Emission-lines of the dwarf elliptical galaxy NGC 185

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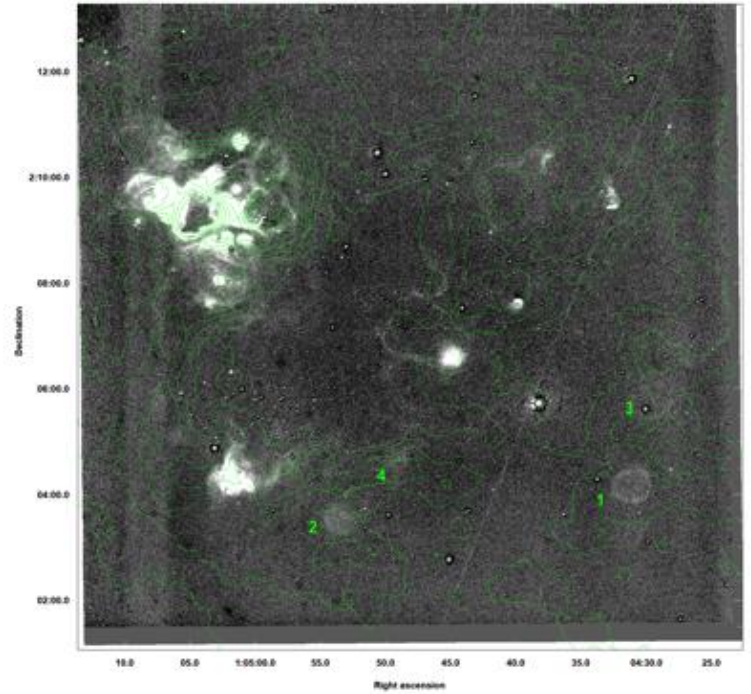
Survey of emission line nebulae by Belgrade group

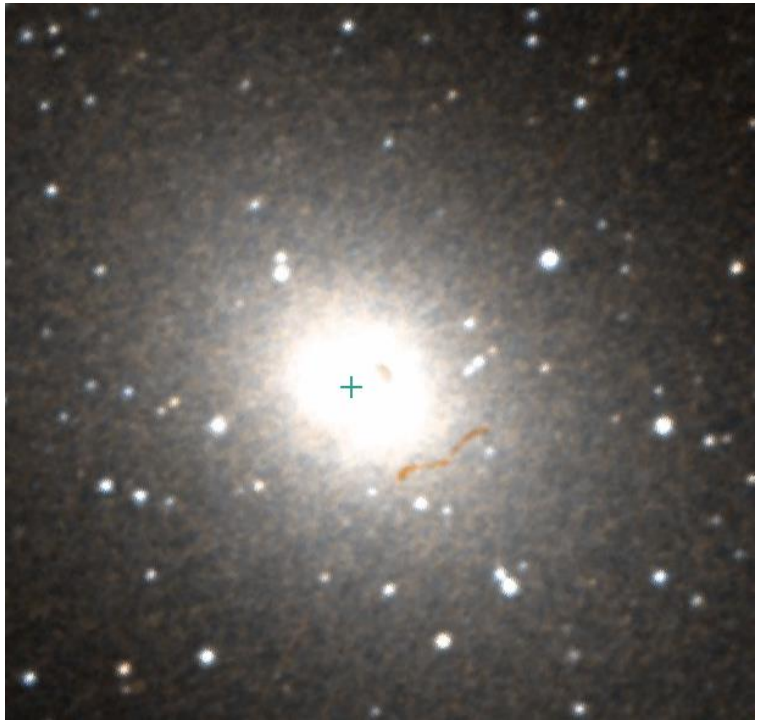
- search for supernova remnants (SNR) and
  H II regions **in near-by galaxies**
- PIs: Milica Vucetic, Bojan Arbutina
  - Rozhen Telescope 2m
  - Tubitak Telescope 2m
- narrow-band photometry of nearby galaxies
- use [SII]/Hα ratio to trace SNR (>0.4)



IC 1613: Hα image (continuum subtracted) with HI contours overlaid

NCG 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)
- Hα narrow band image showed crescent-shaped morphology, and about 17" = 50 pc in diameter, [SII]/Hα=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 Hα emitting population in NGC 185
    - **Strange SNR properties – diameter 2 pc, lower [SII]/Hα ratio of 0.5**

Our observations of NGC 185

2m Rozhen, Bulgaria
Narrow-band photometry

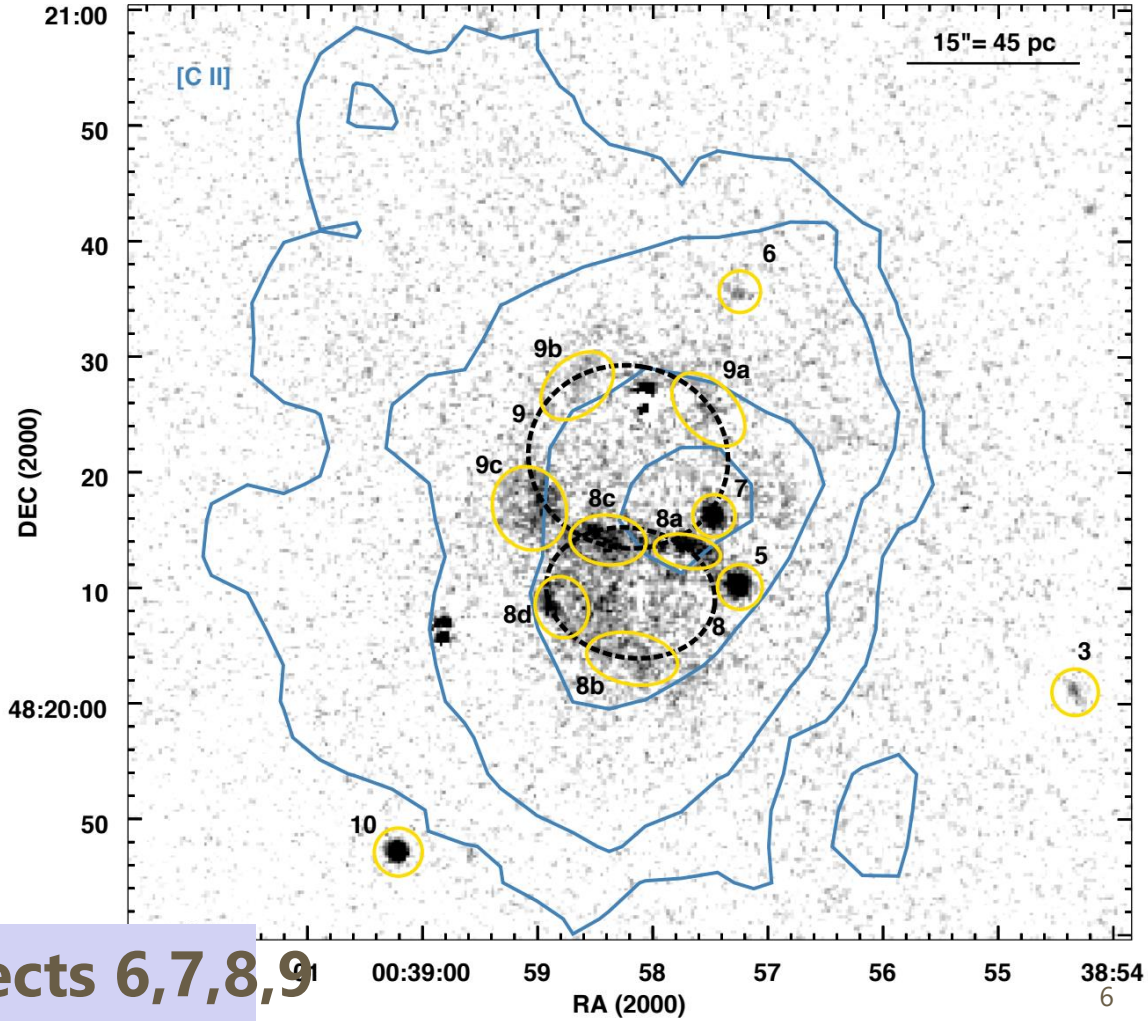
6m BTA, SAO, Russia
Long-slit spectroscopy

