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Preliminary report

OPTICAL OBSERVATIONS OF M81 GALAXY GROUP IN NARROW BAND [SII] AND Hα FILTERS: HOLMBERG IX

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SUMMARY: We present observations of the nearby tidal dwarf galaxy Holmberg IX in M81 galaxy group in narrow band [SII] and Hα filters, carried out in March and November 2008 with the 2m RCC telescope at NAO Rozhen, Bulgaria. Our search for resident supernova remnants (identified as sources with enhanced [SII] emission relative to their Hα emission) in this galaxy yielded no sources of this kind, besides M&H 10-11 or HoIX X-1. Nevertheless, we found a number of objects with significant Hα emission that probably represent uncatalogued HII regions.

Key words. ISM: supernova remnants – HII regions – Methods: observational – Techniques: photometric – Galaxies: ISM – Galaxies: individual: Holmberg IX

1. INTRODUCTION

M81 galaxy group is the nearest interacting group of galaxies, with the main members being 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 probably a result of the galaxy encounters. It is possible that starburst activity, i.e. the enhanced star formation, of M82 was triggered in a close encounter with M81, which as a consequence has a high supernova rate (see e.g. Arbutina et al. 2007, Huang et al. 1994). The third member of the group, NGC 3077, also shows evidence of the enhanced star formation, and, consequently, a higher supernova rate and presence of SNRs. This was partially confirmed by recent radio observations (see Rosa-Gonzales 2005). There is also a number of optical candidates for supernova remnants (SNRs) detected in M81 (Matonick and Fesen 1997). The SNR candidates in optical are usually identified through enhanced [SII] line emission ([SII]/H$\alpha > 0.4$; see e.g. Matonick and Fesen 1997, Blair and Long 2004). The aim of our optical observations was to try to detect new SNR candidates and HII regions in a small "satellite galaxy" of M81 – Holmberg IX (UGC 5336, MCG+12-10-012, LEDA 28757, see Table 1). Holmberg IX and Arp's loop can be seen as two dark knots in the HI image of the M81 triplet of Yun et al. (1994). Dwarf irregular galaxy Holmberg IX could be the youngest nearby tidal dwarf galaxy, perhaps formed during the last close passage of M82 around M81 (Sabbi et al. 2008).

