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THE H 166α RECOMBINATION LINE IN THE CARINA NEBULA

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RESUMEN

Se hicieron observaciones de la Nebulosa de Carina en el Instituto Argentino de Radioastronomía en la frecuencia correspondiente a la línea de recombinación H166α ($\nu \cong 1425$ MHz). Esta línea fue observada con una resolución en velocidad de 2 km s^{-1} en diferentes posiciones dentro de la región de Carina. La característica principal de estos perfiles es la aparición de estructura doble en algunos de ellos, con velocidades (LSR) centradas en -10 y -30 km s^{-1}, respectivamente. Los perfiles simples tienen velocidades centrales entre -20 y -25 km s^{-1}.

Se deducen temperaturas electrónicas bajo la hipótesis de equilibrio termodinámico local (ETL) para diferentes puntos en la nebulosa.

ABSTRACT

Observations of the Carina Nebula were made in the Instituto Argentino de Radioastronomía at the frequency corresponding to the H166α recombination line ($\nu \cong 1425$ MHz). This line was observed with a velocity resolution of about 2 km s^{-1} at different positions within the Carina Region. The main characteristic of these profiles is the appearance of double structure in some of them, with velocities (LSR) centered at about -10 and -30 km s^{-1}, respectively. The single profiles have central velocities between -20 and -25 km s^{-1}.

Electron temperatures are derived, under the assumption of local thermodynamical equilibrium (LTE), for different points in the Nebula.

Key words: NEBULAE-ABUNDANCES – RADIO SOURCES-LINES

I. INTRODUCTION

The study of recombination lines provides relevant information about the physical conditions of the region where they are detected. Up to now, many regions have been the object of these studies and some of them, in particular, have been exhaustively studied at various frequencies. The parameters obtained from the analysis of an H II region, at different radio frequencies, contribute to improve the knowledge of the physical conditions of the ionized gas (Lockman and Brown 1975).

In the southern sky the Carina Nebula has been observed at various radio recombination lines. This nebula has been studied at the lines H129α, H127α (Mc Gee and Gardner 1968), H157α (Mc Gee *et al.* 1969), H109α (Wilson *et al.* 1970; Gardner *et al.* 1970; Huchtmeier and Day 1975), H66α (Abraham *et al.* 1980), and H90α (Mc Gee *et al.* 1975; Huchtmeier and Day 1975).

In this paper we present observations of this region at the frequency corresponding to the H166α line. From these observations estimates have been made of the electronic temperature (T_e), assuming that the line is formed under LTE conditions, which according to Shaver (1980) are not too far from the real physical conditions of galactic H II regions in general. However, a more complete study about the formation and transfer of the line must take into account the emission measure distribution, which is strongly dependent on the electron density structure inside the angle subtended by the antenna beam throughout the nebula (Brown *et al.* 1978). For this more complex analysis it is necessary to consider observations in various frequencies, and it could be the matter of further studies.

A typical characteristic of the Carina Nebula is its complex kinematical structure, which is observed in optical and radio lines. This structure is discussed in this paper.

II. OBSERVATIONS

The observations were made with the 30-m antenna of the Instituto Argentino de Radioastronomía. The noise temperature of the system is about 90°K. The load switch mode was used to perform the observations. The HPBW of the antenna at 21-cm is 34′.

First of all, a survey of the region between 286.0° and 289.0° of galactic longitude and from 1.0° to $-2.0°$ of galactic latitude was made with the wide filter bank (composed by 84 filters each of them 75 kHz wide).

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A profile obtained in such way is shown in Figure 1. This profile was corrected to eliminate baseline effects (a fourth degree polynomial was used). The velocity resolution obtained with these filters is about 16 kms^{-1}. The He166α line cannot be determined from this profile due to baseline uncertainties.

Later on, the points, where the line was detected were observed with the narrow filter bank (112 channels of 10 kHz width each), to obtain a better velocity resolution (2 km s^{-1}). The total integration time for the observations with the narrow filters was about 2 hours.

The region was also observed in the continuum. Several scans in right ascension and declination were made to obtain the continuum temperature, required to estimate the electron temperature (see below).

