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SPECTROPHOTOMETRIC OBSERVATIONS OF VERY LOW IONIZATION HII REGIONS IN THE LMC

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RESUMEN. Se reportan observaciones espectrofotométricas de 17 regiones HII de baja ionización de la Nube Mayor de Magallanes. Se midieron las intensidades de las líneas de emisión y se derivaron las condiciones físicas y la composición química de las regiones. La composición química promedio obtenida es log O/H=8.49±0.08, log N/H=6.91±0.07, log S/H = =6.89±0.10. No se encuentra evidencia de un gradiente de composición química en la Nube Mayor. Las regiones HII ubicadas en las cercanías de los complejos moleculares detectados muestran mayor enrojecimiento.

ABSTRACT. Optical spectrophotometric observations of 17 very low ionization HII regions of the LMC are reported. Physical conditions and chemical composition of these object are derived from the emision line intensities. The average chemical abundances obtained are: log O/H=8.49±0.08, log N/H=6.91±0.07 and log S/H=6.89±0.10. We do not find evidence of any composition gradient in the LMC. The HII regions in the vicinity of the detected molecular cloud complexes show higher nebular reddening.

Key words: GALAXIES-MAGELLANIC CLOUDS — NEBULAE-H II REGIONS — SPECTROPHOTOMETRY

I. INTRODUCTION

Chemical abundances of HII regions in the LMC have been determined by several authors(Dufour, 1983 and references therein); their results suggested that there are no abundance gradients in the LMC (Pagel et al, 1978) like those found in spiral galaxies. Most of the LMC-HII regions, whose abundances have been determined are high ionization ones and the N abundances obtained from the NII optical lines (λλ5755, 6548 and 6584) are affected by large ionization correction factors.

Due to these considerations, we have attemped to obtain chemical abundances by using optical lines of low ionization HII regions where most of the nitrogen is in the form of NII.

II. OBSERVATIONS

After searching an objective prism plate (IIIa-J) taken with the Schmidt Camera and the thin prism of Cerro Tololo Interamerican Observatory we identified about 30 low excitation emission line objects, 17 of which turned out to be low excitation HII regions. The spatial distribution of these region is shown in Figure 1.

Spectrophotometry of each region was done with the CTIO 4m telescope equipped with an R-C Spectrograph and a 2D-Frutti detector. The spectral range between 3700Å and 6800Å was covered at 4Å resolution, the slit was 2" x 50" in size and the aperture used for extraction

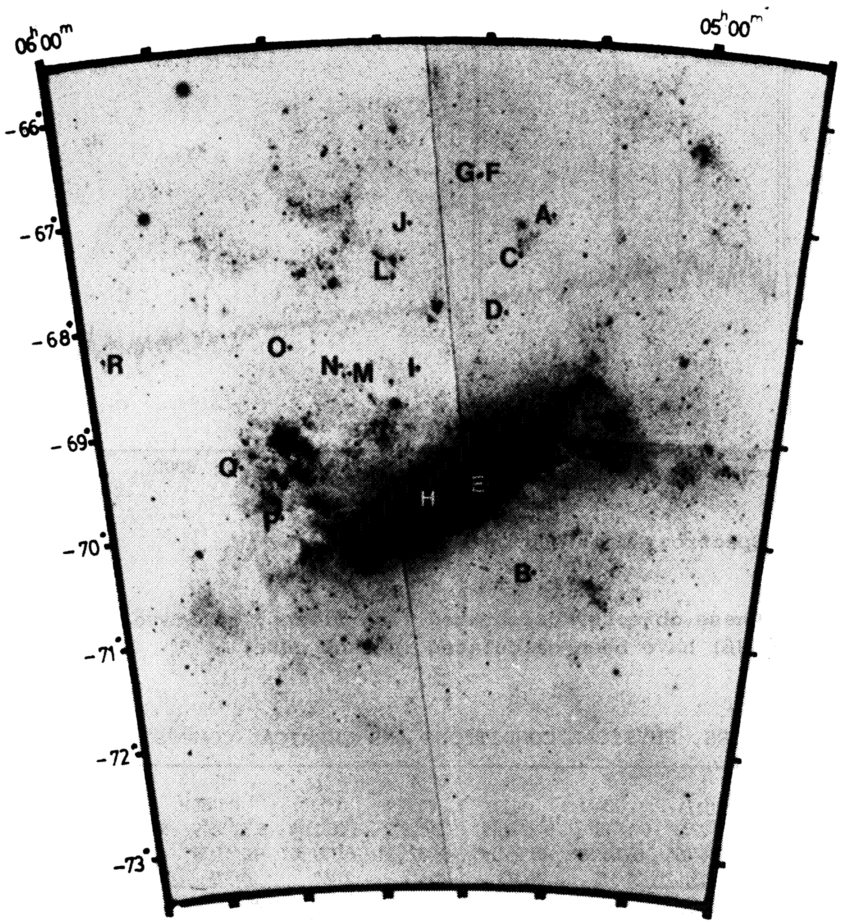

Fig. 1. Distribution of the observed HII regions.

