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PHOTOMETRIC CLASSIFICATION OF EARLY TYPE STARS WITH HYDROGEN EMISSION LINES

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RESUMEN. Este estudio se basa en 145 estrellas con tipos espectrales entre O4 y A1, cuyos espectros tienen o han tenido en alguna ocasión, una o más líneas de hidrógeno en emisión. Las estrellas han sido observadas en dos sistemas fotométricos: a) HKL de Johnson, b) $\alpha(16)$ $\Lambda(9)$ de Mendoza. Las estrellas para su estudio se han dividido en cinco grupos: 1) Wolf-Rayet, 2) Supergigantes, 3) Clásicas Be, 4) Peculiares Be, 5) Ae/Be de Herbig. Se discuten propiedades fotométricas de cada grupo y se bosqueja una clasificación.

ABSTRACT. This study is based upon 145 stars, from O4 to A1, whose spectra have or had at some time, one or more hydrogen lines in emission. They have been observed in two photometric systems: a) Johnson's HKL, b) Mendoza's $\alpha(16)\Lambda(9)$. The stars are divided in 5 working groups: 1) Wolf-Rayet stars, 2) Supergiant stars, 3) Classical Be stars, 4) Peculiar Be stars, 5) Herbig Ae/Be stars. The photometric characteristics of each group are discussed. An outline of classification is given.

Key words: STARS-CLASSIFICATION — STARS-EARLY-TYPE

I. INTRODUCTION.

Stellar classification through photometric methods is in many respects similar to visual classification of spectrograms. The main difference is that the former is usually based on measures pertaining to relatively few suitable selected features of the spectrum. The aim when using photometric techniques is either to make possible the classification of stars too faint to obtain spectrograms, or to obtain a higher precision.

This paper is based on two photometric indices, $\alpha(16)$ and $\Lambda(9)$, and a color index, H-K, from Johnson HKL photometric system. The goal is to separate, by a minimum of photometric quantities, different kinds of early type stars whose spectra have or had at some time one or more hydrogen emission lines.

II. THE OBSERVATIONS

The observations have been carried out at the Observatorio Astronomico Nacional at Tonantzintla, Pue. and San Pedro martir, B.C., Mexico with the 2.1 m, 1.5 m (Johnson Telescope), 1.0 m, and 0.84 m telescopes from 1971 to 1986 in the $\alpha(16)\Lambda(9)$ photometric system (Mendoza 1973, 1975, 1976, 1979a, 1979b, 1981, 1983, and 1986) and Johnson HKL photometric system.

The observational data consists of 145 stars distributed in 9 groups as indicated in Table 1.

III. CLASSIFICATION

A number of stars have the Balmer Hα line, both in absorption and in emission (see for instance Johnson and Mendoza 1980; Mendoza 1981). Since the $\alpha(16)$ index measures the total absorption of this hydrogen line, it means that a 'photometric emission' is obtained when emission dominates the absorption, if any, per example, in P Cygni where the presence of both components is well known: absorption and emission, the classical P Cygni profile.

The same holds for the $\Lambda(9)$ index. However, it should be pointed out that among a sample of nearly 600 stars of all kinds (see Mendoza 1985), none with an $\alpha(16)$ index in absorption has a $\Lambda(9)$ index in emission, as defined above, but there are a number of stars which clearly have a strong photometric emission, and at the same time a strong absorption in the $\Lambda(9)$ index (Mendoza 1981, 1986); sometimes when the spectrum is available it is possible to see a faint emission component in this OI (λ7774 A) line, but nevertheless the absorption is considerably stronger than this emission.

One advantage of the $\alpha(16)\Lambda(9)$ photometric system is its high precision (loc. cit.). However, one should keep in mind the above remarks, and that this kind of technique does not provide any information on line profiles.

A photometric classification of early type stars whose spectra have or had at some time one or more hydrogen emission lines can be determined through the $\alpha(16)\Lambda(9)$-plane (Figure 1) supported by the (H-K) vs $\alpha(16)$ diagram (Figure 2).

Firstly, let us give a glance to the α (16) $\Lambda(9)$-plane. The separation between photometric absorption stars and photometric emission stars is evident as marked by the big cross. It is also clear that a few stars during our observations did not have any photometric emission, such as those from the groups of supergiant, classical Be, and Herbig Ae/Be stars. As matter of fact, most supergiants lie close to the locus of a negligible hydrogen line; the farther to the right, that is, the stronger the total absorption of the OI (λ7774 A) the later the spectral type of these supergiant stars. This statement is valid, approximately, from O9 to F0-type stars of class Ia.