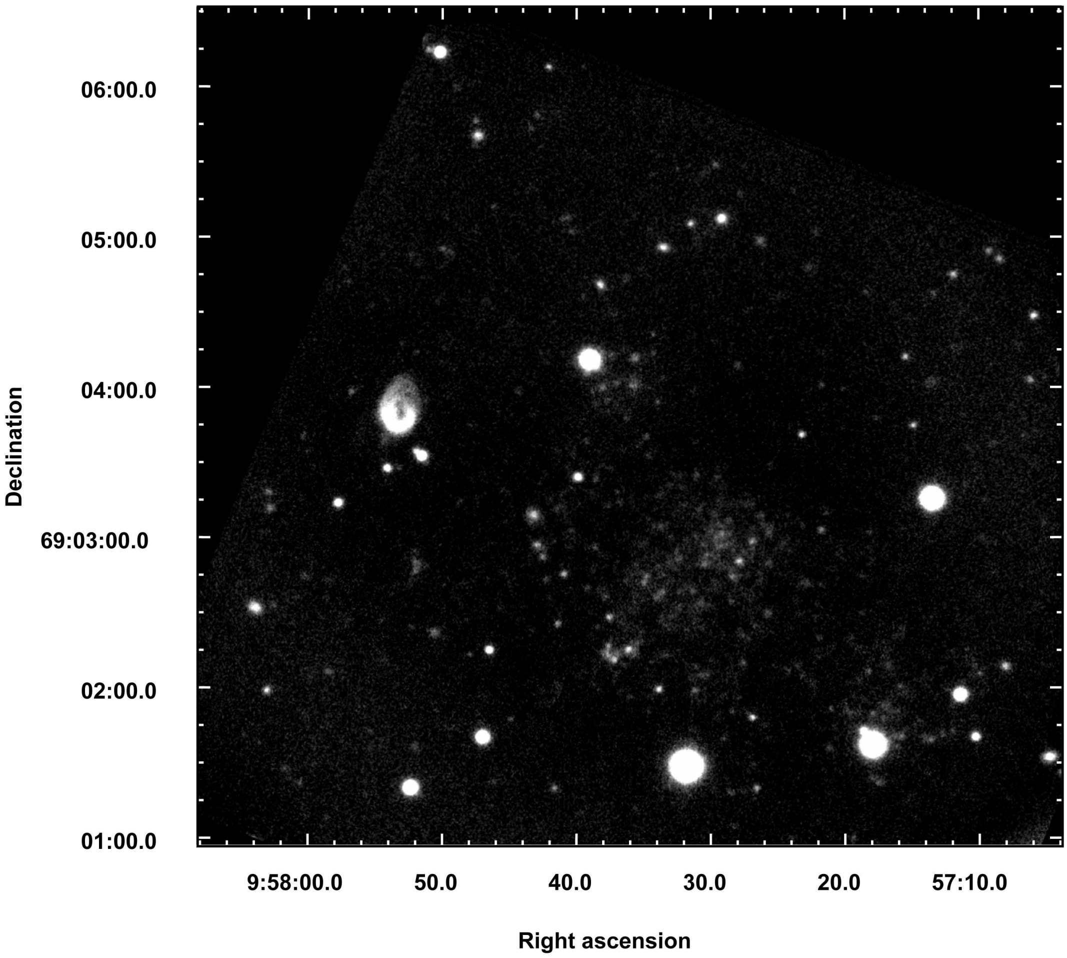

Fig. 1. *The [SII] with continuum image (sky subtracted).*

Table 1. Data for Holmberg IX (MCG+12-10-012) taken from SIMBAD[†].

Right ascension α_{J2000}	Declination δ_{J2000}	Redshift z	Velocity v [km s^{-1}]	Distance[‡] d [Mpc]	Angular size [$'$]	Magnitude	Morphological type
09 57 32.1	+69 02 46	0.000213	64	3.7	2.6×2.2	16.5 (B)	dI

[†]`http://simbad.u-strasbg.fr/simbad/` [‡]Karachentsev and Kashibadze (2006)

The adopted distance to Holmberg IX is d = 3.7 Mpc, which is the distance derived from cepheids distance to M81 and known membership in the M81 group (Karachentsev et al. 2004, Karachentsev and Kashibadze 2006). The location of Holmberg IX, its high gas content, and its youthful stellar population, made of this galaxy the primary target of our search.

