



Emission-lines of the dwarf elliptical galaxy NGC 185

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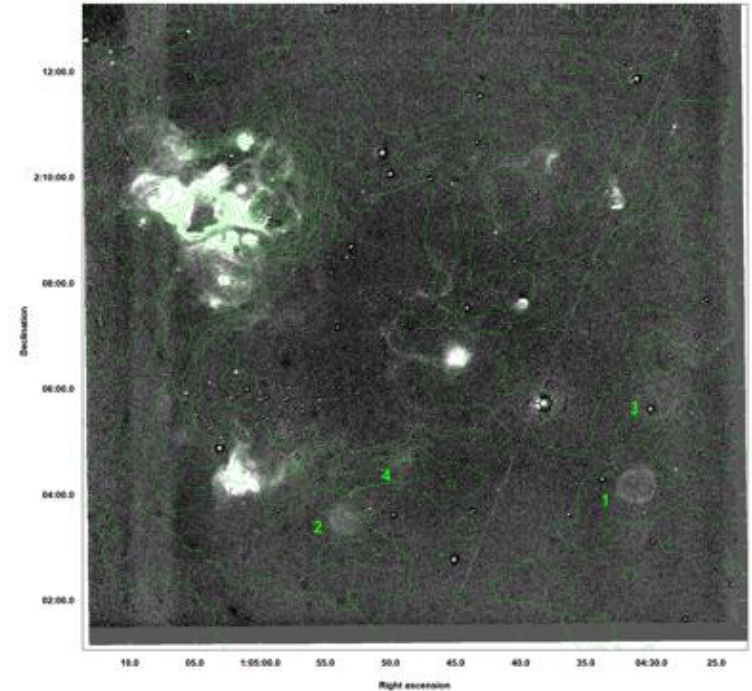
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Survey of emission line nebulae by Belgrade group

- search for supernova remnants (SNR) and H II regions **in near-by galaxies**
- PIs: Milica Vucetic, Bojan Arbutina
 - Rozhen Telescope 2m
 - Tubitak Telescope 2m
- narrow-band photometry of nearby galaxies
- use $[SII]/H\alpha$ ratio to trace SNR (>0.4)



IC 1613: H α image (continuum subtracted) with HI contours overlaid₂

NGC 185 galaxy

- Dwarf elliptical/spheroidal, Andromeda's satellite
- $d=617$ kpc (Ge et al. 2015)
- Showing some population I features – blue stars, young stellar clusters (Baade 1951), gas (Young & Lo 1997), and SNR candidate?
- Star formation a few Gyr ago in the outer parts (HST color-mag. diagram), and a few Myr ago in a central 200 pc of NGC 185
- Was even (wrongly) classified as an AGN (Ho et al. 1997)



DSS

Previous observations of an SNR candidate in NGC 185

- Long-slit spectra across the central part of the galaxy, using 4 m Mayall telescope (Gallagher et al. 1984)
- H α narrow band image showed crescent-shaped morphology, and about 17" = 50 pc in diameter, [SII]/H α =1.5 (Young & Lo 1997)
- Not detected in radio - Dickel et al. (1985), Ho & Ulvestad (2001)
- Not detected in X-rays - Brandt et al. (1997)
- Gonçalves et al. (2012) - Gemini multi-object spectrograph observations of the H α emitting population in NGC 185
 - **Strange SNR properties – diameter 2 pc, lower [SII]/H α ratio of 0.5**

Our observations of NGC 185



2m Rozhen, Bulgaria
Narrow-band photometry



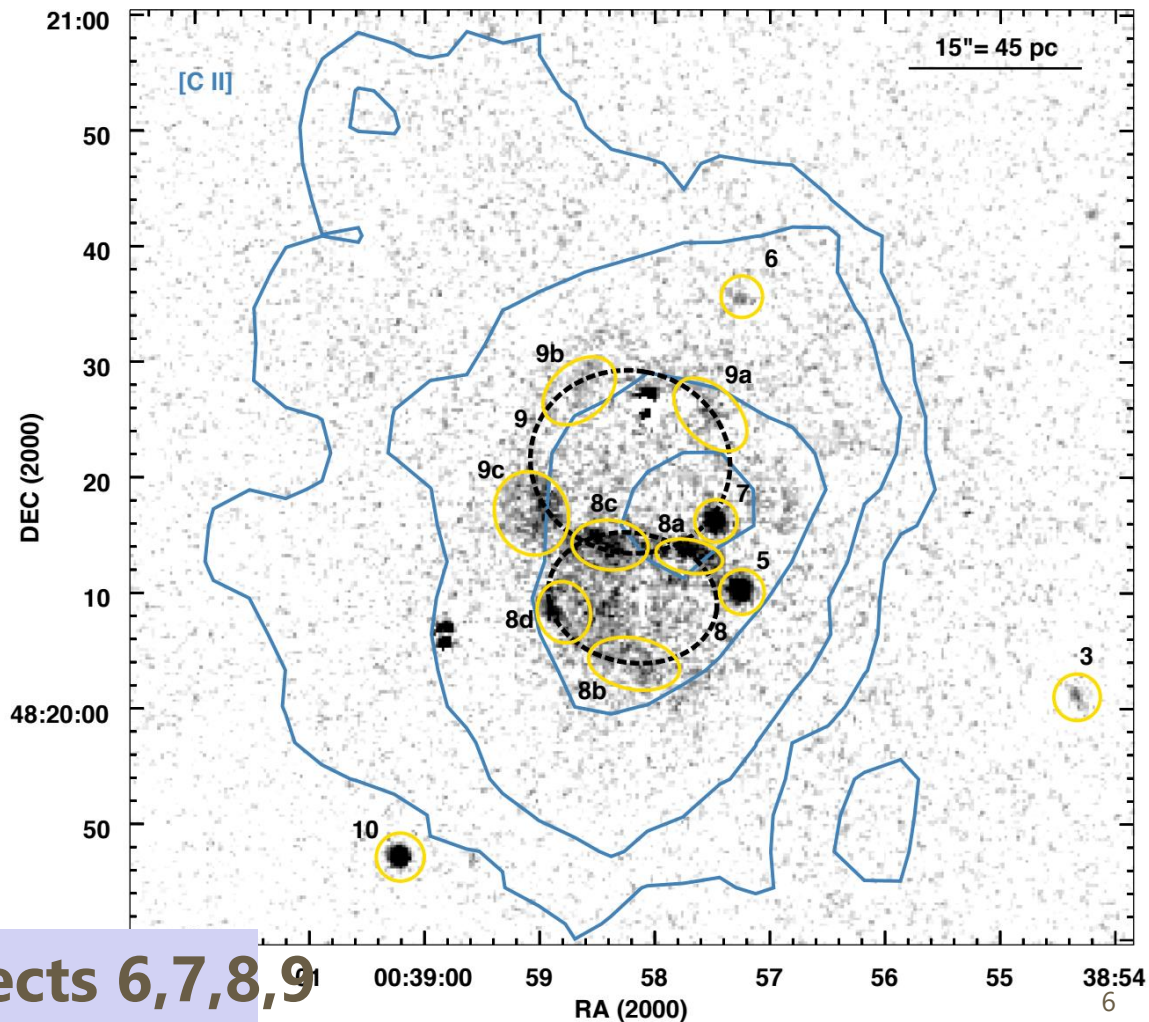
6m BTA, SAO, Russia
Long-slit spectroscopy

