OPTICAL OBSERVATION OF SUPERNOVA REMNANT IN ELLIPTICAL GALAXY NGC 185

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Abstract

In this poster we discuss the previously known optical supernova remnant (SNR) in NGC 185 galaxy, a dwarf elliptical companion of the Andromeda galaxy, in order to gain more information about its properties. To this end, we observed a central portion of NGC 185, through the narrowband Hα and [SII] filters, on a 2m RCC-telescope at National astronomical observatory (NAO) Rozhen, Bulgaria. Also, we performed hydrodynamical (HD) simulation using the Pluto code, for the case of n~1 cm^{-3} environmental density and high temperature, in order to discuss evolution of an SNR in a this dwarf galaxy.

Introduction

NGC 185 is a satellites of M31, at the distance of around 617 kpc (McConnachie 2012). Even though NGC 185 is an elliptical galaxy, it has been known that this galaxy contains gas (Young & Lo 1997). Also, there are evidences that this galaxy have undergone recent star formation activity (a few $\times 10^8$ years ago), present in the form of numerous blue stars/clusters and other Population I features, such as dust clouds, HI and molecular gas, and an SNR (Martinez-Delgado 1999; Martins et al. 2012; De Looze et al. 2016).

Observations

We observed central part of NGC 185 galaxy using a 2 m telescope at NAO Rozhen, on November 2-3, 2015. The observations were performed through the narrowband [SII], Hα and red continuum filters, with total exposure time of 80 minute for each filter. Typical seeing was 1.25” – 2.25”. See Vučetić et al. (2013) for all details on procedure of data reduction and flux calibration.

HD simulation

Our numerical simulations were performed by using PLUTO code (v4.2) which solves system of conservation laws by using the finite volume approach based on Godunov-type schemes, neglecting the effects on shock dynamics caused by the back reaction of accelerated cosmic rays and radiative cooling (Mignone et al. 2007). Initial conditions are given in Figure 3, and are chosen to fit already known properties of galaxy and SNR – type Ia SNR, temperature from unresolved X-ray emission (Ge et al. 2015). It is, however, questionable, if this temperature is real, how can a remnant be radiative? We are also not sure what the density of this central region is, and whether it is homogenous. In simulation we assumed n~1 cm^{-3}, the above temperature would suggest much lower density, but Gonsalves et al. (2012) estimated n~300 cm^{-3} for the SNR.

Previous observations of an SNR candidate in NGC 185

Gallagher, Hunter & Mould (1984) were the first to notice that some of the emission in spectra of NGC 185 galaxy could originate from shock heated plasma - SNR. A year later, Dickel, D'Odorico & Silverman (1985) conducted unsuccessful radio search for this SNR, at 20 cm using VLA. Young & Lo (1997) observed HI and CO gas components of the NGC 185 galaxy, and also took Hα narrow band image of this galaxy. They suggested that extended SNR emission is approximately coincident with the peak HI column density. Martinez-Delgado et al. (1999) performed new Hα observations of the central region of NGC 185 under good seeing conditions (~0.7”), which suggested that it might be a portion of a larger, old remnant. Gonsalves et al. (2012) obtained deep spectroscopic observations of the Hα emitting population of NGC 185 using the Gemini multi-object spectrograph at the Gemini North telescope. They determined physical characteristics of this SNR.

Results

In order to reveal more details about SNR candidate in NGC 185 galaxy, we preformed narrow band photometry through Hα and [SII] filters. This was the first time that this galaxy was observed through [SII] filter. Ratio between Hα and [SII] fluxes of an emission nebula can tell us whether we observe shock heated object (such as an SNR) - if [SII]/Hα>0.4; or a photoionized nebula (like HII region or PN) - if [SII]/Hα<0.4, and usually much lower (Matonick & Fesen 1997).

We detected **12 objects** emitting in Hα and/or [SII] lines (Figure 1, Table 1). Among detected objects are already known SNR candidate and possible new SNR candidate; 6 previously known PNe, five bright, and one from Gonsalves et al. (2012), and one new PNe candidate; two diffuse objects, possible HII regions, out of which one was designated as PN-7 by Gonsalves et al. (2012). We also detected very low brightness emission, both in Hα and [SII], at the position of recently detected symbiotic star (Gonsalves et al. 2012).

