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NEUTRAL OXYGEN OBSERVATIONS IN STARS*

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SUMARIO

En el Observatorio Astronómico Nacional del Instituto de Astronomía de la Universidad Nacional Autónoma de México en San Pedro Mártir, B. C. se han obtenido datos, en un nuevo sistema fotométrico, para treinta y una estrellas.

El sistema consiste en mediciones con tres filtros de interferencia de las líneas λ7774 Å de oxígeno neutro y el continuo alrededor de ellas.

Los resultados indican que este sistema fotométrico separa claramente las estrellas supergigantes de las que no lo son. La absorción total depende primariamente de la luminosidad estelar y secundariamente de la temperatura efectiva de la estrella, medida por el tipo espectral.

ABSTRACT

At the Observatorio Astronómico Nacional of the Instituto de Astronomía de la Universidad Nacional Autónoma de México in San Pedro Mártir, B. C., we have performed photoelectric photometry for 31 stars in a narrow-band system. The system allows the measurements of total absorptions of neutral oxygen at λ7774 Å through three interference filters (20-25 Å half-width).

The preliminary results are very encouraging: supergiant stars can be clearly separated from other luminosity classes, the total absorptions depend strongly on the stellar luminosity and, to a lesser degree on the effective temperature (spectral type) of the star.

I. Introduction

Photoelectric narrow-band photometry has proved to be very important for the quantitative classification of stellar spectra (cf. Strömgren, 1966). Measurements of the strength of Balmer lines have been used by many authors as luminosity criteria for B, A and F stars.

As early as 1934, Merrill (1934) noticed that the neutral oxygen lines at λ7774 and λ8446 are much stronger in supergiant than in other luminosity classes. Keenan and Hynek (1950) investigated the behavior and abundance of oxygen in stars ranging in spectrum from the later subdivisions of type B to type G. For this purpose they made use of the O I lines at λ7774 and λ8446. These are the only lines of neutral oxygen which attain any considerable strength in the "visual" region of the spectrum. We show in Figure 1 (after Keenan and Hynek, 1950) the configuration of energy levels from which these lines arise. The λ7774 line has actually three components (7771.90, 7774.18 and 7775.40) from the transition $3^5S°-3^5P$ (see Fig. 1). The λ8446 line has also three components; the latter arises from the transition $3^3S°-3^3P$.

The intensity of λ7774 is one of the most sensitive criteria known for the recognition of supergiants in types B5-G0 (Merrill 1934; Keenan and Hynek 1950), and it is a very suitable one for narrow-band photometry since the nearby continuum is free from contamination.

II. Interference Filters

This study is an attempt to measure the total absorption of neutral oxygen by the use of interference filters; our original attempt was to obtain three filters of 10 Å half-width, one centered on λ7774, and the other two on either side of this line, and separated from it by 20 Å. The filters obtained from Oriel Optics Corporation have half-widths somewhat larger: on the average they are around 23 Å. The data on each filter, as supplied by the manufacturer, are listed in Table 1 and illustrated graphically in Figure 2.

At the Observatorio Astronómico Nacional of the University of Mexico at San Pedro Mártir, B. C., we have carried out narrow-band photometry with the above three filters; a lens was added, to ensure parallel light at the filters, avoiding thus an increase in their half-width.

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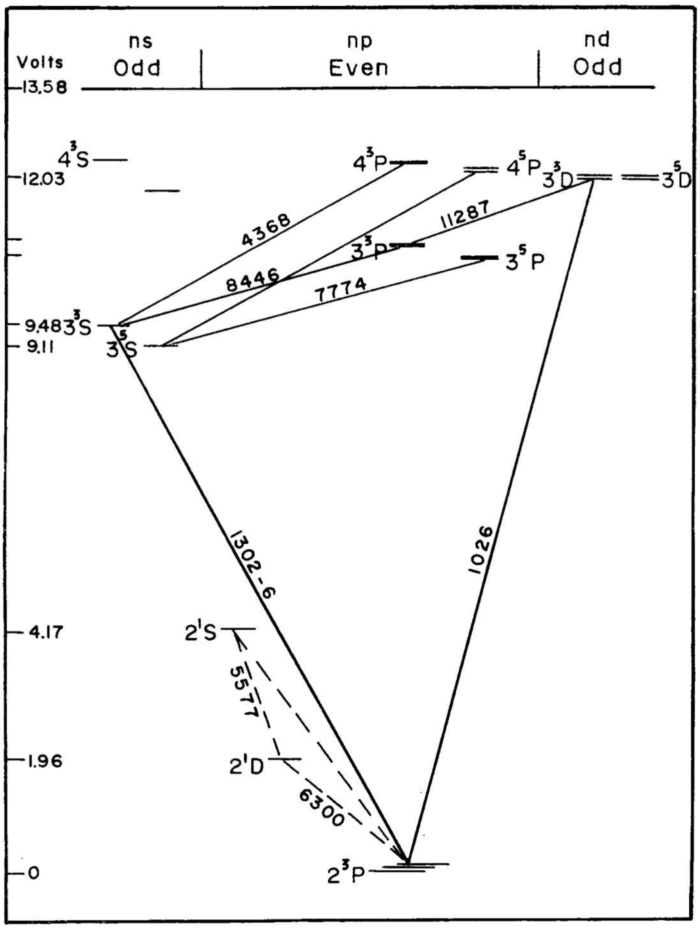

