?ev. Mexicana Astron. Astrof., 6, 237-242 (1981)

DIFFERENT STELLAR WINDS IN O-TYPE STARS

R. Costero

Instituto de Astronomía
Universidad Nacional Autónoma de México

and

R. Stalio

Osservatorio Astronomico di Trieste
Italia

RESUMEN

Presentamos resultados preliminares del análisis de espectros ultravioletas de veintinueve estrellas O. Se sugiere que las diferencias en abundancias químicas del grupo CNO pueden explicar los diferentes desplazamientos hacia longitudes de onda más cortas, medidos en las líneas de resonancia de N V y C IV en una misma estrella. Las diversas abundancias relativas del grupo CNO se deberían, probablemente, a efectos de evolución estelar.

ABSTRACT

We present some preliminary results on the analysis of the far UV spectra of twenty-nine O-type stars. We suggest that the possible effects of CNO chemical abundance variations may explain differences of maximum wavelength displacements in the N V and C IV resonance lines in hot stars. The CNO relative abundance differences would be due to evolutionary effects.

Key words: **STARS-CIRCUMSTELLAR SHELLS – STARS-EARLY TYPE – STARS-MASS LOSS – ULTRAVIOLET-SPECTRA**

This is a progress report on the analysis of the *IUE* ıigh-resolution, far-UV spectra of a moderately exten-ݵive sample of O4-B0 and sdO stars. Our study concerns the resonance lines of Si IV, C IV and N V in those stars. Here we mention only some morphological properties of the N V λλ1238-1242 lines and from a comparison with the C IV λλ1548-1551 profiles, we explore the possibility of different CNO abundance effects in the stars of our sample.

The high-ionization resonance lines are known to be suitable probes of wind structure in early-type stars. In principle, information about wind velocities and ionic densities can be obtained from their profiles. However, in practice, several assumptions have to be made regarding the origin and the acceleration mechanism of the wind, its geometry and temperature structure. These and other assumptions might be better justified, or found to be unacceptable, on the basis of the statistical analysis of some properties pertaining to the resonance lines in the stellar spectra.

In Table 1 we present the stars in our sample. The HD or BD numbers are given, together with the common name, when applicable. The spectral types were obtained mostly from Walborn (1971, 1972, 1973). All the subdwarf stars have been classified sdO, regardless of their temperature; the coolest one is probably HDE 269696, an eclipsing and single-lined spectroscopic binary with temperature 3-4 × 10^4 °K (Conti *et al.* 1981; Kilkinney *et al.* 1981). The spectral types of θ^2 Ori A, HD 93521 and BD+ 33 °2642 are those given by Conti and Alschuler (1971); Bisiacchi *et al.* (1976, 1978) and Klemola (1962), respectively. The short-wavelength, high-dispersion *IUE* image number and the OB association to which the star probably belongs are listed in columns 4 and 5. Columns 6 and 7 contain the maximum expansion velocity at which N V and C IV can be detected in our spectra, respectively (see below). On the last column we list some remarks regarding the binary nature of the stars and their kinematics. We have adopted the notation VB = visual binary; SB = spectroscopic binary; V_r "runaway" when the |peculiar radial velocity,| > 30 km s^{-1}, according to Cruz-González *et al.* (1974); and μ "runaway" defined by its large space velocity, mainly its large proper motion, according to Blaauw (1961). An asterisk in this column indicates that there is an explanatory note for the star at the end of the table.

The N V profiles of 18 stars are shown in Figures 1*a* and 1*b*. The spectra are presented in increasing order of maximum negative displacement of the absorption wings. All the stars in Figure 1*b* show very strong P Cygni-type profiles *and* large negative displacements. In the case of HD 149408, the displacement is blended with the Ly α interstellar absorption. We believe that the P Cygni shape is also present in all the stars of Figure 1*a*. This is quite evident for HD 93521, HD 49798 and λ

