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A SEARCH FOR H159α AND H200β IN SOUTHERN H II REGIONS AND THE GALACTIC CENTER

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RESUMEN

Se han realizado observaciones de las líneas H159α y H200β en nueve posiciones alrededor del centro galáctico, y en los puntos centrales de la región extragaláctica 30 Doradus, y de las regiones H II galácticas RCW 38 (G 268.1−1.1), RCW 97 (G 327.3−0.6), RCW 74 (G 305.2+0.1), Carina (G 287.5−0.5) y W 33 (G12.67−0.33). Hay evidencias de emisión estimulada en las zonas centrales de más alta densidad de RCW 38, RCW 74 y la nebulosa de Carina. Sólo en dos de las nueve posiciones alrededor del centro galáctico, se pudo detectar la línea H200β por encima del ruido.

ABSTRACT

H159α and H200β lines observation of nine positions close to the galactic center, the extragalactic H II region 30 Doradus, and the galactic H II regions RCW 38 (G 268.1−1.1), RCW 97 (G 327.3−0.6), RCW 74 (G 305.2+0.1), Carina (G 287.5−0.5) and W 33 (G 12.67−0.33) are reported. RCW 38, RCW 74 and the Carina Nebula show evidence of stimulated emission (in their central parts of highest density). Only in two of the nine positions close to the galactic center, the H200β line was detected above the noise-level.

Key words: **GALAXY-CENTER – NEBULAE- H II REGIONS**

I. INTRODUCTION

The importance of stimulated emission of radio frequency recombination lines from ionized regions was first pointed out by Goldberg (1966). Since then, interpretations of radio recombination lines from H II regions have taken this effect into consideration. The evidence for this effect is usually indirect, in the form of the departure of line strengths from predictions based on Local Thermodynamical Equilibrium, LTE. The recombination line intensity from an H II region can be enhanced by stimulated emission generated by continuum radiation from either thermal or non-thermal sources placed behind the H II region. This stimulated emission may produce non-LTE effects. Departures from LTE may be studied by comparing different-order transitions that emit at approximately the same frequency, to avoid problems associated with different beamwidths. The present paper reports observations of the transitions H159α (1620.672 MHz) and H200β (1619.690 MHz), with an antenna beam of 29′ in nine positions (separated 0.5° from each other) close to the galactic center and the central points of RCW 38, RCW 97, RCW 74, Carina (G 287.5–0.5), W 33, and the extragalactic region 30 Doradus (located in the Large Magellanic Cloud), RCW 38, RCW 74 and the Carina Nebula show evidence of stimulated emission, in their central high-density parts. Only in two positions in the galactic center region, those corresponding to l = 0.5°, b = –0.5°, and l = 0.0°, b=0.0°, the H200β line was detected above the noise level. We refer in the next section to the observations.

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II. THE OBSERVATIONS

The observations of both the H159α and H200β lines were made with the 30 meter-antenna of the Instituto Argentino de Radioastronomía. The HPBW of the telescope at 18-cm was 29′. The receiver consisted of a room temperature GaAs FET amplifier and a filter-bank spectrometer of 84 channels of 75 kHz width. The velocity resolution at this wavelength was 13.9 km s^{-1}. Frequency-switching mode was used to carry out the observations. The local oscillator was switched by an amount less than the observing bandwidth, in order to obtain two independent spectra, which were then averaged. The system temperature on cold sky was 89 K. The typical integration time for each position was 4-5 hours.

III. RESULTS

The profiles obtained from the central points of W 33 (G 12.67–0.33), RCW 38 (G 268.1−1.1), Carina (G 287.5–0.5), RCW 74 (G 305.2+0.1), RCW 97 (G 327.3–0.6), and the extragalactic region 30 Doradus are shown in Figures 1 to 6. The profiles corresponding to the points l = 0.5°, b = –0.5°, and l = 0.0°, b = 0.0°

(galactic center), are shown in Figures 7 and 8. Each baseline was fitted by a third, fourth or fifth order polynomial, through the channels free of signal. Table 1 lists the basic results of the H159α and H200β recombination line observations. In all cases, we estimated the power ratios of the lines- P(H200β)/P(H159α). That is compared with the theoretical prediction for LTE conditions, which is P(200β)/P(159α) $\simeq$ 0.28, for oscillator-strength values given by Menzel (1969). The errors given for the β/α ratios were derived from those of the integral powers of the respective profiles. It is possible that in some cases