Fig. 1.—*The lower energy levels of neutral oxygen (after Keenan and Hynek 1950).*

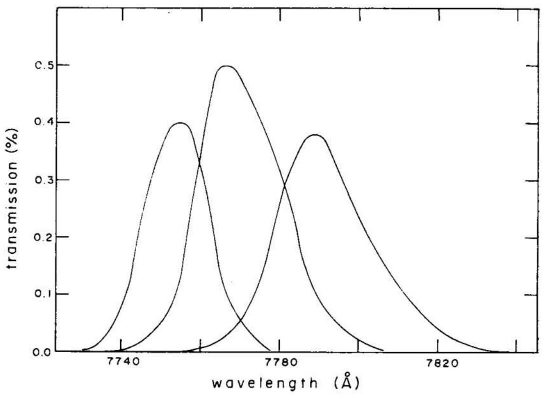

Fig. 2.—*The transmission curves of the interference filters.*

TABLE 1

The Peak Wave-lengths and the Half-widths of the Interference Filters

Filter	*Peak wave-lengths* (Å)	*Half-widths* (Å)
1	7755	20
2	7772	25
3	7792	25

III. The Observations

All observations were obtained in the period June-September 1971, with the *R, I* photometer (cf. Mendoza 1968) attached to the 152-cm photometric telescope.* Each program star was observed at least twice during the same night, and also on three different nights, on the average. We followed this technique to test the stability of the system, the atmospheric extinction effects and the internal errors.

In the present paper we report only on a Λ-index which measures the total absorptions of neutral oxygen. The provisional definition of this index runs as follows:

$$\Lambda = \tfrac{1}{2}\,[m\ (F1) + m\ (F3)] - m\ (F2)$$

(see Table 1); we designate by m $(F\ i)$ the magnitude obtained through filter i $(i = 1, 2, 3)$.

* Property of the University of Arizona, operated under the direction of the Instituto de Astronomía of the Universidad Nacional Autónoma de México through an agreement between both universities.

The results indicate that the Λ-index is independent of atmospheric extinction. However, it seems to depend slightly on the amount of precipitable water vapor content of the overlying atmosphere. The probable error of a single observation for a bright star (see Table 2) is ±0.004 mag. The observing time necessary to attain this accuracy is nine minutes, approximately. For a faint star, such as V1057 Cygni (see Table 3), twenty seven minutes are needed to achieve this accuracy. The observations include the measurement of a standard source which ensures an increase in the accuracy of the magnitudes, by allowing for the change of sensitivity of the detector (RCA 7102) with telescope position.

The new observational data on the system described above for 31 stars are given in Tables 2 and 3. The columns of Table 2 contain, first, the name of the star; second, the Bright Star Catalogue number BS (Hoffleit 1964); third, the Λ-index (in magnitudes); fourth, the number of nights during which the stars were observed (α Lyrae and α Cygni were observed every night); fifth, the MK-type as quoted by Hoffleit (1964); and last, equivalent width of the total absorption (in angstroms) obtained by Keenan and Hynek (1950). The columns of Table 3 list, first, the name of the object; second, the Λ-index (in magnitudes); third, the number of nights in which they were observed; and last, the spectral type (cf. Mendoza 1971).