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

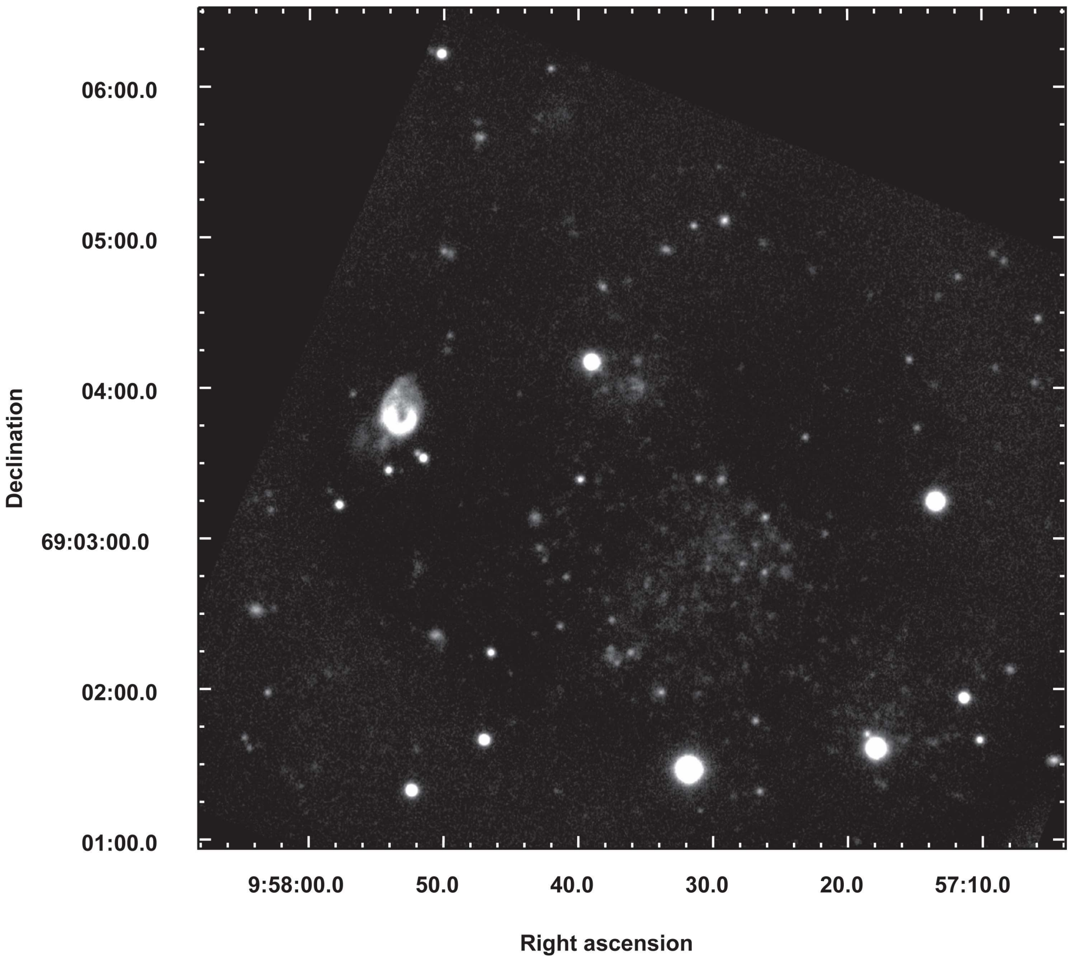

Fig. 2. *The Hα with continuum image (sky subtracted).*

Table 3. The observations log.

Object/SS	Integration time [s]					
	2008 March 3			2008 November 30		
	Cont.	Hα	[SII]	Cont.	Hα	[SII]
	1800	1200	1200	1800	1200	1200
Holmberg IX	1800	1800	1800	1800	1200	1200
	2400	1800	1800	1800	1200	1200
	180	120	120	–	–	–
Feige 34	240	120	120	–	–	–
	180	120	120	–	–	–
	–	–	–	300	120	120
G191-B2B	–	–	–	300	120	120
	–	–	–	300	120	120