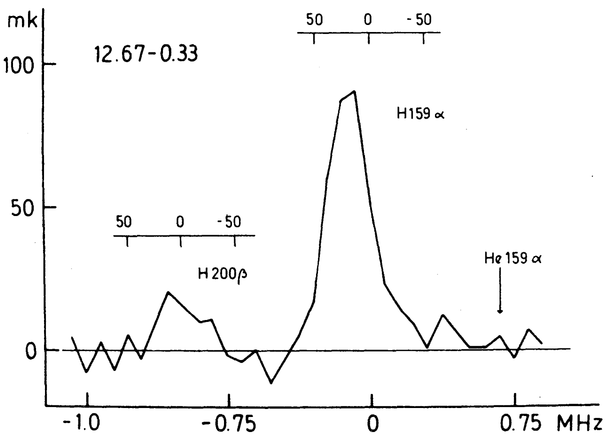

Fig. 1. Profile corresponding to the W 33 region. The coordinates indicate the antenna temperature as a function of the frequency in MHz. The origin of the abscissa axis corresponds to the laboratory frequency of the H159α line. In the upper part of each peak, the LSR velocities in km s^{-1} are indicated. The sam^ is valid for the other figures.

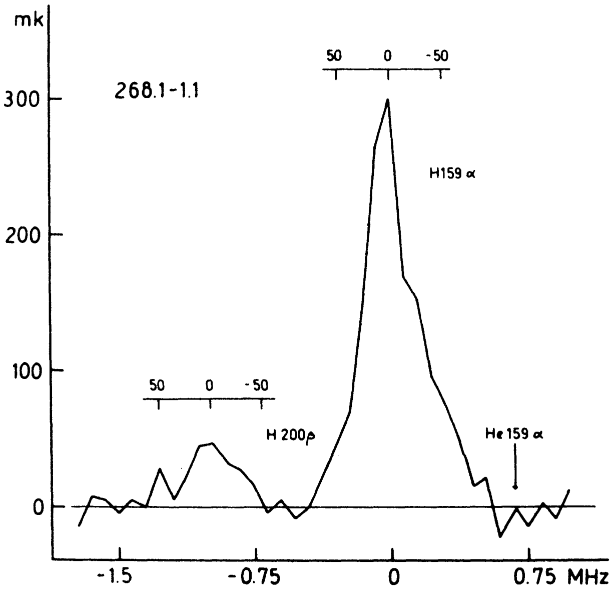

Fig. 2. Profile corresponding to RCW 38.

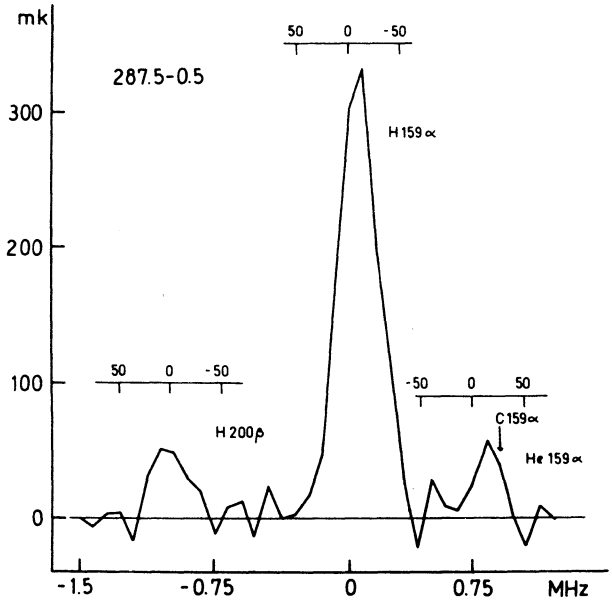

Fig. 3. Profile corresponding to G 287.5−0.5 (Carina).