Optical photometry

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

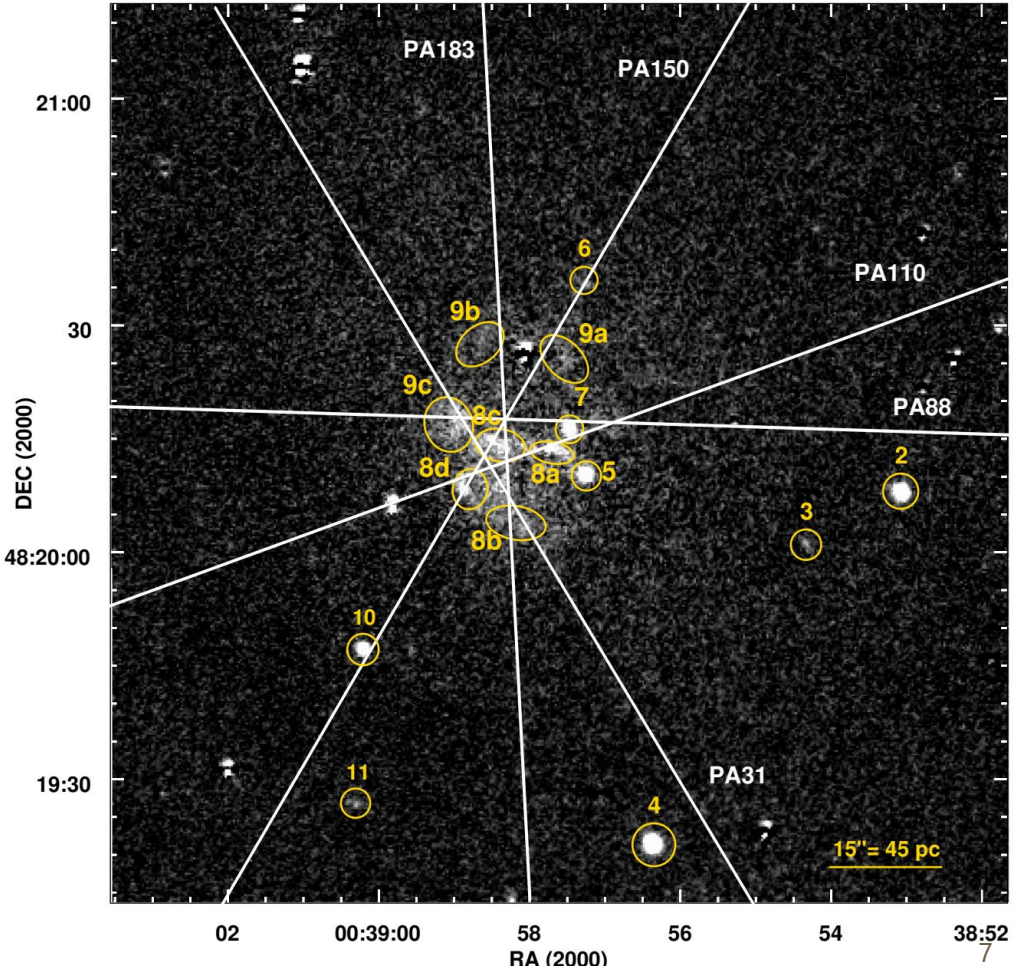
1. six PNe (1, 2, 3, 4, 5, 10)
2. one symbiotic star
3. **one H II region!!** (7)
4. **two SNR candidates** (8, 9)
5. one PN with shocks? (6)

