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VLA observations of the H53α recombination line toward the super star clusters galaxy NGC 5253

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Abstract. The H53α recombination line and radio continuum at 43 GHz were observed towards the galaxy NGC 5253 using the VLA at 2$''$ angular resolution. The H92α and H53α recombination lines emission was modeled along the radio continuum emission from 1-200 GHz using a collection of HII regions. According to the models the ionized gas has a density of $\sim 6 \times 10^4$ cm^{-3} and a Lyman continuum photon rate of 10^{52} s^{-1} in needed to sustain the ionization.

Key words. Galaxies: star formation – Galaxy: globular clusters – Galaxy: star formation – radio recombination lines

1. Introduction

NGC 5253 is a blue dwarf irregular galaxy (located at $\sim$ 4 Mpc; Saha et al. 1995) with an infrared luminosity of $\sim 2 \times 10^9$ L$_\odot$ (Beck et al. 1996). NGC 5253 hosts several groups of young star clusters, called super star clusters (SSC) (Gorjian 2001; Calzetti et al. 1997). The optical spectrum of NGC 5253 shows signatures of large numbers of Wolf-Rayet (WR) stars (Campbell, Terlevich & Melnick et al. 1986; Walsh & Roy 1989; Schaerer et al. 1997). A nearly flat radio continuum spectra also indicates that free-free emission is the dominant emission mechanism and that NGC 5253 is a young starburst galaxy.

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2. Observations

The H53α line observations were carried out in the D configuration of the VLA on 2004. Two frequency windows were used to observe the RRL H53α, centered at 42885.1 and 42914.9 MHz. The radio continuum images were obtained by combining the continuum channels of each frequency window using the task DBCON from AIPS and self-calibrated after the combination was performed.

We also reprocessed high angular resolution ($< 1''$) radio continuum data from the VLA archive carried out towards NGC 5253 at 2, 1.3 and 0.7 cm. This was done in order to determine the radio continuum properties of the nuclear regions of NGC 5253 over angular scales < 7″. The angular resolution of all the images at these three frequencies is 0.″2 × 0.″1 (P.A.=0°).

3. Results

The measured radio continuum flux at 43 GHz towards the center of NGC 5253 is 47 ± 3 mJy over an area of 20″ × 40″. The spectrum is nearly flat ($\alpha = 0.1$; $S \propto \nu^{-\alpha}$) over the frequency range of 1-230 GHz. In order to explain the observed flux densities in the frequency range of 1-230 GHz three components are necessary: 1) an optically thin free-free component with electron density (n_e) of $\sim 10^3$ cm^{-3}, 2) an optically thick free-free component with $n_e \sim 6 \times 10^4$ cm^{-3} and 3) a non-thermal component with $\alpha = 0.75$ and $S_{2.6\ cm} = 2$ mJy.

The position of the 43 GHz continuum peak is in agreement with previous observations at 2 and 1.3 cm and coincident with the position of the source labeled "source A" by Turner, Ho & Beck (1998).

Using the H53α line observations we have obtained the integrated H53α line with peak line flux density of $S_L = 5.3 \pm 0.6$ mJy, a FWHM of 58 ± 12 km s^{-1} and a central velocity of 397 ± 5 km s^{-1}. The integrated H53α line flux density is 0.31 ± 0.03 Jy km s^{-1}. The isovelocity contours observed in the velocity field are nearly parallel to each other suggesting solid body rotation in the supernebula. The dynamical mass M*sin i* in the 1.5 pc supernebula is $\sim 3 \times 10^5$ M$_\odot$. This mass implied by the velocity gradient is consistent with the luminosity implied by the starburst models with this N_{Lyc} (Leitherer et al. 1999). The H53α line FWHM of 58 ± 5 km s^{-1} confirms that the supernebula is gravity bounded.

4. Models

Models that consists of HII regions, as those used by Rodriguez-Rico et al. (2006) were used to estimate the electron density of the ionized gas. These models were constrained by 1) the physical size of the region associated with RRL emission 2) the measured radio continuum and flux densities of RRLs H92α (Mohan et al. 2001) and H53α (this work). Based in previous observations with high angular resolution (0.″2 × 0.″1) the diameter of the ionized gas is $\sim$ 1.5 pc. We assumed the RRLs H92α and H53α arise from the same 1.5 pc nebula. Acceptable models are those that reproduce the radio continuum and both RRLs measurements with maximum diameter of 1.5 pc. We used model that consists of HII regions ionized by O7 (10^{49} s^{-1}) early-type stars. The models of RRL emission take into account deviations from LTE. The electron density obtained from the models is $\sim 6 \times 10^4$ cm^{-3} and the Lyman continuum photons rate needed to ionize the 1.5 pc region is 10^{52} s^{-1}, corresponding to $\sim$ 2000 O7 stars ($\sim 4 \times 10^4$ M$_\odot$).

5. Conclusions

We observed the radio continuum and RRL H53α line emission toward NGC 5253. VLA archival data were reprocessed at 2, 1.3 and 0.7 cm with angular resolution of 0.2″ × 0.1″. The models that consist of a collection of single density ($n_e \sim 6 \times 10^4$ cm^{-3}) HII regions reproduced the radio continuum and RRLs H53α and H92α emission from the central region $\sim$ 1.5 pc. The Lyman continuum photons rate necessary to ionize the gas in the central region of NGC 5253 is 2×10^{52} s^{-1} or 2000 O7 type stars. The peak in the H53α line coincides with the 1.6 μm IR peak within 1″. The velocity gradient if interpreted as rotation implies a mass of 3×10^5 M$\odot$ in the central 20 pc suggesting that the motion of the ionized gas is governed by gravity.

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