TABLE 1

Collection of early type stars with hydrogen emission lines

Group	n
Of	5
Oe	6
Op	3
O9-A1 luminosity class I	25
Classical Be	39
Bpe	15
Wolf Rayet	3
Herbig Ae/Be	49

We go first from weak to strong emission in the Hα line to find the Of and O-type supergiant stars, followed by a bunch of classical Be stars to end up with a number of Herbig Ae/Be stars. The first departure from this apparent main relationship is shown by the shell stars, defined herein as non supergiant B-type stars with an extended envelope; the larger the $\Lambda(9)$ index, the stronger the total absorption of the OI (λ7774 A) line, and most likely the larger the envelope.

It seems, since our data is too scanty, that Nitrogen Wolf Rayet stars have stronger Hα emission than Carbon Wolf Rayet stars; however the latter probably have a more extended envelope, since the $\Lambda(9)$ index is larger for WRC than for WRN as shown in Figure 1. More data on Wolf Rayet stars are certainly needed to confirm these findings.

Next, the Herbig Ae/Be stars can be divided in three photometric groups:

a) Those that follow the main relationship mentioned above, from normal O,A,B stars to extreme classical Be stars, and extending this relation to stronger emissions in both lines (Hα and OI).
b) Those which clearly show a stronger OI (λ7774 A) line than the indicated by the main relationship. These stars are plotted in Figure 1 at the left.
c) Those which have a strong absorption in the OI (λ7774 A), but at the same time they also show a strong emission in the Balmer Hα line. These stars are plotted in the middle of

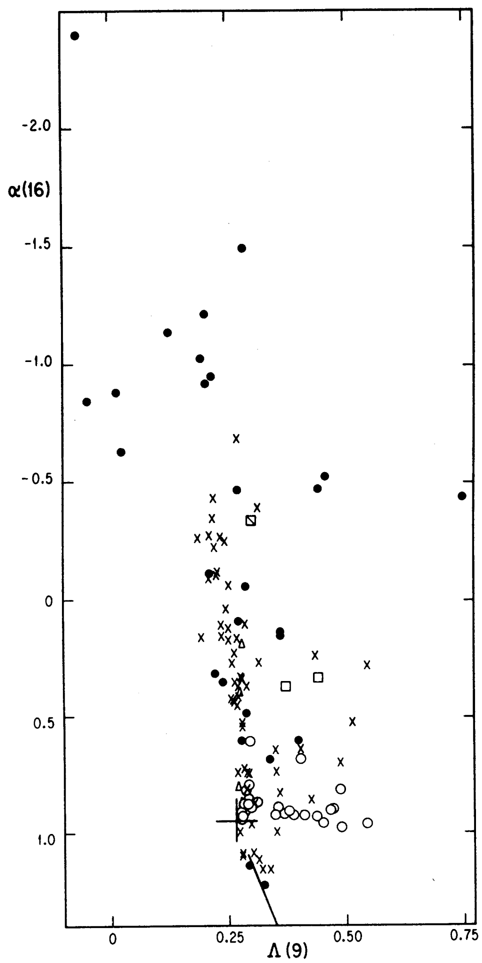

Fig. 1. The α(16)Λ(9) plane for early type stars with hydrogen emission line.
Coding: filled circles, Herbig Ae/Be stars; crosses, Oe, Op, Bp, and classical Be stars; open circles, O-A1 luminosity class I stars; open triangles, Of stars; open squares, Wolf-Rayet stars (the barred square, WN star; the remaining squares, WC stars); the line segment, MK standards stars of luminosity class V; the big cross marks the point where stars with a negligible equivalent width lie (see text). Above the horizontal line of this cross lie stars with an Hα line in emission, the higher is located the object, the stronger the hydrogen emission. To the left of the vertical line of this cross lie objects with an emission in the neutral oxygen line (λ7774 A); the emission increases further to the left; conversely, the farther to the right, the stronger the total absorption of this oxygen line.

