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RESEARCH NOTE: β AND α RECOMBINATION LINES FROM A REGION AROUND THE GALACTIC CENTER

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RESUMEN

Se realizaron observaciones de las líneas de recombinación H159α (ν = 1620.672 MHz) y H200β (ν = 1619.690 MHz) en nueve posiciones alrededor de la región del centro galáctico (separadas entre sí por 0.5°), utilizando la antena de 30-m del Instituto Argentino de Radioastronomía. El propósito de las observaciones fue estimar el apartamiento de las condiciones de Equilibrio Termodinámico Local (ETL) en esa región. Sólo en dos de las nueve posiciones, se pudo detectar la línea H200β por encima del nivel de ruido. Para esas dos posiciones, se determinó el cociente: P(H200β)/P(H159α), con el objeto de verificar el apartamiento de las condiciones de ETL.

ABSTRACT

H159α (ν = 1620.672 MHz) and H200β (ν = 1619.690 MHz) recombination line observations of nine positions around the galactic center region (separated by 0.5° from each other) were made with the 30-m antenna of the Instituto Argentino de Radioastronomía. The observations were made with the purpose of checking the departure from the Local Thermodynamic Equilibrium (LTE) conditions in this region. Only in two positions the H200β line was detected above the noise-level. The ratio P(H200β)/P(H159α) was determined for these two positions, in order to check the departure from LTE conditions.

Key words: **GALAXY-CENTER — H II REGIONS**

1. INTRODUCTION

Important physical information can be obtained from radio recombination line observations of H II regions, such as electron density, emission measure, and electron temperature of the nebulae. The importance of stimulated emission effects in the observed radio recombination lines that strengthen the intensity of the lines was first pointed out by Goldberg (1966). He was the first to suggest that the intensity of radio recombination lines can be essentially dependent on the non-equilibrium of the population of highly excited levels (non-LTE effect). Since then, the possible presence of stimulated emission has been taken into account for the interpretation of recombination line observations (Dupree & Goldberg 1969; Brocklehurst & Seaton 1972; Brown, Lockman, & Knapp 1978). The stimulated emission produces departures from LTE conditions in the ionized gas.

These non-LTE effects can be investigated by observations of α and β transitions at about the same frequency (Dupree & Goldberg 1970). In the case of H159α and H200β the P(H200β)/P(H159α), integrated intensity line ratio, is $\simeq$ 0.28 for LTE conditions.

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To investigate the presence of non-LTE effects in a region around the galactic center, we have made observations of both lines in nine positions in this zone (separated 0.5° from each other). The frequencies of the lines are: 1620.672 MHz for the α and 1619.690 MHz for the β transition.

2. THE OBSERVATIONS

The observations were made with the 30-m antenna of the Instituto Argentino de Radioastronomía. The receiver was a room temperature GaAs FET amplifier. The system temperature on cold sky was 89 K. The aperture efficiency was $\eta_a = 0.45$. The conversion factor from antenna temperature to flux densities for the system is 8.7 Jy/K. The antenna beam at 18-cm was 29′. The spectral analysis was performed with a filter-bank of 84 channels of 75 kHz width each; that allowed a velocity resolution of 13.9 km s^{-1}. The frequency switching mode was used to make the observations. The local oscillator was switched by an amount less than the observing bandwidth, to obtain two independent spectra, which were then averaged. Third and fourth order polynomials were used to correct baseline effects. The integration time for each position was 4–5 hr, which resulted in an r.m.s. of 7 mK. The integration time for the observation of the galactic center itself (ℓ) = 0.0°, b = 0.0°) was 6 1/2 hr.

3. RESULTS

The following points were observed: $\ell = -0.5°$, $b = +0.5°$; $\ell = -0.5°$, $b = 0.0°$; $\ell = -0.5°$, $b = -0.5°$; $\ell = 0.0°$, $b = +0.5°$; $\ell = 0.0°$, $b = 0.0°$; $\ell = 0.0°$, $b = -0.5°$; $\ell = +0.5°$, $b = +0.5°$; $\ell = +0.5°$, $b = +0.0°$; $\ell = +0.5°$, $b = -0.5°$. Only in the galactic center itself (G0.0+0.0), and the point G0.5−0.5 the H200β line was detected above the noise level. We show in Table 1 the observed line parameters for these two cases. In this table, T_L is the line temperature, Δv is the linewidth, V_{lsr} is the central velocity of the line, and T_c is the continuum temperature. We discuss below the results.

