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OPTICAL OBSERVATIONS OF THE NEARBY GALAXY IC342 WITH NARROW BAND [SII] AND Hα FILTERS. I*

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SUMMARY: We present observations of a portion of the nearby spiral galaxy IC342 using narrow band [SII] and Hα filters. These observations were carried out in November 2011 with the 2m RCC telescope at Rozhen National Astronomical Observatory in Bulgaria. In this paper we report coordinates, diameters, Hα and [SII] fluxes for 203 HII regions detected in two fields of view in IC342 galaxy. The number of detected HII regions is 5 times higher than previously known in these two parts of the galaxy.

Key words. galaxies: individual: IC342 – HII regions

1. INTRODUCTION

IC 342 is a spiral galaxy with a nearly face-on orientation (inclination angle $\sim 20°$ - Tully (1988)). It is heavily obscured by Galactic disk, and that is why it was often avoided in optical observations. Optical observations of IC 342 are hampered by the low Galactic latitude and accompanying high extinction along the line of sight to this galaxy: for this reason, many properties of this galaxy remain poorly known. Like for many galaxies, published distance estimates to IC 342 have varied widely (from 1.8 to 8 Mpc): in this paper, we adopt a distance to this galaxy of 3.3 Mpc that was determined by Saha et al. (2002) based on Cepheid observations located in the galaxy. In Table 1, we give basic data on this galaxy.

We aimed to conduct a census of the emission nebulae in this galaxy: these nebulae have not been well-studied in the literature except for several prominent sources. For example, a diffuse optical counterpart to the ultra-luminous X-ray source IC 342 X-1 (also known as the "Tooth Nebula") has been discussed by many authors (Roberts et al. 2003, Bauer et al. 2003, Abolmasov et al. 2007, Feng and Kaaret 2008, Mak et al. 2011, Cseh et al. 2012).

*Based on data collected with 2-m RCC telescope at Rozhen National Astronomical Observatory

Table 1. Data for IC342 taken from NED[1].

Right ascension α_{J2000}	Declination δ_{J2000}	Redshift z	Velocity v [km s^{-1}]	Distance[2] d [Mpc]	Angular size [′]	Magnitude [mag]	Gal. extinction[3] [mag]
03 46 48.5	+68 05 47	0.000103	31	3.3	21.4 × 20.9	9.1	2.024 (B)

[1]http://ned.ipac.caltech.edu/

[2]Saha et al. (2002)

[3]Schlafly and Finkbeiner (2011)

This particular nebula (which is associated with an ultra-luminous X-ray source) appears to be an unusual shock-powered object. Other studies of the emission nebulae in IC 342 include the work by D'Odorico et al. (1980) who conducted an optical search for supernova remnants (SNRs) in this galaxy using optical narrow band [SII] and Hα images, and found four candidates. Hodge and Kennicutt (1983) in their atlas of HII regions in galaxies detected 666 HII regions across the entire extent of the galaxy but only positions of sources were given by these authors. Recently, Herrmann et al. (2008) undertook an imaging survey using narrow band [OIII] and Hα images to identify planetary nebulae: 165 such sources were found in this galaxy.

To improve our understanding of the properties of the emission nebulae in this galaxy, we have observed IC 342 through narrowband Hα, red continuum and [SII] filters, in order to detect resident HII regions and SNRs. Observing through these filters allows us to distinguish between HII regions and SNRs by using the criterion that SNR candidates are those objects with [SII]/H$\alpha > 0.4$ (see e.g. Matonick and Fesen 1997). Here, we present detection of 203 HII regions in IC342 galaxy while the detection of SNR candidates will be presented elsewhere.

2. OBSERVATIONS AND DATA REDUCTION

The observations were carried out on November 27-28 2011, with the 2 m Ritchey-Chrétien-Coudé (RCC) telescope at the National Astronomical Observatory (NAO) Rozhen, Bulgaria ($\varphi = 41°41'35''$, $\lambda = 24°44'30''$, $h = 1759$ m). The telescope was equipped with VersArray: 1300B CCD camera with 1340×1300 px array, and plate scale of 0.″257732/px (pixel size is 20 μm), giving a $5'45'' \times 5'35''$ field of view (FOV).