TABLE 2

Neutral Oxygen Observations

Name	*BS*	Λ	*n*	*MK*	*W(Å)*
Sun*	—	−0.005	3	G2 V	—
β Cas	21	+0.003	2	F2 IV	0.96
α Per	1017	+0.016	1	F5 Ib	1.15
80 UMa	5062	−0.004	3	A5 V	—
—	5660	+0.046	3	F0 I	—
λ Ser	5868	−0.003	3	G0 V	(0.1)
o Sco	6081	+0.024	3	A5 II	—
σ Ser	6093	+0.007	2	F0 V	—
—	6196	+0.014	3	G8 II	—
—	6392	+0.030	2	G5 Ia	—
β Dra	6536	+0.015	3	G2 II	(0.5)
58 Oph	6595	+0.001	2	F5 V	—
ι Sco	6615	+0.046	2	F2 Ia	—
—	6619	+0.015	1	A0 Ib	—
89 Her	6685	+0.027	1	F2 Ia	—
ν Her	6707	+0.008	1	F2 II	—
α Lyr	7001	0.000	St	A0 V	1.05
γ Cyg	7796	+0.015	3	F8 Ib	1.16
41 Cyg	7834	+0.009	3	F5 II	(1.2)
β Del	7882	+0.010	3	F5 IV	0.68
α Cyg	7924	+0.019	St	A2 Ia	2.19
σ Cyg	8143	+0.019	2	B9 Iab	1.72
β Agr	8232	+0.011	2	G0 Ib	0.54
9 Peg	8313	−0.001	2	G5 Ib	(0.4)
α Agr	8414	+0.005	2	G2 Ib	(0.6)
ι Peg	8430	+0.005	2	F5 V	0.52
ξ Peg	8665	+0.006	3	F7 V	(0)
η Peg	8680	−0.001	4	F2 IV	(0.3)

* The actual observations correspond to Jupiter's Galilean satellites

TABLE 3

Λ-index for Three Non-normal Stars

Name	Λ	*n*	*Sp*
R CrB	0.041	3	Fpep
P Cyg	0.006	3	Bp
V 1057 Cyg	0.038	3	A1:

IV. Discussion

Two characteristics of the Λ-index are of great interest to us, namely, its capability to separate supergiant stars from the rest of the luminosity classes, and the possibility it offers for a comparison with the total absorptions of λ7774 with those given by Keenan and Hynek (1950).

To show the first characteristic we have selected from Table 2 all the stars of luminosity classes V, Ib and Ia. They are plotted in Figure 3 as filled circles, crosses and open circles, respectively. Based on this Figure we may state that indeed supergiant stars are clearly separated from main sequence stars. This Figure also shows small scatter for luminosity classes V and Ib. The scatter among class Ia is larger than the other two luminosity classes. However, all the plotted stars with luminosity class Ia lie above luminosity class Ib. We also notice from Figure 3 that there seems to exist a maximum Λ-index, for each luminosity class; this maximum falls around the spectral type F0-F2, and is to some extent, flatter in luminosity classes V and Ib than in luminosity class Ia.

Figure 4 shows graphically the comparison between our photometry and the equivalent widths given by Keenan and Hynek (1950). The agreement is generally satisfactory.

