MODELS OF H II REGIONS FROM RECOMBINATION LINE OBSERVATIONS

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Abstract. In order to study the ionized gas with low electron density the H159 and H200 radio recombination lines (v = 1.62 GHz) at l = 30°5 and l = 31°0 in the galactic plane, observed with the NRAO 43 m radiotelescope, are analyzed. The profiles show the LTE $I/\beta$ intensity ratio for the more distant component of the profiles ($\theta_{\text{LSR}} = 100 \text{ km s}^{-1}$) (Cersosimo and Onello, 1991).

To derive the electron density and temperature of the emitting gas a new interpretation of the radio recombination lines is made. We suppose that the emission originates in a superposition of ionized gas layers with different densities along the line of sight. The number of layers in the model is equal to the numbers of different order transitions observed. By solving an equations set, the contribution of different components can be calculated. The method is used to estimate the electron density and temperature of the gas. Eleven models of two non-LTE components are considered. The photon flux required to ionize the regions are calculated and the results are compared with previous observations obtained in the region at 3 cm (H85, H87, H88 lines) (Lockman, 1989).

Our results suggest that the necessary photon flux to ionize the extended envelopes of the regions is at least one order of magnitude larger than that needed for ionizing the core of the regions.

1. Introduction

Weak centimetric recombination lines are observed at almost all locations along the galactic plane for $|l| < 50°$. Surveys at 1425 MHz were made by Lockman (1976), Hart and Pedlar (1976), and at 325 MHz by Anantharamaiah (1985a, b) in the first quadrant. A 1425 MHz survey in the fourth quadrant was made by Cersosimo et al. (1989).

Determining the properties and distribution of low density ionized gas in the Galaxy is crucial to our understanding of the interstellar medium and its constituents. If it is widespread, the ionization source is unknown and may require a substantial source of energy input into the ISM which cannot be currently explained by supernovae related phenomena. On the other hand, if the gas responsible for the low-frequency recombination lines is not widespread, but it is associated with envelopes of 'normal' H II regions, as suggested by Anantharamaiah (1986) its analysis is important for our knowledge of the evolution and dynamics of H II regions. H166 observations of H II

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regions have been made in the IAR mostly in the fourth quadrant, which suggest the low frequency recombination lines originate in extended envelopes of H II regions (Azcárate et al., 1986, 1987a, b, Azcárate, 1991).

We analyze in the present paper observations of $\alpha$ and $\beta$ transitions of RRL's at 18 cm carried out with the 43 m NRAO radiotelescope. For detail of the observations see a previous paper (Cersosimo and Onello, 1991).

### 2. Interpretation of Radio Recombination Lines

One approach for interpretation of RRL's from inhomogeneous nebula is using a multicomponent region. The model consists of $i$-cylinders. The length of each cylinder is equal to its diameter. For such a model the peak intensity observed for each transition is

$$T_\alpha = m_1 T_{\alpha,1} + m_2 T_{\alpha,2} + \cdots + m_n T_{\alpha,n},$$

$$T_\beta = m_1 T_{\beta,1} + m_2 T_{\beta,2} + \cdots + m_n T_{\beta,n},$$

$$T_\gamma = m_1 T_{\gamma,1} + m_2 T_{\gamma,2} + \cdots + m_n T_{\gamma,n};$$

where $T_{\alpha,i}$, $T_{\beta,i}$, etc., are the contributions of the $i$th component for the different order transitions $\alpha$, $\beta$, etc. The line temperature for the different order transitions is calculated by the expression given in the literature (Cersosimo and Onello, 1991). Solving the equation set for the unknowns we get the contribution of each component. The $m_i$ is a sampling factor which takes into account the unknown number of H II regions of each component observed in the beam of the telescope; $m_i$ must be a positive quantity.

The models consider cases with incident background radiation and no incident background radiation. The results, for the more distant kinematical component of the profiles ($v_{L,sr} = 100$ km s$^{-1}$, a distance of 6.0 kpc is assumed) are shown in Table I. In this Table, Y (yes) or N (no) indicate if there is or not physically significant solution for each model, $T_B$ is the temperature of the background; $T_e$, the electron temperature; $N_e$, the electron density; $S$ the linear diameter of each component, $m_1$ and $m_2$ are the sampling factor for each component in the models (high and low density, respectively). It is assumed that the denser region is embedded in the cooler diffuse gas.

### 3. Source of Ionization

To determine the production rate of Lyman continuum photons emitted per sec by the ionizing OB stars ($N_{LYC}$) we assume that an improved estimation of the $N_{LYC}$ is obtained by addition of the $N_{LYC}$ (dense core of the H II region) and the corresponding quantity of the Extended Low Density Envelope (ELDE). That is supported by Güsten and Mezger (1982).

We derive the ionization rate from the observations made by Lockman (1989) at 3 cm