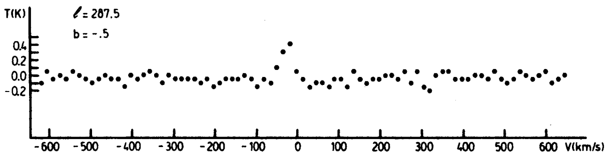

Fig. 1. Profile obtained with the wide filter bank (75 kHz each) at the point corresponding to galactic coordinates ℓ = 287.5°, b = –0.5°.

III. RESULTS

We show several profiles in Figure 2. Only the profiles where the line was detected above the noise level are shown. Two of these profiles clearly show double structure (ℓ = 287.5°, b = –0.5° and ℓ = 287.5°, *b* = –1.0°). The velocity of each one of the components in these profiles (obtained by Gaussian fit) are –10 and –30 km s^{-1}, respectively.

The other profiles are single, in agreement with observations of Huchtmeier and Day (1975) (see discussion). In particular, the point corresponding to ℓ = 287.0°, *b* = –1.0°, was observed with a longer integration time (about 5 hours) to reduce the noise; we show it in Figure 3, that shows it could be a single or double profile.

Under the assumption of LTE we derived the electron temperatures corresponding to each point. We consider the total power under the line. The values of T_e are given in Table 1. For the calculations we used:

$$\int \frac{T_L\,dv}{T_c} = \frac{7439}{a(\nu,T_e)}\ \frac{1}{[1 + N(He^+)\,/\,N(H^+)]} \times \left(\frac{\nu}{GHz}\right)^{1.1} \left(\frac{T_e}{°K}\right)^{-1.15} ,$$

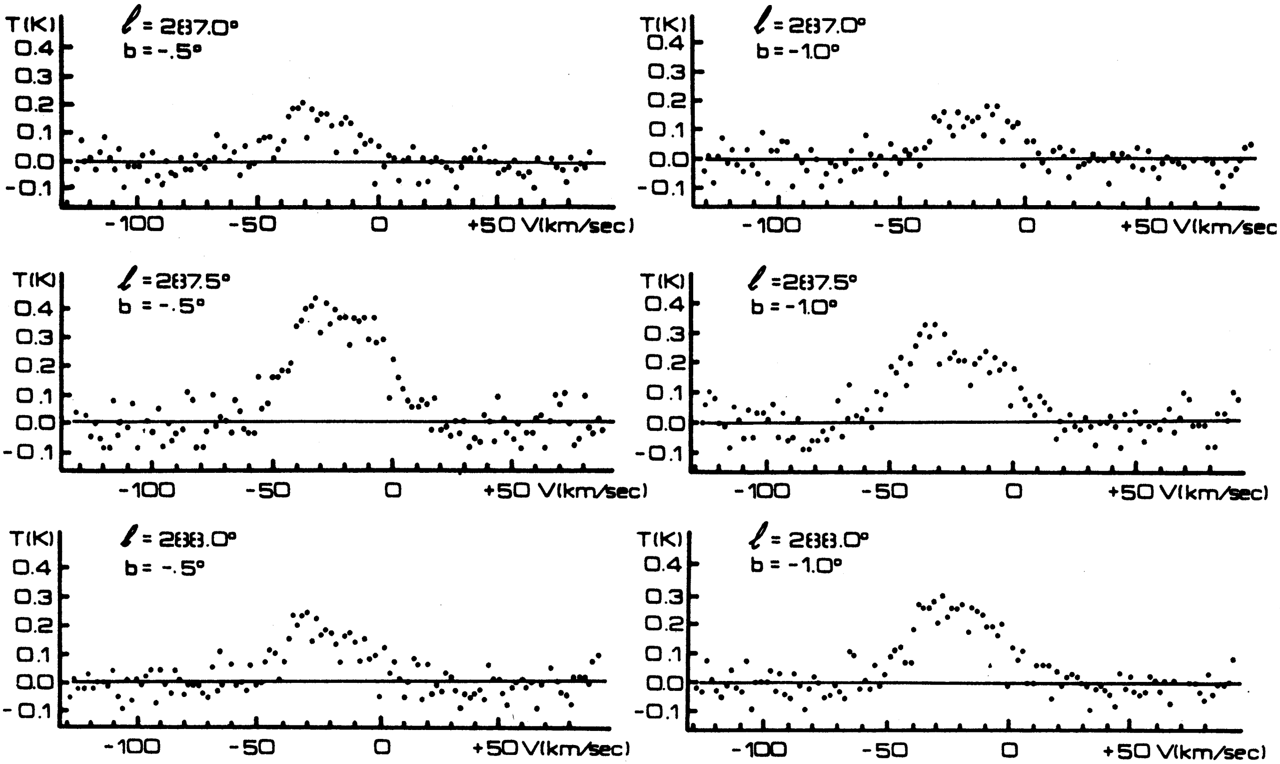

Fig. 2. Profiles obtained with narrow filters. In some of them, the double structure is clear.