Optical photometry

- 2m telescope, Rozhen
- H α , [SII] and cont. narrow filters (3 nm FWHM)
- deep exposure (80 mins)
- we have found:

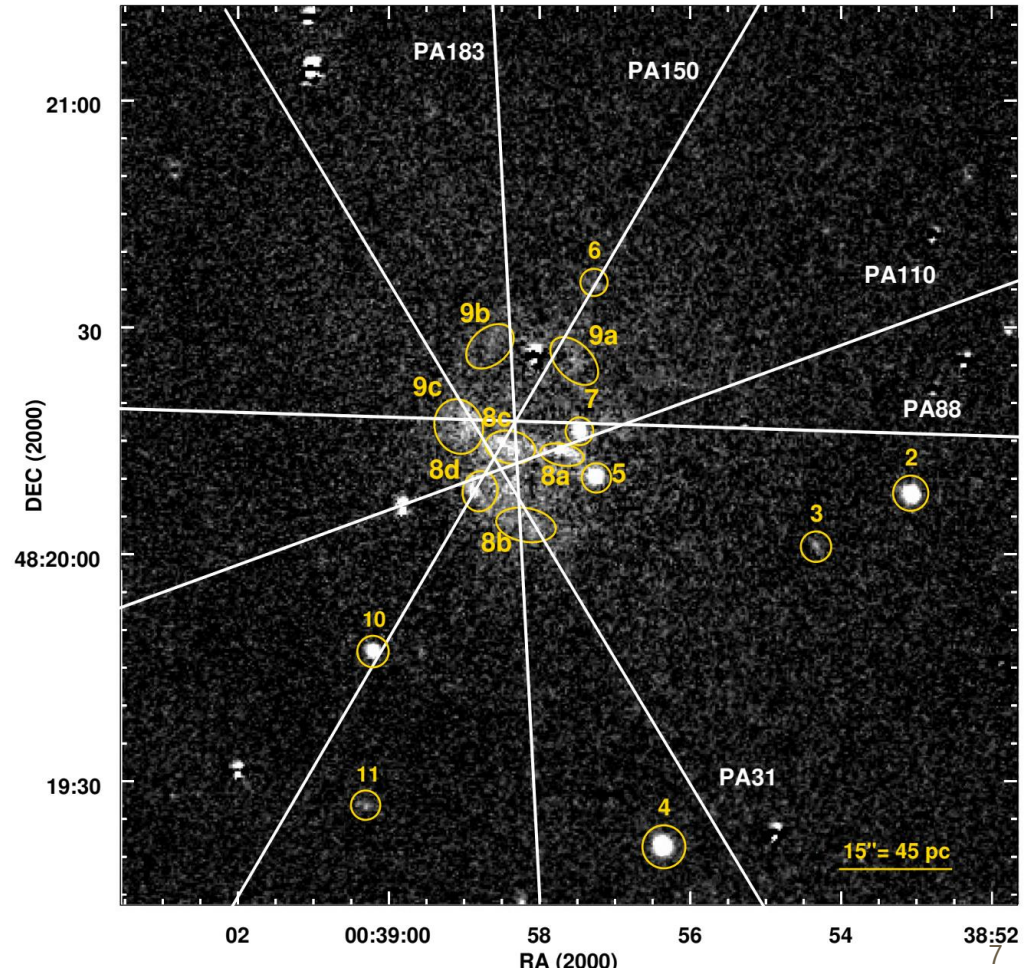
1. six PNe (1, 2, 3, 4, 5, 10)
2. one symbiotic star
3. **one H II region!!** (7)
4. **two SNR candidates** (8, 9)
5. one PN with shocks? (6)

keep in mind objects 6,7,8,9



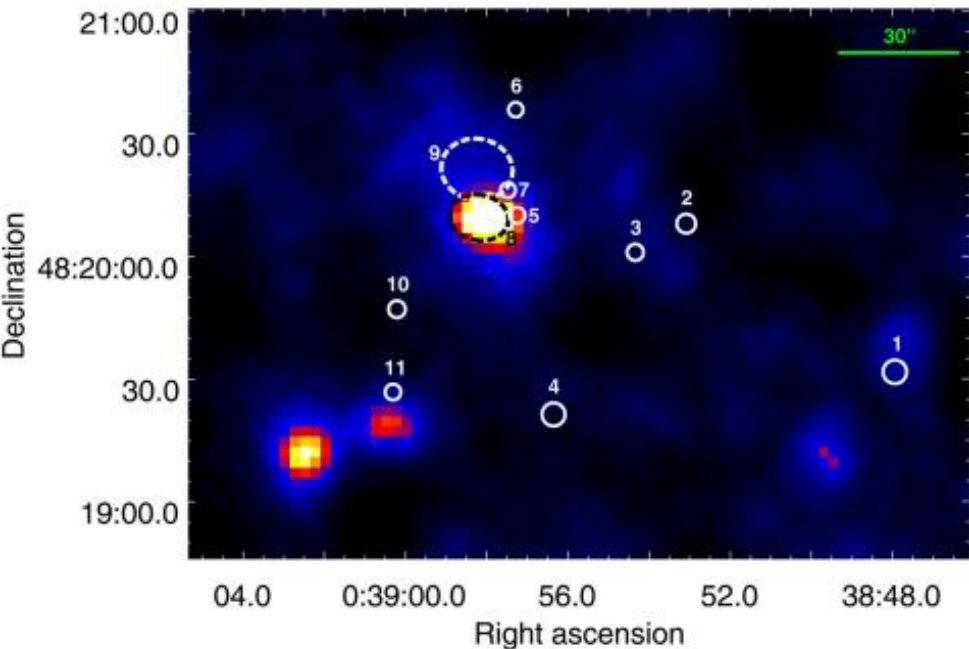
Optical spectroscopy

- **6-m telescope of SAO RAS** with SCORPIO-2 multi-mode focal reducer in long-slit mode
- **Two slit positions in low resolution mode** (FWHM~500 km/s) PA88, PA150; **three slit positions in high res. mode** (FWHM~120 km/s)
 - Emiss. line fluxes and ratios
 - Line of sight velocity – **shock velocity**
 - Velocity dispersion

