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A PRELIMINARY REPORT ON Hα, OI-PHOTOMETRY OF YOUNG OBJECTS

EUGENIO E. MENDOZA V.

Instituto de Astronomía
Universidad Nacional Autónoma de México
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RESUMEN

En este trabajo se presenta la fotometría $\alpha(16)$, $\alpha(35)$, $\Lambda(9)$ and $\Lambda(16)$ de veinte estrellas de tipo O y tres de la familia T Tauri. Se confirma la excelencia de usar la línea Hα como criterio de luminosidad en las estrellas de tipo O. El oxígeno de éstas es muy parecido al del Sol. Algunos objetos T Tauri presentan sus líneas Hα y OI contaminadas por emisión, con intensidades que probablemente varíen con el tiempo. Por tanto, su uso en la obtención de luminosidades no siempre resulta adecuado.

ABSTRACT

This paper presents $\alpha(16)$, $\alpha(35)$, $\Lambda(9)$ and $\Lambda(16)$ indices for twenty O-type stars and three T Tauri-like objects. It is confirmed that Hα is an excellent luminosity indicator of the O star's luminosity. The multiplet neutral oxygen lines at λ7774Å for O-type stars, on the average, have the same strength as in the Sun. Hα and OI for T Tauri-like objects may be contaminated by emission, and probably they also vary with time. Hence, their use as luminosity criteria may not be adequate in many cases.

Key words: NARROW BAND PHOTOMETRY — LUMINOSITY — O STARS — T TAURI-LIKE OBJECTS.

I. INTRODUCTION

Members of O and T-associations are among the youngest objects in the Galaxy. It has been found that luminosity effects in O-stars were more pronounced at Hα than at other Balmer lines (see, for instance, Andrews 1968). The strength of the triplet neutral oxygen line at λ7774Å is an excellent criterion to separate high luminosity stars of spectral types A-F (Mendoza, 1971*b*). There are many T Tauri-like stars in this spectral range.

This paper presents observations in the ($\alpha(35)$, $\Lambda(16)$) and ($\alpha(16)$, $\Lambda(9)$)-photometric systems (Mendoza 1976*b*) of twenty O-stars and three T Tauri-like objects.

II. OBSERVATIONS

The observations were carried out at Tonantzintla with the 40-inch telescope in the photometric systems already described (*cf.* Mendoza 1976*b*). The results are given in Table 1. The columns of Table 1 contain, first, the star designation (name, HD or BS number); second through fourth, UBV-photometry, taken from Jaschek *et al.* for the O-stars, and from Mendoza (1968, 1971*a*), for the T Tauri-like objects; fourth through eighth, the Hα, OI-photometry; ninth, the number of independent observations in each system; tenth, the spectral type, taken from Morgan and Keenan (1973) (MK standards) and Cruz-González *et al.* (1974), for the remaining O-

stars (the T Tauri-like objects' spectral type was taken from the same source as the UBV-photometry); and last, remarks.

The observational errors for a single observation are ±0.01 mag approximately. They are larger than for the A-stars (Mendoza 1976*a*), because the objects are fainter and some of them may have variable Hα and OI-indices. In addition, many of them were observed at air masses larger than two.

A comparison of $\alpha(35)$ and $\alpha(16)$ with Rα (Andrews 1968) is given in Figures 1 and 2. The correlation is good. A comparison of $\alpha(35)$ and $\alpha(16)$ with the β-index (Crawford 1975) is given in Figures 3 and 4. Here the correlation is not as good. This is because the Hβ and Hα lines do not behave ailke in the O-type stars. This is an example where Hα is preferred to Hβ.

III. DISCUSSION

a) *O-Stars*

The Hα-line of the O-stars correlates very well with luminosity. As an example, data for the O9 and O9.5 stars have been plotted in Figure 5. Morgan's MK standards (crosses) define a narrow line, which is also present in the ($\alpha(16)$, luminosity class)-array. The α-indices of the Of stars show the hydrogen line Hα in emission. The same is true for the most luminous O-stars, indicating the presence of extended envelopes. Perhaps the smaller the hydrogen index the larger the envelope. It seems that there is a smooth transition from absorption to emission, as the stellar luminosity increases (see also Crawford *et al.* 1975).

The oxygen-indices $\Lambda(16)$ and $\Lambda(9)$ in O-type stars, on the average, are very much like the Sun's, measured by observing Callisto (Jupiter IV). Perhaps HD 93521 (Op) is oxygen-deficient with respect to hydrogen by a small factor.

b) *FU Orionis*

The $\alpha(16)$-index corresponds to an A-supergiant star. However if it is contaminated by emission it may correspond to a later type and to lower luminosity. The index probably is variable, since it changed 0.05 mag. in only 24 hours. Under the assumption that FU Ori is an F-type star, the $\Lambda(9)$-index indicates a luminosity class II, a bright giant. If this index is contaminated slightly by emission, then the luminosity would be brighter.