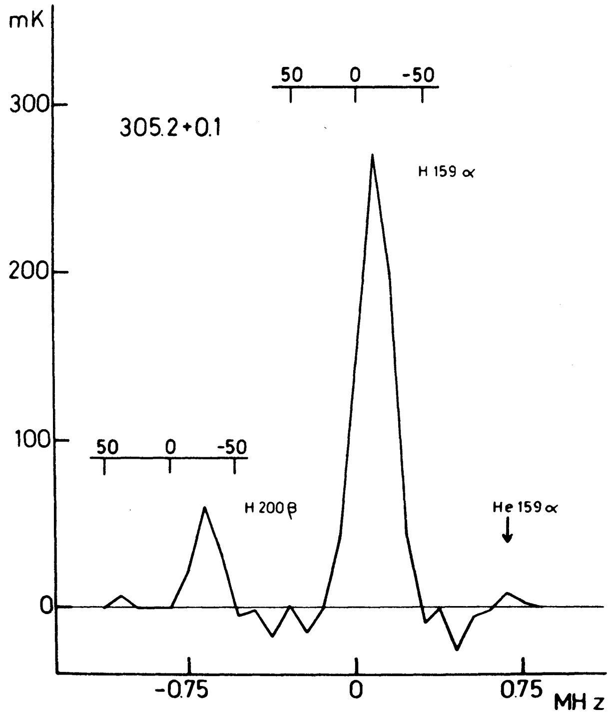

Fig. 4. Profile corresponding to RCW 74.

TABLE 1

OBTAINED PARAMETERS FROM H159α AND H200β OBSERVATIONS OF SOME H II REGIONS AND THE GALACTIC CENTER

Region	W33	RCW 38	Carina	RCW 74	RCW 97	30 Doradus	G 0.0+0.0	G 0.5−0.5
P(α)[a]	25.06	94.45	99.68	35.59	49.875	11.77	107.21	74.62
P(β)[b]	5.02	14.20	12.26	5.18	14.015	3.35	26.6	13.87
P(β)/P(α)	0.20	0.15	0.12	0.14	0.28	0.28	0.24	0.18
Error	0.04	0.04	0.04	0.04	0.04	0.14	0.04	0.04

a. P(α) is the H159α line power in K, kHz. b. P(β) is the H200β line power in K, kHz.

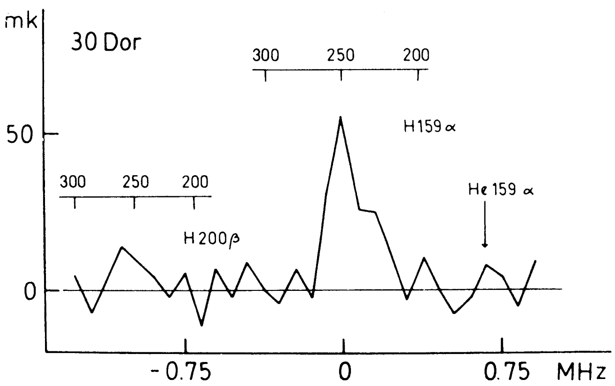

Fig. 5. Profile corresponding to 30 Doradus.

the errors were larger than estimated, and therefore the departures from LTE lower than apparent. Anyway, in the cases where the departures appear to be significant (RCW 38, RCW 74 and Carina), these correspond to the high density central parts of the nebulae (densities $N_e \simeq 10^2 - 10^3$ cm^{-3}), and not to the associated extended low-density ionized gas ($N_e \simeq 5 - 10$ cm^{-3}). In what follows we will describe each region.

a) *W33 (G 12.67−0.33)*

This is an extended region, hardly observed at other frequencies. The β/α ratio obtained is ≃ 0.20±0.06, which suggests that the lines are formed by spontaneous emission mechanism, that is, there is no stimulated emission.

b) *RCW 38 (G 268.2−1.1)*

This region has been observed in H109α (Wilson *et al.* 1970), H76α (Mc Gee and Newton 1981), H90α (Mc Gee, Newton and Batchelor 1975), H166α (Azcárate, Cersosimo and Colomb 1987*b*), and in the molecular lines H_2CO (Whiteoak and Gardner 1974) and CO (Gillespie *et al.* 1977). The β/α ratio obtained in this experiment (H159α and H200β), is ≃ 0.15±0.04. This result suggests some contribution of stimulated radiation, at least in the central parts of the nebula. However, non LTE effects do not seem to be significant in the H166α observations of the nebula (Azcárate *et al.* 1987*b*).