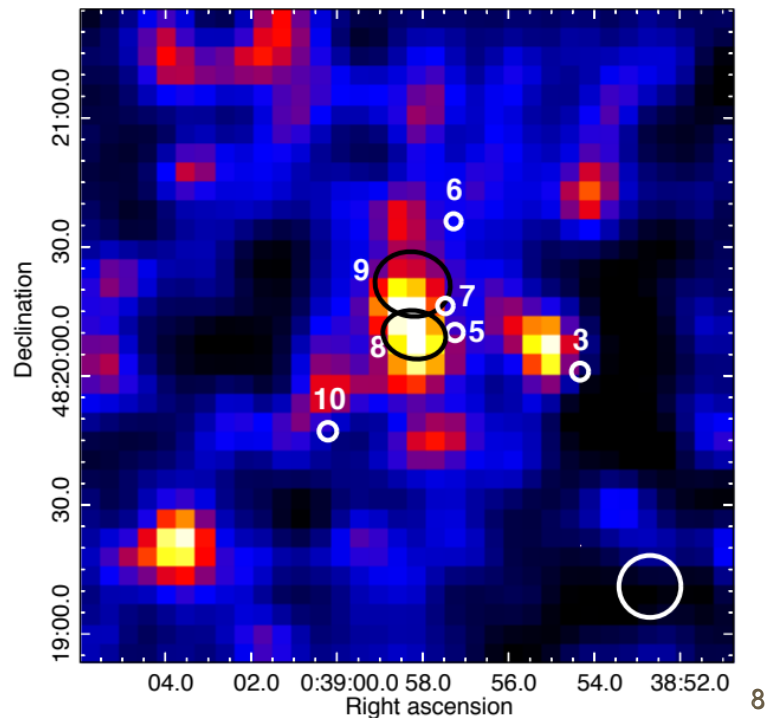


Archival data – XMM-Newton & VLA

- 0.4 keV - 7.0 keV; ~90 ks combined EPIC
- soft, thermal origin source; diameter 14''
- high intrinsic absorption

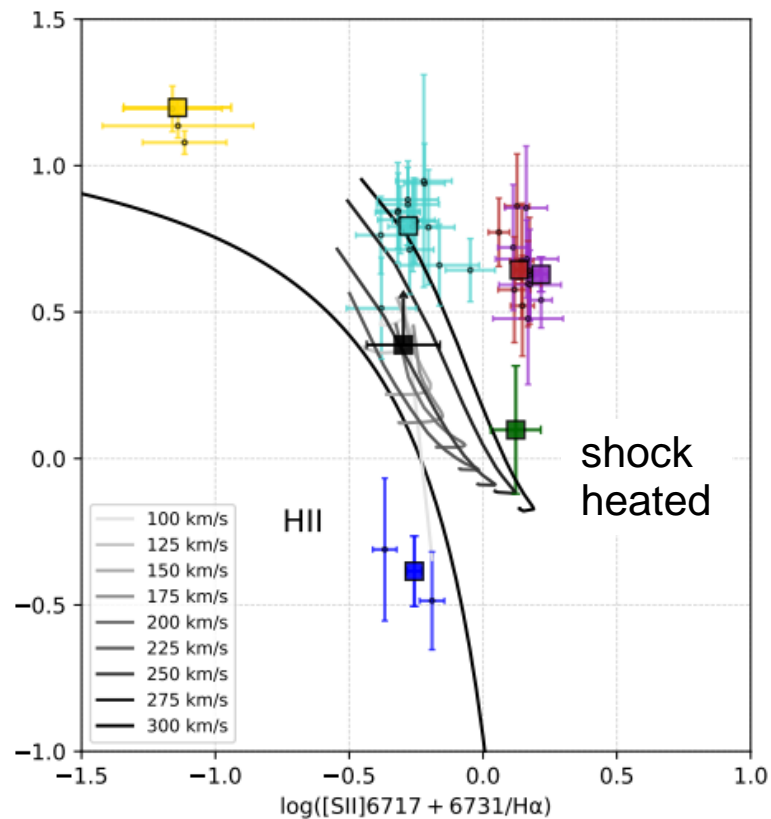
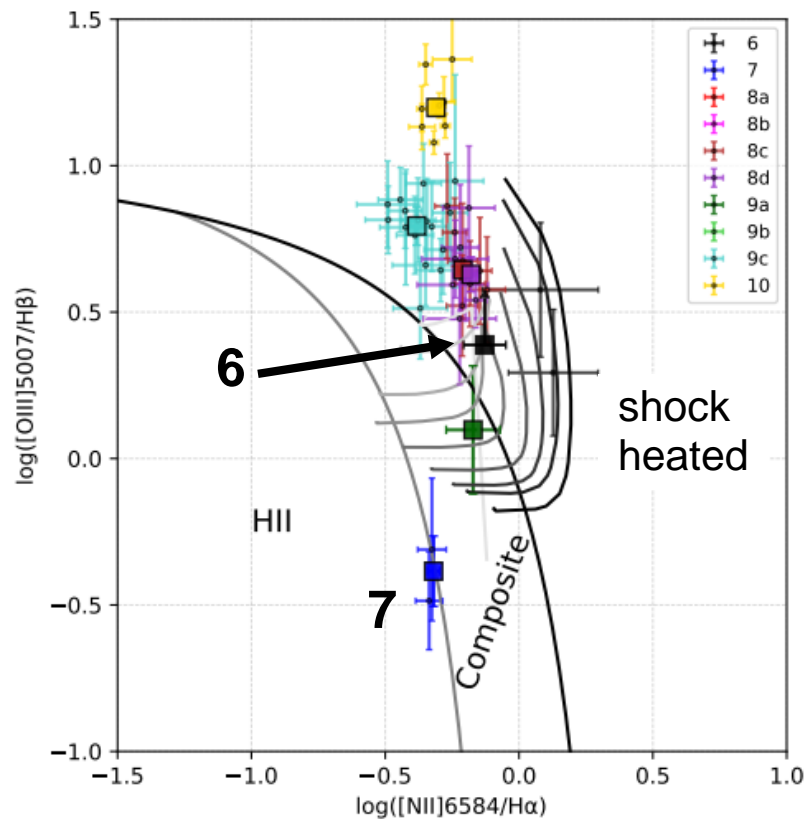


- beam size 14.4'', 1.4 GHz
- indication of the diffuse radio continuum emission
- flux of SNR 8 ~1.4 mJy