keep in mind objects 6,7,8,9



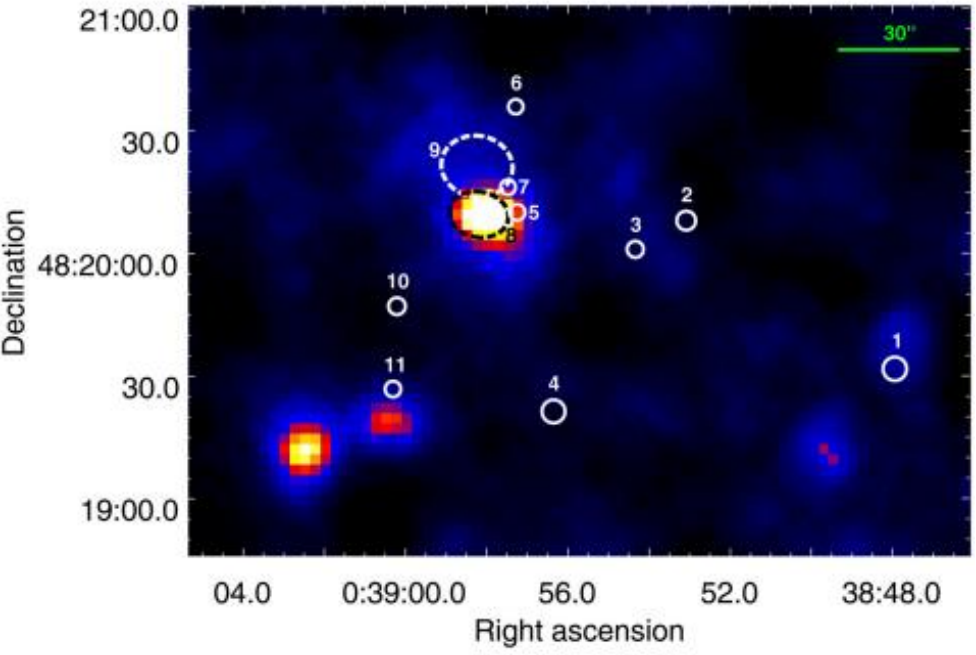
Optical spectroscopy

- **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

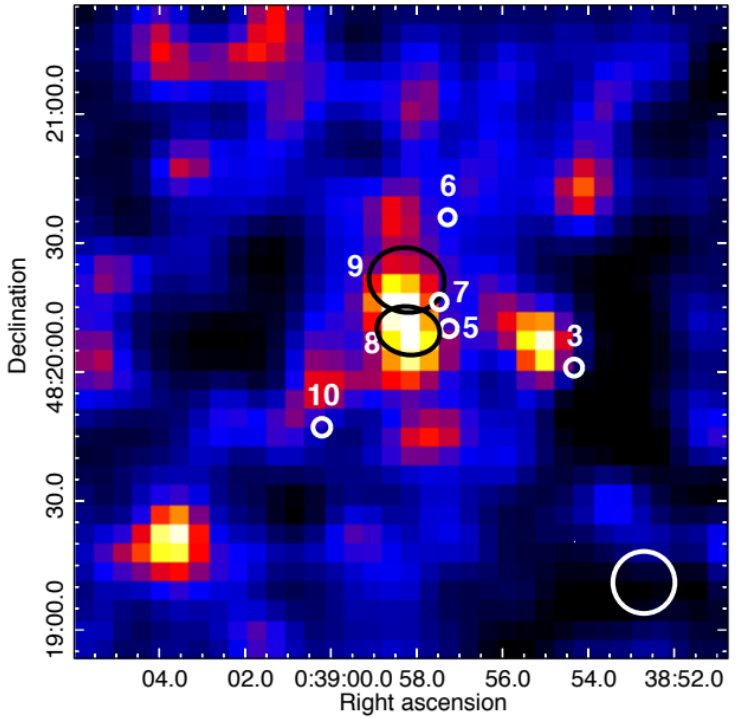


Archival data – XMM-Newton & VLA

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

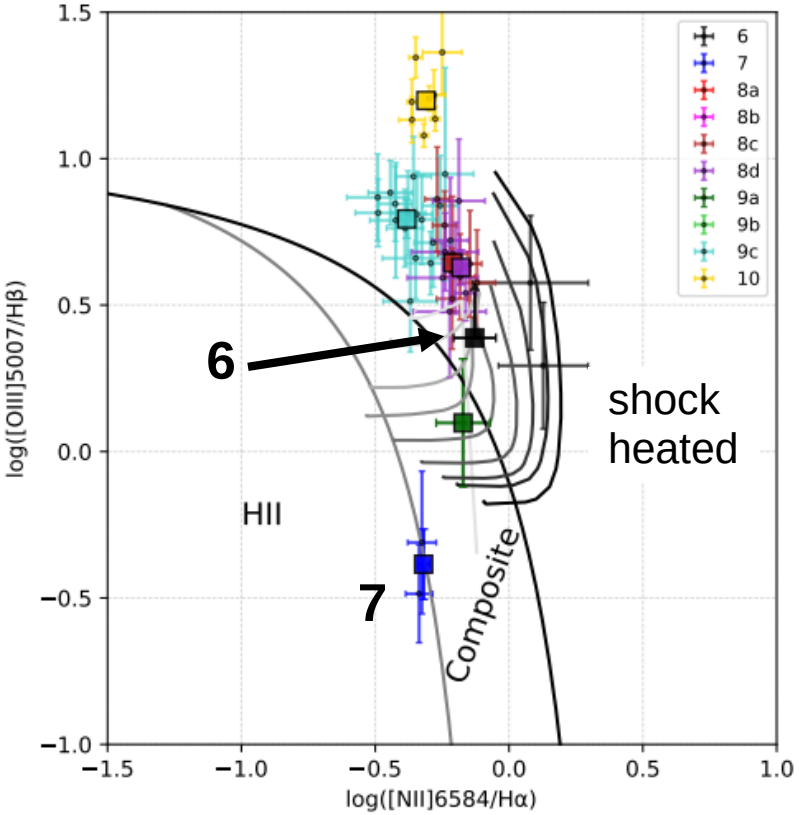


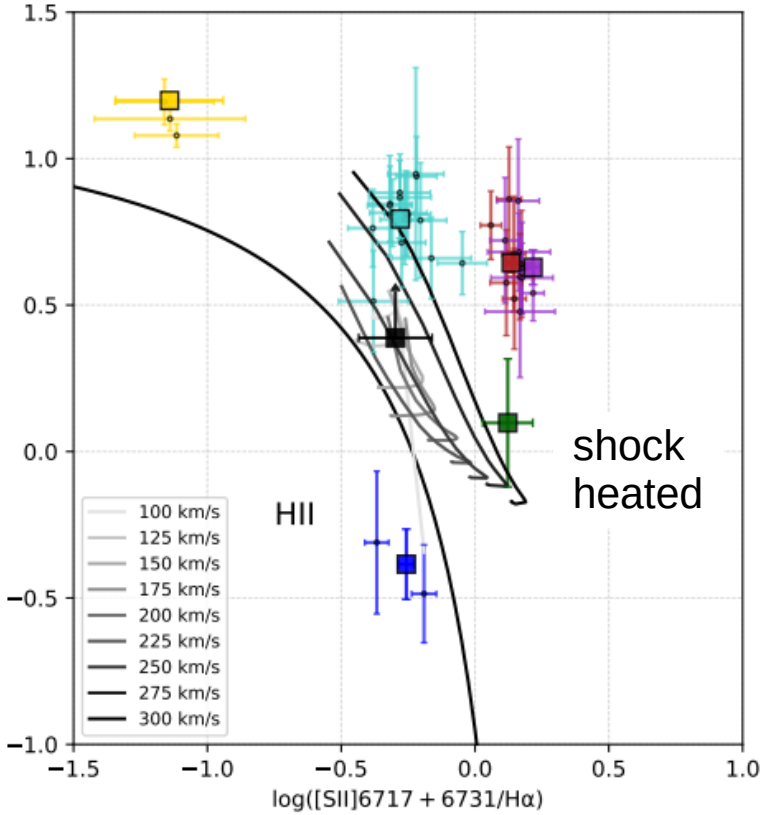
-beam size 14.4”, 1.4 GHz
- indication of the diffuse radio continuum emission
-flux of SNR 8 ~1.4 mJy