TABLE 1

CHARACTERISTICS OF STARS IN OUR SAMPLE

HD, BD or CD (1)	Name (2)	Spectral type (2)	IUE SWP (3)	OB Assoc (4)	V_{edge} (km s^{-1})		Remarks (7)
					N V (5)	C IV (6)	
24912	ξ Per	O7.5 III ((f))	4017	Per 2	2590	2580	V_r runaway
30614	α Cam	O9.5 Ia	4044	*	1820	1900	μ runaway
34078	AE Aur	O9.5 V	4043	*	880	1100	V_r and μ runaway
36486	δ Ori	O9.5 II	4018	Ori 1	2400	2560	SB
269696	LB 3459	Sd O	3729	––	––	––	SB
36861	λ Ori A	O8 III ((f))	4042	Ori 1	2230	2570	VB
37041	θ² Ori A	O9 V	1391	Ori 1	––	––	SB, VB
37128	ε Ori	B0 Ia	3536	Ori 1	––	––	––
37742	ζ Ori	O9.7 Ib	4019	Ori 1	1960	2480	VB
38666	μ Col	09.5 V	4039	*	1070	1020	V_r and μ runaway
48099		O7 V	3347	Mon 2	2810	3430	SB; in NGC 2244
49798		Sd O	1699	––	1410	<180	SB
57061	τ CMa	O9 II	4040	NGC 2362	2280	2530	SB
– 31°4800		Sd O	2074	––	<620:	<100	––
66811	ζ Pup	O4If	1547	Gum?*	2740	2760	V_r runaway
+ 75°325		Sd O	3205	––	<680	<120	––
93521		O9.5 II pop II	1607	––	830	900:	SB:?
112244		O8.5 Iab (f)	4193	––	1770	2130	V_r runaway
127493		Sd O	4860	––	<500:	< 80	––
+ 33°2642		B0 II pop II	4791	––	650:	350:	––
149404		O9 Ia	4322	Ara 1a	2960::	3100	SB?*
162978		O7.5 II ((f))	4195	Sgr 1	––	––	––
164794	9 Sgr	O4 V ((f))	2815	Sgr 1	3450	3580	SB?; in NGC 6530
164816		O9.5 III-IV	2814	Sgr 1	630	1070	In NGC 6530
175754		O8 II ((f))	6269	––	2470	2500	––
193322		O9 V	2346	Cyg 9?	770	1820	VB; SB?
201345		ON9 V	6480	?*	1480	500	V_r runaway
210839	λ Cep	O6 I fp	4015	Cep 2	2520	2580	V_r runaway*
214680	10 Lac	O9 V	4016	Lac 1	1120	1410	––

α Cam, AE Aur and μ Col: These stars could have been ejected from a nearby OB associations (Blaauw 1961).
ζ Pup: See Brandt *et al.* (1971). The star maybe is not a runaway, but may have the radial velocity perturbed by its f characteristics.
HD 149404: N V is blended with interstellar Ly α.
HD 201345: very doubtful member of Cyg OB 4.
λ Cep: the star maybe is not a runaway. See ζ Pup.