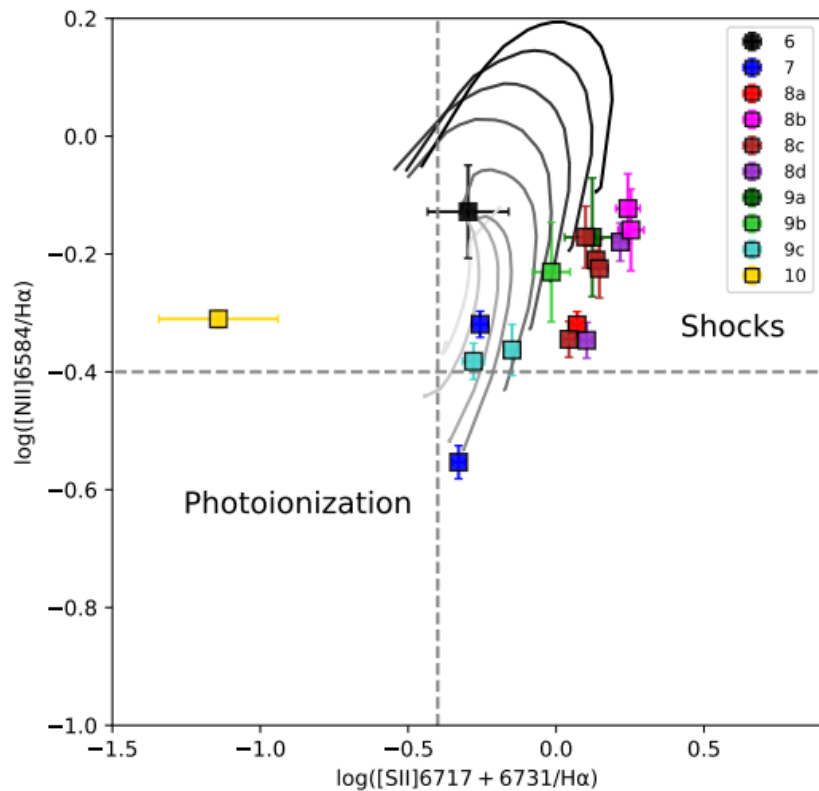


BPT diagrams

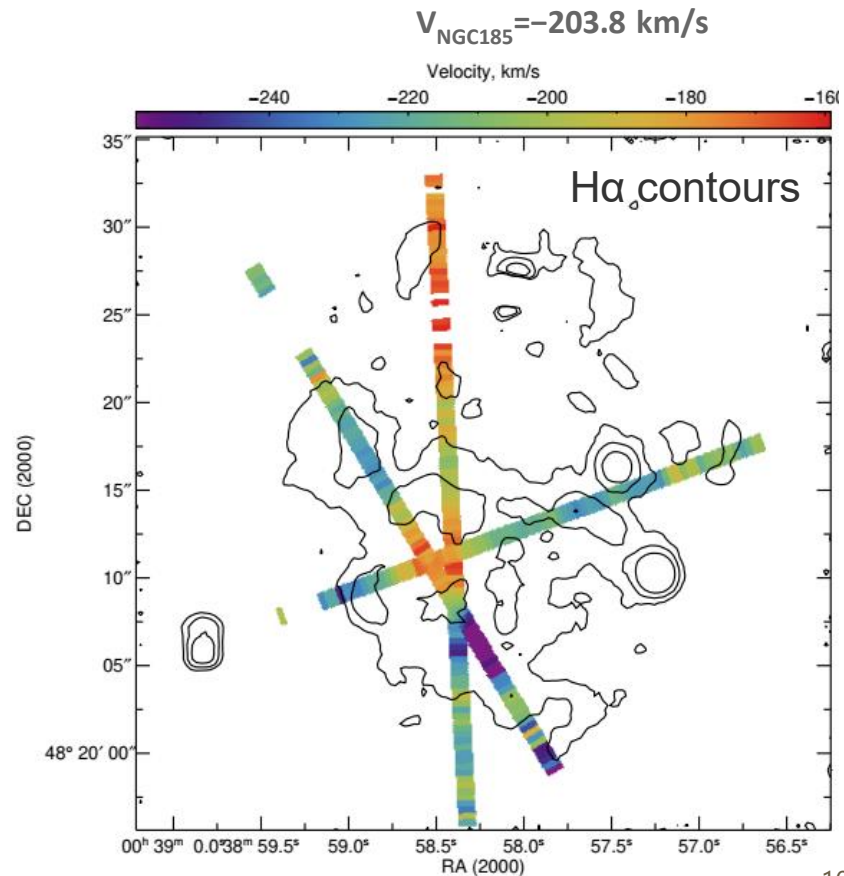
-Overlapped Allan et al. (2008) radiative shock models; $n=10 \text{ cm}^{-3}$, Solar abundances



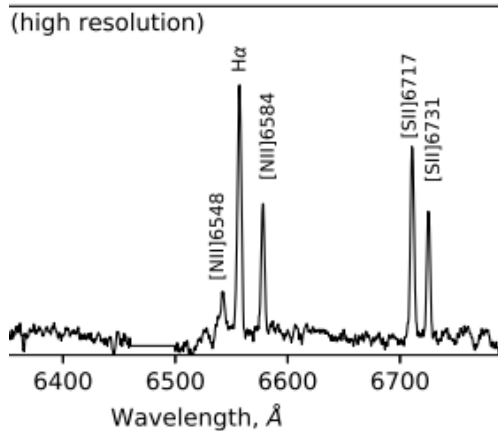
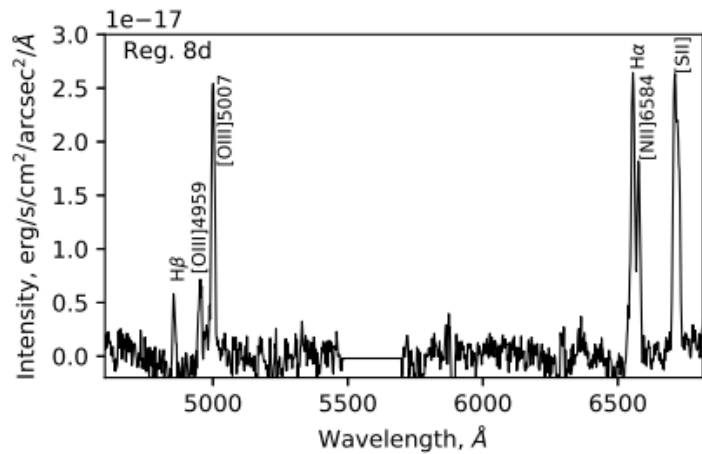
Diagnostic diagram