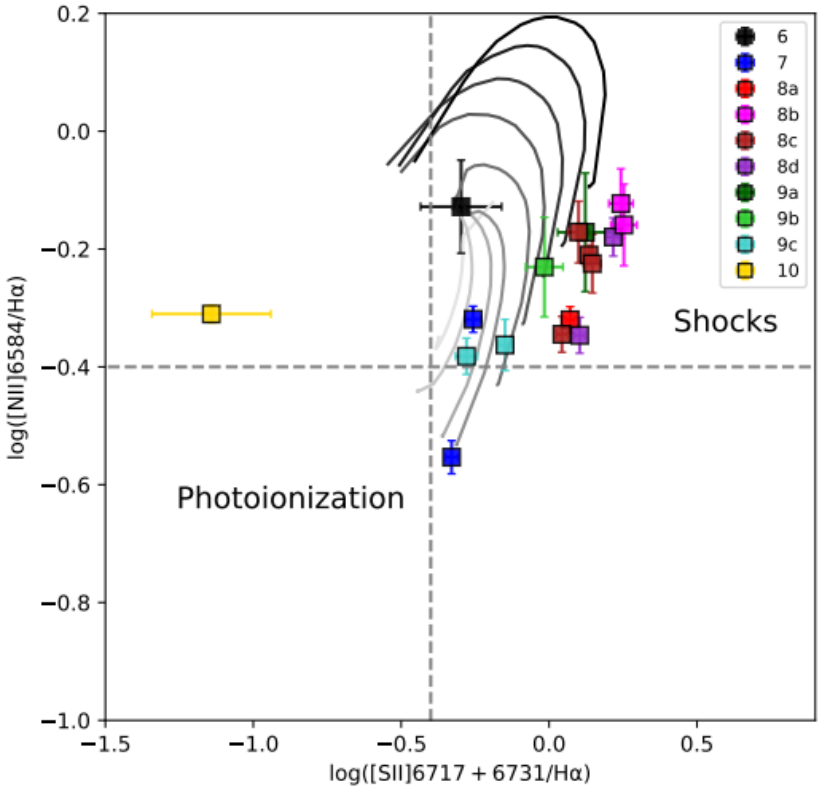
BPT diagrams

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



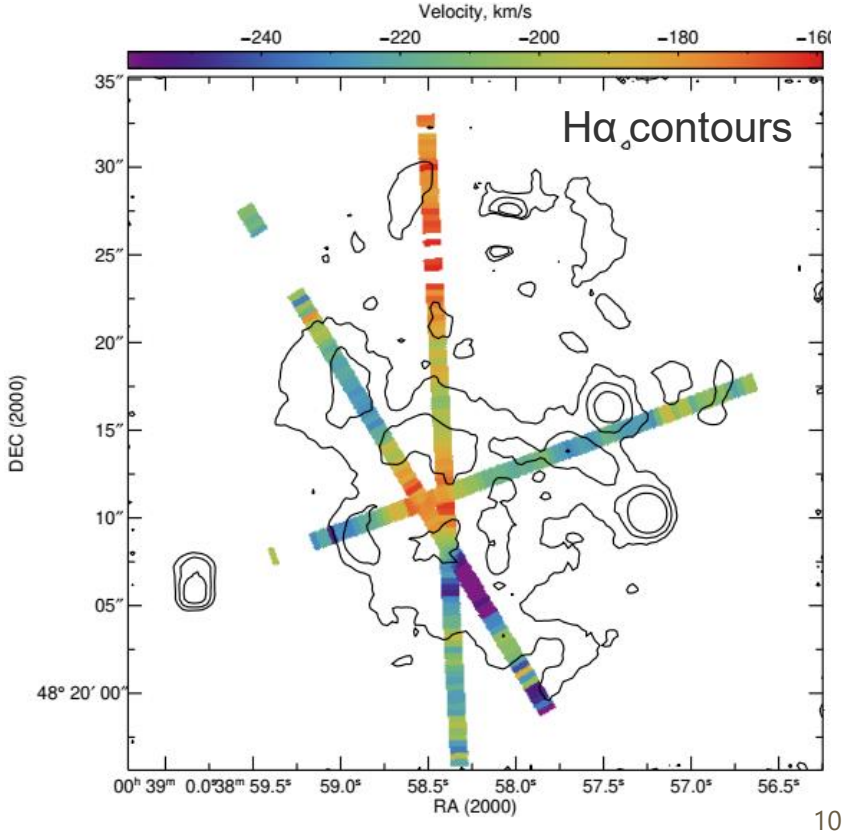


Diagnostic diagram

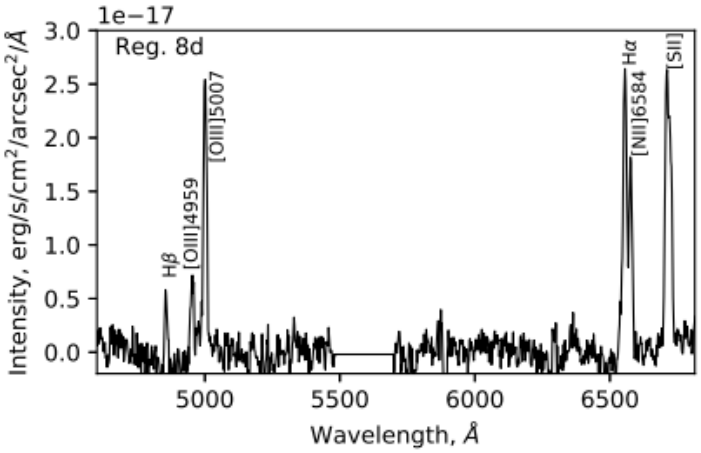


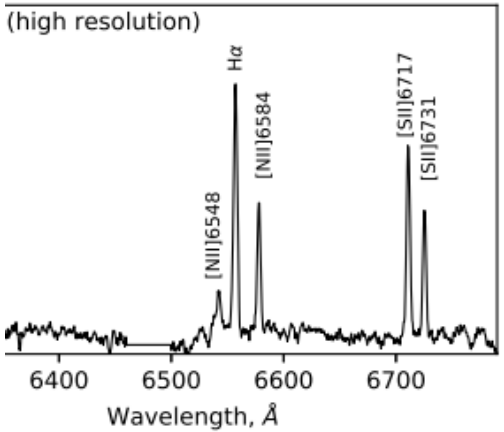
Velocity map

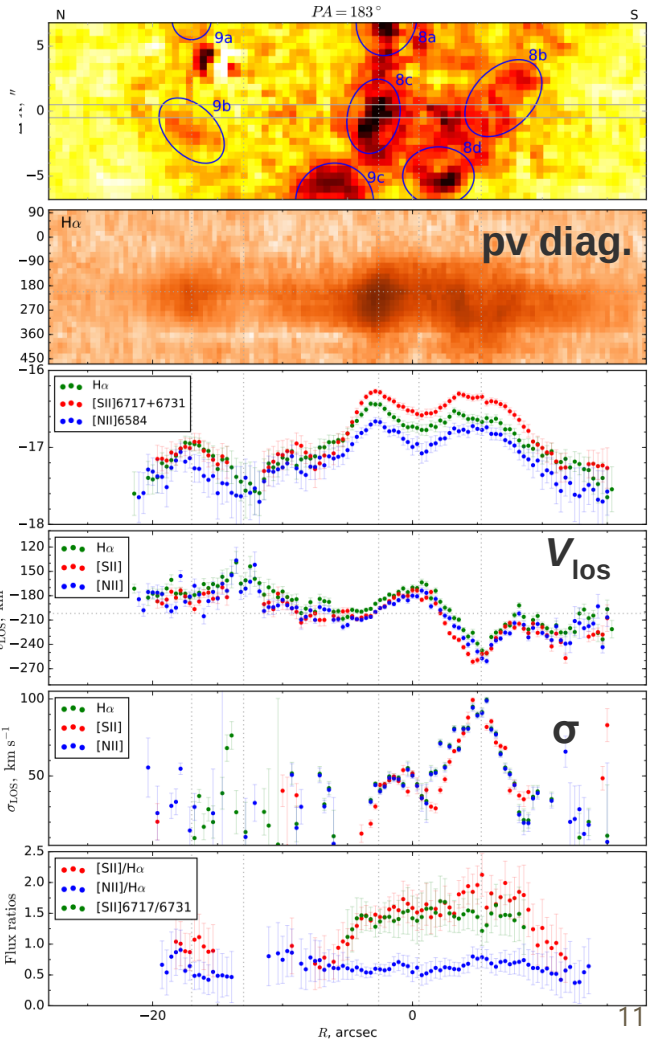
