OBSERVATIONS OF NGC 3077 GALAXY IN NARROW BAND [SII] AND H\(\alpha\) FILTERS

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Abstract. We present observations of the HI tidal arm near dwarf galaxy NGC 3077 (member of the M81 galaxy group) in narrow band [SII] and H\(\alpha\) filters. Observations were carried out in March 2011 with the 2m RCC telescope at NAO Rozhen, Bulgaria. Our search for possible supernova remnant candidates (identified as sources with enhanced [SII] emission relative to their H\(\alpha\) emission) in this region yielded no sources of this kind. Nevertheless, we found a number of objects with significant H\(\alpha\) emission that probably represent uncatalogued, low brightness HII regions.

Key words: ISM: HII regions, supernova remnants – Methods: observational – Techniques: photometric – Galaxies: individual: NGC 3077

1. INTRODUCTION

The M81 galaxy group is the nearest interacting group of galaxies whose main members are M81, M82 and NGC 3077. Yun et al. (1994) found prominent HI structures surrounding these galaxies with large HI complexes and tidal bridges that are a result of the galaxy encounters. VLA HI observations (Walter et al. 2002) showed that 90% of atomic hydrogen around NGC 3077 is located eastward of the galactic center, in the tidal arm, called "Garland" (Barbieri et al. 1974, Karachentsev et al. 1985). The estimated HI mass in NGC 3077 is about \(10^8\) \(M_\odot\). Simulations showed that the Garland was created by tidal disruptions between NGC 3077 and M81, about \(3 \times 10^8\) years ago (Thomasson & Donner 1993, Yun 1999).

Tidal interaction between galaxies in this group is supposed to lead to enhanced star formation. As a consequence, we expect to detect many supernova remnant (SNR) and HII region candidates. Karachentsev et al. (2007) reported that Garland has the highest star formation rate (SFR) per luminosity among 150 galaxies of the Local Volume with known SFRs.

The aim of this work was to perform an optical search, using narrow [SII] and H\(\alpha\) filters, to identify SNR and HII region candidates in interaction regions in the
Table 1. Data for NGC 3077 taken from SIMBAD\textsuperscript{†}.

| Right ascension | Declination | Redshift | Velocity | Distance\textsuperscript{‡} | Angular size | Magn. | Morph. |
|----------------|-------------|----------|----------|-----------------------------|--------------|-------|--------|
| \(\alpha_{\text{J2000}}\) | \(\delta_{\text{J2000}}\) | \(z\) | \(v\) [\(\text{km s}^{-1}\)] | \(d\) [Mpc] | \(\prime\) |       |        |
| 10 03 19.1 | +68 44 02.2 | 0.00004 | 12 | 3.83 | 2.97 \times 2.37 | 10.9 (B) | I D |

\textsuperscript{†}http://simbad.u-strasbg.fr/simbad/ \textsuperscript{‡}Dalcanton \& al. (2009)

M81 galaxy group, particularly in the tidal feature Garland, near NGC 3077. In this analysis we use the fact that the optical spectra of SNRs have elevated [SII]/H\(\alpha\) emission-line ratios compared to the spectra of normal HII regions (Blair \& Long 2004, Matonick \& Fesen 1997). This ratio is an accurate means of differentiating between shock-heated SNRs (ratios >0.40, but often considerably higher) and photoionized nebulae (0.40, but typically <0.2).

We observed a region of maximum HI emission located in a prominent tidal arm, approximately 4 kpc east from the center of the galaxy. So far, 36 HII regions have been detected in this region (Walter et al. 2006), out of which 30 were in our observed field of view. Concerning SNRs, there are only 3 candidates in NGC 3077 for now, but these detections were done in the radio and X ray range (Rosa-Gonzales 2005). Chandra observations found no X ray emission originating from prominent tidal feature (Ott et al. 2003).