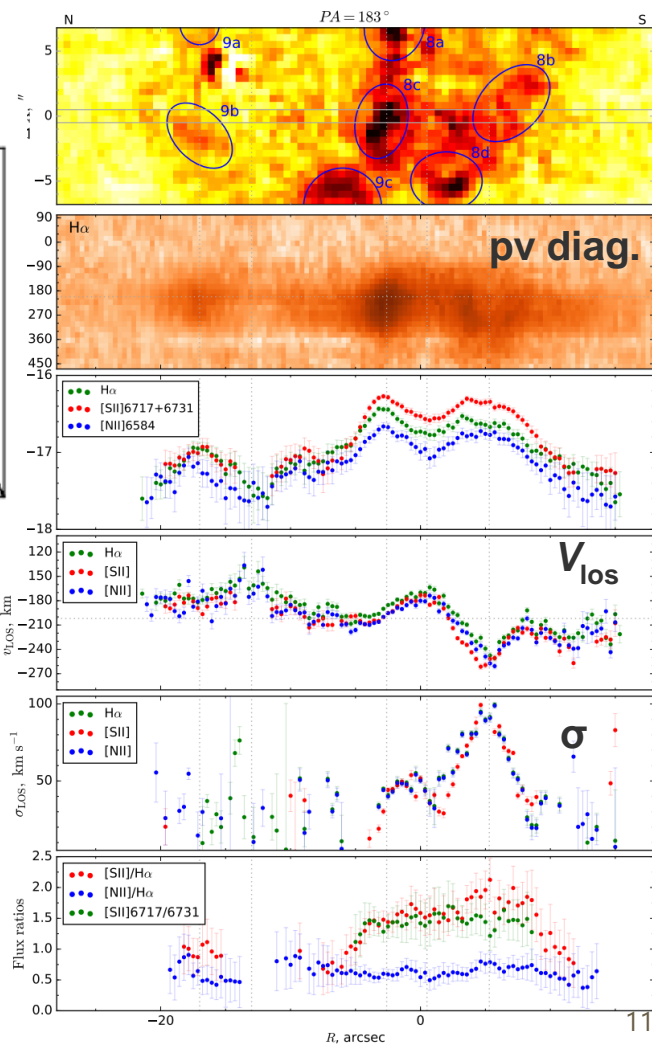
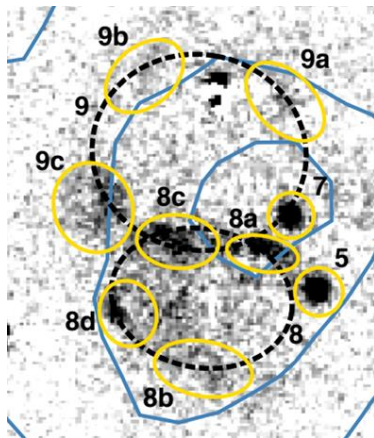
Velocity map



Object 8 - SNR

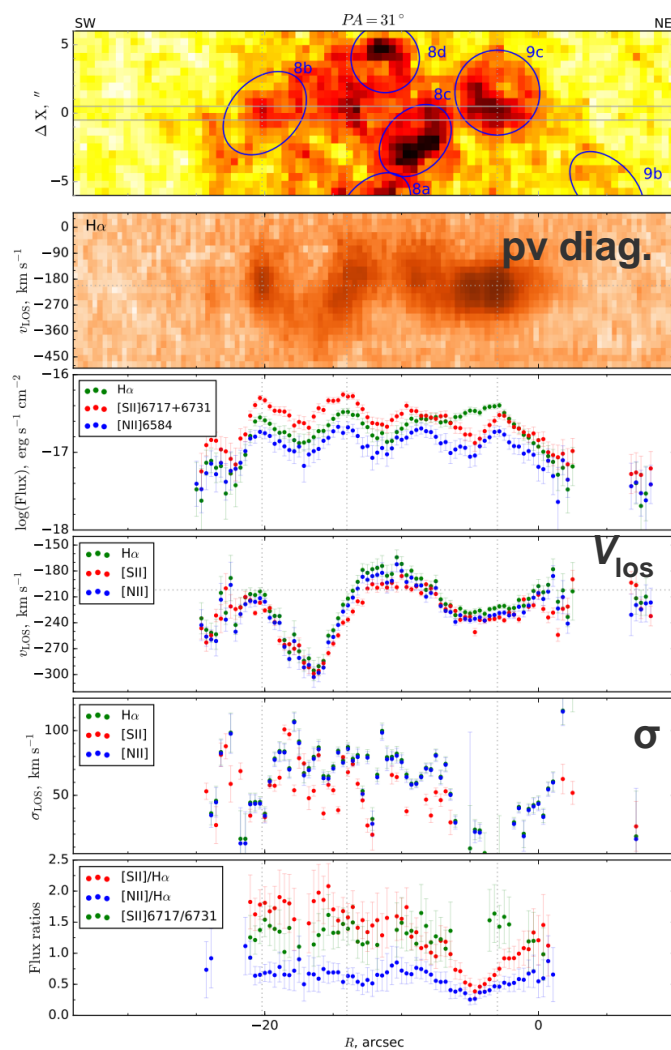
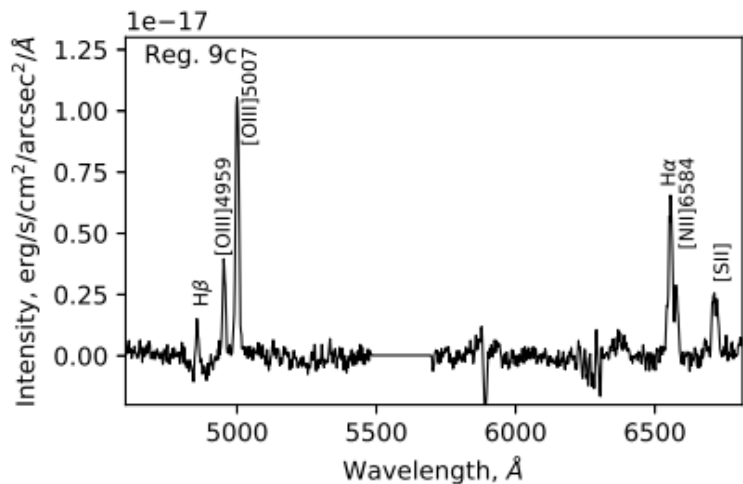
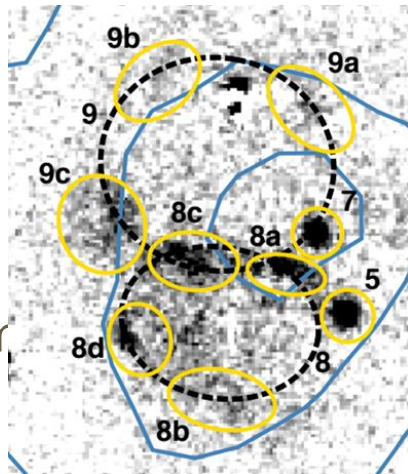


- $[\text{SII}]/\text{H}\alpha \sim 1.5\text{-}2.0$
- diameter 45 pc
- expansion velocity $\sim 90 \text{ km/s}$
- $n_e \sim 200 \text{ cm}^{-3}$
- age $\sim 1 \times 10^5 \text{ yrs}$ (for Sedov-Taylor solution)
- in late radiative phase (faint in radio)