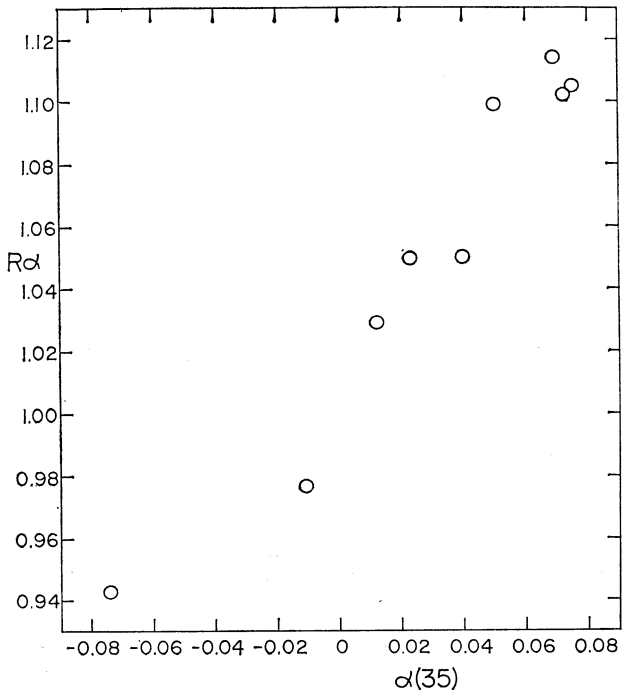

FIG. 1. The relationship between $\alpha(35)$ and Rα (Andrews 1968).

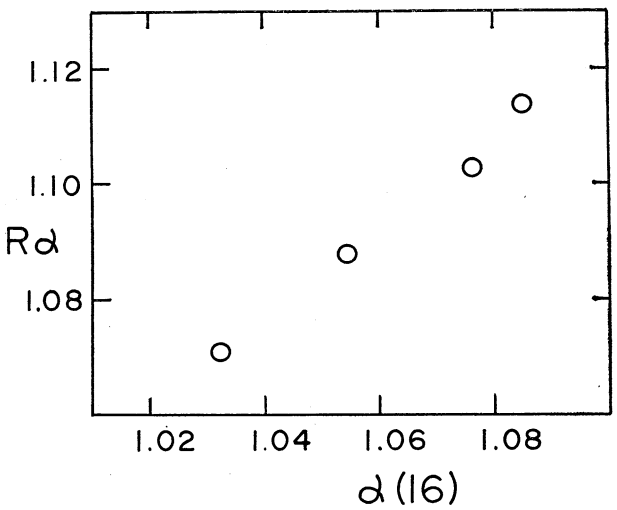

FIG. 2. *The relationship between α(16) and Rα.*

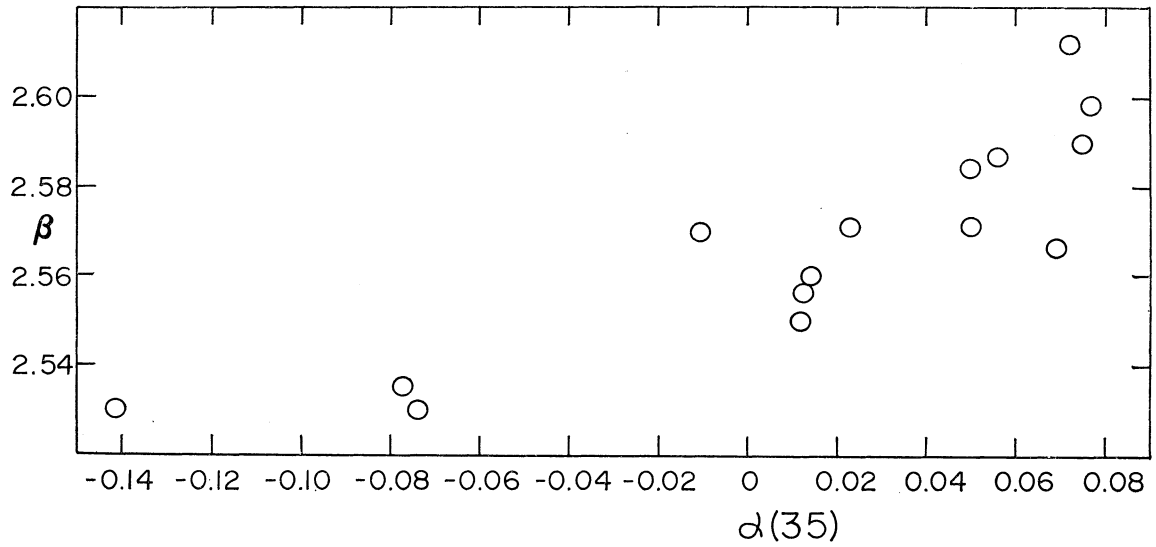

FIG. 3. The relationship between $\alpha(35)$ and β-index (Crawford 1975).