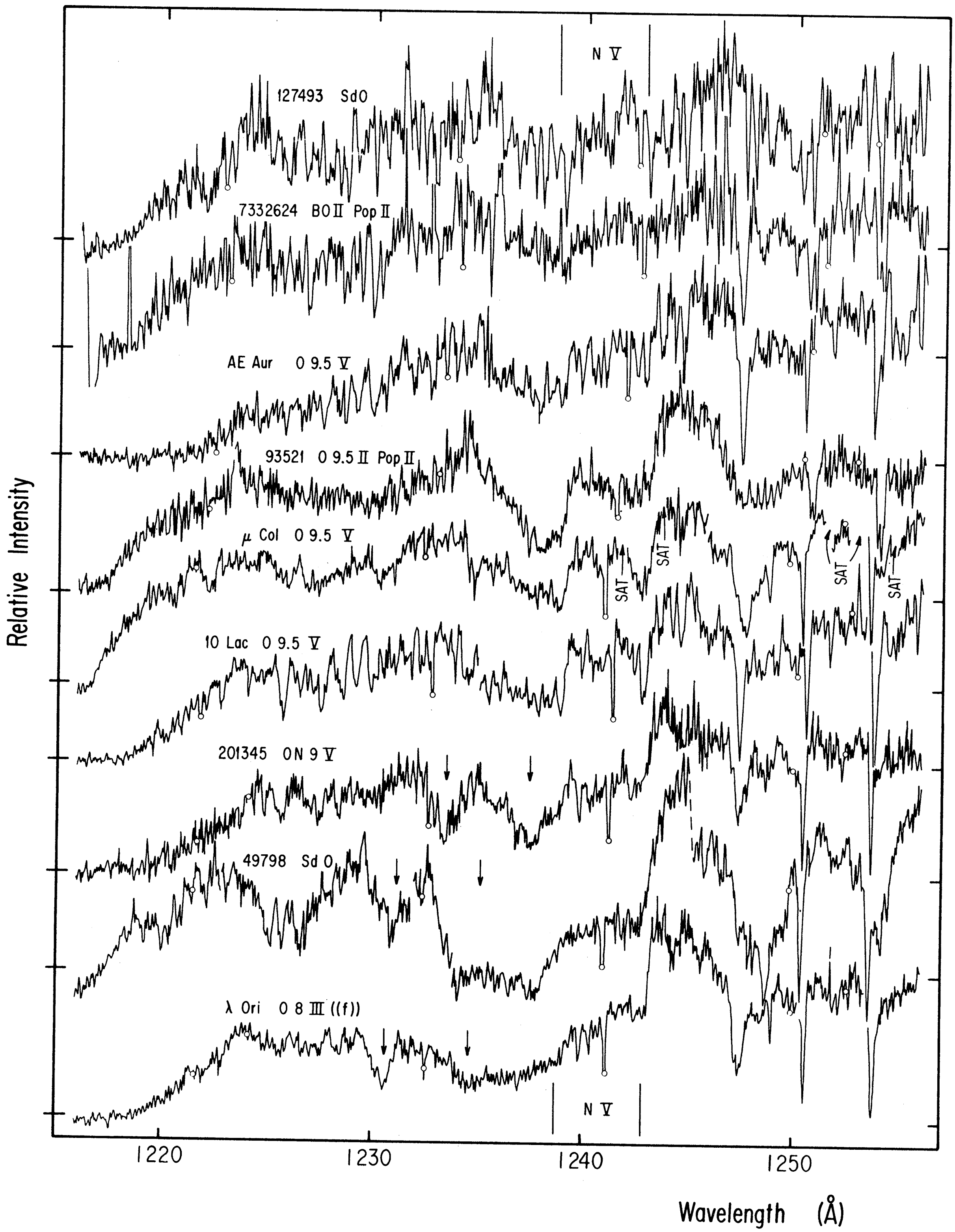
Ori, but not so for the other six stars which show profiles that can be fitted with the mean, incipient P Cygni shown in Figure 2.

It is worth mentioning that the stellar group with incipient P Cygni profile includes HD 127493, a hot, He-rich subdwarf $T_{eff} = 42500$ °K, log $g = 5.25$, $Y \approx 0.6$; Grushinske *et al.* (1980) and BD +33°2642, a Population II, high-luminosity B star ($T_{eff} = 22900$ °K, log $g = 2.3$; Travin 1962). Well defined P Cygni profiles in N V are displayed by HD 49798, a hot, He-rich subdwarf ($T_{eff} = 47500$ °K, log $g = 4.25$ and $Y \approx 0.5$; Simon *et al.* 1980) and by HD 93521 a population II, high-luminosity O star ($T_{eff} \cong 33000$ °K log $g \cong 3.3$ Bisiacchi *et al.* 1978). The four stars are low-mass, subluminous objects and the presence of expanding atmospheres in them is not always expected.

Some of the stars in Figures 1*a* and 1*b* also show shortward displaced absorption N V features of FWHM much smaller than the wavelength displacement. The positions of these "shell-like" absorptions are marked with arrows; some of them are superimposed to the P Cygni profiles and hence are not easily detectable.

By measuring the maximum wavelength displacement for each star, we can estimate the highest expansion velocity at which an ion can be detected in our spectra. We call this the "edge velocity" (V_{edge}) for the ion, as has been done by Carrasco *et al.* (1981). Our preliminary estimates of V_{edge} for the N V and C IV ions are listed in Table 1.