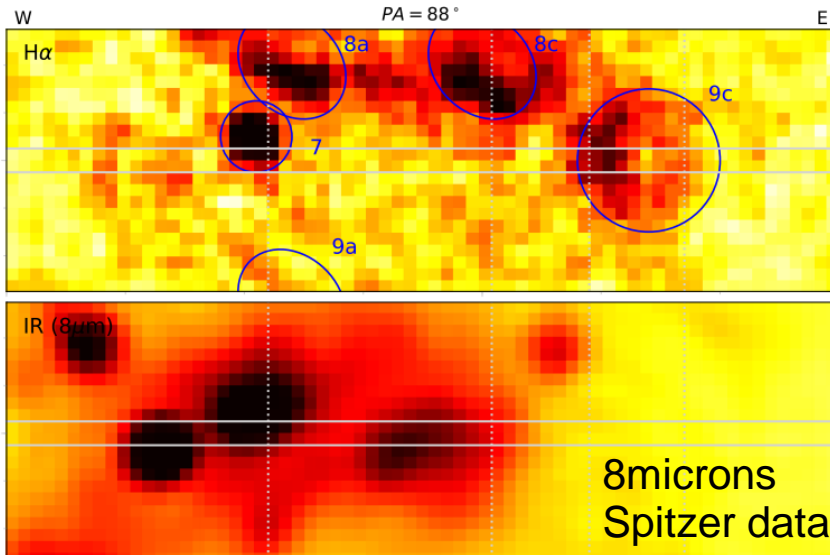
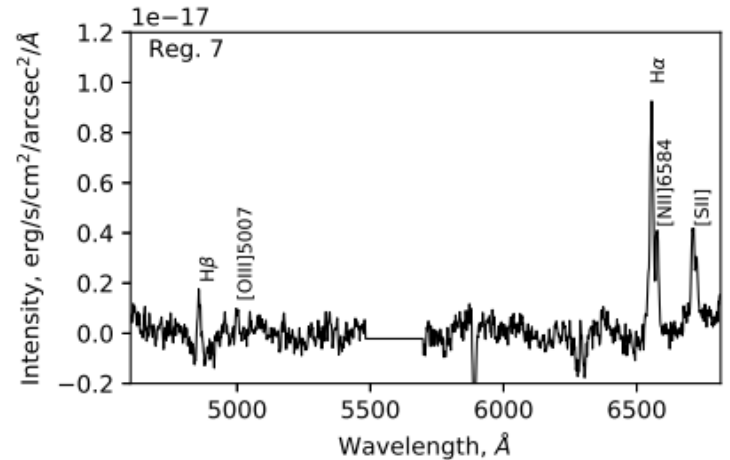
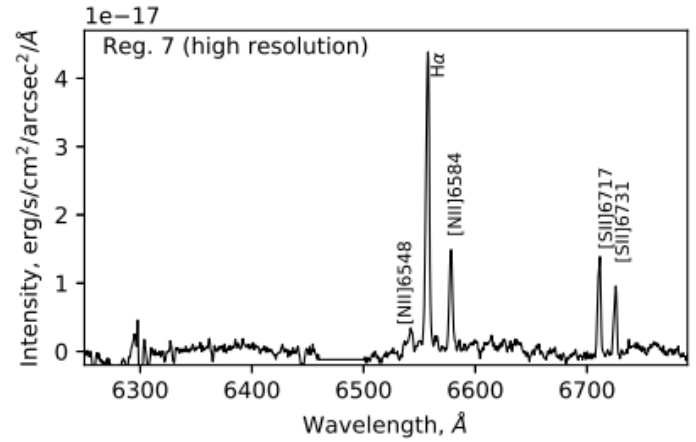
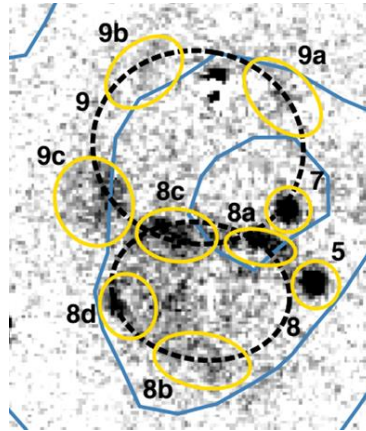
Object 9 – SNR – NEW!

- [SII]/H α 0.7-1.2
- diameter 50 pc
- expansion velocity ~ 30 km
- age $\sim 3.5-6 \times 10^5$ yrs

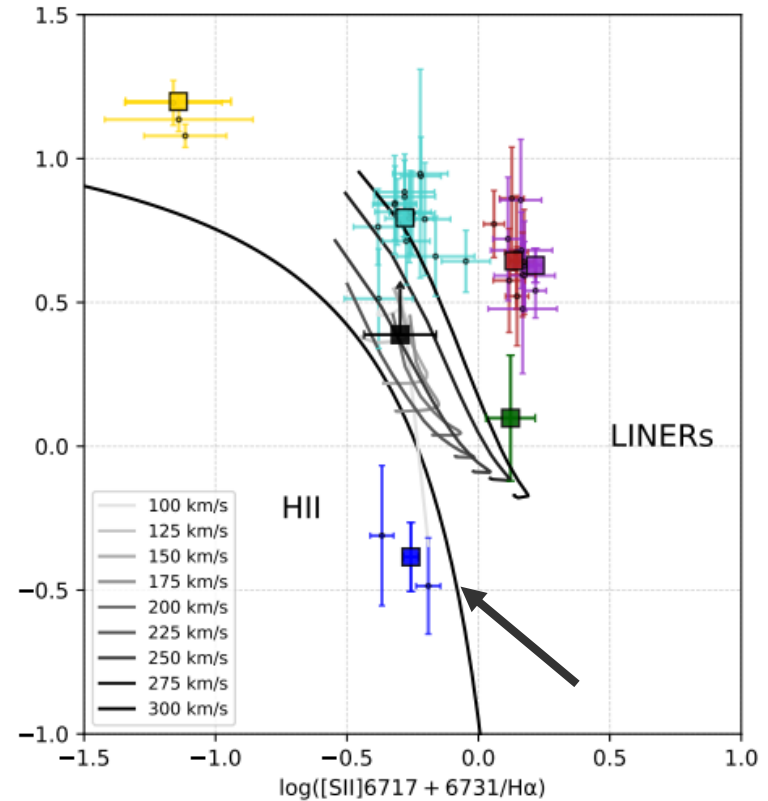
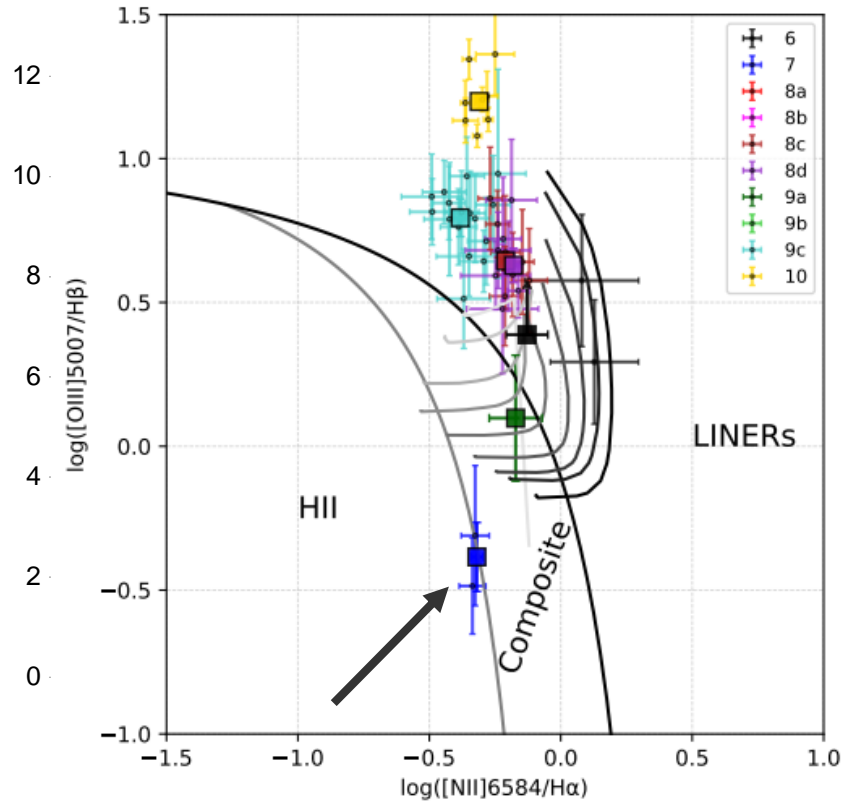