of each object is indicated in Table 1. The sky was subtracted using parts of the slit that showed no evidence of emission. During the night three flux standard stars as well as a He-Ne-Ar lamp after each object were observed in order to flux and wavelength calibrate the spectra. The data reduction was performed at the CTIO La Serena Computing Facilities.

Figure 2 show a typical spectra of the observed HII regions. Integration times were generally about 20 minutes.

III. PHYSICAL CONDITIONS AND CHEMICAL COMPOSITION

In Table 1, we present the unreddened fluxes for the objects whose Balmer lines are not affected by underlying absorption. The logarithmic reddening correction at H_β, $C(H_\beta)$ was derived from the Balmer decrement. The intrinsec line intensities, relative to H_β, were calculated according to

$$\log I_\lambda/I_{H\beta} = \log F_\lambda/F_{H\beta} + C(H\beta)f_\lambda$$

were F_λ is the observed calibrated line flux and f_λ is the normal reddening function (Seaton, 1979).

For objects where the Balmer decrement of the nebular emission lines could be affected by the absorption Balmer lines of the exciting star, no attempt was made to deredden

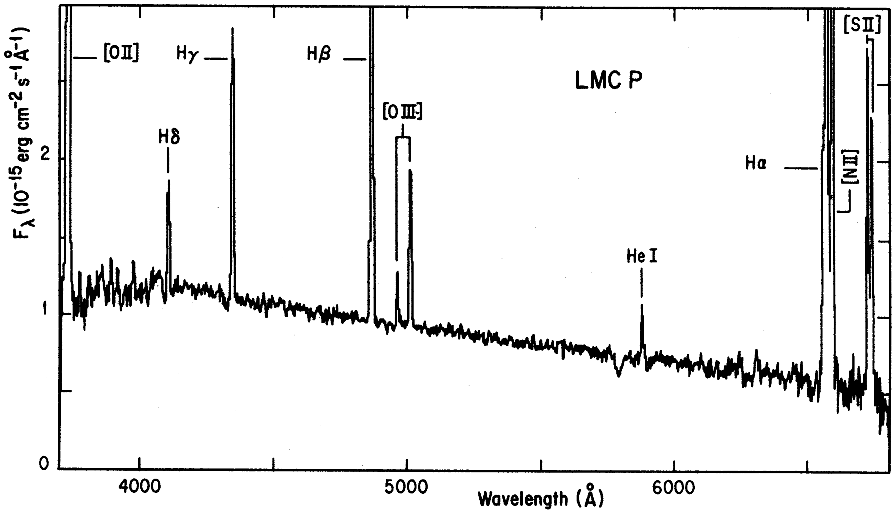

Fig. 2 Spectrogram of region P(N 159H)

the line fluxes. For these objects, calibrated line fluxes, relative to Hα, are given in Table 2. Upper limits for C(Hβ) have been calculated in each case.

TABLE 1. LINE INTENSITIES, PHYSICAL CONDITIONS AND CHEMICAL COMPOSITION OF LMC-H II REGIONS.