We observed three FOV, which covered the west, south and north-east part of the IC342 galaxy (Fig. 1). Centers of FOV are: FOV1 – R.A.(J2000) = 03:45:45.7, Decl.(J2000) = +68:04:11.3; FOV2 – R.A.(J2000) = 03:46:49.9, Decl.(J2000) = +68:00:47.6; FOV3 – R.A.(J2000) = 03:47:12.2, Decl.(J2000) = +68:08:27.7. FOV1 and FOV2 were observed on the first night, while FOV3 was observed on the second night, at conditions that were non-photometric, so that we present here only objects detected in FOV1 and FOV2.

The observations were performed with the narrowband [SII], Hα and red continuum filters. Filter characteristics are given in Table 2. We took sets of three images through each filter, with total exposure time of 2700s for each filter. Typical seeing was 1.″5 – 2.75″. Standard star images, bias frames and sky flat-fields were also taken.

Table 2. Characteristics of the narrow band filters.

Filter	λ_o [Å]	FWHM [Å]	$\tau_{\max}$ [%]
[SII]	6719	33	83.3
Hα	6572	32	86.7
Red cont.	6416	26	58.0

Basic data reduction (bias substraction and flatfielding) was done using standard procedures in IRAF[†]. Further data reduction (image registration, coaddition, sky-removal, etc.) was performed using IRIS[‡] (an astronomical images processing software developed by Christian Buil). Three images in each set were combined using the sigma-clipping method, and then sky-substructed (`SUBSKY`). The commands `MAX, MIN` were used for cosmetic corrections (bad pixels, cosmic rays removal). Before coaddition, each frame was multiplied by the factor $10^{0.4\cdot\kappa X}$, where X is the air mass for a single frame and κ is the extinction coefficient for each filter, in order to remove atmospheric extinction. Atmospheric extinction coefficients through red continuum, Hα and [SII] filers were measured to be 0.10, 0.08 and 0.09 mag airmass^{-1}, respectively. An astrometric reduction of the images was performed by using U.S. Naval Observatory's USNO-A2.0 astrometric catalogue (Monet et al. 1998). Each image was then flux calibrated using the observations of the standard star Feige 34 from Massey et al. (1988).