In order to look for a possible dependence of the "edge" velocity with ionic abundances, we have compared in Figure 3 the N V V_{edge} values with the preliminary estimate of V_{edge} for the C IV resonance lines. There is a general trend indicating smaller values of



. 1*a*. Spectra of the OB stars in the N V resonance doublet region. The arrows show the positions of the shifted, shell-like features. ; vertical lines at top and bottom indicate the rest position of the N V λ1238.8 line. The spectra have been normalized to about the ie continuum height near λ1240; the horizontal lines at both sides of the figure are the corresponding *IUE* zero levels for each :trum. Open circles indicate the positions of reseau marks.

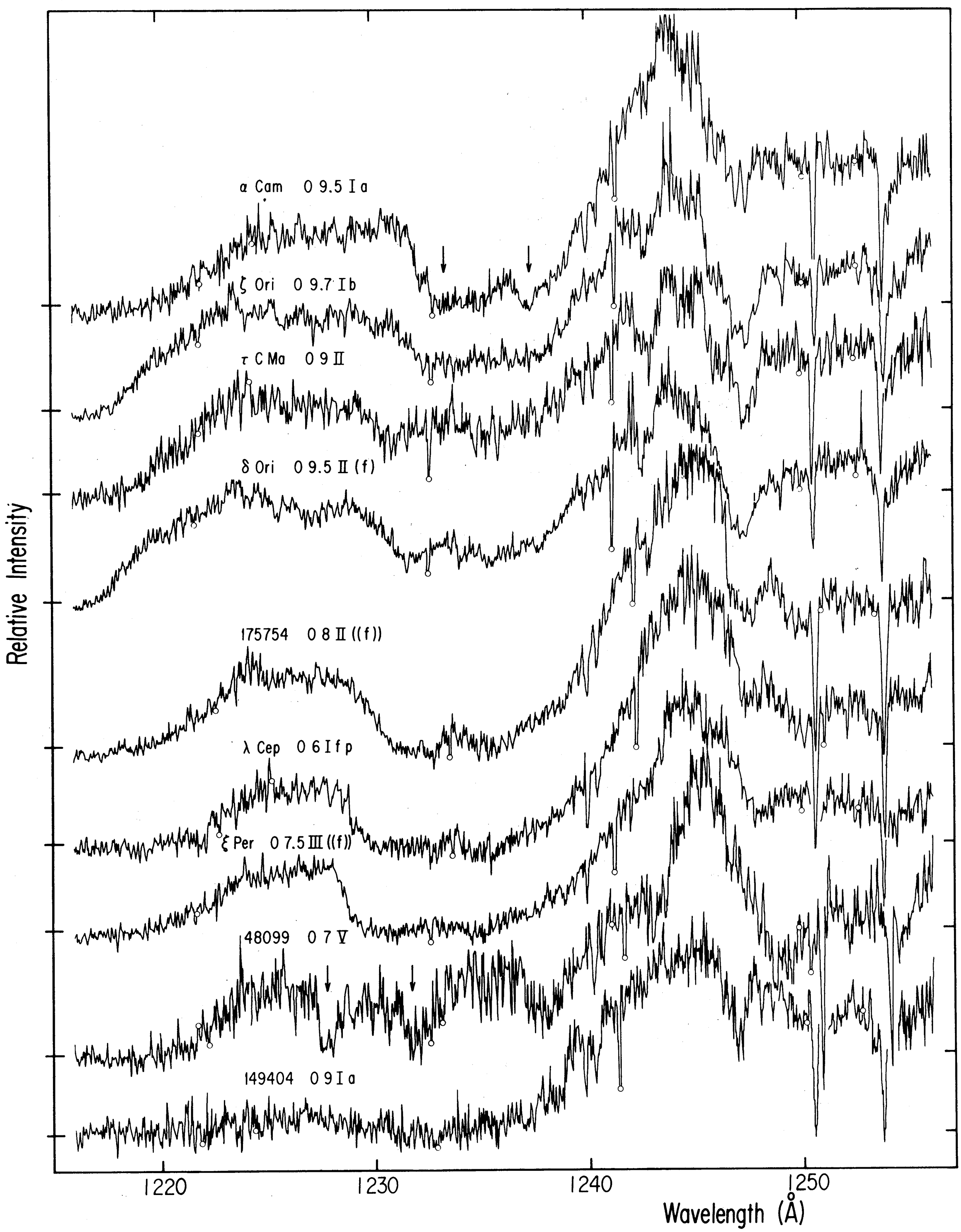


Fig. 1*b*. Same as Figure 1*a*.