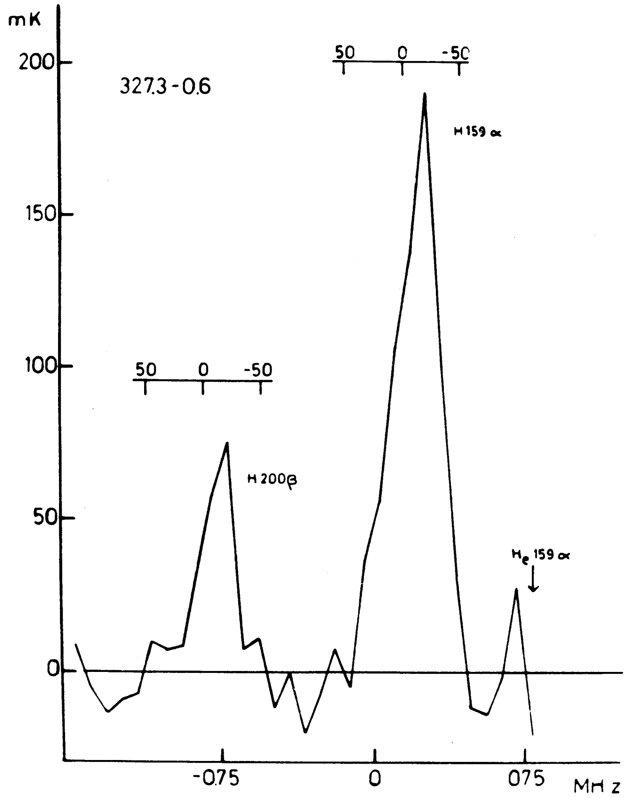

Fig. 6. Profile corresponding to G 327.3−0.6.

c) *Carina Nebula (G 287.5−0.5)*

This extended region has been observed in several radio recombination lines, such as H109α, H90α, H76α, H166α, H252α, and also at optical wavelengths (see Cersosimo, Azcárate and Colomb 1984, and references therein).

The spectrum observed in a zone (1 = 287.5°, b = −0.5°) close to the continuum radiosources Car I (1 = 287.4°, b = −0.4°), and Car II (1 = 287.6°, b = −0.4°), shows emission of the H159α, H200β and He 159α lines. The P(200β)/P(159α) ratio of $\simeq$ 0.12±0.05 suggests a contribution of stimulated emission in the central part of the nebula. This stimulated emission may be caused by the radio-continuum emission from the Car I and Car II sources, and also by the non-thermal continuum source G 287.8−0.5 observed by Jones (1973) at 30 MHz. The non-LTE effects are not significant in the extended outer low-density envelope, as shown by H166α observations of the nebula (Cersosimo *et al.* 1984).

d) *RCW 74 (G 305.2+0.1)*

This region has been observed at several recombination lines, such as H109α, (Wilson *et al.* 1970), H76α (Mc Gee and Newton 1981), H252α (Batty 1974), H166α (Azcárate, Cersosimo and Colomb 1986), and also molecular lines as CO (Gillespie *et al.* 1977; Brand *et al.* 1984), and H_2CO (Whiteoak and Gardner 1974).

The P(H200β)/P(H159α) ratio is $\simeq$ 0.14±0.05. This result suggests the presence of stimulated emission (in the central part of the nebula). However, the H166α observations of the low-density region associated show that the LTE approximation is valid for this low-density ionized gas (Azcárate *et al.* 1986).

e) *30 Doradus*

This extragalactic region is located in the Large Magellanic Cloud. The profile observed in this nebula has a low signal-to-noise ratio, with about 4–5 hours of integration time for this observation. The H159α line has a velocity of 250 km s^{-1}, in good agreement with the H166α observations by Cersosimo and Loiseau (1984). The P(200β)/P(159α) ratio observed is $\simeq$0.28±0.15, but the poor signal-to-noise ratio does not allow to consider this result as significant.

f) *RCW 97 (G 327.3 −0.6)*

This region has been observed at H166α (Azcárate, Cersosimo and Colomb 1987*a*), H109α (Wilson *et al.* 1970), H76α (Mc Gee and Newton 1981), and molecular lines of H_2CO (Whiteoak and Gardner 1974), OH (Caswell and Robinson 1974) and CO (Gillespie *et al.* 1977). The P(200β)/P(159α) ratio is $\simeq$ 0.28±0.03, value which suggests that there is no stimulated emission. The same result is obtained from H166α observations of the low-density gas associated to the H II region (Azcárate *et al.* 1987*a*).