V_{NGC185}=−203.8 km/s

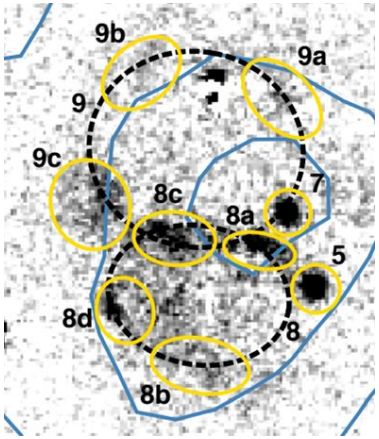


Object 8 - SNR









-[SII]/Hα ~1.5-2.0
-diameter 45 pc
-expansion velocity ~ 90 km/s
-n_e~200 cm^{-3}
-age ~1x10^5 yrs (for Sedov-Taylor solution)
-in late radiative phase (faint in radio)

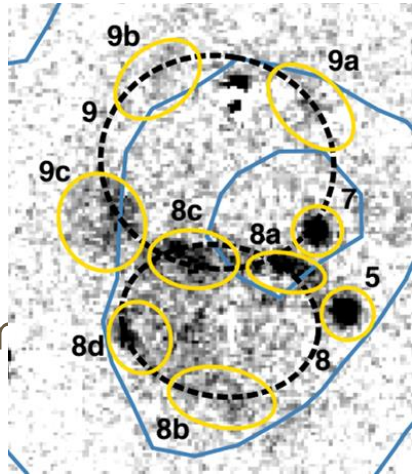
Object 9 – SNR – NEW!