			A (N26)	E (N117)	F (N34A)	H (N129)	I (N138D)	L (N51D)	M (N148D)	N (S 121)	O (N68)	P (N159H)	R (N75A)
α(1950)			$5^h10^m44\overset{s}{.}4$	$5^h17^m27\overset{s}{.}9$	$5^h17^m28^s$	$5^h22^m48\overset{s}{.}9$	$5^h24^m28\overset{s}{.}2$	$5^h26^m21\overset{s}{.}4$	$5^h31^m35\overset{s}{.}9$	$5^h32^m08\overset{s}{.}6$	$5^h37^m15\overset{s}{.}7$	$5^h39^m56\overset{s}{.}8$	$5^h55^m55\overset{s}{.}7$
δ(1950)			-67°08'23"	-69°36'46"	-66°46'18"	-69°45'19"	-68°32'25"	-67°39'38"	-68°33'39"	-68°28'42"	-68°16'00"	-69°48'50"	-68°10'04"
APERTURE			2"x3"3	2"x3"3	2"x3"3	2"x3"3	2"x4"2	2"x5"	2"x3"3	2"x3"3	2"x3"3	2"x3"3	2"x5"
λ(Å)	ION	f_λ	LOG $I_\lambda/I(H_\beta)$										
3726+29	[OII]	+0.26	0.92	0.84	0.84	0.89	0.86	0.89	1.00	0.76	0.82	0.82	0.68
4101	H_δ	+0.17	-0.55	-0.64	-0.64	-0.71	-0.65	-0.66	--	-0.67	-0.57	0.67	-0.67
4340	H_γ	+0.13	-0.33	-0.33	-0.34	-0.32	-0.33	-0.36	-0.33	-0.32	-0.33	-0.33	-0.33
4861	H_β	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5007	[OIII]	-0.04	-1.31	-0.49	-0.55	-0.76	-0.61	-0.03	-0.51	-0.20	-0.93	-0.72	-0.83
5876	HeI	-0.21	-1.88	-1.17	-1.52	-1.47	-1.31	-1.18	-1.22	-1.26	-1.40	-1.37	-1.17
6563	H_α	-0.32	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
6584	[NII]	-0.33	-0.36	-0.31	-0.38	-0.25	-0.41	-0.57	-0.43	-0.59	-0.46	-0.42	-0.45
6717+13	[SII]	-0.35	-0.45	-0.36	-0.94	-0.42	-0.29	-0.45	-0.35	-0.63	-0.49	-0.48	-0.33
$L(H_\beta)$ (10^{-11} ERG CM^{-2}S^{-1})			3.81	11.7	17.7	10.7	3.30	16.2	4.07	1.13	4.84	4.77	4.35
$C(H_\beta)$ (a)			0.26	0.60	1.04	1.07	1.02	0.54	1.16	1.50	0.44	1.15	0.41
LOG X (b)			<-2.60	-2.50	-0.48	-1.44	-1.60	-1.78	-1.88	-1.60	-1.08	-1.32	<-2.80
ADOPTED t_e (c)			0.95	0.98	0.97	0.98	0.98	0.98	0.98	0.98	0.95	0.95	0.95
LOG O/H (d)			8.58	8.46	8.59	8.50	8.47	8.54	8.61	8.40	8.49	8.49	8.35
LOG N/H			6.97	7.01	6.92	7.04	6.85	6.84	6.87	6.81	6.88	6.92	6.90
LOG S/H			6.89	6.94	6.87	6.88	7.01	6.85	6.95	6.67	6.85	6.86	7.02

(a) $C(H_\beta)$ IS THE LOGARITHMIC REDDENING CORRECTION AT H_β

(b) $X = Ne/10^4 (t_e)^{1/2}$

(c) $t_e = 10^{-4}\ T_e$

(d) LOG N(H) = 12.00

The [SII]6717/6731 line ratios show that most of the observed regions are in the low density limit with $N_e < 250 cm^{-3}$. On the other hand, the O^+/O^{++} line intensity ratios suggest that the exciting stars of the observed regions have effective temperatures $T_* \lesssim 35{,}000K$, that is, spectral types later than O9V, which is consistent with the spectral types estimated from the absorption line spectra of the exciting stars, when available.

Taking into account these considerations, we compared the observed line fluxes with the predictions of models by Stasinska, 1982 and Rubin, 1985, having element abundances adequate for the LMC. From the models we have adopted an electron temperature, T_e, for each

Table 2. Line intensities and physical conditions of very low ionization HII regions$^{(a)}$.

	B (N193C)	C (N30C)	D (N32)	G (N34C)	J (N47)	Q --
α(1950)	$5^h12^m58^s$	$5^h13^m55^s$	$5^h15^m50^s$	$5^h17^m31^s$	$5^h24^m31^s$	$5^h43^m20^s$
δ(1950)	-70°28'22"	-67°30'39"	-68°02'03"	-66°46'34"	-67°11'45"	-69°17'46"
Aperture	2"x4".2	2"x5"	2"x5"	2"x3".3	2"x8".4	2"x3".3
λ (Å)			log Fλ/(Hα)$^{(b)}$			
[OII]3727+29	-0.02	-0.22	-0.21	-0.14	0.08	-0.19
HI 4861	-0.67	-0.72	-0.83	-0.58	-0.71	-0.85
[OIII]5007	-1.99	-1.65	-1.95	-	-	-2.13:
[NII]6584	-0.78	-0.87	-0.86	-0.79	-0.81	-0.89
[SII]6717	-1.06:	-1.01	-1.03	-0.90	-0.85	-1.05
[SII]6731	-1.20:	-1.18	-1.08	-1.01	-0.97	-1.23
L (Hα) (10^{-13}erg cm^{-2}s^{-1})	0.40	2.99	3.76	1.70	1.58	2.54
C(H_β) (c)	0.73	0.82	1.00	0.41	0.82	1.23
log x (d)	-2.56	-3.0	-1.50	-1.80	-2.05	-3.0
log N^+/H^+ (e)	7.01	6.92	6.93	7.00	6.98	6.90
log S^+/H^+	6.06	6.10	6.12	6.23	6.27	6.12