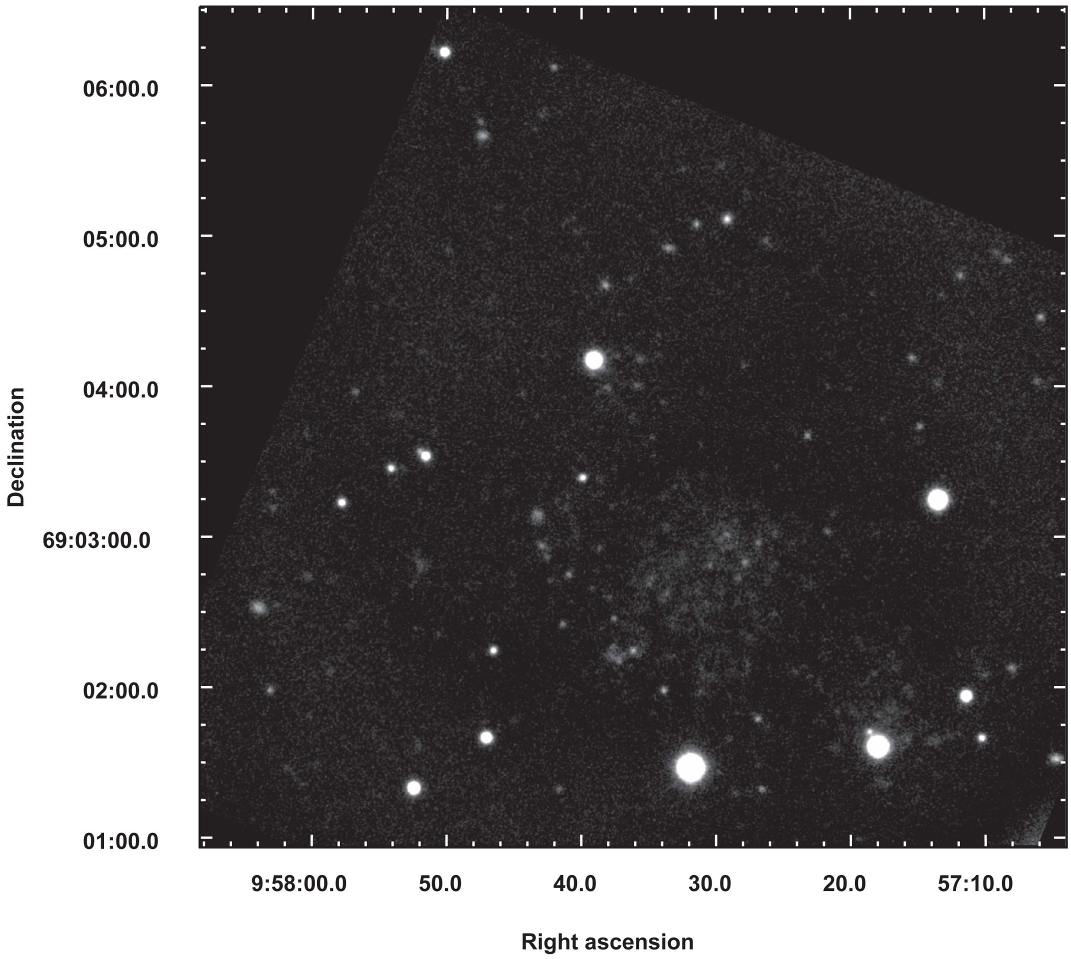

Fig. 3. *The red continuum image (sky subtracted).*

2. OBSERVATIONS AND DATA REDUCTION

The observations were carried out in March and November 2008 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). In the RC focus of the telescope, the equivalent focal length is 16 m and the field-of-view is one square degree with a scale $12\overset{''}{.}89$/mm. The telescope is equipped with VersArray: 1300B CCD camera with 1340×1300 px array, and the plate scale of $0\overset{''}{.}257732$/px (pixel size is 20 μm), giving a field of view of $5'45'' \times 5'35''$.

We used the narrow-band filters for [SII], Hα and red continuum. We took sets of three images through each filter, on both nights, with exposure times ranging from 1200–2400 s. Typical seeing was $1\overset{''}{.}5 - 3''$. Standard stars images (Feige 34 and G191-B2B), bias frames and sky flat-fields were also taken. Filters characteristics and details of the observations are given in Tables 2 and 3. The Hα image (λ6563) is contaminated with some [NII] emission (λ6583), so in principle the "Hα" is actually Hα+[NII] image. The [SII] filter should collect most of the emission from both [SII] λ6716 and λ6731 lines.

Data reduction was performed by using IRIS[1] (an astronomical images processing software developed by Christian Buil). The data were bias subtracted and flat-fielded using the standard methods. Three images in each set are combined using procedures `NGAIN3` and `COMPOSIT`, and then sky-substructed (`SUBSKY`). Commands `MAX, MIN, EDGE` were used for cosmetic corrections (bad pixels, cosmic rays removal). Since the images were taken with different exposures, depending on the filters, we scaled all the images normalizing them to the flux of the stars in the field. Images taken on two nights are then combined to increase the counts, rotated, aligned and distortion corrected by using the procedure `COREGISTER`. Images obtained after all these corrections are given in Figs. 1–3.

