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Observations of HII regions at millimeter wavelengths with the O.A.S.I. telescope at Terra Nova Bay

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Abstract. We report on our latest investigations into strong HII regions lying on the Galactic plane. They are sources of free-free emission in radio and dust emission in IR, but they have not been observed in the millimeter range until now. Our efforts to understand their behaviour in this range will be displayed. These observations were carried out with the O.A.S.I. telescope at Terra Nova Bay from November to December 2001. The receiving system consisted of a bolometric detector operating at wavelengths of 1.25 and 2 millimeter, with a resolution of 5 arcmin. We will briefly describe the observational techniques and the preliminary results for two of these sources, G291.6 -0.5 and G291.3 -0.7; we will also discuss some improvements to be introduced for further observations.

Key words. HII regions – mm-observations – dust emission spectra

1. Introduction

HII regions are among the strongest sources in the Galaxy. They represent the final stages of the birth of hot stars with O or B spectral types. When reaching the Zero Age Main Sequence, the young massive star is still deeply embedded in a dense gas and dust nebula; the star heats the dust and ionises the hydrogen in the surrounding envelope and can be detected as a strong source in the far infrared and as a HII region in the radio. Radio observations are dominated by free-free emission originated in the ionized nebula; the infrared part of the spectrum, instead, is due to dust emission coming from the outer halo and can be described by a modified blackbody curve. While many radio and IR observations of these objects are available, only few of them

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have been observed in the millimeter range since now.

There are many interesting problems still unsolved about physical properties of the ionized region and the dust cloud in which it is embedded, such as dust composition, its temperature and spectral index. Moreover, a considerable reason supporting this work is its importance for Cosmic Microwave Background (CMB) measurements; in fact, HII regions may contribute to the galactic emission and so affect the observations of CMB anisotropies at intermediate Galactic latitude. HII regions are also good candidates as calibrators and as probes of the pointing and beamshape for CMB imaging experiments, such as the PLANCK mission. In fact they are non-variable, bright, compact sources and have quite a well-known spectrum.

We selected a sample of southern compact HII regions from radio catalogues, using Paladini et al. (2003) list; the selection criteria lead to a list of 12 sources, which have been observed during the XVII Italian Antarctic Expedition. In this paper, we report our results for two of the observed regions, G291.6 -0.5 and G291.3 -0.7.

2. Equipment and observing strategy

The observations were carried out in the period from October to December 2001 from O.A.S.I. telescope (Infrared and Submillimetric Antarctic Observatory) located near the Italian Base at Terra Nova Bay, at coordinates: Lat. 74°41'42"S, Long. 164°07'23"E. The telescope has a Cassegrain configuration, with a 2.6 m primary mirror, supported on an altitude-azimuth mount. For more details on the telescope we refer to Dall'Oglio et al. (1992).

The detector is a bolometric system cooled at 0.3 K with a ^{3}He refrigerator operating at $\lambda_1 = 1.25$ mm and $\lambda_2 = 2$ mm of wavelength (corresponding to frequencies ν_1=240 GHz and ν_2=150 GHz respectively). The mesh filters used for the observations define the spectral bandwidths of $\Delta\nu_1$=70 GHz and $\Delta\nu_2$=40 GHz for the two channels, suitable to match the atmospheric windows. In this configuration, the FWHM beamwidth is 5 arcmin.

In order to remove the atmospheric contribution we adopted an ON-OFF technique, spending 15 minutes tracking the source (ON) and 15 minutes tracking the blank sky (OFF); the signal acquired on-source V_{ON} is due to both source and atmosphere, while the signal acquired off-source V_{OFF} is due only to the atmosphere. The source peak flux density is obtained by subtracting V_{OFF} to V_{ON}.

Moreover, we adopted a modulating secondary mirror to achieve a beam-switching and subtract any linear gradient of temperature; in this three-fields modulation, the source is kept in the central field. The modulation is sinusoidal, with an amplitude of 18 arcmin and a frequency ν_{mod}=5.3 Hz. The modulation frequency is chosen in a range where the bolometers have an optimal frequency response and are not affected by the 1/f noise; the modulation is always parallel to the horizon. The signal due to the central field, which has a frequency of two times the modulation frequency ν_{mod}, is demodulated by a lock-in amplifier. The lock-in amplifier is also used to integrate the detector signal for 3 seconds to remove high frequency fluctuations.

For flux density calibration we used Venus, adopting a temperature of 276 K for the first channel (λ_1=1.25 mm) and 294 K for the second one (λ_2=2 mm), with an error of 7%.

The atmospheric transmission was evaluated using models based on the vertical distribution of the atmospheric constituents; in particular, the content of water vapor was monitored using data kindly provided by ENEA. The precipitable water volume, as determined from ENEA radiosoundings twice a day, was $pwv = 3 \pm 1$ mm during the whole period, a typical value for Antarctic summer at sea-level; for the observations concerning this paper, the pwv is found between 2.6 and 3 mm, corresponding to an atmospheric transmission of about 80% for the 1.25 mm channel and 90% for the 2 mm one.

