New Measurements of the ^{4}He Abundance in Galactic HII Regions

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Abstract. Preliminary results of the ^{4}He relative abundance determination from Radio Recombination Lines observations at different frequencies in the Orion, Rosette and W3 HII regions are presented. The Orion HII region has been mapped at both 22 GHz and 36 GHz with the same beamwidth (2 arcmin) using the Medicina and Puschino radio telescopes respectively. The RRLs parameters, together with their variation with frequency and with distance were determined by centering the map on the star θ^1OriC. Three positions were observed in the Rosette HII region at 8.3 GHz leading to the first detection in this region of the transition He92α. The derived ^{4}He relative abundance is considerably greater than the ones obtained from previous measurements. The W3 HII region was observed at 36 GHz and the ^{4}He/H value derived was compared with previous measurements performed with higher spatial resolution.

1 Introduction

More than 90% of the observed helium (Hoyle & Tayler, 1964) must have been produced at the pregalactic epoch and it is commonly supposed to be produced by Big Bang nucleosynthesis. The observations of H and He Radio Recombination Lines (RRLs) in galactic and extragalactic HII regions gives the possibility to measure the primordial helium abundance with a 10% accuracy and provide a better understanding of the astrophysical processes acting inside the observed regions. With these aims a mid-term program has been started involving Italian and Russian groups which are using the two radio telescopes of Medicina (32 m), Bologna (Italy), and Puschino (22 m), Russia. In the following sections the first preliminary results of such a program are reported.

2 Observations

22.4 and 36.5 GHz maps of Orion were made with the Medicina and Puschino radio telescopes respectively, the two different $n\alpha$ transitions of RRLs, 66α

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(22GHz) and 56α (36.5 GHz), were observed with the same beam width (2 arcmin). The mapped grid has been centered on θ^1OriC ($\alpha = 5^h32^m49^s.0$, $\delta = -5^o25'16''.0$). At 22 GHz three rings separated by 2 arcmin were observed for a total of 13 different positions in addition to the central one. An autocorrelator spectrometer with bandwidth of 20-25 MHz was used at the Medicina radio telescope to simultaneously observe the H and the He lines; it was possible to gain a factor of two in integration time by using the two available polarizations. The instrumental configuration provided a 0.65 km/s velocity resolution allowing enough accuracy to measure the expected line width (20-30 km/s), typical for our target RRLs in HII regions. The adopted observational technique was the position switching mode, the total integration time is greater than 40 minutes on each position. Both the Orion mapping at 36.5 GHz and W3a observations at 36.5 and 34.6 GHz were made with the RT22 at Puschino. A filter bank spectra analyzer with a 4.1 km/s (36.5 GHz) and a 4.3 km/s (34.6 GHz) velocity resolution was used.

The Medicina radio telescope was also used to observe three positions in the Rosette HII region at 8.3 GHz which corresponds to the 92α RRL transitions. The bandwidth to detect both H and He lines was set at 12.5 MHz with a velocity resolution of 0.88 km/s. Due to the weakness of the lines a long on source integration time was necessary (greater than 4 hours on each observed position) to obtain good S/N. A standard data reduction procedure was followed to get the final spectra: the spectra obtained at each position, or ring in the case of the Orion observations, were averaged together after a first quality check to look for interferences; then an high order (6-9) polynomial was substracted as baseline.

3 Results

3.1 Orion

By mapping the center of the Orion HII region a radial distribution of the ^{4}He/H relative abundance (y^+) has been obtained at two frequencies. The resulting two values for y^+ at each map position agree very well within the errors. The high spectral resolution, combined with a good signal to noise ratio, allows to separate the C66α which is blended with the He66α and generally pollutes the ^{4}He abundance determination (Figure 1a). Figure 1c shows the derived y^+ abundances as a function of the radial distance from the map center (θ^1OriC). Under the 'standard' assumption that helium is almost completely ionized in HII regions and that the contribution due to y^{++} is negligible (Churchwell et. al, 1974) the primordial helium abundance can be determined using the relation: $Y = Y_p + Z * dY/dZ$ (Y: total helium abundance; Y_p: primordial helium abundance; Z: heavy elements abundance).

