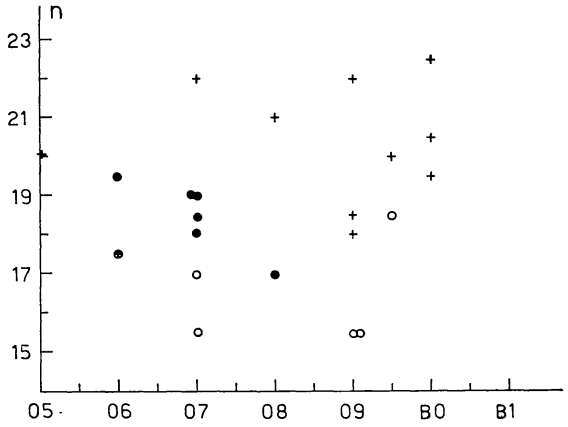

FIG. 3

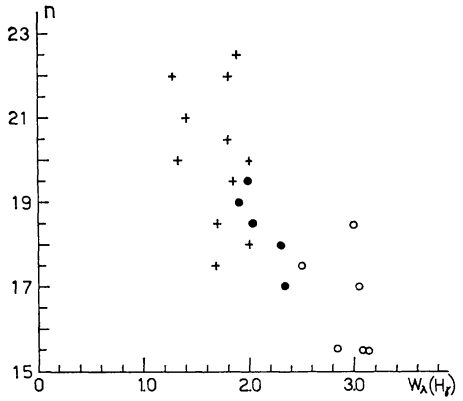

FIG. 4

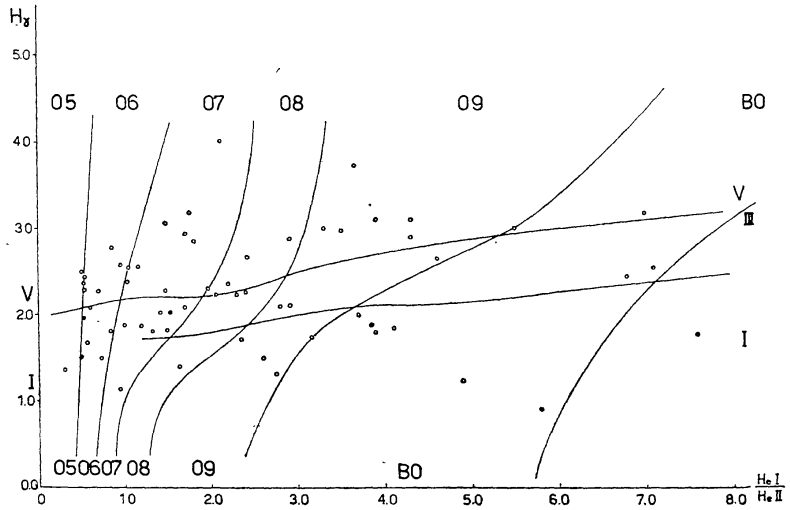

FIG. 5

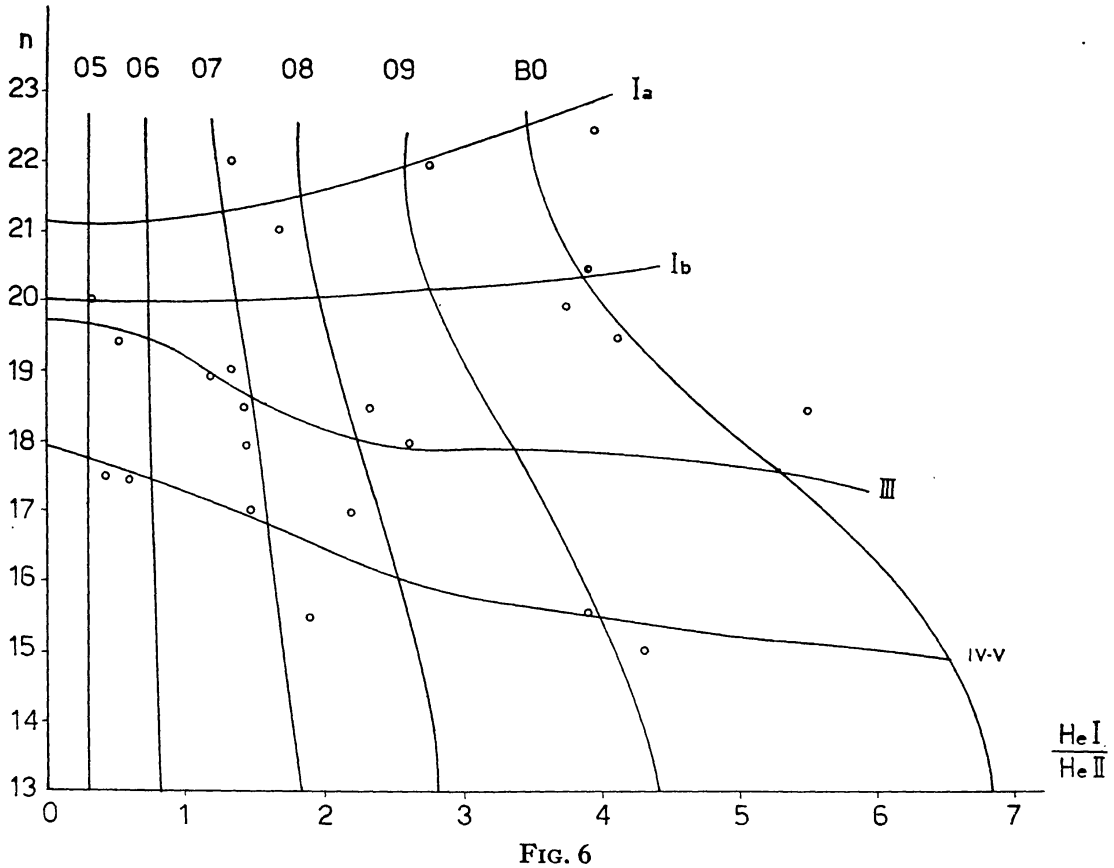

FIG. 6

At the present date we have classified about 100 stars between O5 and B1. The best temperature criterion has been found to be the ratio $\text{He I}/\text{He II} = 4471/\frac{(4541 + 4200)}{2}$ which has already been used by Petrie (5). This criterion is practically independent of the luminosity for spectral types earlier than O9 (Figure 1).