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

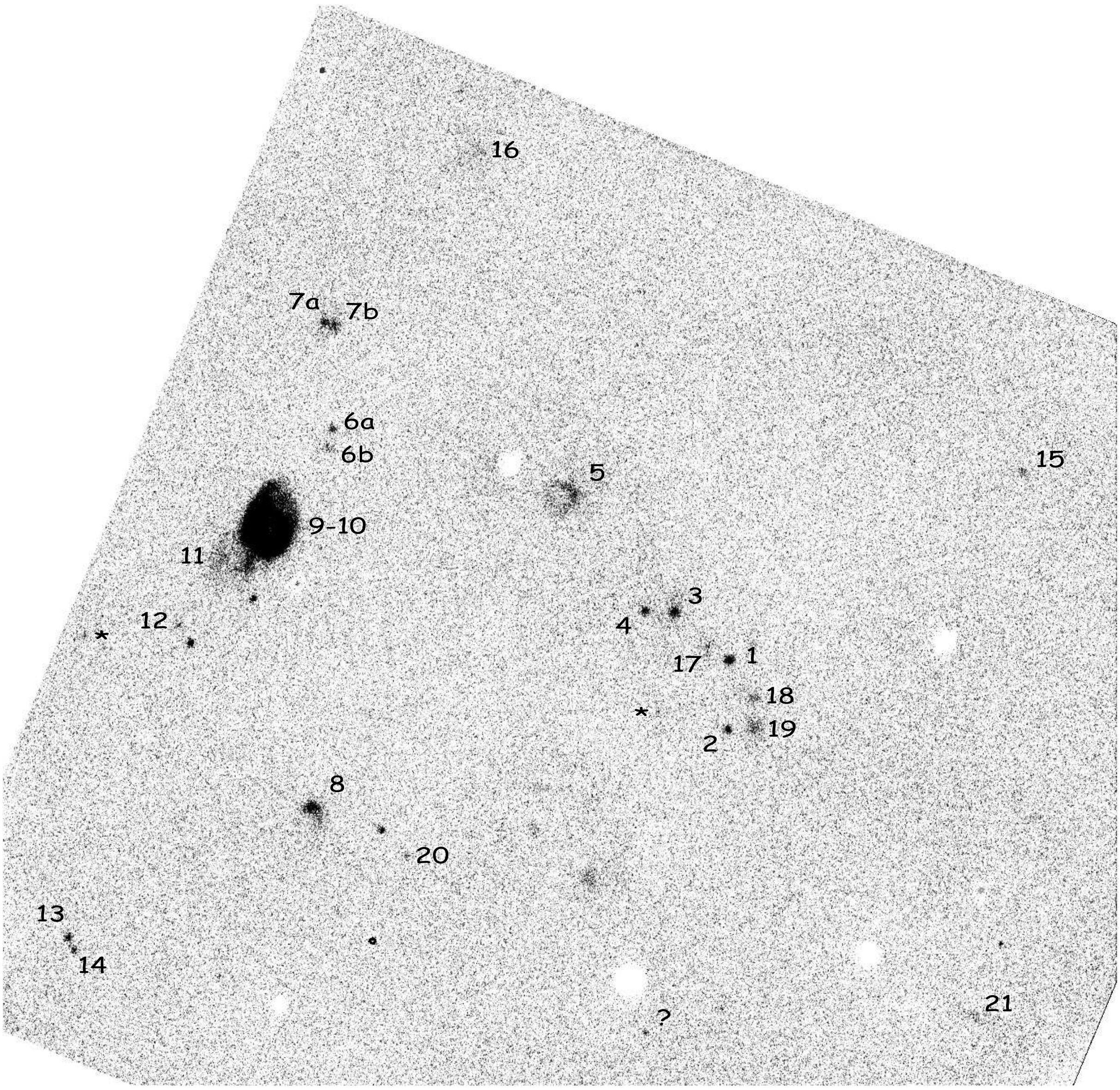

Fig. 4. *The continuum-subtracted Hα image. Dark features that are marked are sources. Additional dark features are stars not subtracted well (compare Figs. 2 and 3).*

The Hα and [SII] images are then continuum-subtracted and final images once again background subtracted to obtain background as flat as possible. The continuum-subtracted Hα image is given in Fig. 4.