2. OBSERVATIONS AND DATA REDUCTION

The observations were made on 28th February 2011 with 2 m Ritchey-Chrètien-Coudé telescope at the National Astronomical Observatory, Bulgaria. The equivalent focal length of the telescope is 16 m and the field-of-view is one square degree with a scale 12.89\(\prime\)/mm. The telescope is equipped with VersArray:1300B CCD camera with 1340\(\times\)1300 px array, with a plate scale of 0\(\prime\).25732/px, giving a field of view 5\(\prime\).45\(\times\)5\(\prime\).35\(\prime\). We used the narrow-band filters for [SII], H\(\alpha\) and red continuum (details in Table 2). We took sets of 23 images through the [SII] and red continuum filter, and 19 images through the H\(\alpha\) filter, with 200s exposure time for each image. Typical seeing was 1.25\(\prime\) - 1.75\(\prime\). Standard star images, bias frames and sky flat-fields were also taken, through each of the filters.

Standard reduction procedures including bias subtraction, trimming, flat-fielding, image alignment and sky substraction were performed with the help of the IRIS\textsuperscript{1} software package. Afterwards, images taken through the same filters were combined using a sigma clipping algorithm (command COMPOSIT). Since the images were taken with different total exposure times, depending on the filters, we scaled all the images, normalizing them to the flux of the stars in the field. The H\(\alpha\) and [SII] images are then continuum-subtracted. The continuum-subtracted H\(\alpha\) image is given in Fig.2.

Sources in the continuum-subtracted H\(\alpha\) image are extracted by smoothing the image and then drawing 1\(\sigma\) contours from the median value. Relative fluxes (total counts) are then calculated using IRIS photometric tools. Finally, an astrometric reduction of the H\(\alpha\) image was performed by using U.S. Naval Observatorys USNO-A2.0 astrometric catalogue (Monet et al. 1998).

\textsuperscript{1}Available from http://www.astrosurf.com/buil/
Observations of NGC 3077 galaxy in narrow band [SII] and Hα filters

Table 2. Characteristics of the narrow band filters.

| Filter | λ₀ [nm] | FWHM [nm] | τmax [%] |
|--------|---------|-----------|----------|
| Red cont. | 641.6 | 2.6 | 58.0 |
| Hα | 657.2 | 3.2 | 86.7 |
| [SII] | 671.9 | 3.3 | 83.3 |

Fig. 1. The continuum-subtracted Hα image. New HII region candidates, and objects used for flux calibration (Walter et al. 2006) are numbered. Additional dark and bright features are stars not substracted well.

3. ANALYSIS AND RESULTS

In Figure 1 we present the continuum-subtracted Hα image of the observed region. In the Hα filter we detected 12 new possible objects (marked with "a" + number in Fig. 1), with high Hα emission presumably HII regions. The continuum-subtracted [SII] image did not show any object with an enhanced [SII] emission, so it appears that there were no SNR candidates. Six newly detected sources are compact, while the other six are diffuse. In Table 3 we give positions of these 12...
Table 3. New HII region candidates in Garland

| Source | Right ascension | Declination | Hα Flux |
|--------|-----------------|-------------|---------|
|        | α J2000         | δ J2000     | F_Hα [×10^{-15} erg cm^{-2} s^{-1}] |
| a1     | 10 03 20.3      | 68 40 40.1  | 0.085   |
| a2     | 10 03 20.6      | 68 42 02.1  | 2.730   |
| a3     | 10 03 27.2      | 68 42 48.7  | 0.248   |
| a4     | 10 03 33.0      | 68 41 20.3  | 2.129   |
| a5     | 10 03 32.4      | 68 39 44.9  | 0.096   |
| a6     | 10 03 42.3      | 68 42 08.4  | 0.606   |
| a7     | 10 03 49.7      | 68 42 14.1  | 1.191   |
| a8     | 10 03 56.6      | 68 43 05.4  | 0.332   |
| a9     | 10 03 57.6      | 68 42 13.3  | 0.530   |
| a10    | 10 03 56.9      | 68 40 54.9  | 0.040   |
| a11    | 10 03 58.5      | 68 40 50.9  | 0.180   |
| a12    | 10 04 06.8      | 68 41 14.6  | 0.184   |

sources, and their measured Hα fluxes. The Hα image (λ656.3) is contaminated with some [NII] emission (λ658.3) transmitted by the filter, so in principle the Hα flux is actually Hα+[NII] flux. The absolute flux calibration of the continuum-subtracted Hα image was performed using the fluxes of sources identified by Walter et al. (2006), as was done by Arbutina et al. (2009).

More detailed analysis about star formation rate in Garland, estimated from Hα emission, will be given in a future paper.

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