The criteria which proved to be useful for a luminosity classification are: the intensity of $H\gamma$, the quantum number n of the last resolved Balmer line, the ratio $r = \frac{4650\ \text{C III} + 4097\ \text{N III} + 4116\ \text{Si IV} + 4089\ \text{Si IV}}{H\gamma + H\delta}$.

Table 1

Spectral type and luminosity class	Adopted visual magnitude
Class Ia	− 7·5
O5	− 7
O6 Ib	− 7
II	− 6·6
III	− 6·3
IV	− 5·5
V	− 5·0
O7 Ib	− 6·8
II	− 6·5
III	− 6·0
IV	− 5·25
V	− 4·5
O8 Ib	− 6·8
II	− 6·3
III	− 6·0
IV	− 4·9
V	− 4·4
O9 Ib	− 6·5
II	− 6·0
III	− 5·7
IV	− 4·7
V	− 4·4

Also the ratio R_c/W between the central depth and the equivalent width of $H\gamma$ proved to be a useful criterion of luminosity. It is, however, less satisfactory than the others because R_c is affected by instrumental resolution, by stellar rotation and by central emission. Figures 2, 3 and 4 show the dependence of $H\gamma$ and n upon the luminosity class.

The two pairs of families of curves $\text{He I}/\text{He II} = f(L, T)$ and $H\gamma = f(L, T)$; $\text{He I}/\text{He II} = f(L, T)$ and $n = f(L, T)$ which are used for classifying our spectra are shown in Figures 5 and 6.

The ratio $H\gamma/n$ is probably a better luminosity criterion, because $H\gamma$ and n have the same kind of dependence upon temperature, both decreasing with increasing temperature and displaying an opposite kind of dependence upon luminosity, $H\gamma$ decreasing and n increasing with increasing luminosity. Therefore using the ratio $H\gamma/n$ the dependence upon T is partly cancelled, while the dependence upon L is enhanced. Observations of n are in progress for this purpose.

An average spectral type is derived by using these four different luminosity criteria (which give results generally in good agreement). A relation between spectral type and absolute magnitude is found by using the absolute magnitudes given by Kopylov (**6**) and by Underhill (**7**) derived from the membership of the stars in the clusters and for stars members of binary systems. The more probable relation between spectral types and absolute magnitudes is given in Table 1.

References

1. Botto, P., Hack, M. *Mem. Soc. astr. Ital.* **33**, 159, 1962.
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5. Petrie, R. M. *Publ. Dom. astrophys. Obs.* **7**, 321, 1947.
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7. Underhill, A. B. *Publ. Dom. astrophys. Obs.* **10**, 169, 1955.

DISCUSSION

Slettebak: Were any Of stars included in your sample, and if so, what kind of luminosities did they show?

Hack: Yes. They appear to be more luminous than the absorption line O-type stars, but this may be because of emission in the lines.

Slettebak: This is an interesting result. Some years ago I found a correlation between the strength of the HeII + NIII emission in Of stars and their luminosities, in the sense that the stars with strong emission appeared to be more luminous. My result is quite uncertain, however, because of the small sample of stars considered.

Thackeray: It is very gratifying that we have at last some criterion for distinguishing luminosities among the early O stars. I would mention that in the Large Magellanic Cloud we find the absorption O stars coming in at about twelfth magnitude at brightest, or about $M_v = -7$, which in itself suggests that there must be a spread in M_v of about 2 magnitudes.

Buscombe: The Of stars in galactic clusters with photometric distance moduli are somewhat more luminous than the absorption line O stars.

Hack: We observed some Of stars and according to my criteria they appear to be supergiant stars. However, this can partly be due to the presence of an emission component in $H\gamma$. The best criterion is the quantum number n, which is not affected by emission. Four Of stars, for which values of n were observed, appear to belong to class Ia (two stars) and I (two stars).

Beer: In conjunction with Miss Hack's interesting remarks, I should like to draw attention to some work in hand, at present, in collaboration with Dr Schmidt-Kaler. This work aims at a unified system comprising all hitherto measured indicators of equivalent width of the main Balmer lines, i.e. measurements obtained by photographic or by photo-electric spectrophotometry of $H\alpha$, $H\beta$, $H\gamma$, and $H\delta$. Some 60 observational series are available, covering work over more than three decades, differing considerably in extent, accuracy and

inner consistency. These data are programmed for electronic computer work with an IBM 7070 outfit, with the aim of obtaining in an exact manner valid intercorrelations between these series, as well as relative weights. The type of dependence of these indicators on apparent brightness, spectrum and luminosity class is being analysed at the same time, using all series with a considerable overlap of stars, and appropriate corrections are applied. The resulting final "equivalent width" system of the O7-B9 stars, calibrated with the help of all existing reliable cluster data will then lead, applied to different stellar age-groups, to an improved insight into the structural characteristics of galactic features, spiral arms or otherwise. The outcome of this homogenization should soon be available to all astrophysical workers. Any values of equivalent width which are still unpublished will be most welcome to us.