Table 1.: Detected emission-line objects in NGC 185 galaxy

ID	RA (h:m:s) J2000	dec (d:m:s) J2000	Hα flux[a] [10^{-15} egr/cm²s]	[SII] flux [10^{-15} egr/cm²s]	[SII]/Hα ratio	D[b] [pc]	ID – Goncalves et al. (2012)	Comment
1	00:38:47:9	48:19:32	1.7	-	-	<6	5-PN5	PN
2	00:38:53.1	48:20:08	11.6	-	-	<6	1-PN1	PN
3	00:38:54.4	48:20:01	1.0	-	-	<6	10-PN8	PN
4	00:38:56.4	48:19:21	18.1	-	-	<6	4-PN4	PN
5	00:38:57.3	48:20:10	7.3	-	-	<6	2-PN2	PN
6	00:38:57.3	48:20:35	0.8	-	-	6	8-PN7	Diffuse; HII?
7	00:38:57.5	48:20:16	2.0	0.6	0.44	6	9-SNR1	SNR?
8	00:38:58.2	48:20:09	18.4	1.8	1.27	45		SNR?
9	00:38:59.0	48:20:17	5.5	-	-	20		Diffuse; HII?
10	00:39:00.2	48:19:47	5.8	-	-	<6	3-PN3	PN
11	00:39:00.3	48:19:27	0.9	-	-	<6	13-StSy	Symbiotic star
12	00:39:02.7	48:22:24	1.0	-	-	<6		Compact; new PN?

[a]Flux has been corrected for [NII] emission, as described in text, and for Galactic extinction, assuming that A(Hα)=$0.6A_B$; A_B=0.667.
[b]1”=3 pc for NGC 185 distance of 617 kpc

Discussion and conclusions

In Figure 2 we see partial shell of a shock-heated object, having a **[SII]/Hα ratio 1.27** (as in Gallagher et al. 1984), and a diameter of **15”= 45 pc**, assuming a distance of 617 kpc. For the same distance, Martinez-Delgado et al. (1999) estimated a diameter of 80 pc and a flux of 30 x 10^{-15} erg/cm s^2. We estimated slightly lower Hα flux for this object – **18 x 10^{-15} erg/cm²s**, but our flux is with removed [NII] line emission, and also we have measured emission from smaller area. We suppose that Martinez-Delgado et al. (1999) considered that SNR extends between our object 6 and 7 to the North, and that could be the reason why they measured twice larger diameter. According to their diameter, and assuming that SNR is in Sedov-Teylor phase, Martinez-Delgado et al. (1999) estimated SNR age to 10^5 years. Also, with the assumption that the SFR in NGC 185 for the last 100 Myr is zero, they concluded that this SNR originates from a type Ia event. From our simulation, we estimate the age of SNR to ~ 23000 years.

Gonsalves et al. (2012) detected emission-line object with a diameter of 2 pc, at the position of our object 7. They claimed that this object is an SNR detected by Gallagher et al. (1984). For this object they measured [SII]/Hα = 0.53. Since they did not detect any [OIII] emission in spectrum, they concluded that the shock velocity of SNR is less than 85 km/s, which agreed well with their assumption that this is an old, evolved SNR. They further suggested that the bright emission-line object might be a central part of the SNR, since it is located approximately in the center of the arc-like structure

We question this scenario, since in our image, arc-like structure (our object 8) forms almost full shell, typical for an evolved SNR, while smaller source (our object 7) is located on the outer part of this shell. We speculate that this object could be additional, young SNR, in accordance with its small diameter, and that its [SII]/Hα = 0.44 ratio is very different from the rest of the arc-like SNR. Since spectrum of object 7 (from Gonsalves et al. 2012) does not suggest that Hα line could have two components, narrow and wide, and has strong [SII] and [NII] lines, it could not be spectrum of the so-called Balmer dominated shock, which is typically found in young type Ia SNRs. On the other hand, spectra containing only Balmer and metal forbidden lines are found in some filaments of type Ia Kepler SNR, which probably, due to interaction with denser ISM, become radiative very fast (Blair et al. 1991).