Object 7

- [SII]/H α ~0.5
- diameter <6 pc
- faint [OIII] lines!!
- no bulk velocity



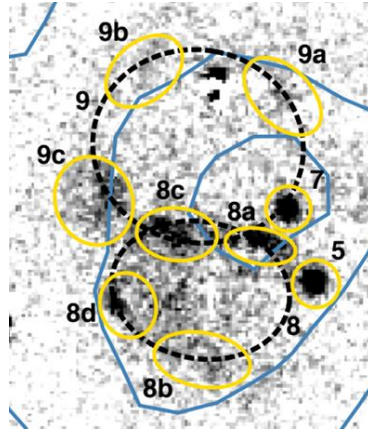
Object's 7 position on BPT



column 1
column 2
column 3

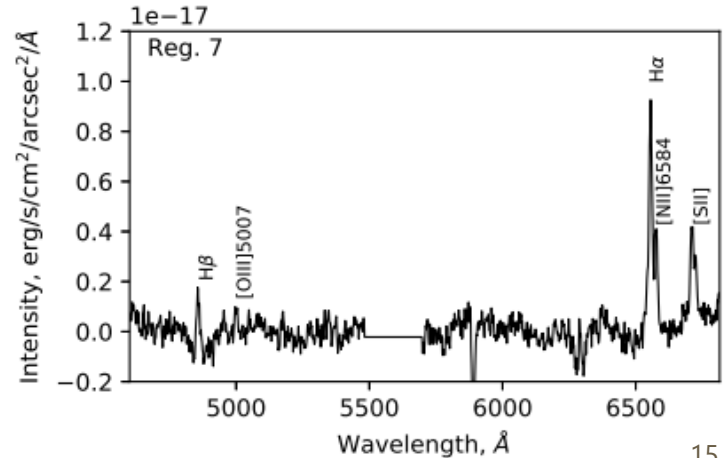
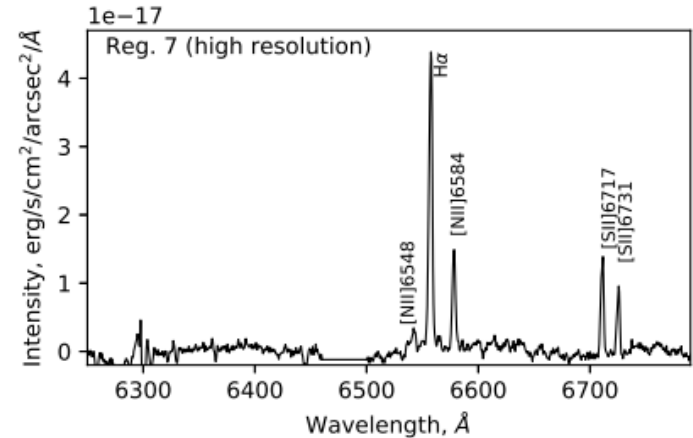
Object 7- ?

- [SII]/H α \sim 0.5
- diameter <6 pc
- faint [OIII] lines
- no bulk velocity



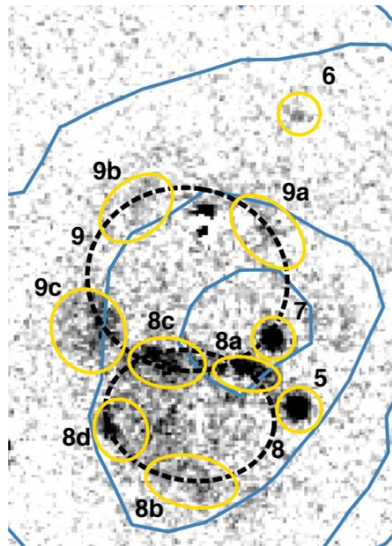
Two possibilities:

- a compact **H II region** with overlaid shock-ionized gas from objects 8 or 9 (or both)
- a **part of the old evolved SNR** – of object 8 or 9, encountering an ISM condensation