[†]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

[‡]Available from http://www.astrosurf.com/buil/

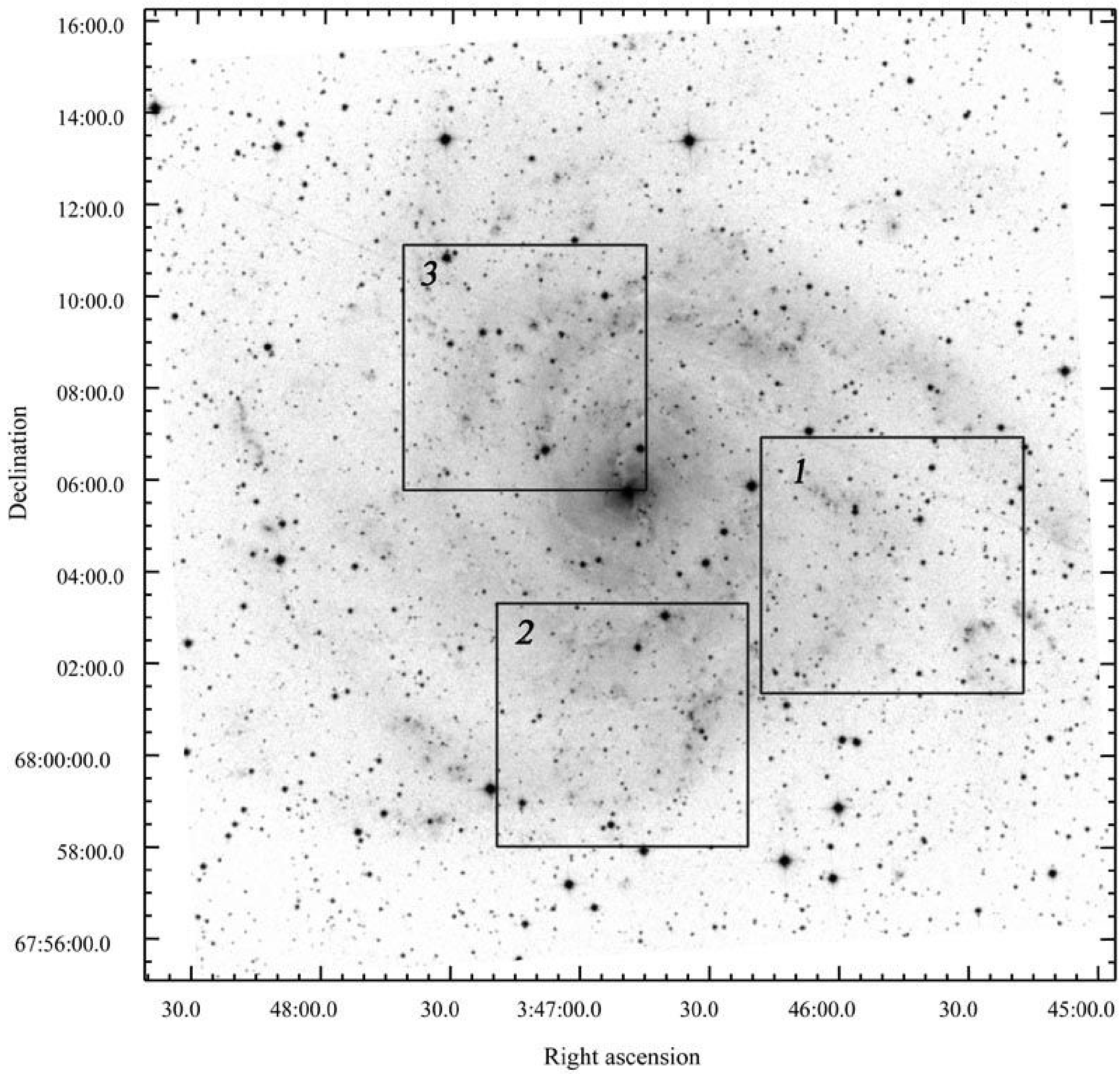

Fig. 1. *IC342 galaxy and observed FOV (image from Digital Sky Survey).*

Afterwards, the continuum contribution was removed from the Hα and [SII] images. Ratio between integrated filter profiles for line and continuum filters is a scaling factor used for continuum image before it was subtracted from the emission-line image. The next step in getting images with pure absolute flux-calibrated line emission is a correction for filter transmission.

The Hα image ($\lambda6563$) is contaminated with [NII] emission ($\lambda6548, 6583$). To obtain the absolute flux only from the Hα line, we need to make corrections for the [NII] lines as well as for the filter transmission. We use the fact that the [NII]-6548 line is approximately 3 times weaker than the [NII]-6583 line (James et al. 2005). Also, we adopt that the integrated (sum of both components) [N II]$\lambda6548, 6583$/Hα ratio is 0.54 (Kennicutt et al. 2008). Knowing the ratios between these lines and the filter transmission at each of them, we found that the continuum-subtracted Hα image should be multiplied by 0.99 to get the absolute flux-calibrated Hα-line emission (see Appendix).

In the [SII] image, we collect emission from both [SII] $\lambda6716$ and $\lambda6731$ lines. Assuming that their ratio is 1.5 (case of extremely rarefied plasma, Duric 2004), and knowing filter transmissions at both wavelengths, we found that the continuum-subtracted [SII] image should be multiplied by 1.54 to obtain the absolute flux-calibrated [SII]-line emission.