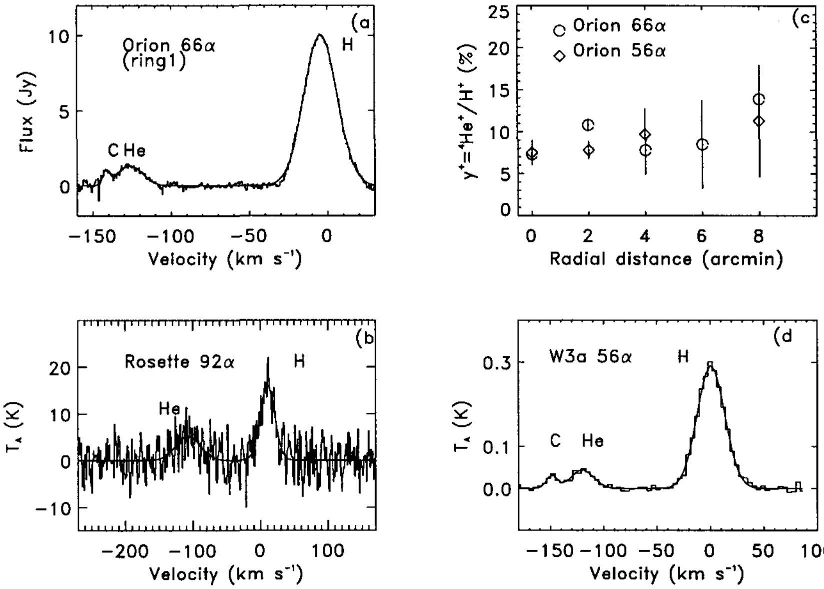

Fig. 1. 1a - spectrum of the transition 66α of ring1 in the Orion HII region; 1b - spectrum of the transition 92α of one position ($\alpha = 6^h28^m15^s.7$, $\delta = +4^o44'05''$) in the Rosette HII region; 1c - distribution of the relative abundance y$^+$ for both transitions (56α and 66α) in the Orion HII region; 1d - spectrum of the transition 56α in the W3a HII region.

3.2 Rosette

The 8.3 GHz frequency was chosen for the Rosette observations for two main reasons. First of all no RRLs observations had been previously performed at this high frequency towards this target. The second reason was to better understand the instrumental behaviour and sensitivity limits at this frequency in view of our future goal to observe the ^{3}He$^+$ hyperfine transition at 8.665 GHz. Three positions have been observed in Rosette, the same ones done by Celnik (1985) at lower frequency (5 GHz). A V_{LSR} dependence versus the quantum number has been detected and a new physical model, which proposes a T_e gradient, was built from the observed line parameters (Cortiglioni et al., 1997). Such a model shows that the expansion of the nebula modifies the helium profile more than the hydrogen profile especially towards the center. The importance of measuring accurately the helium line parameters lies in the role they have in determining the nebula expansion. Figure 1b shows the spectrum of the transition 92α taken at ($\alpha = 6^h28^m15^s.7$, $\delta = +4^o44'05''$) in the Rosette nebula. The derived value for y^+ is much higher than the one found by Celnik, but to confirm the measured value further observations and a much finer mapping of the region at 8.3 GHz are needed.

3.3 W3

A ^{4}He abundance $y^+ = 9.7 \pm 0.8$ has been measured at the wavelength of 8 mm. The difference between the measured abundance obtained and the increase in y^+ value, about 10% to 40% from center to the edge of W3, is due to the higher resolution observations (Roelfsema & Goss, 1991). Corcerning the recent model proposed by Gulyaev et al., 1997 the actual ^{4}He abundance (8.9%) is smaller than the observed one. Figure 1d shows the spectrum of the transition 56α in W3a.

4 Conclusion

Preliminary results of a program started few months ago have been presented. We are confident we can pursue the project to successfully achieve the stated 10% accuracy on the primordial ^{4}He abundance determination. Further observations are still necessary on all our target HII regions, Orion, Rosette and W3 using both radio telescopes of Medicina and Puschino.

In particular towards Rosette we will also increase the number of mapped positions to better understand the chemical and physical conditions in the region and its dynamics.

In addition, the excellent sensitivity reached at 8.3 GHz in the Rosette spectra (rms less than 3 mK with an on source integration time of about 14 hours) lead to optimistic expectations for the ^{3}He$^+$ abundance determination by measuring the hyperfine ^{3}He$^+$ line at 8.665 GHz. Observations have being continued at Medicina towards W3 aimed at confirming the detection of Balser et al. (1994).

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