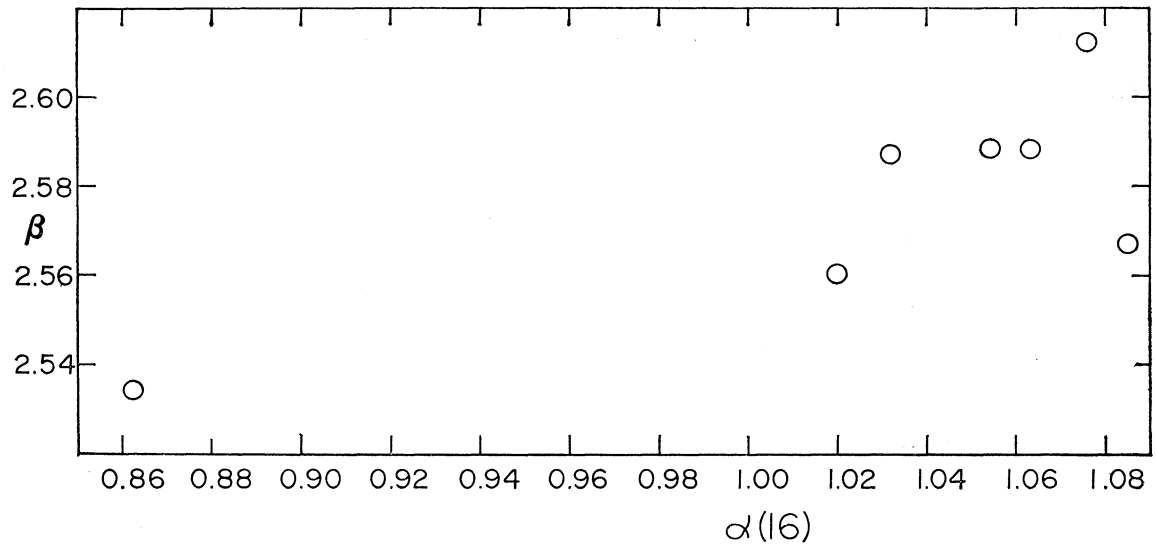

FIG. 4. The relationship between $\alpha(16)$ and β-index.

c) *R Coronae Australis*

Both $\alpha(16)$ and $\Lambda(9)$-indices indicate that the lines are strongly contaminated by emission, especially the hydrogen line. Though these indices probably have larger observational errors than the other objects listed in Table 1, the presence of the emission seems certain.

d) *V1057 Cygni*

V1057 Cyg is very much like FU Ori. The $\alpha(16)$-index, indicates also an A-supergiant star. The previous OI observations (Mendoza 1971*b*; $\Lambda = \Lambda(25)$) also indicated an A-supergiant star. However the $\Lambda(9)$-index (see Table 1) corresponds to a main-sequence A-type star. Probably the triplet neutral

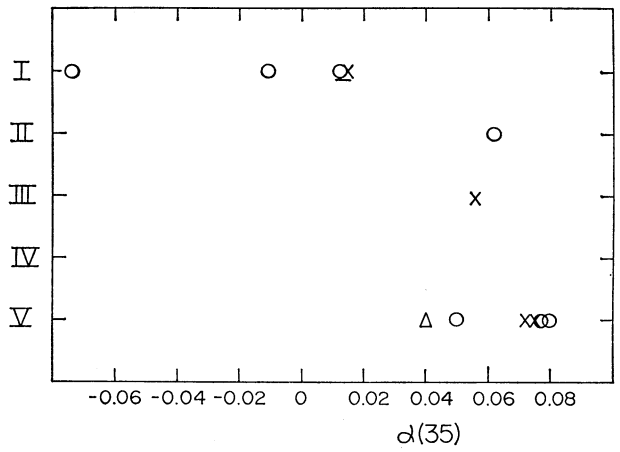

FIG. 5. The relationship between $\alpha(35)$ and luminosity class for O9 and O9.5 stars. The symbols represent: crosses, MK standards (Morgan and Keenan 1973); circles, types from Cruz-González *et al.* The triangle, HD 93521 (Op).

oxygen line at λ7774Å is now contaminated by emission.

