LETTERS TO THE EDITOR

ASTRONOMY

Hydrogen Recombination Lines 126α and 166α observed in Galactic HII Regions

USING the Parkes radiotelescope, we have searched the Southern Milky Way for the 126α hydrogen recombination line of rest frequency 3248·713 Mc/s. (The notation $n\alpha$ indicates a transition from the level of quantum number $(n+1)$ to level n; $n\beta$ indicates a transition from $(n+2)$ to n.) Nineteen sources were inspected and the line was detected in fifteen, all of which were well known HII regions. The nebulae[1] were

Orion Nebula	*RCW* 57	*NGC* 6334
IC 434	*RCW* 74	*NGC* 6357
RCW 38	1608–51	*M* 17
η Carinae (two positions)	1617–50	*W* 49
	1618–49	*W* 51

Four neighbouring points were checked in the Orion Nebula and *M* 17 to establish that the maximum line intensity corresponded to the maximum continuum temperature.

A probable detection was made in the galactic centre source at $l_{II} = 40'$, $b^{II} = -2'$. No detections were made in the two non-thermal sources, Sagittarius *A* and the Crab Nebula. The extra-galactic source, 30 Doradus in the Large Magellanic Cloud, gave a negative result, possibly because the sensitivity was not great enough.

The three most intense HII regions, Orion Nebula, *M* 17 and *RCW* 38, were later observed for the 166α line, with a rest frequency 1424·736 Mc/s.

Table 1 shows details relating to the three sources of: (i) T_L, the peak line intensity in terms of aerial temperature; (ii) the ratio T_L/T_C, where T_C is the corresponding aerial temperature in the continuum; (iii) Δν, the half-intensity width of the line, corrected for broadening with 37 kc/s filters; and (iv) the central line radial velocities (referred to the local standard of rest).

Table 1. SUMMARY OF OBSERVATIONS OF HYDROGEN RECOMBINATION LINES 126α, 166α

Source	Line	T_L (° K)	T_L/T_C (per cent)	Δν (kc/s)	Radial velocity (km/s)
Orion Nebula	126α	6·4 ± 0·1	3·5	430 ± 10	−2
	166α	1·9 ± 0·1	0·8	215 ± 10	0
M 17	126α	5·7 ± 0·1	3·1	388 ± 10	+20
	166α	3·0 ± 0·1	1·05	203 ± 20	+20
RCW 38	126α	2·4 ± 0·1	2·5	398 ± 15	+4
	166α	1·2 ± 0·1	1·05	156 ± 20	+8

Palmer and Zuckerman[2] have detected the 166α line in only *M* 17. Their values of T_L/T_C and Δν are 0·9 ± 0·2 per cent and 183 ± 60 kc/s when corrections are made for their 80 kc/s bandwidth.

Recently, we have considered[3] the ratio of the peak intensities of the 126α line to the β lines, 159β and 158β, at nearby frequencies, 3211·245 and 3272·219 Mc/s, respectively. In the source *M* 17, the ratio *I* (158β)/*I* (126α) of 0·22 ± 0·04 was close to the theoretical value 0·224 derived from formulae set down by Kardashev[4]. In the Orion Nebula, however, the ratio was considerably lower: 0·13 ± 0·03. Without observations at lower frequency to give bandwidths near 158α it was impossible to infer whether this resulted from departures from local thermodynamic equilibrium of the populations or to appreciable broadening of the energy levels involved in the 158β, 159β transitions (and the corresponding α transitions) in the Orion Nebula. As the Bohr radius is proportional to the square of the principal quantum number, the 158, 159 levels will be more affected by electron and ion densities than levels near 126. It is well known that the density is considerably higher in Orion than in *M* 17.

In Fig. 1, T_L/T_C and Δν have been plotted against frequency over the range of the present observations so that values for the 158α line may be obtained by interpolation. The results for the 126 and 158 α-lines for the Orion Nebula may be compared with those for *M* 17. The 126 and 158 α-lines have been observed under similar conditions except for the increase in beamwidth from 6′ arc to 14′ arc. *I*(158α)/*I*(126α) is 0·31 for the Orion Nebula and 0·43 for *M* 17; that is, the Orion value is 0·73 of the *M* 17 value. The ratio *I*(158β)/*I*(126α) for the two sources was 0·59. The small difference could be accommodated within the experimental errors.

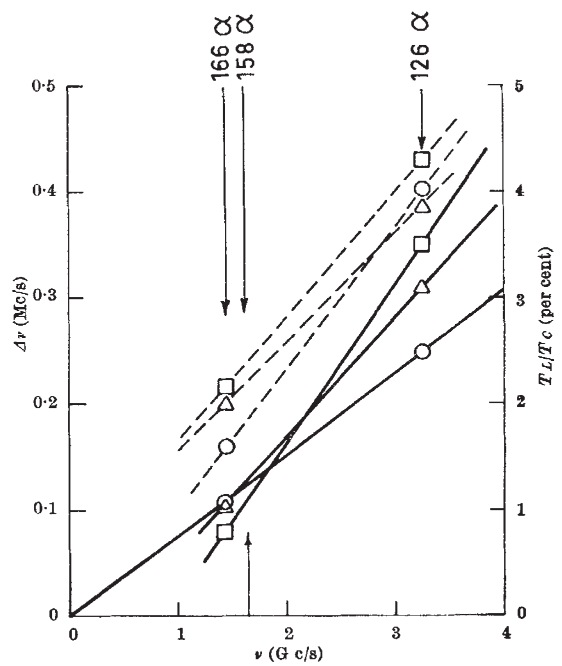

Fig. 1. Recombination line half-width, Δν (broken lines), and the ratio of line intensity to continuum intensity, T_L/T_C (full lines), are plotted against frequency (in G c/s) over the range of the 166α and 126α lines for the HII nebulae. □, Orion Nebula; △, *M* 17; ○, *RCW* 38.

On the other hand, the corresponding ratio of Δν for the two lines is effectively the same (0·96) for both sources, and thus broadening is inadequate to account for the intensity ratios.

We infer from the results that the populations at least for Orion are not in agreement with a Boltzmann distribution. The likelihood of such a situation has been discussed by Goldberg[5].

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[1] *RCW* numbers refer to the catalogue by Rodgers, Campbell and Whiteoak, *Mon. Not. Roy. Astro. Soc.*, **120**, 1 (1960). *W* refers to Westerhout, *Bull. Astro. Inst., Netherlands*, **14**, 215 (1958). Numbers such as 1608–51 are co-ordinate numbers of sources in the *Parkes Catalogue, Austral. J. Phys.*, **17**, 340 (1964).

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[4] Kardashev, N. S., *Soviet Astro. J.*, **3**, 813 (1959).

[5] Goldberg, L., *Astrophys. J.*, **144**, 1225 (1966).

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