Another possibility is that object 7 is indeed a part of old evolved SNR, but that it has encountered ISM condensation of higher concentration at that position. Another argument that this could be true is that peak of HI, CO and [CII] emission in NGC 185 galaxy coincides with the position of object 7 (De Looze et al. 2016).

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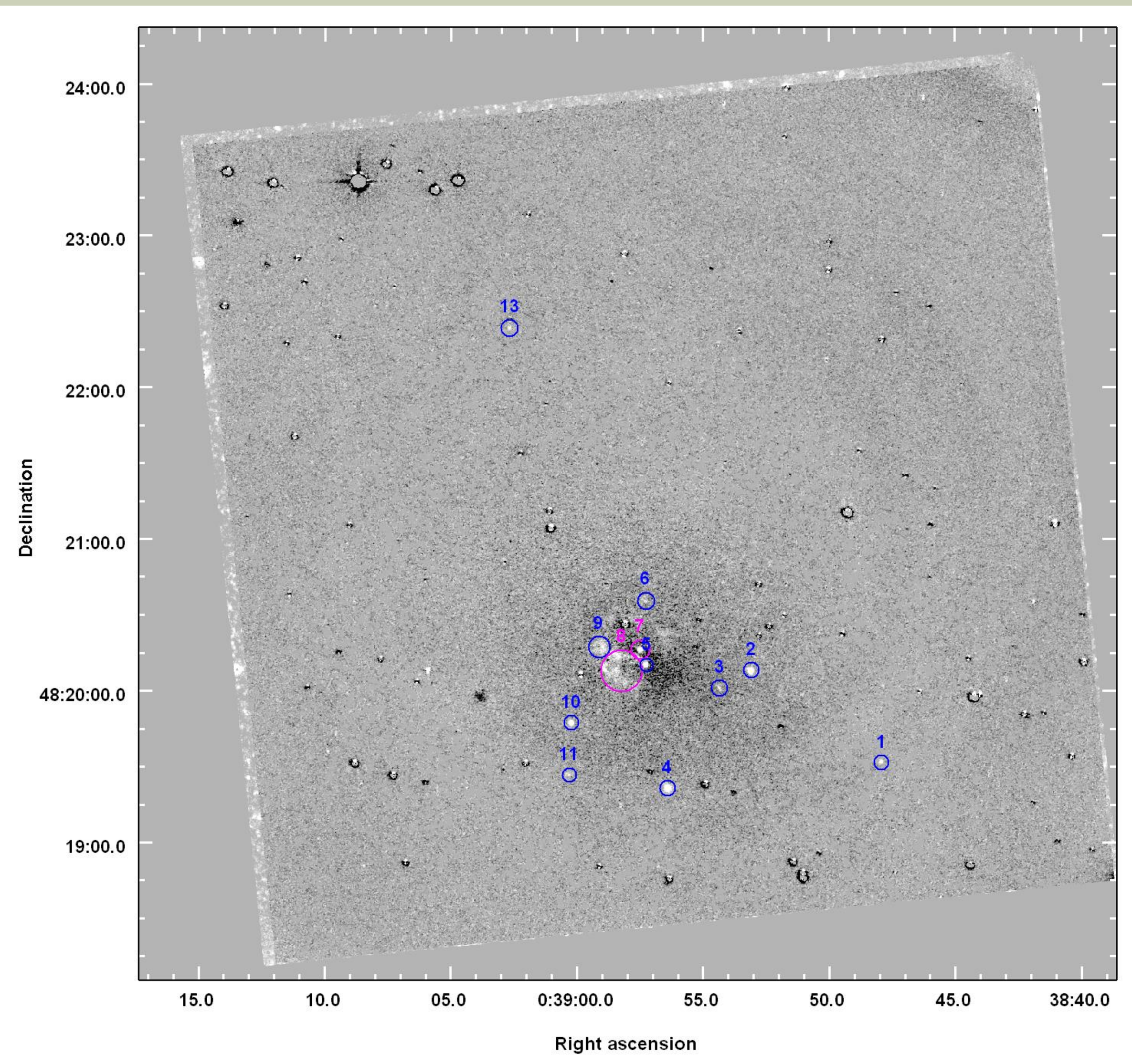