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

3. ANALYSIS AND RESULTS

The continuum-subtracted [SII] image did not show any new object with an enhanced [SII] emission, besides M&H 10-11 or HoIX X-1 (Miller and Hodge 1994, Miller 1995, Grisé et al. 2006), a strong optical line source and ultraluminous X-ray source (a possible hypernova remnant or super-shell), and thereby is omitted. As for the continuum-subtracted Hα image, we detected 21 sources – probable HII regions (see Fig. 4; additional dark features are stars not subtracted well).

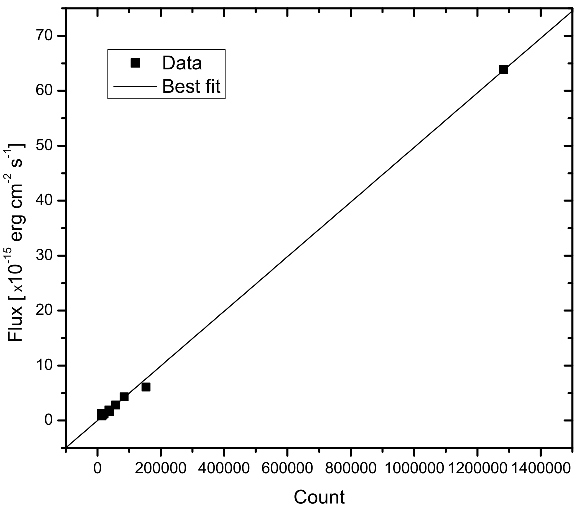

Fig. 5. *Flux – Count ($F-N$) relation used for absolute calibration. Slope of the relation is calibration coefficient:* $c=(4.97\pm0.05)\times10^{-5}$.

Table 4. Sources used for absolute calibration.

Source	Count this paper	Hα Flux [$\times10^{-15}$ erg cm^{-2} s^{-1}] from M&H
M&H 1	20721	1.30
M&H 2	12884	1.27
M&H 3	38559	1.65
M&H 4	17229	0.99
M&H 5	83939	4.32
M&H 6	12807	0.83
M&H 7	36059	1.92
M&H 8	57565	2.83
M&H 9-10	1282274	63.87
M&H 11	153357	6.10

Eleven sources (1–11) were previously identified by Miller and Hodge (1994) and one by Boone et al. (2005) (source 12).[2] Thus, we found nine new sources (13–21).

Table 5. HII regions in Holmberg IX.

Source	Right ascension $\alpha_{\rm J2000}$	Declination $\delta_{\rm J2000}$	Hα Flux $F_{\rm H\alpha}$ [$\times10^{-15}$ erg cm^{-2} s^{-1}]	Comment
Aea 1	09 57 26.1	+69 03 09	1.03	M&H 1
Aea 2	09 57 26.2	+69 02 47	0.64	M&H 2
Aea 3	09 57 29.4	+69 03 24	1.92	M&H 3
Aea 4	09 57 31.1	+69 03 24	0.86	M&H 4
Aea 5	09 57 35.6	+69 04 01	4.17	M&H 5
Aea 6A	09 57 49.5	+69 04 21	0.38	M&H 6
Aea 6B	09 67 49.8	+69 04 16	0.26	M&H 6
Aea 7A	09 57 49.9	+69 04 55	1.03	M&H 7
Aea 7B	09 57 49.5	+69 04 54	0.76	M&H 7
Aea 8	09 57 50.5	+69 02 22	2.86	M&H 8
Aea 9-10[a]	09 57 53.1	+69 03 49	63.71	M&H 9-10
Aea 11	09 57 55.2	+69 03 40	7.62	M&H 11
Aea 12	09 57 58.5	+69 03 19	0.24	–
Aea 13	09 58 04.7	+69 01 41	0.56	–
Aea 14	09 58 04.4	+69 01 37	0.36	–
Aea 15	09 57 09.0	+69 04 08	0.33	–
Aea 16	09 57 41.0	+69 05 50	0.70	–
Aea 17	09 57 27.4	+69 03 13	0.43	–
Aea 18	09 57 24.6	+69 02 57	0.55	–
Aea 19	09 54 24.6	+69 02 47	1.13	–
Aea 20	09 57 45.0	+69 02 07	0.13	–
Aea 21	09 57 11.8	+69 01 18	0.29	–

[a]Possible hypernova remnant or super-shell.