ıich is similar to the one used by Mezger and Ellis)68).

From this formula we derive

$$T_e = \left(9584 \frac{T_c}{\int T_L dv}\right)^{0.87} .$$

In these expressions ν is the line frequency in GHz, $\Gamma_L dv$ is the total power under the line, T_c is the ntinuum temperature, $N(He^+)/N(H^+)$ is the abun-nce relation between ionized helium and hydrogen, ›,T_e) is a function tabulated by Mezger and Henderson 967) which is very close to unity. We took the value 15 for the helium abundance, given by Mc Gee *et al.* 969) for the Carina Nebula.

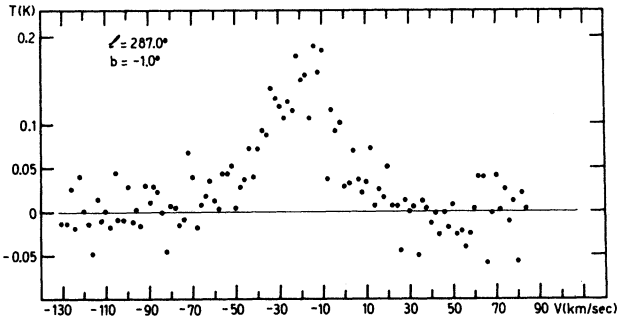

Fig. 3. Profile corresponding to the point with galactic coordinates $\ell = 287.0°$, $b = -1.0°$, obtained with a longer integration time.

TABLE 1

VALUES OF T_e OBTAINED FROM THE H166α PROFILES IN CARINA

ℓ	b	$\int T_L dv / T_c$	T_c	$\Delta v_{1/2}^a$	v_0^b	T_e
(°)	(°)	(km s^{-1})	(°K)	(km s^{-1})	(km s^{-1})	(°K)
287.5	–0.5	0.421	40	44 ± 6	–22 ± 2	6200 ± 600
287.5	–1.0	0.291	38	50 ± 6	–23 ± 2	7800 ± 700
288.0	–1.0	0.355	30	38 ± 4	–21 ± 2	7200 ± 700
287.0	–0.5	0.301	18	40 ± 4	–25 ± 3	8300 ± 800
287.0	–1.0	0.495	13	36 ± 4	–20 ± 2	5400 ± 500
288.0	–0.5	0.314	20	50 ± 6	–26 ± 3	6800 ± 600

a. $\Delta v_{1/2}$ is the half maximum line width.
b. v_0 is the central velocity for each profile.

IV. DISCUSSION

Both the radio and optical observations show similar nematic characteristics in the Carina Nebula region. ɜharveng and Maucherat (1975) observed a splitting of e Hα and N II lines, close to the radio sources Carina II = 287.6°, $b = -0.6°$) centered at LSR velocities of ›out –20 km s^{-1}. This splitting was also observed in :tended regions of the Nebula in [N II], [O III] and Hα ıes (Walborn and Hesser 1975).

In regard to the radio recombination lines, the nebula as studied by Mc Gee and Gardner (1968) in H129α ıd H127α. They observed a very broad profile in Carina and assumed the presence of more than one compo-ɜnt. Their velocity resolution was about 4 km s^{-1}. ıter on, Gardner *et al.* (1970) observed at different ɔints in the nebula at the frequency corresponding to 109α, finding double structure in the profiles close to ırina II and single profiles in the side close to the ırina I radio source ($\ell = 287.4°$, $b = -0.6°$).

A more complete study was made by Huchtmeier and ay (1975) at H109α and H90α. They show that the double structure appears limited to a region around the Carina II source, whereas near the side of Carina I and to the west, south and east of the continuum peaks, they observed single profiles. The baricentric velocities of their profiles are about –20 km s^{-1}. They derived, assuming LTE conditions, electron temperatures between 6000 and 9000°K.