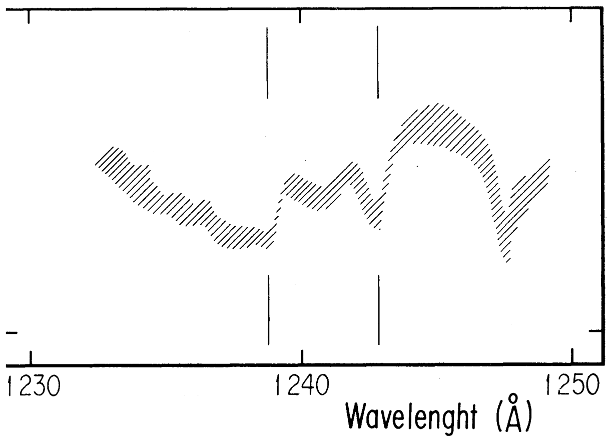


Fig. 2. Incipient P Cygni profile to which most N V profiles shown in Fig. 1*a* can be fitted. The vertical and horizontal lines have the same meaning as in Figure 1*a*.

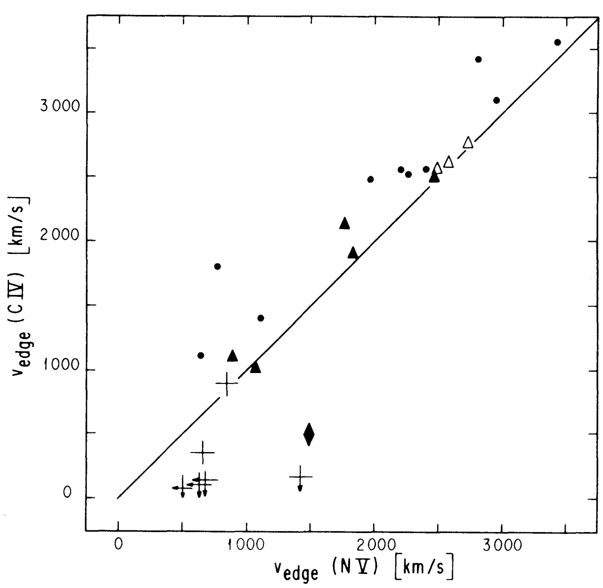


Fig. 3. Comparison of the edge velocities as estimated from the C IV (vertical axis) and N V (horizontal axis) resonance lines in the same stars. Symbols represent: crosses, population II stars; circles, low-velocity stars inside OB associations or galactic clusters; open triangles, high-velocity stars inside OB associations or young clusters (runaways?); filled triangles, high-velocity stars *not* inside an OB association or galactic cluster (runaways or disk UV-stars?). The diamond is HD 201345, a nitrogen-rich star (see text).

N V V_{edge} as compared with those of C IV. The exceptions are, almost invariably, the Population II stars (crosses in Figure 3): O-subdwarfs, HD 93521 and BD + 33 °2642. Some subdwarf O-stars are known to be strongly nitrogen overabundant (e.g., Grushinske *et al.* 1980), so the explanation to the detection of stellar winds in their atmospheres *only* in the N V ion would reasonably be the overabundance of the element. This interpretation is strengthened by the much larger V_{edge} measured in N V than that in C IV for HD 201345, an ON star. The "runaway" stars and those not in OB associations, represented by triangles in Fig. 3, seem to show similar N V and C IV "edge" velocities, as compared with the low velocity-dispersion stars belonging to young associations. This last result may also be interpreted as a chemical abundance effect; following Carrasco *et al.* (1980), the "runaway" may be interpreted as low-mass, evolved, hot stars similar to the UV-bright stars in globular clusters.

We conclude that the difference in shortward displacement measurable in different resonant lines of a star, may be explained by evolutionary effects that tend to increase the nitrogen abundance with time.