Figure 1.: Hα image (continuum subtracted), with marked objects, numbered as in Table 1. Candidate SNRs are marked with magneta color. FOV ~ 5" x 5"

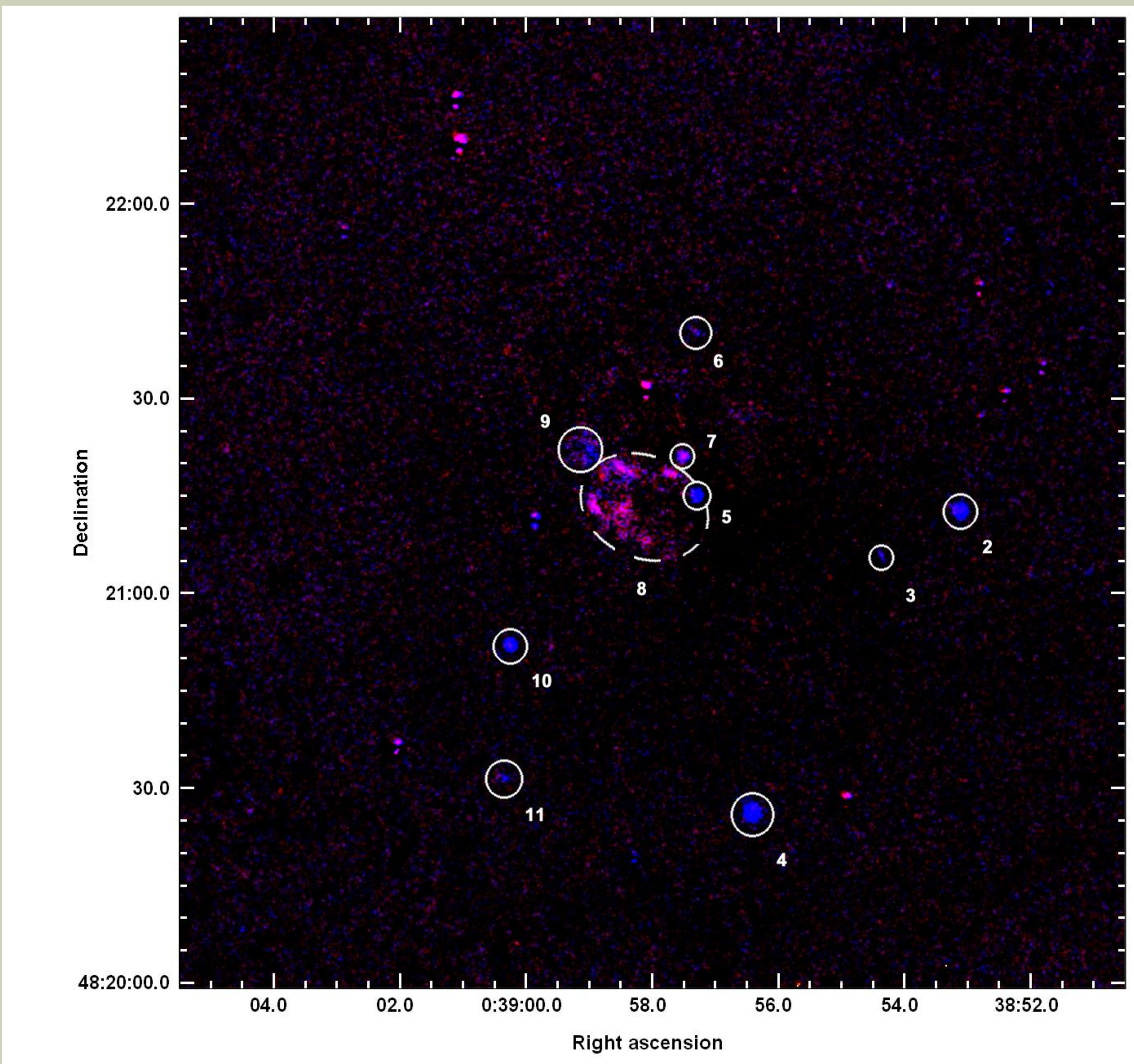

Figure 2.: composite image: Hα (blue) + [SII] (red) emission. Objects which have higher [SII]/Hα ratio, possible SNRs, are purple colored.