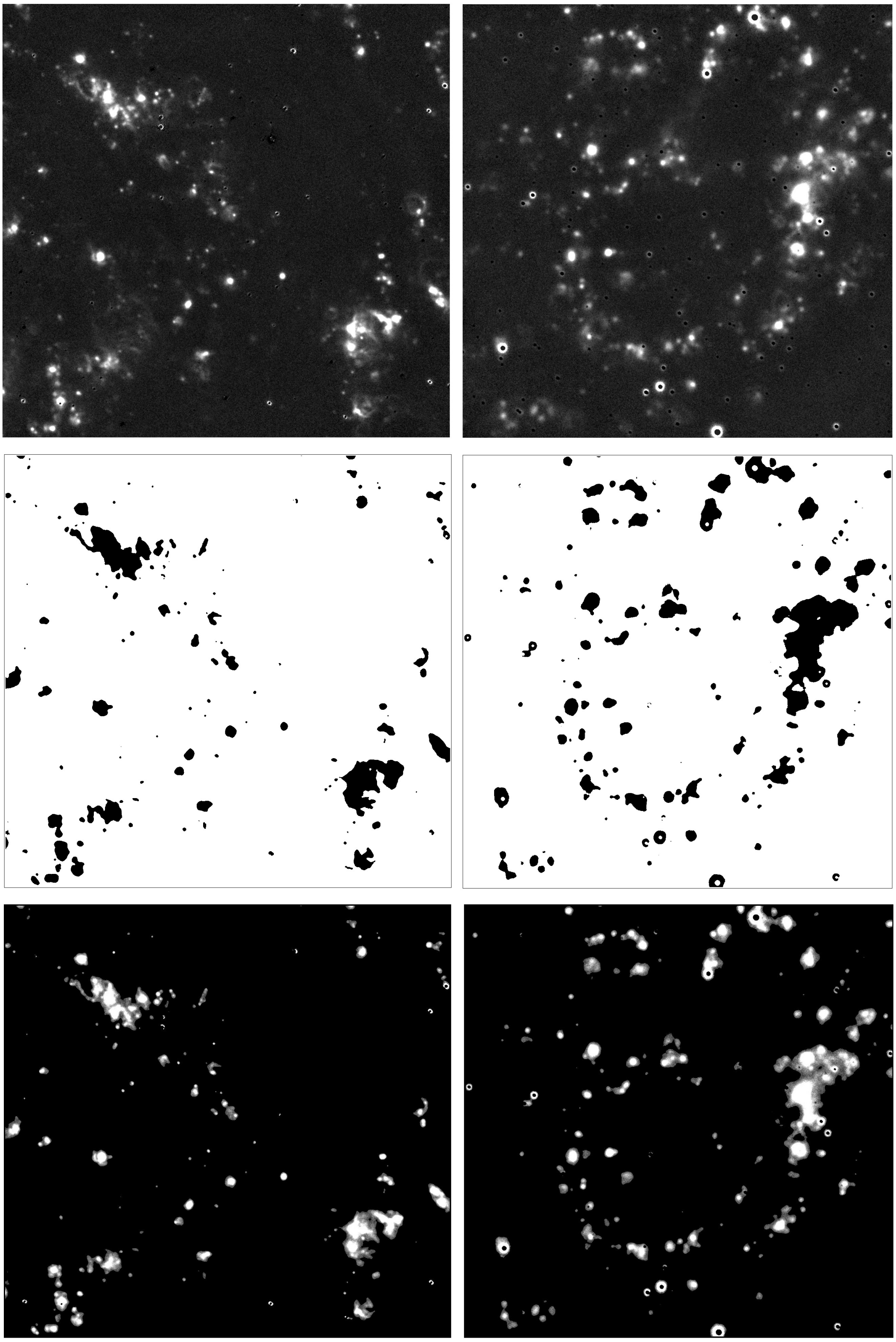

Fig. 2. *Procedure for obtaining final images for photometry (FOV1 – left, FOV2 – right). At the top are flux-calibrated images, in the center are the "masks" and at the bottom are the final Hα images.*

Table 3. Data for IC342 HII regions.[a]