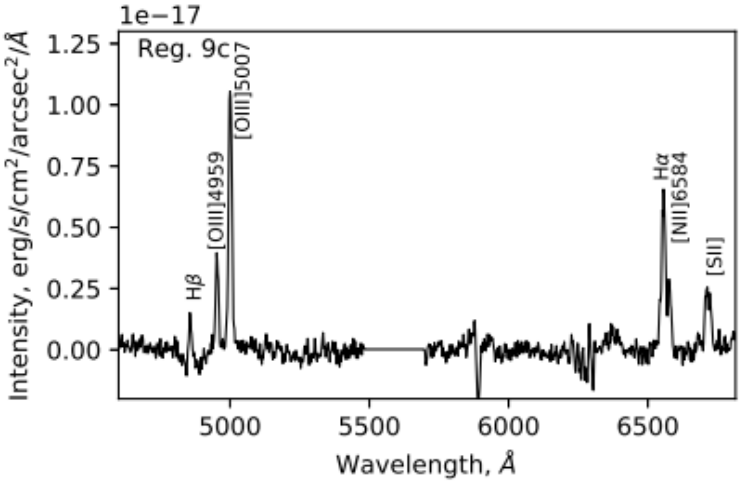
-[SII]/Hα 0.7-1.2

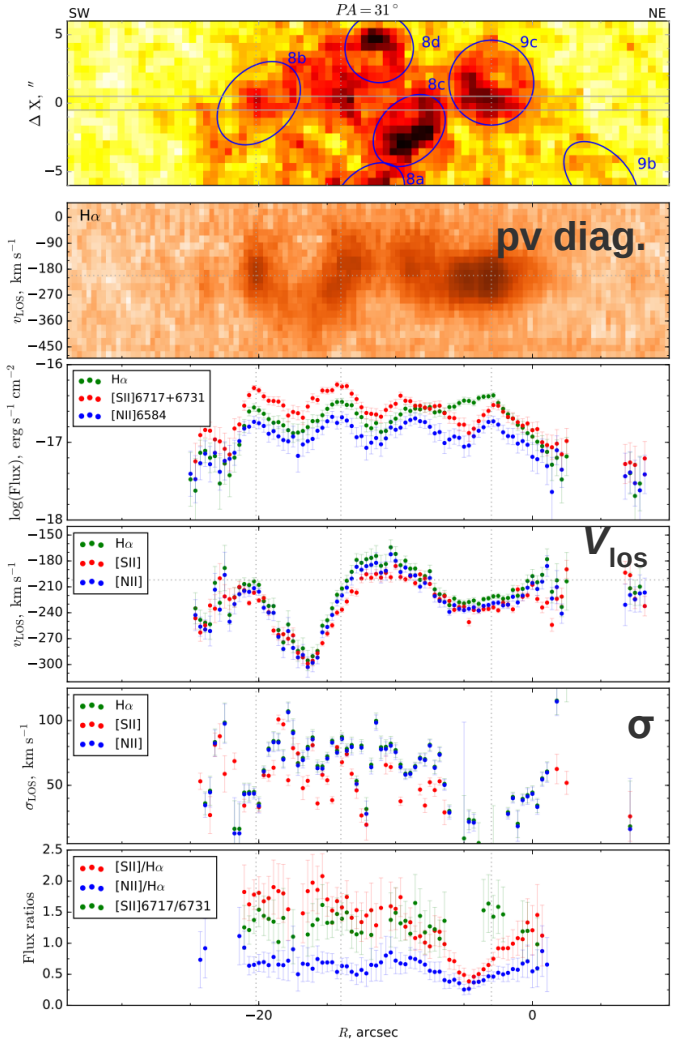
-diameter 50 pc

-expansion velocity ~30 km

-age ~3.5-6 x10^5 yrs







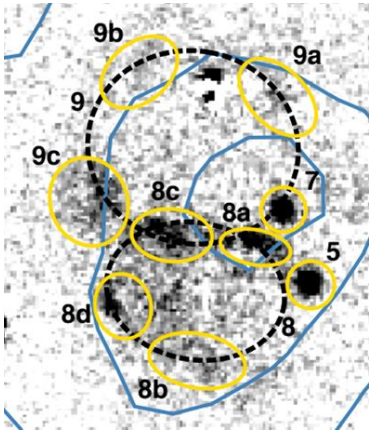
Object 7

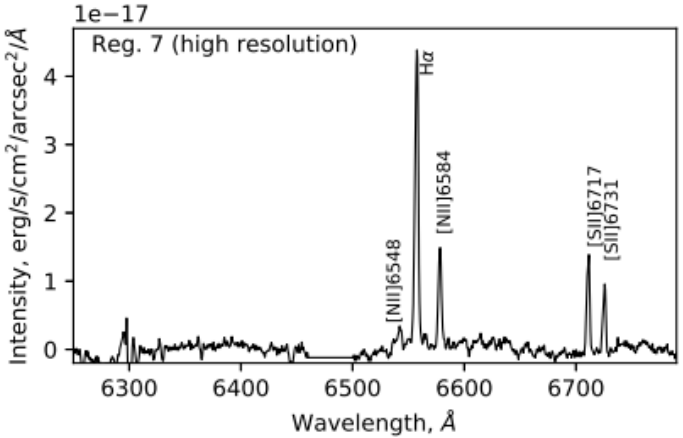
-[SII]/Hα ~0.5

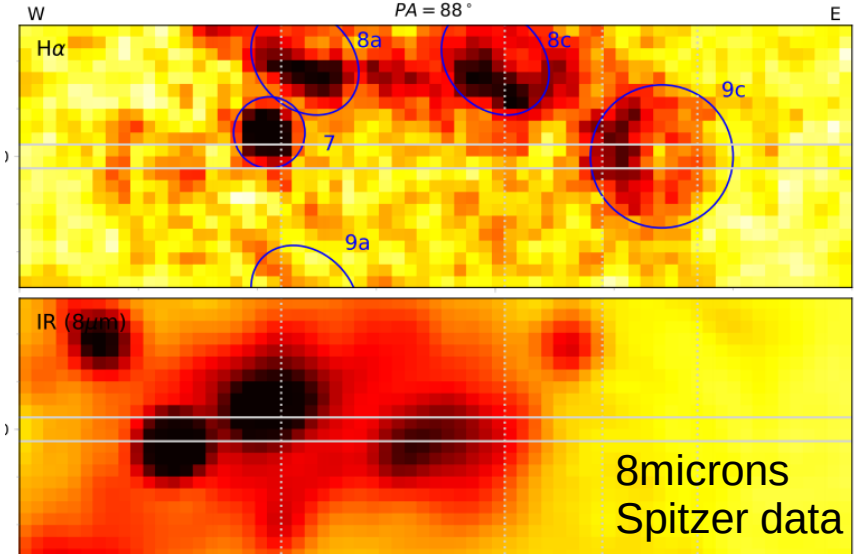
-diameter <6 pc

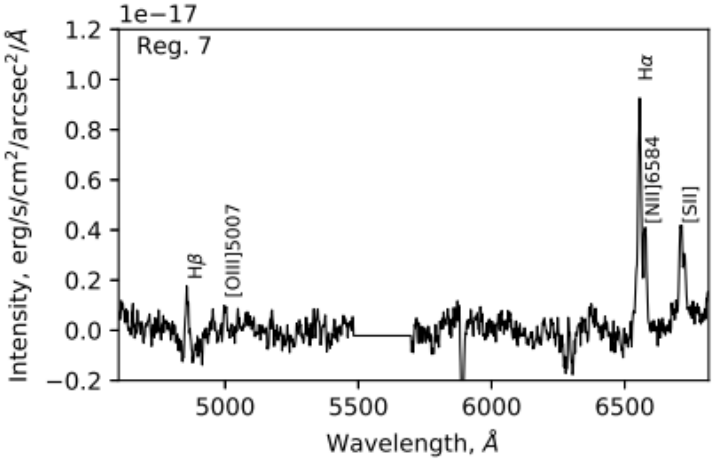
-**faint [OIII] lines!!**

-**no bulk velocity**

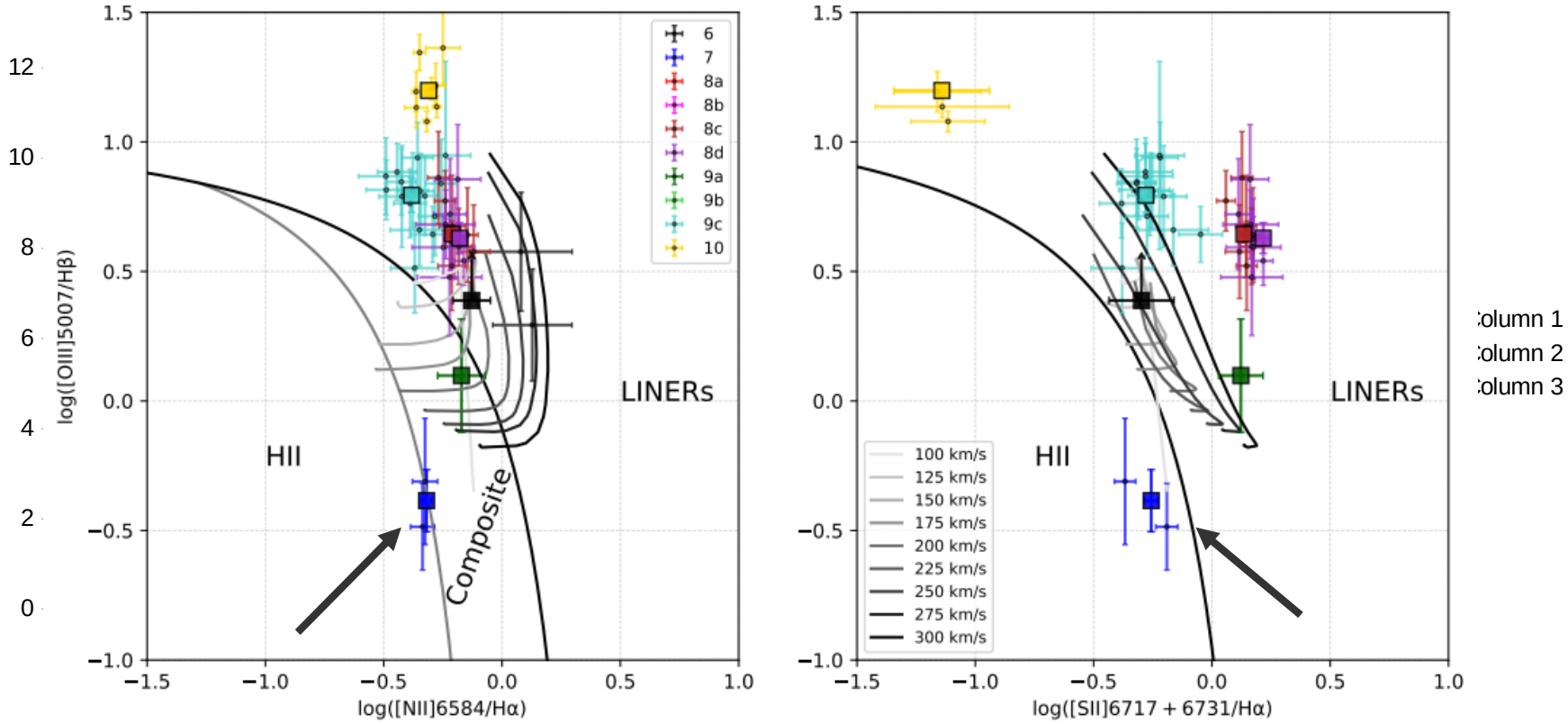








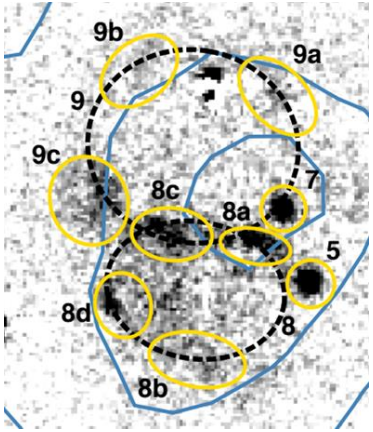