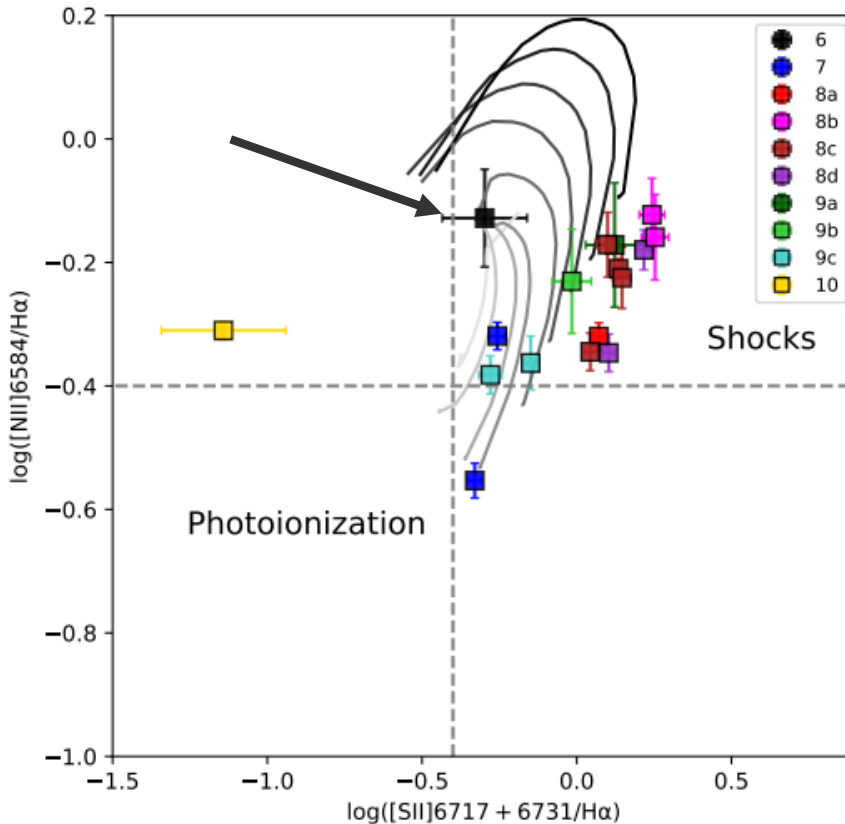
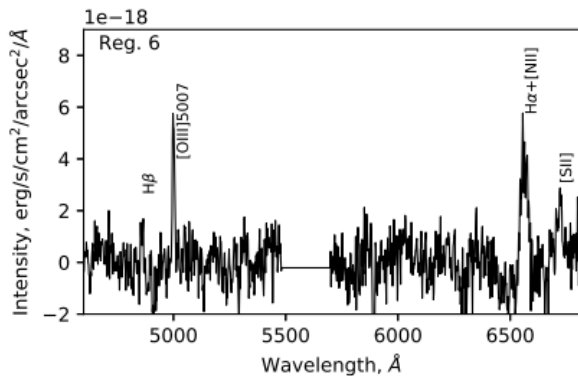


Object 6 - ?

- [SII]/H α \sim 1.0
- [NII]/H α \sim 0.7-2.0
- diameter < 6 pc
- low [OIII] lines
- suggested as PN by Gonsalves et al. (2012)

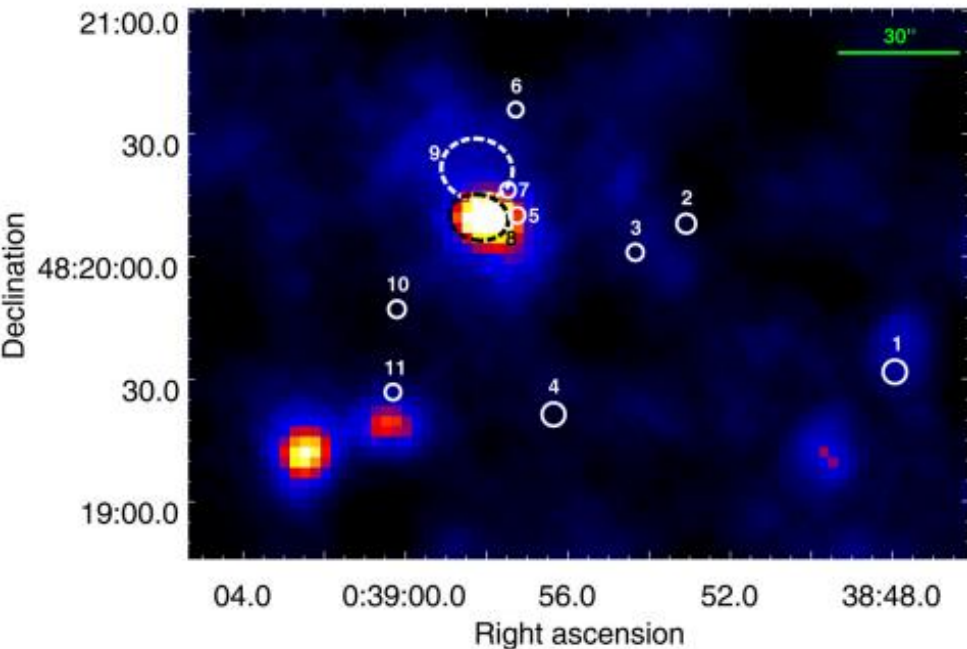


- **additional shock heating?**

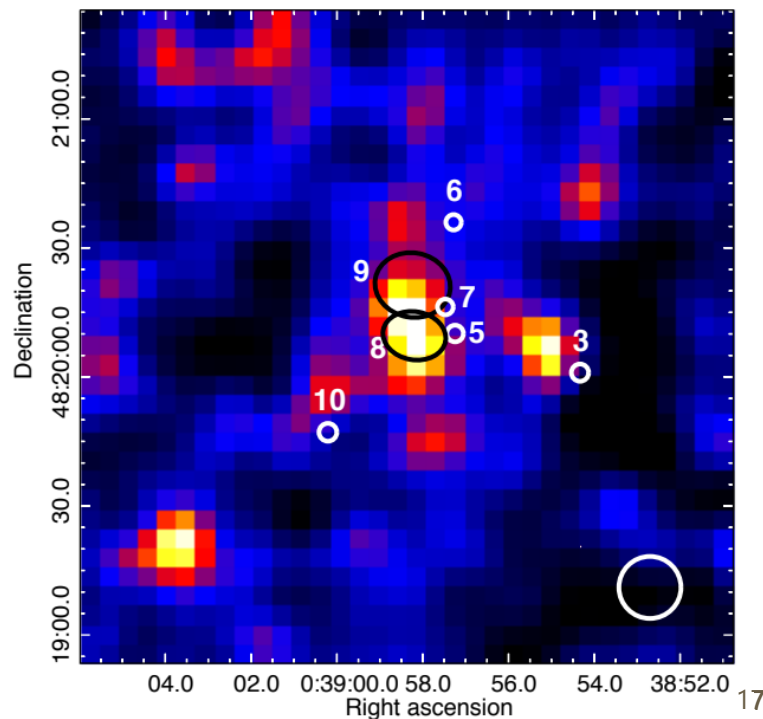


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- beam size 14.4", 1.4 GHz
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Proposal sent to Chandra

- we hope to get better resolution and resolve the object 8 in X-ray
- we plan to apply for new radio observations (VLA or GMRT)



Summary

- H α and [S II] observations detected 11 objects – out of which 1 PN with some shock ionization; 1 previously known SNR, 1 **NEW optical SNR** candidate; 1 composite object (photoionization with some signatures of shock, probably **H II region**)
- **Spectroscopic observations confirmed 2 SNRs and HII region**
- complex kinematics: extended emission with filaments (expansion $\sim 50 - 90 \text{ km s}^{-1}$)
- Estimated electron density $\sim 200 \text{ cm}^{-3}$ (higher than expected in elliptical galaxy)
- XMM-Newton: presence of an extended source in projection of our SNR candidate 8
- VLA radio data: weak and unresolved, diffuse radio continuum emission in the center of NGC 185
- **...and we need more data**

THANK YOU!