Object No.	Right ascension α_{J2000}	Declination δ_{J2000}	Hα flux[b] $[10^{-15}$ erg s^{-1} cm$^{-2}]$	S[II] flux[b] $[10^{-15}$ erg s^{-1} cm$^{-2}]$	S[II]/Hα ratio	Major axis[c] a [″]	Minor axis[c] b [″]	Comment
1	03:45:17.7	+68:05:57.2	8.27	0	0	5	4	
2	03:45:18.0	+68:03:08.7	334.80	73.81	0.22	29	12	multiple
3	03:45:18.3	+68:06:02.8	13.33	0	0	5	4	
4	03:45:18.3	+68:06:23.4	24.36	0	0	8	5	
5	03:45:18.3	+68:06:22.1	34.69	6.23	0.18	5	5	
6	03:45:20.4	+68:04:07.8	34.23	0	0	7	5	
7	03:45:20.9	+68:04:15.1	70.51	3.53	0.05	18	6	shell
8	03:45:24.9	+68:03:21.4	30.49	8.42	0.28	6	5	
9	03:45:24.9	+68:02:51.5	636.02	156.14	0.25	30	21	multiple
10	03:45:25.5	+68:03:24.4	36.17	8.18	0.23	6	5	
11	03:45:25.9	+68:03:41.2	58.70	6.25	0.11	6	5	
12	03:45:26.3	+68:03:24.2	21.45	1.51	0.07	5	4	
13	03:45:26.5	+68:06:27.7	3.17	0	0	3	3	
14	03:45:26.9	+68:02:11.2	22.96	0	0	7	5	
15	03:45:28.5	+68:02:29.0	49.12	0	0	12	7	diffuse
16	03:45:28.6	+68:01:43.1	186.18	18.99	0.10	16	15	irregular
17	03:45:28.7	+68:02:39.1	21.72	0	0	4	4	
18	03:45:28.9	+68:02:45.8	750.68	176.34	0.23	23	20	multiple
19	03:45:28.9	+68:06:16.4	93.90	0	0	11	9	
20	03:45:29.1	+68:06:28.6	6.90	0	0	3	3	
21	03:45:29.8	+68:02:13.0	2.93	0	0	3	3	
22	03:45:30.0	+68:06:37.8	21.90	0	0	7	5	
23	03:45:30.1	+68:02:32.2	353.54	95.49	0.27	14	14	multiple
24	03:45:32.3	+68:02:45.5	3.27	0	0	3	3	
25	03:45:33.7	+68:02:38.2	2.23	0	0	3	3	
26	03:45:39.3	+68:03:26.1	71.29	2.34	0.03	6	6	
27	03:45:43.3	+68:03:52.5	3.98	0	0	3	3	
28	03:45:45.9	+68:04:12.7	56.79	0	0	12	9	diffuse
...	...	...	...	...	...	...	...	
203	03:47:18.0	+68:02:59.8	10.27	0	0	4	4	

[a] The table with all 203 objects is available online at `http://saj.math.rs/187/Table3.dat`.

[b] Reddening corrected (Schlafly and Finkbeiner 2011).

[c] From ellipse fitting. Mean angular diameter is $\theta = \sqrt{ab}$. One arcsec corresponds to 16 pc for an assumed distance to IC 342 of 3.3 Mpc.