Figure 1, but extending to the right. Note that one of them, VV Serpentis, has the largest Λ(9) index of all, that is, the strongest absorption, and probably it's the object with the largest envelope of all the 145 stars included in this study. No supergiant star, regardless the spectral type, has this large value. As matter of fact, all the supergiants so far measured have a Λ(9) index smaller than 0.60 magnitudes.

Probably, the combination of strong emission in Hα , and strong absorption in OI is also shared by a number of Novae stars (Mendoza 1987).

The Herbig Ae/Be stars look better separated from the remaining emission objects in the (H-K) vs α(16) diagram than in the α(16)Λ(9)-plane as illustrated in Figure 2. Additional information may be obtained from the two color diagram (H-K) vs (K-L), such as infrared color excesses, if any, and its possible causes as shown in Figure 3.

IV. CONCLUSION

A Photometric classification has been given for hot stars with hydrogen emission lines. The results indicate that it is possible to separate several groups of stars, namely,

1) Herbig Ae/Be stars
2) Shell stars
3) Wolf Rayet stars
4) Supergiant stars

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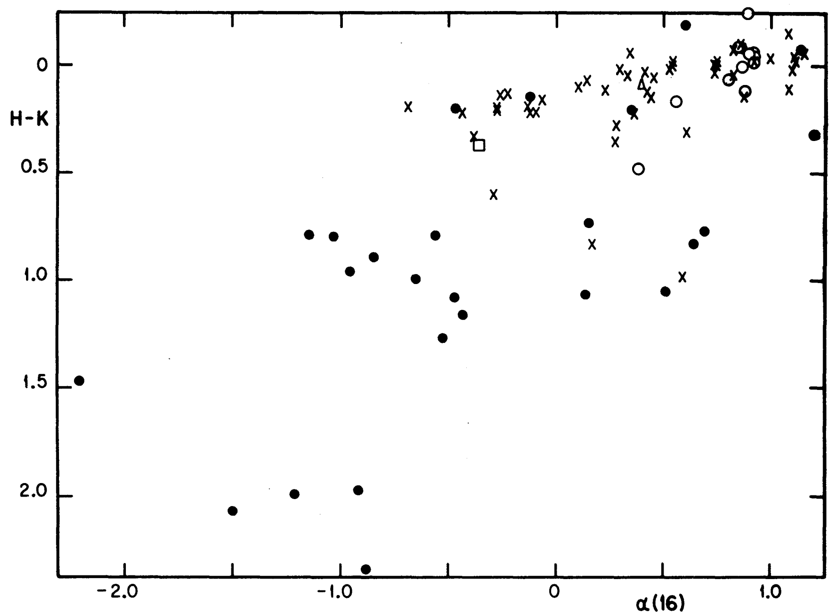

Fig. 2. The (H-K) vs α(16) Diagram for early type stars with hydrogen emission lines. Coding as in Figure 1.

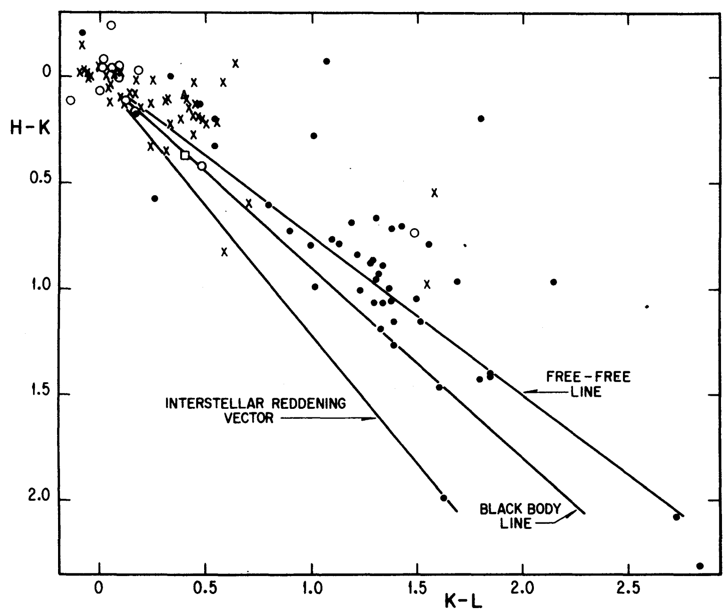

Fig. 3. Two color diagram for early type stars with hydrogen emission lines. Coding as in Figure 1.

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