3. Analysis of observations

Both the detector signal, acquired as a voltage across the bolometer, and the output of the lock-in amplifier for the two channels were collected by a data acquisition system, which sampled the output 64 times per second.

We had to use a polynomial fit to remove the baseline variations and so improve data quality. The polynomial has been chosen on the basis of a chi-square test; we found that a parabolic fit well reproduces the fluctuations on time-scale of 30 minutes. The removal of the baseline greatly reduces the signal fluctuations, reducing them from 20% to 12%. After the removal of the baseline, we performed the difference $V_i = V_i^{ON} - V_i^{OFF}$ for each ON-OFF cycle; our best estimate for the peak flux density of the source is determined as the mean $\sum_{i=1}^{N} \frac{V_i}{N}$, multiplied by the corresponding calibration coefficient.

In order to convert the peak flux density to an integrated one it is essential to know intrinsic size of the source, so that integration is made over the full extent; informations about the size may be obtained using radio maps (Caswell & Haynes (1987), Goss & Shaver (1970), Thomas & Day (1969)) and FIR maps (Schlegel, Finkbeiner & Davis (1998)). Assuming a Gaussian profile for the sources, we derive an integrated flux density S_{tot} from the observed peak flux S_{peak} using $S_{tot} \propto S_{peak}\theta_1 \times \theta_2$, where θ_1 and θ_2 are the beamsmoothed widths of each source along its main axes. The angular sizes, obtained with an extrapolation from radio and FIR values, are found to be 10'×6.5' for the G291.6 -0.5 and 4.3'×4' for G291.3 -0.7.

The absolute error on these observations, considering calibration uncertainities and atmospheric residual contamination, is slightly lower than 20%.

4. Results

Figures 1 and 2 report our results for integrated flux density for the two observed HII regions, including error bars, together with data from literature at radio and FIR wavelengths.

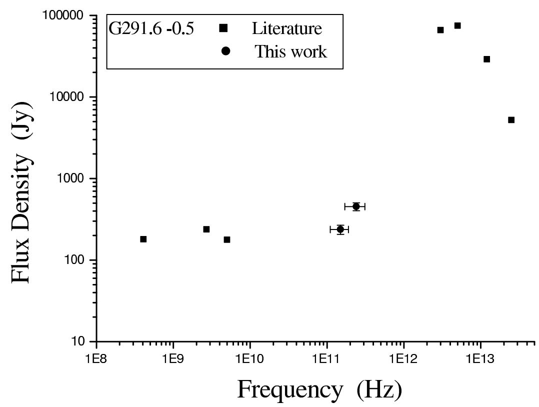

Fig. 1. Spectrum of the region G291.6 -0.5.

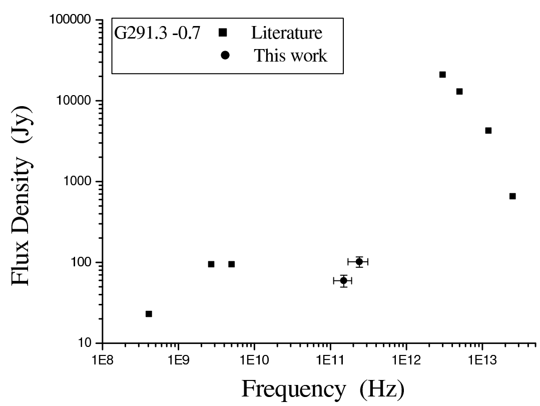

Fig. 2. Spectrum of the region G291.3 -0.7.

These results allow the determination of physical properties of dust clouds around the two regions. By fitting a modified Planck curve of the form $\lambda^{-\alpha} B_\nu(T_d)$ to the observations at FIR and millimetric wavelengths we obtain values for spectral index α and dust temperature T_d; we found that is not possible to describe the whole set of data with a single curve. In fact, even changing the temperature and the spectral index, our observations do no match with the IRAS spectrum: they could be explained by assuming the existence of a different spectral component; thus, only IRAS observations at 100 μm, together with our results at 1.25 and 2 mm, were used in the present analysis. Values for flux density were corrected by subtracting free-free contribution, to account only for the dust content; free-free contribution was evaluated by extrapolating radio values with a trend proportional to $\nu^{-0.15}$, a good approximation for high frequencies (Mezger & Henderson (1967)). Our results for α and T_d are summarized in table 1.

Source	α	T_d (K)
G291.6 -0.5	1.4	12.9
G291.3 -0.7	1.1	15.0

Table 1. Results for spectral index α and dust temperature T_d.

5. Conclusions

The present work gives the first observational results of two strong compact HII regions lying on the galactic plane, observed at 1.25 and 2 mm of wavelength. Dust parameters (spectral index and temperature) are derived for the two sources by combining our observations with data obtained by IRAS.

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