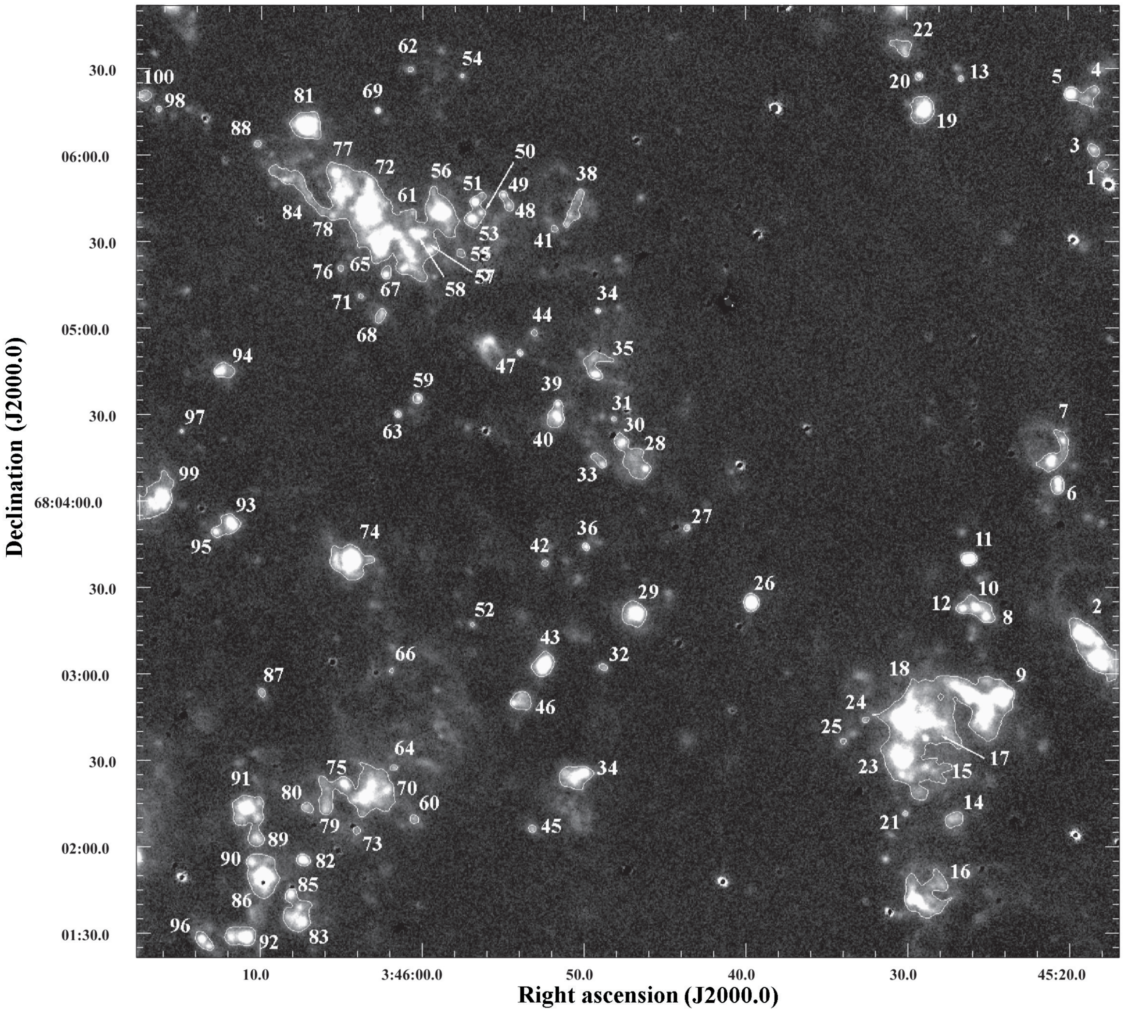

Fig. 3. *The continuum-subtracted Hα image for FOV1. Numbers correspond to the entries in Table 3.*

The final images are once again background subtracted to obtain the background as flat as possible and equal to zero. After we have removed the continuum contribution, corrected Hα emission for the [NII] contamination, and corrected fluxes for filter transmission, we have absolute flux-calibrated emission line images from which we can measure fluxes of the identified objects.

3. RESULTS AND CONCLUSIONS

To extract sources from the flux-calibrated image we use the `BIN-UP[parameter]` command in IRIS. This command sets all the pixels having an intensity higher than `parameter` to 255, while other pixels are assigned value 0. After smoothing (command `SMEDIAN`) and normalizing this image we have the "mask". Multiplying our flux-calibrated image with this "mask" image, gives us only sources in the image (Fig. 2). For the Hα image, we extract sources above 5σ of the background, and from the [SII] image, since the signal-to-noise ratio is lower, we extract sources above 2.5σ. Absolute fluxes are then easily measured by using the single aperture, whose size depends on the size of the source. The final images with the sources are given in Figs. 3 and 4. Positions and diameters of the sources were measured by fitting ellipse to the outer source contour, using the SAOImage DS9.

In Table 3 we give coordinates, diameters, Hα and [SII] fluxes, and the [SII]/Hα ratio for 203 HII regions detected in two FOV observed in IC342 galaxy. The number of detected HII regions is 5 times higher then the number that Hodge and Kennicutt (1983) detected in these two parts of the galaxy. An analysis of supernova remnant candidates revealed by our observations and identified based on their elevated [SII]/Hα ratios will be given in a forthcoming paper, as well as new observations planned for this galaxy.