IV. CONCLUSION

The main conclusions may be summarized as follows:

1) The $\alpha(35)$ and $\alpha(16)$ indices are excellent indicators of luminosity in O-type stars. The correlation with Morgan's classification (Morgan and Keenan 1973) is good. The correlation with $R\alpha$ is satisfactory.
2) The $\Lambda(16)$ and $\Lambda(9)$ indices indicate that O-type stars are a homogeneous group. The strength of the multiplet neutral oxygen lines is very much like that of the Sun.
3) The $\alpha(16)$ index for FU Ori and V1057 Cyg can be interpreted as that of an A-supergiant

TABLE 1

Hα, OI-PHOTOMETRY OF YOUNG STARS

Object	V	B−V	U−B	α(35)	α(16)	Λ(16)	Λ(9)	n	Sp	R
				(in magnitudes)						
AO Cas	6.1v	0.03	−1.01	0.012		−0.014		3,0	O9.5 I	
HD 24431	6.7:	0.37	−0.61	0.079		−0.007		2,0	O9.0 V	
ξ Per	4.04	0.02	−0.92	0.023		−0.006		2,0	O7.5 I	
α Cam	4.3:	0.02	−0.82	−0.074		−0.010		2,0	O9.5 I	
ι Ori	2.76	−0.25	−1.07	0.056	1.063	−0.005	0.294	1,1	O9 III	1
σ Ori	3.8:	−0.24	−1.03	0.072	1.076	−0.009	0.292	1,1	O9.5 V	1
ζ Ori	1.8:	−0.21	−1.06	−0.011		−0.009		1,0	O9.7 Ib	
FU Ori	8.94	1.41	+1.00		1.098		0.349	0,4	F2	2
HD 46150	6.74	0.13	−0.83		1.054		0.299	0,1	O5	1
HD 46223	7.27	−0.22	−0.78		1.032		0.302	0,1	O4	1
15 Mon	4.66	−0.25	−1.06	0.069	1.085	−0.007	0.298	3,1	O7	1
BS 2467	6.37	−0.05	−0.94	0.050		−0.007		1,0	O6.5 V	
UW CMa	4.9v	−0.15	−1.01	−0.141		−0.008		3,0	O8.5 If	
τ CMa	4.4:	−0.15	−0.98	0.014	1.020	−0.011	0.290	1,1	O9 Ib	1
BS 2806	6.42	−0.20	−1.03	0.050		−0.008		1,0	O9.0 V	
ζ Pup	2.26	−0.28	−1.12	−0.077	0.862	−0.008	0.299	2,1	O5 f	1
BS 3219	6.44	−0.01		0.013		−0.009		1,0	O9.7 Ib	
BS 3525	5.98	−0.10		0.077		−0.002		1,0	O9.0 Vn	
BS 3527	5.10	−0.21	−0.98	0.062		−0.011		3,0	O9.5 II	
HD 93521	6.89			0.040		−0.016		2,0	O9.0 Vp	
R CrA	10.74	0.56	+0.10		−1.22:		0.20:	0,1	A5	
V1057 Cyg	9.47	1.23	+0.58		1.036		0.311	0,3	A5	3
10 Lac	4.88	−0.20	−1.04	0.075		−0.011		3,0	O9 V	1

1. MK type from Morgan and Keenan (1973). Type from Cruz-González *et al.* (1975) for MK standards: ι Ori, O8.5 III; σ Ori, O9.5 V; HD 46150, O5.5f; HD 46223, O5.0f; 15 Mon, O8.0 III, τ CMa, O9.0 I; ζ Pup, O4.0 I(n)f; 10 Lac, O8.0 III.
2. FU Ori is suspected of a variable $\alpha(16)$-index. It changed from one night to the next by $\Delta m = 0.05$ mag.
3. V1057 Cyg, $\Lambda(25) = 0.038$ (Mendoza 1971b).

star, or of a later type and lower luminosity if it is contaminated by emission. In this case, the luminosity class and spectral type are more difficult to obtain from the Hα-photometry. The photometry for R Cr A indicates the presence of Hα in emission.

4) The Λ(9) index listed in Table 1 for T Tauri-like objects may also be contaminated by emission, but probably very little, if any, in FU Ori and V1057 Cyg. The OI emission in R Cr A is less doubtful than in the other two objects. The intensity of the triplet neutral oxigen line at λ7774Å for V1057 Cyg has changed enormously from 1971 to 1976, perhaps because of a recently formed emission OI-line superimposed on the stellar OI absorption.

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