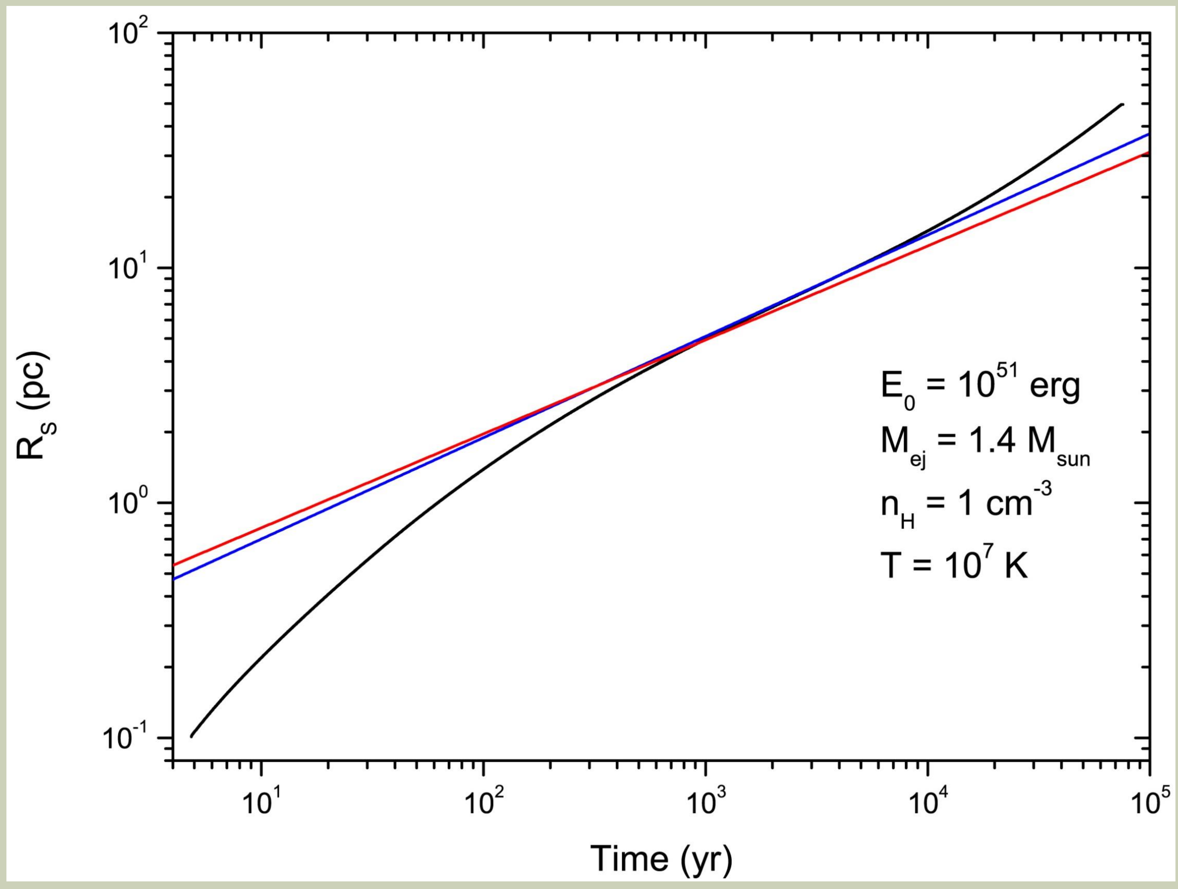

Figure 3.: Evolution of SNR radius. The black solid line represent the numerical simulation results, red line corresponds to the analytic Sedov solution, while blue line stands for Tang and Wang analytic generalization of Sedov solution.

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