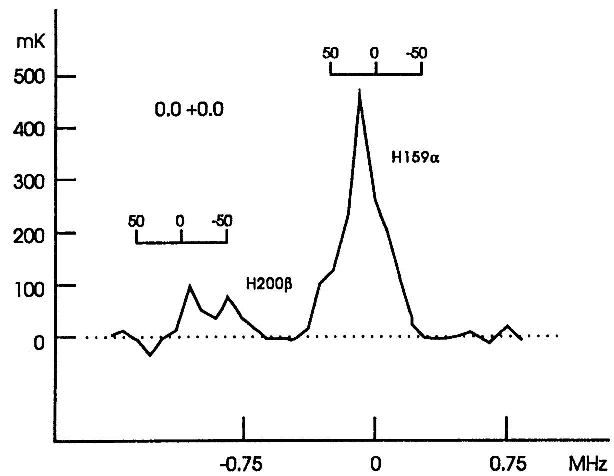

Fig. 1. Profile corresponding to the G0.0−0.0 position. In the ordinate axis, the antenna temperature is given in mK. In the abscissa axis the frequency is given in MHz. The origin of this last axis corresponds to the laboratory frequency of the H159α line. The LSR velocities are given in the upper part of each peak. The same indications are valid for Figure 2.

3.1. G0.0+0.0

The profile corresponding to this position is shown in Figure 1. The P(H200β)/P(H159α) ratio is 0.24 ± 0.04, where P(H200β)/P(H159α) is the integrated intensity line ratio. We could interpret this result as an indicator that the LTE departures are not significant. That could be explained by the presence of overlapping low-density H II regions along the line of sight. In these low-density H II regions and with this large beam (29′) we would not have observable non-LTE effects (Shaver 1980a, b). To have β/α ratios close to 0.28 is not enough to decide that the LTE departures are not significant, since the β and α lines can be out of the LTE in the same direction and the ratio still be 0.28. The derived electron temperature from the H159α observation is 6960 ± 400 K.

TABLE 1

OBSERVED LINE PARAMETERS

Region	α (1950)	δ	Line	T_L (K)	Δ_V (km s^{-1})	V_{lsr} (km s^{-1})	T_c (K)
G0.0+0.0	265.604	−28.927	H159α	0.45	50 ± 3	+8 ± 3	61 ± 3
			H200β	0.11	50 ± 5	−2 ± 3	
G0.5−0.5	266.389	−28.762	H159α	0.29	40 ± 3	+8 ± 3	17 ± 2
			H200β	0.09	26 ± 3	−2 ± 3	

3.2. G0.5−0.5

We show in Figure 2 the profile corresponding to galactic coordinates $\ell = 0.5°$, $b = -0.5°$. The β/α ratio is 0.20 ± 0.04 which is an indication of the presence of non-LTE effects. These effects can be attributed to stimulated emission caused by the strong non-thermal galactic continuum radiation. In this case, the number of H II regions (probably most of them of low density) that appear in the line of sight is almost certainly much lower than in the direction of the galactic center. On the other hand, the low β/α ratio could not be explained by pressure broadening effects, since the broadening in the β line is not larger than that of the α line. Therefore, what we see is most probably α and β emission in the region G0.5−0.5 itself, stimulated by the non-thermal galactic continuum radiation.

The derived electron temperature form the H159α observation at this position is 4100 ± 300 K. For the other seven observed positions, we can give an upper limit to the H200β line intensity of 25 mK.

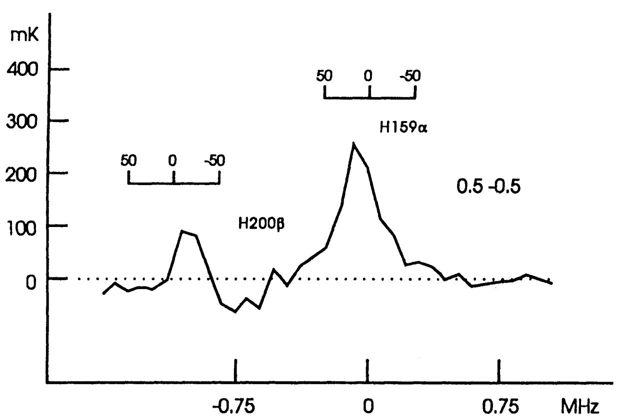

Fig. 2. Profile corresponding to the G0.5−0.5 position.

4. CONCLUSIONS

In this basically observational work, we have carried out H159α and H200β recombination line observations in a region around the galactic center (nine positions) with the 30-m antenna of the IAR, with a HPBW of 29′. Due probably to the relatively low sensitivity of the receiver ($T_{sys} \simeq 89$ K), only in two positions the H200β line was detected. For these positions we obtained β/α ratios which in one of the positions (G0.5−0.5) seem to indicate the presence of non-LTE effects, caused most probably by the non-thermal galactic continuum radiation. For this position, the low β/α could not be explained by the presence of pressure broadening effects.

For the other position, corresponding precisely to the galactic center (G0.0+0.0) there does not seem to be stimulated emission. The explanation for this fact could be the presence of a superposition of low-density H II regions, in which there would not be observable non-LTE effects for observations made with the large beam used by us, of 29′ (Shaver 1980a,b). We do not have observational evidence of the presence of pressure broadening effects in this case.

The upper limits for the positions with no positive β detection are 25 mK for the intensity of this recombination line. More sensitive observations would be necessary to detect the H200β line and test the possible departures from LTE conditions in the other positions.

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