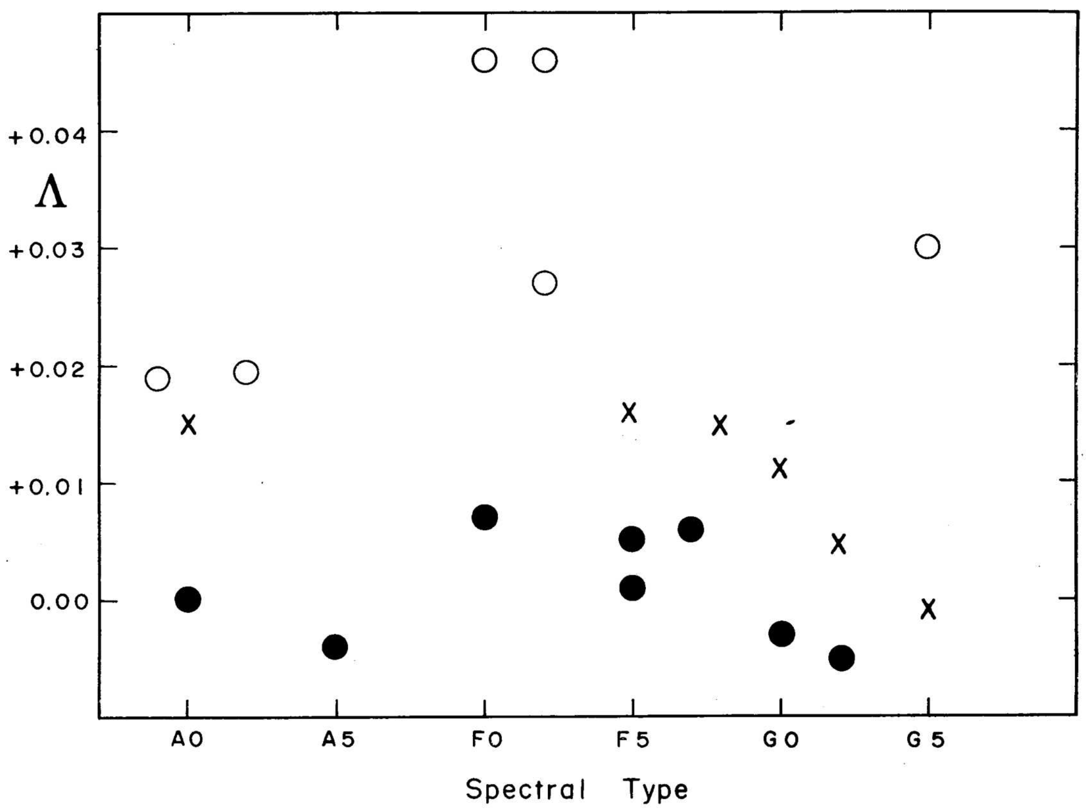

Fig. 3.—*Variation of total absorption of λ7774 with spectral type. The symbols used in this Figure are filled circles for luminosity class V; crosses for class Ib; open circles for class Ia, Iab and I (see Table 2).*

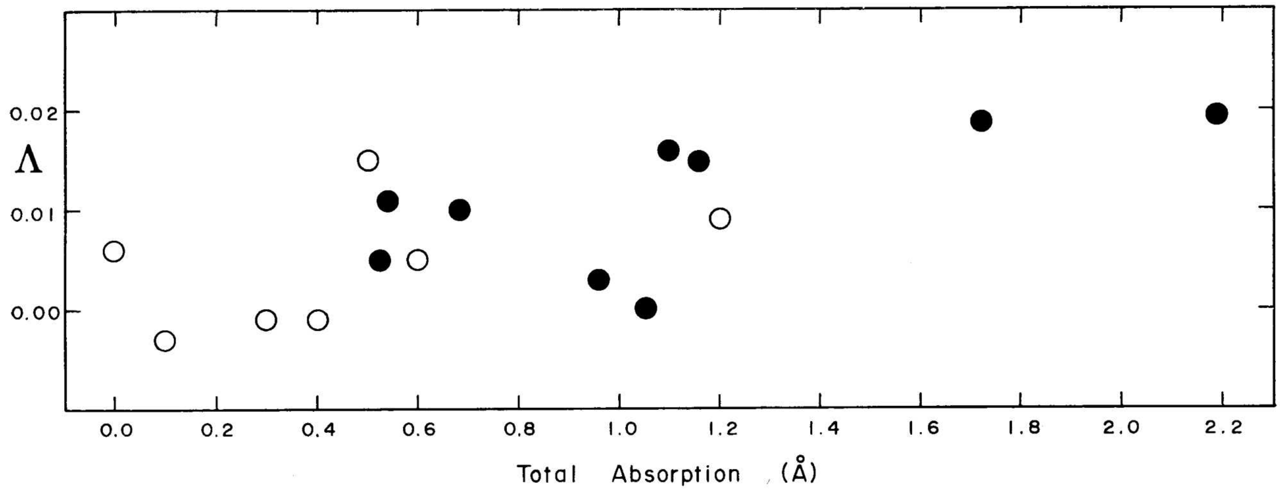

Fig. 4.—*The comparison of total absorption of neutral oxygen observed by Keenan and Hynek (1950) with those of the present study. The symbols used in this Figure are filled circles for the best measurements of Keenan and Hynek; open circles for less accurate values.*

V. Concluding Remarks

It is most likely that the results shown above can be improved by using narrower filters. The use of narrower filters (10 Å half-width) may not change the limiting magnitude appreciably, but it will separate better the luminosity classes. However, the results listed in Tables 2 and 3 are already very encouraging. On the other hand, there are detectors that can be used with a much higher quantum efficiency which of course will clearly reduce the observing time considerably.

Observations should therefore be continued, specially for those objects in which the spectra are highly peculiar and for which very little can be learned through spectroscopic techniques. Examples of this are the objects listed in Table 3. At the present time, as a working hypothesis, we may assume that in the majority of cases the Λ-index is, indeed, a luminosity criterion. However, it should be pointed out that this index may also depend on chemical composition. Taking all these factors into account probably all the objects listed in Table 3 are located above the main sequence.

We are indebted to Dr. D. Malacara and Mr. J. Castro for constructing the lenses used on top of the interference filters, and to Miss T. Gómez for drawing the Figures.

REFERENCES

Hoffleit, D. 1964, *Catalogue of Bright Stars* (New Haven: Yale University Observatory).
Keenan, P. C., and Hynek, J. A. 1950, *Ap. J.*, **111**, 1.
Mendoza, E. E. 1968, *Ap. J.*, **151**, 977.
———. 1971, *Ap. J. (Letters)*, **169**, L117.
Merrill, P. W. 1934, *Ap. J.*, **79**, 183.
Strömgren, B. 1966, *Annual Review of Astronomy and Astrophysics*, Vol. **4**, Ed. L. Goldberg (Palo Alto: Annual Reviews) p. 433.