(a) Balmer lines affected by underlying absorption. (b) Reddened calibrated fluxes.

(c) Upper limits of the logarithmic reddening correction at H_β. (d) $x = N_e/10^2\sqrt{T_e}$

(e) log H = 12.00, T_e = 9,500 K has been adopted.

region wich is indicated in Table 1. For the region F, T_e=9700K±300K is derived from the [NII] λλ5755/6584 line ratio.

Ionic abundances of O^+, O^{++}, N^+ and S^+ have been calculated using the intrinsec line intensities and the physical conditions discussed above (no temperature fluctuations have been assumed). For the objects of Table 1, the total abundances of N, O and S were obtained from:

$$O/H = (O^+ + O^{++})/H^+$$
$$N/H = (N^+/H^+)\times(O/O^+),$$
$$S/H = 8.0\ (S^+/H^+).$$

The ionization correction factor for N is from Peimbert and Costero, 1969, and for S we have used models D4961 and D4962 by Rubin, 1985.

The most important source of error, in the abundance determinations, is the electron temperature determination. A difference of ±300°K between the real temperature and the adopted value (which is not excluded) would produce a difference of ∓0.06 in the log O/H and ∓0.04 in the log N/H.

IV. DISCUSSION AND RESULTS.

O, N and S abundances have been determined for 11 low ionization HII region in the LMC. The average values of the derived nebular abundances are <log O/H>=8.49 ± 0.08,<log N/H> =

=6.91±0.07 and <log S/H> =6.89±0.10. These values are in good agreement with previous determinations by other authors for the LMC-HII regions (Peimbert and Torres-Peimbert 1974, Pagel et al. 1978, Dufour et al. 1982). In this work, the ionization correction factors used for N abundance determinations are negligible in most of the cases, due to the low degree of ionization of the observed regions; consequently, the agreement between our values and the previous determinations confirm the ionization correction scheme normally used for N.

We did not find any systematic deviation of the derived chemical abundances from the average values. The differences in chemical composition of the observed HII regions are not significative and can be produced by small differences (some hundred degrees) between the real T_e and the adopted value. Therefore, no relation between the chemical abundance and the position of the nebula is found, in agreement with the conclusions of Pagel et al. (1978).

Most of the observed HII regions are affected by large reddening. Caplan and Deharveng (1986) reported similar large reddening for some HII regions located nearby HI-molecular cloud complexes. In this work, we found that the position of the nebulae with $C(H_\beta)>1$ coincide with the position of some molecular clouds detected in the LMC (Rubio, 1986), in wich case the large extinction could be attributed to the presence of local dust mixed with the molecular material. This is confirmed by the fact that most of the HII regions reported were, also coincide with IRAS-point sources, with maximum infrared fluxes at 100μ.

A complete description of this work will be submitted to Astronomy and Astrophysics.

REFERENCES

Caplan, J. and Deharveng, L. 1986, *Astron. Astroph.* 155, 297.
Dufour, R.J. 1983 in "Structure and Evolution of the MC" *IAU Symp. No. 108*, p. 353.
Dufour, R.J., Shields, G.A., and Talbot, R.S. 1982. *Ap. J.* 252, 461.
Pagel, B.E.J., Edmunds, M.G., Fosbury, R.A.E. and Webster, B.L. 1978, *M.N.R.A.S.* 184, 569.
Peimbert, M. and Costero, R. 1969, *Bol. Obs. Tonantzintla y Tacubaya.*, 5, 3.
Peimbert, M. and Torres-Peimbert, S. 1974, *Ap. J.*, 193, 327.
Rubin, R.H. 1985, *Ap. J. Suppl.* 57, 349.
Rubio, M. 1986, *These Memorias.*
Seaton, M.J. 1979., *M.N.R.A.S.*, 185, 57p.
Stasinska, G. 1982., *Astron. Astroph. Suppl.*, 48, 299.

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