Object's 7 position on BPT

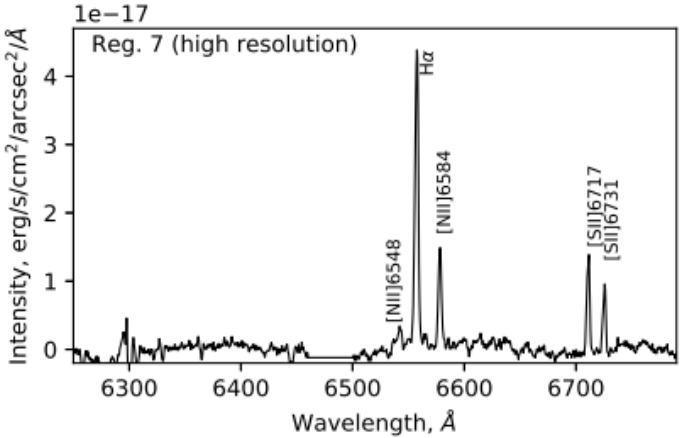


:olumn 1
:olumn 2
:olumn 3

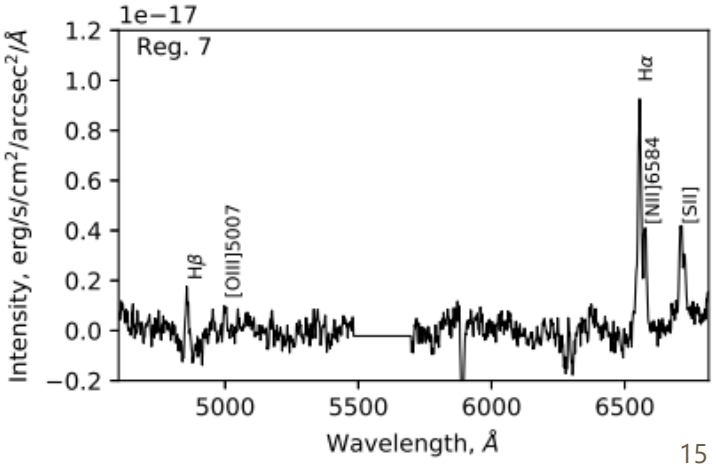
Object 7- ?

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



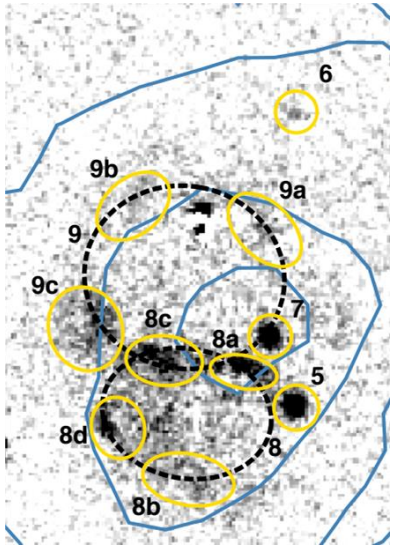


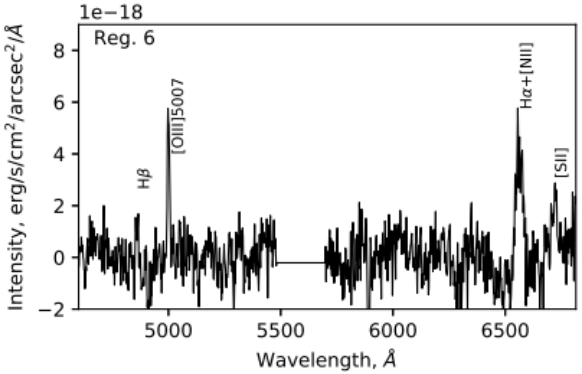
Two possibilities:
(i) a compact **H II region** with overlaid shock-ionized gas from objects 8 or 9 (or both)
(ii) a **part of the old evolved SNR** – of object 8 or 9, encountering an ISM condensation