Our results show two clearly double profiles, for points corresponding to galactic coordinates $\ell = 287.5°$, $b = -0.5°$ and $\ell = 287.5°$, $b = -1.0°$. In other positions the profiles are single. These results agree with the observations of Huchtmeier and Day, considering our lower angular resolution. To explain the double profiles, Huchtmeier and Day assume the presence of an expanding shell.

From the observed profiles we derived electron temperatures between 5000 and 8000°K. To compute these values, we considered the total power under the line, and obtained Gaussian fits to the observed double profiles. The electron temperatures for each component (corresponding to velocities of about –10 and –30 km s^{-1}) were calculated using the already cited relation of

Mezger and Ellis (1968). T_e is given by the following expression:

$$T_e = \left(8997 \frac{T_c}{T_L \Delta v}\right)^{0.87}$$

In this formula, Δv is the half maximun line width, T_L is the peak line temperature obtained from the Gaussian fit, and T_c is the continuum temperature, assumed to be fifty per cent for each component of the observed continuum temperature, for the corresponding point. The resulting electron temperatures vary between 6000 and 8000°K for the component corresponding to the velocity -10 km s^{-1} and 5000 and 6000°K for the other component (-30 kms^{-1}).

These values do not differ too much from the electron temperatures computed considering the total power under the lines. On the other hand the temperature values obtained by us are somewhat lower than those given by Peimbert *et al.* (1978), derived by optical methods.

V. CONCLUSIONS

The appearance of two components in some profiles could be explained by the presence of an expanding shell, which has been mentioned by other authors. Another interpretation could be the presence of two objects at different distances on the line of sight. If we consider the profile $\ell = 287.0°$ $b = 1.0°$ to be formed by two components, the presence of two objects on the lin of sight is an acceptable explanation.

On the other hand, the electron temperatures derive from the H166α line are of the same order than thos obtained in other radiofrequencies. These values, in th central region of the nebula, are about 25% lower tha those obtained by optical methods (Peimbert *et a* 1978). We suppose that this difference can be explaine by departures from the LTE conditions in this region.

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REFERENCES

Abraham, Z., Lépine, J.R.D., and Braz, M.A. 1980, *M.N.R.A.S* in press.
Brown, R.L., Lockman, F.J., and Knapp, G.R. 1978, *Ann. Re Astr. and Ap.*, 16, 445.
Deharveng, L., and Maucherat, M., 1975, *Astr. and Ap.*, 41, 2
Gardner, F.F., Milne, D.K., Mezger, P.G., and Wilson, T.L. 197 *Astr. and Ap.*, 7, 349.
Huchtmeier, W.K. and Day, G.A. 1975, *Astr. and Ap.*, 41, 15
Lockman F.J. and Brown, R.L. 1975, *Ap. J.*, 201, 134.
Mc Gee, R.X. and Gardner, F.F. 1968, *Aust. J. Phys.*, 21, 14
Mc Gee, R.X., Batchelor, R.A., Brooks, J.W., and Sinclair, M.I 1969, *Aust. J. Phys.*, 22, 631.
Mc Gee, R.X., Newton, L.M., and Batchelor, R.A. 1975, *Aust. Phys.*, 28, 185.
Mezger, P.G. and Henderson, A.P., 1967, *Ap. J.*, 147, 471.
Mezger,P.G. and Ellis, S.A. 1968, *Ap. Letters*, 1, 159.
Peimbert, M., Torres-Peimbert, S., and Rayo, J.F. 1978, *Ap.* 220, 516.
Shaver, P.A. 1980, *Astr. and Ap.*, 90, 34.
Walborn, N.R. and Hesser, J.E. 1975, *Ap. J.*, 199, 535.
Wilson, T.L., Mezger, P.G., Gardner, F.F., and Milne, D.K 1970, *Astr. and Ap.*, 6, 364.

DISCUSSION

Peimbert: ¿Tienen proyectado determinar la abundancia de helio en Carina?
Cersósimo: Sí, por el momento estamos estudiando la manera de aumentar el cociente señal/ruido de las observaciones para detectar señales débiles como lo es la de la emisión de He166α.

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