g) *G 0.00−0.0*

The profile corresponding to the galactic center is shown in Figure 7. From this profile we obtain a β/α ratio $\simeq$ 0.24±0.04, in good agreement with previous results (Shaver 1977). LTE departures do not seem to be significant. Shaver interprets his results as being close to LTE conditions in terms of line-of-sight, low-density H II regions, similar to those seen in other directions.

h) *G 0.5−0.5*

The profile corresponding to galactic coordinates 1 = 0.5°, b = −0.5° is shown in Figure 8. The P(H200β)/P(H159α) ratio is $\simeq$ 0.19±0.03. That would indicate the presence of non-LTE effects. These effects can be attributed almost certainly to stimulated emission caused by the strong non-thermal continuum galactic radiation.

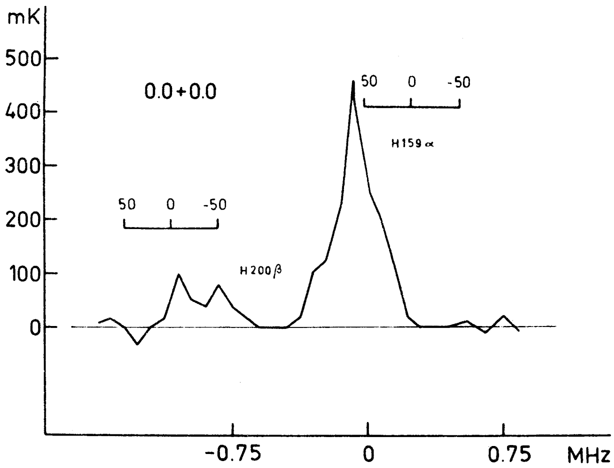

Fig. 7. Profile corresponding to the galactic center. In this figure, the origin of the LSR velocities (for the H159α line) is shifted to the right side. This origin in fact must coincide with the origin of the abscissa axis (that corresponds to the laboratory frequency of the H159α line).

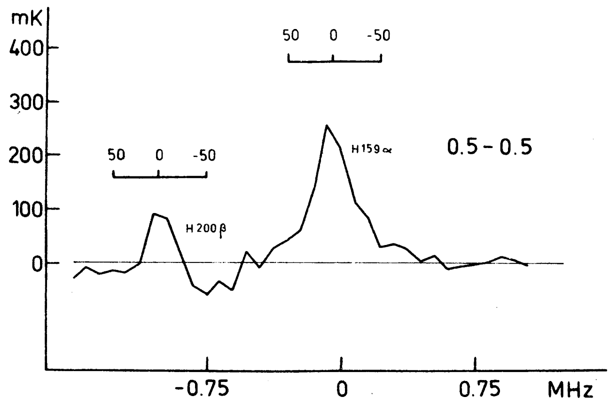

Fig. 8. Profile corresponding to G 0.5−0.5.

IV. CONCLUSIONS

The results indicate that there are departures from LTE conditions in some of the observed galactic H II regions (in their central high density parts). These LTE departures are not expected to be present in the extended, low-density ionized gas present in the outer parts of the regions ($N_e \simeq 10$ cm^{-3}), as is shown in RCW 38, RCW 97, RCW 74 and Carina (G 287.5−0.5) by previous H166α and 1.4 GHz continuum observations (Cersosimo *et al.* 1984; Azcárate *et al.* 1986; Azcárate *et al.* 1987*a,b*). In the case of the galactic center (1 = 0.0°, b = 0.0°) the β/α relation obtained, close to the LTE expected ratios, can be explained by the same argument given by Shaver (1977), the presence of low-density H II regions along the line of sight. However, that does not seem to occur in the point with galactic coordinates 1 = 0.5°, b = −0.5°, where the relation obtained is $\simeq 0.19 \pm 0.04$. In this direction, the number of H II regions (probably several of them of low-density) present in the line of sight is almost certainly much lower than in the precise direction of the galactic center (1 = 0.0°, b = 0.0°). Therefore, what we see is most probably H159α and H200β emission originated in this region itself (G 0.5 −0.5), and this emission is stimulated by the galactic continuum radiation, which produces non-LTE effects.

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