[2]See Aladin Sky Atlas: `http://aladin.u-strasbg.fr/`.

Additionally, we resolved sources M&H 6 and M&H 7, which we see as two pairs. There are, possibly, two more smaller sources, marked with asterisk (*) in Fig. 4, at $\alpha_{\rm J2000} = 09^{\rm h}57^{\rm m}30\overset{\rm s}{.}3$, $\delta_{\rm J2000} = +69°02'52''$ and $\alpha_{\rm J2000} = 09^{\rm h}58^{\rm m}04\overset{\rm s}{.}0$, $\delta_{\rm J2000} = +69°03'16''$, for which we haven't measured fluxes. Question mark (?) in Fig. 4 marks the position of a source of unknown origin ($\alpha_{\rm J2000} = 09^{\rm h}57^{\rm m}30\overset{\rm s}{.}9$, $\delta_{\rm J2000} = +69°01'12''$) which we saw in March 2008 Hα images, but not in November 2008.

The absolute flux calibration of the continuum subtracted Hα image was performed by using the fluxes of sources identified both by us and by Miller and Hodge (1994) (See Fig. 5 and Table 4). The listed fluxes for sources M&H 6 and M&H 7 correspond to the sum of the fluxes for the two sub-regions (A and B). We adopted simple linear relation

$$F = c \cdot N, \tag{1}$$

where N is the source's total count, F the flux in units 10^{-15} erg cm^{-2} s^{-1}, and $c = (4.97 \pm 0.05) \times 10^{-5}$ is the calibration coefficient obtained from the fit.

We define the fractional error

$$f = \left| \frac{F_{\rm M\&H} - F}{F_{\rm M\&H}} \right|, \tag{2}$$

where $F_{\rm M\&H}$ is the Hα flux from Miller and Hodge (1994), whereas F is our measurement, in order to get an estimate of the accuracy of the obtained values. We find $f_{\max} = 0.50$ i $\bar{f} = 0.16$.

Estimated fluxes for all sources (HII regions) and approximate positions of their centers are given in Table 5.

4. CONCLUSIONS

We presented observations of Holmberg IX galaxy in narrow band [SII] and Hα filters. Our search for objects with an enhanced [SII] emission – possible supernova remnant candidates, has yielded no sources of this kind, besides M&H 10-11 or HoIX X-1. Nevertheless, we identified 21 objects with significant Hα emission. Eleven sources (1–11) were previously identified by Miller and Hodge (1994) and one by Boone et al. (2005) (source 12). Thus, we found nine new sources (13–21) – not catalogued HII regions. We estimated their Hα fluxes and gave their approximate positions.

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ОПТИЧКА ПОСМАТРАЊА ГРУПЕ ГАЛАКСИЈА M81 У УСКИМ ФИЛТЕРИМА [SII] И Hα: ХОЛМБЕРГ IX

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Претходно саопштење

У раду су представљена посматрања оближње патуљасте галаксије Холмберг IX у групи галаксија везаних за M81. Посматрања су извршена у марту и септембру 2008. године двометарским RCC телескопом на НАО Рожен, Бугарска, коришћењем уских филтера [SII] и Hα. Потрага за објектима са појачаном емисијом [SII] у односу на Hα емисију – потенцијалним кандидатима за остатке супернових, није резултирала новим објектима, поред M&H 10-11 или HoIX X-1, али је зато детектован један број објеката са значајном Hα емисијом који вероватно представљају до сада непознате HII регионе.