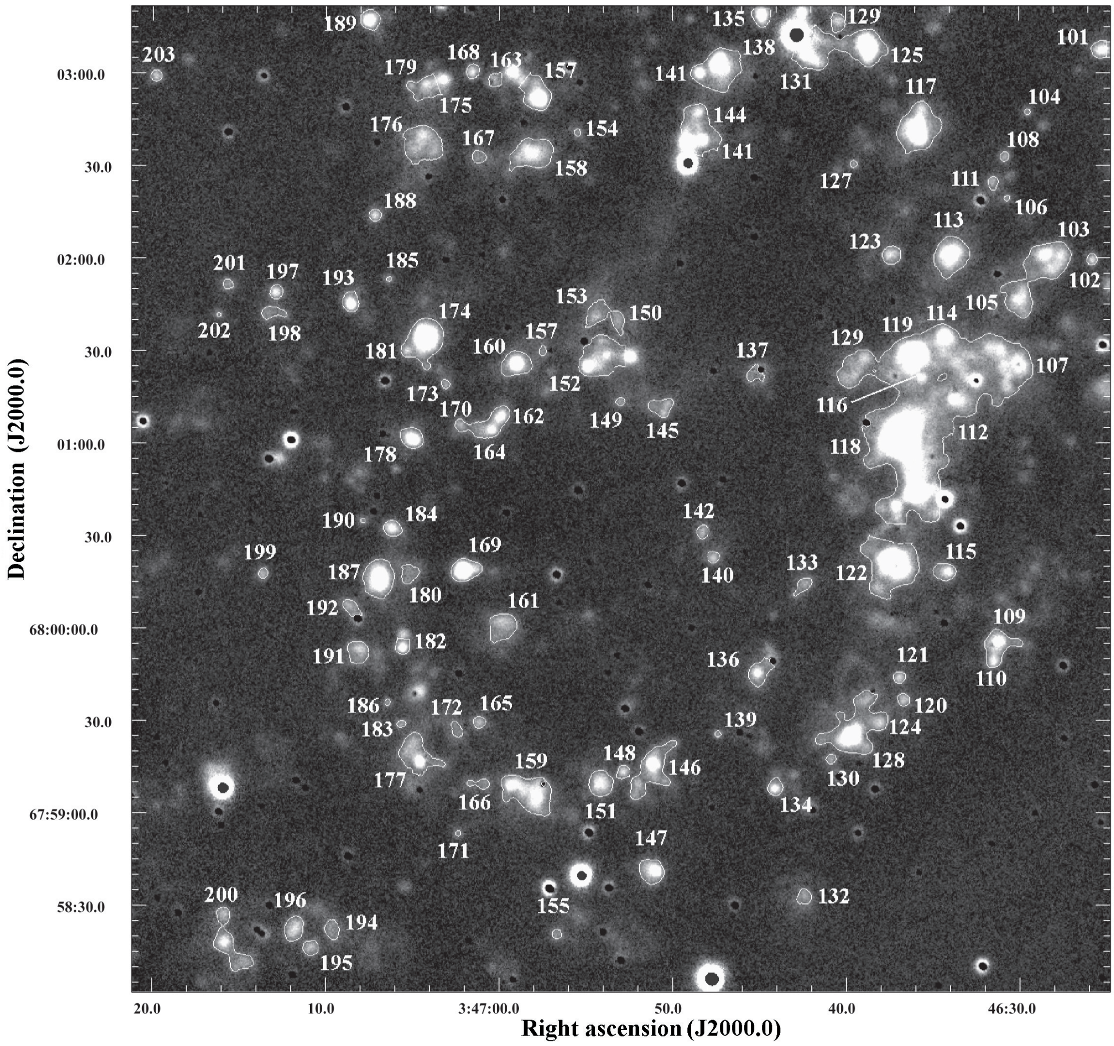

Fig. 4. *The continuum-subtracted Hα image for FOV2. Numbers correspond to the entries in Table 3.*

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APPENDIX

Let us suppose that we collect emission from three lines in a filter

$$I = I_0\tau_0 + I_1\tau_1 + I_2\tau_2, \quad (1)$$

and we want to find I_0 (in our case Hα), knowing that the line ratios are $r = \frac{I_2}{I_1}$ and $R = \frac{I_1+I_2}{I_0}$, and filter transmissions at each of the lines are τ_1, τ_2 and τ_3. Then

$$I_0 = \frac{(1+r)I}{(1+r)\tau_0 + R\tau_1 + rR\tau_2}. \quad (2)$$

If we want to find the total emission of two lines with the line ratio $r = \frac{I_2}{I_1}$ and we measure $I = I_1\tau_1 + I_2\tau_2$, then

$$I_1 + I_2 = \frac{(1+r)I}{\tau_1 + r\tau_2}. \quad (3)$$

which would be the total corrected [SII] emission in our case.

ОПТИЧКА ПОСМАТРАЊА БЛИСКЕ ГАЛАКСИЈЕ IC342 КРОЗ УСКЕ [SII] И Hα ФИЛТЕРЕ. I

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Оригинални научни рад

У раду су представљена посматрања оближње спиралне галаксије IC342 кроз уске [SII] и Hα филтере, извршена у новембру 2011. године двометарским телескопом Националне астрономске опсерваторије Рожен у Бугарској. У два посматрана видна поља детектовано је укупно 203 HII региона чији су положаји, као и Hα и [SII] флуксеви наведени у раду. У односу на претходне студије, у овом делу IC342 галаксије детектовано је 5 пута више HII региона.