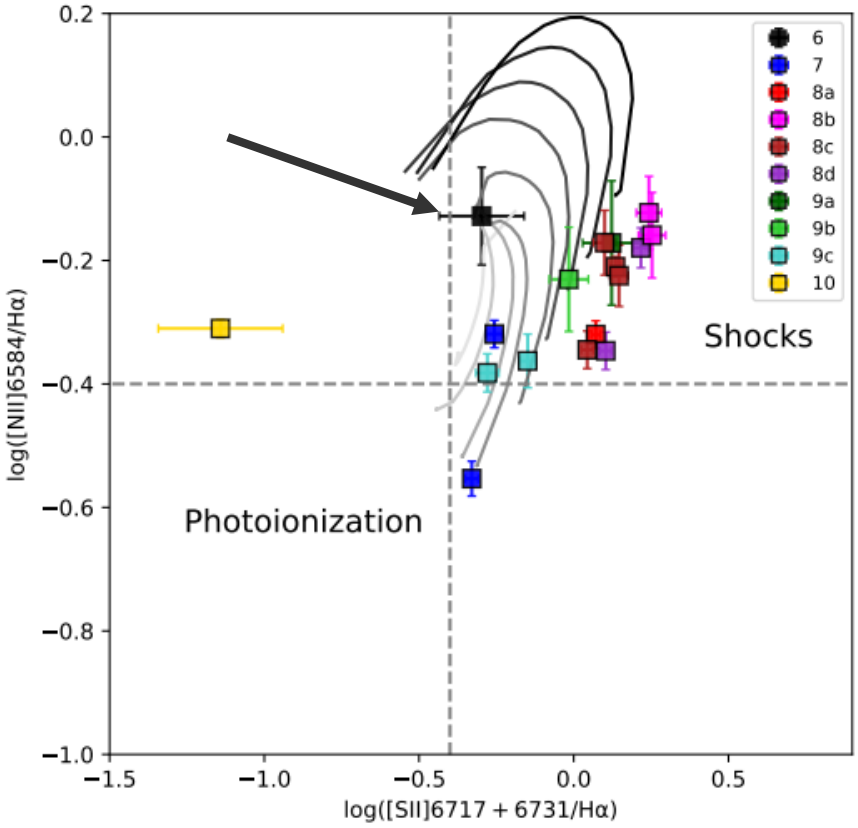


Object 6 - ?

-[SII]/Hα ~1.0
-[NII]/Hα ~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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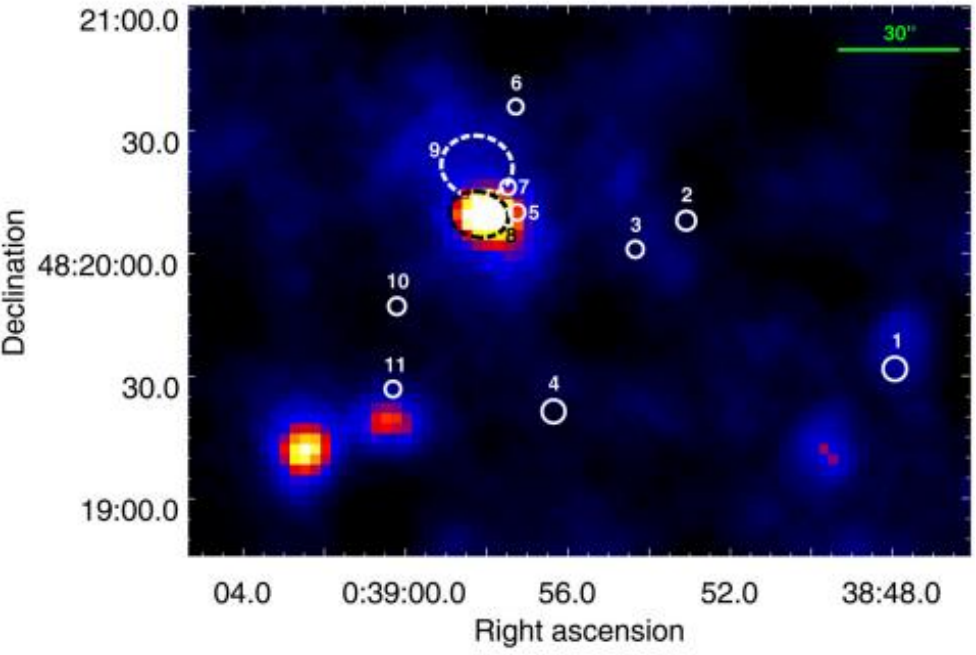

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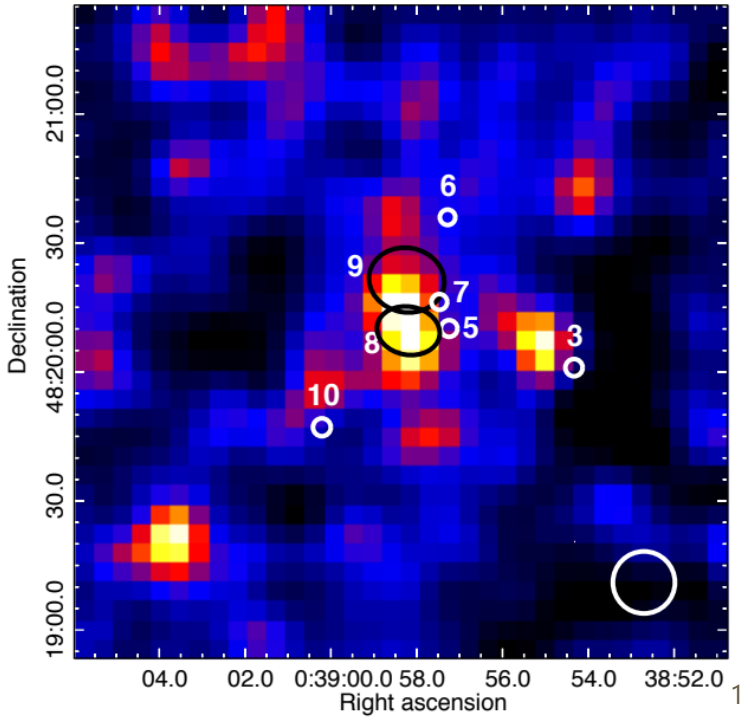

Proposal sent to Chandra

- 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

- Hα 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 ~50 – 90 km s^{-1})
- Estimated electron density **~200 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!