This is Contribution No. 22 of Instituto de Astronomía, UNAM.

REFERENCES

Bisiacchi, G.F., Firmani, C., Ortega, R., and Peniche, R. 1976, *Rev. Mexicana Astron. Astrof.*, 2, 13.
Bisiacchi, G.F., Carrasco, L., Costero, R., and Firmani, C. 1978, *Rev. Mexicana Astron. Astrof.*, 2, 309.
Blaauw, A. 1961, *Bull. Astr. Inst. Netherlands,* **15**, 265.
Brandt, J.C., Stecher, T.P., Crawford, D.L., and Maran, S.P. 1971, *Ap. J. (Letters),* **163**, L99.
Carrasco L., Bisiacchi, J.F., Cruz-González, C., Firmani, C., and Costero, R. 1980, *Astr. and Ap.*, **92**, 253.
Carrasco, L., Costero, R., and Stalio, R. 1981, *Astr. and Ap.*, **100**, 183.
Conti, P.S. and Alschuler, W.R. 1971, *Ap. J.,* **170**, 325.
Conti, P.S., Dearborn, D., and Massey, P. 1981, *M.N.R.A.S.*, in press.
Cruz-González, C., Recillas-Cruz, E., Costero, R., Peimbert, M., and Torres-Peimbert, S. 1974, *Rev. Mexicana Astron. Astrof.*, **1**, 211.
Grushinske, J., Hunger, K., Judritzki, R.P., and Simon, K. 1980, in *Proceedings of the Second European IUE Conference*, (Tübingen), ESA SP-137, p. 311.
Kilkenney, D., Hill, P.W., and Penfold, J.E. 1981, *M.N.R.A.S,* **195**, 165.
Klemola, A.R. 1962, *A.J.* 67, 740.
Simon, K., Grushinske, J., Hunger, K., and Kudritzki, R.P. 1980, in *Proceedings of the Second European IUE Conference*, (Tübingen), ESA SP-137, p. 305.
Traving, G. 1962, *Ap. J.,* **135**, 439.
Walborn, N.R. 1971, *Ap. J. Suppl.,* **23**, 257.
Walborn, N.R. 1972, *A.J.,* 77, 312.
Walborn, N.R. 1973, *A.J.,* 78, 1069.

DISCUSSION

Mendoza, E.: 1) ¿Han realizado un estudio comparativo entre sus espectros UV y los espectrogramas existentes en el visible? 2) ¿Cuáles son sus criterios para llamar a una estrella supergigante de tipo temprano, población I o población II?

Costero: No lo hemos realizado, planeamos hacerlo con más detalle que usando solamente el criterio de considerar iguales los espectros en el visible de dos estrellas, sólo porque han sido clasificados iguales espectroscópicamente. Para distinguir entre poblaciones I y II hemos usado tres criterios: (1) que la estrella tenga alta velocidad espacial (velocidad radial principalmente), (2) que no esté asociada a cúmulos galácticos o a asociaciones OB, y (3) sobreabundancia en nitrógeno, tipo ON (sólo para el caso de una estrella). Este último criterio es quizás muy débil pero en otro estudio que se realiza en nuestro instituto, se ha encontrado una muy alta proporción de estrellas ON fuera de asociaciones jóvenes.

Niemela: ¿La diferencia que ustedes observan estaría de acuerdo con la teoría de fluctuaciones, explicando la pérdida de masa de Andriesse?

Costero: Me parece que no, puesto que la teoría de fluctuaciones no predice variaciones de la velocidad "terminal" y de los perfiles de líneas de resonancia en escalas de tiempo intermedias.

Alvarez: Creo que no sería suficiente considerar el efecto de la temperatura exclusivamente para la formación y variación en el viento solar. ¿Sería conveniente considerar el mecanismo de formación del viento solar para entender mejor estos procesos?

Costero: Nuestro interés es, precisamente, demostrar que es necesario incluir algo más que los parámetros estelares, luminosidad y temperatura, para describir completamente a los vientos estelares de estrellas calientes.

Rafael Costero: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México.
Roberto Stalio: Osservatorio Astronomico, Via G.B. Tiepolo 11, 34131 Trieste, Italia.