Nature of central emission nebulae in the dwarf galaxy NGC 185

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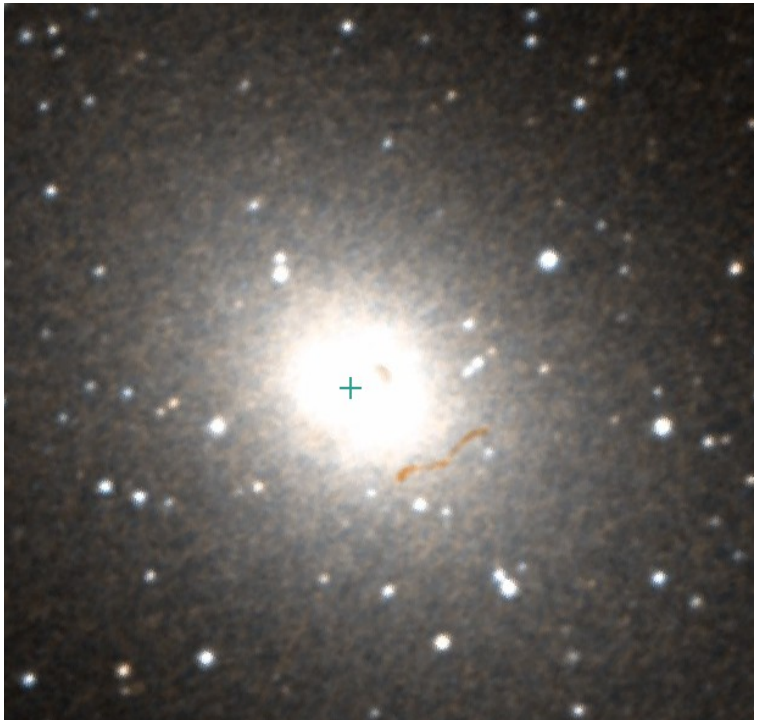
Motivation

- Search for extragalactic SNRs
- Advantages: all objects at same distance, low Galactic extinction
- Disadvantages: resolution limits
- Optical SNRs: [SII]/Hα > 0.4
- Confirmation of SNR detection: spectroscopy, non-thermal radio source, soft X-ray source...

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



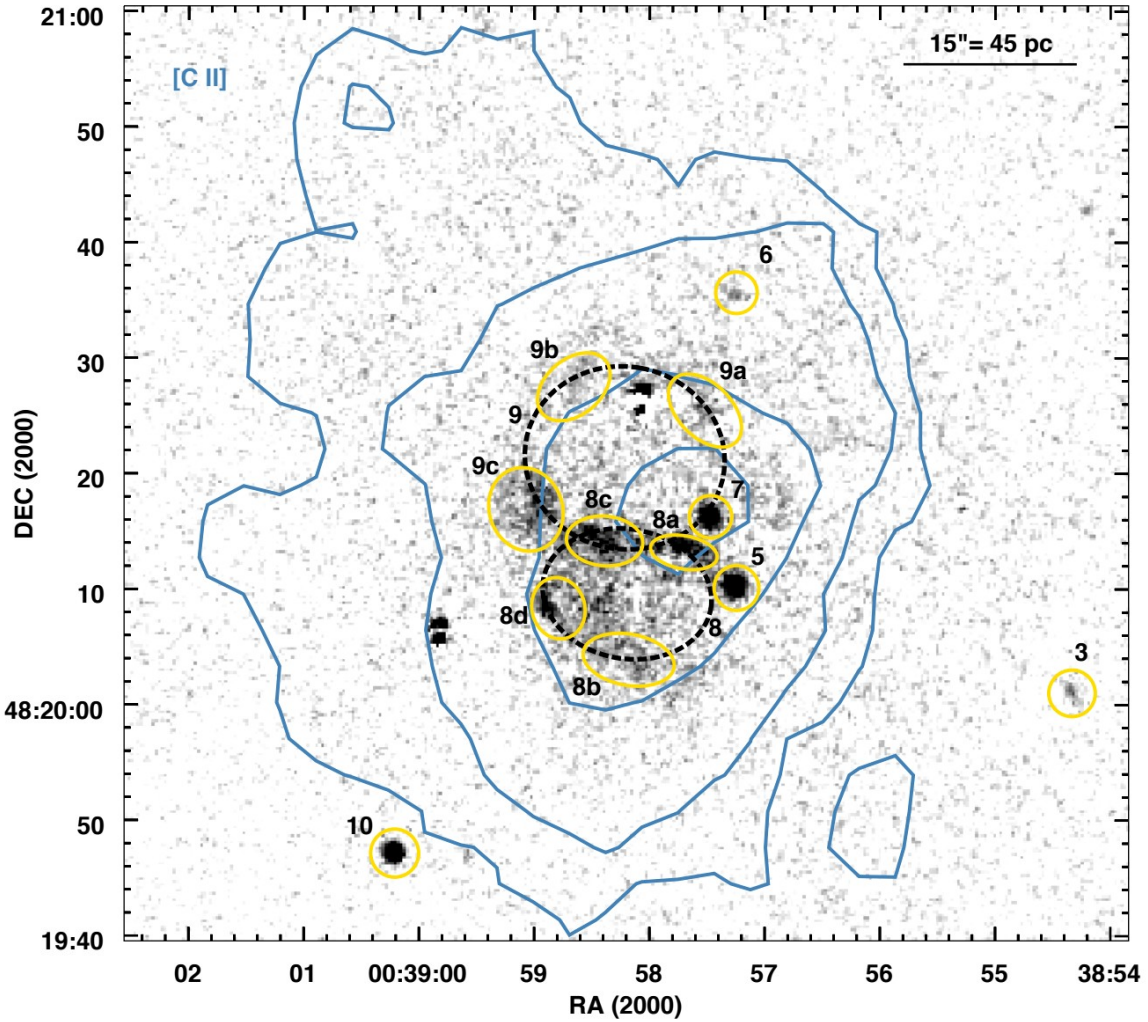
DSS

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**

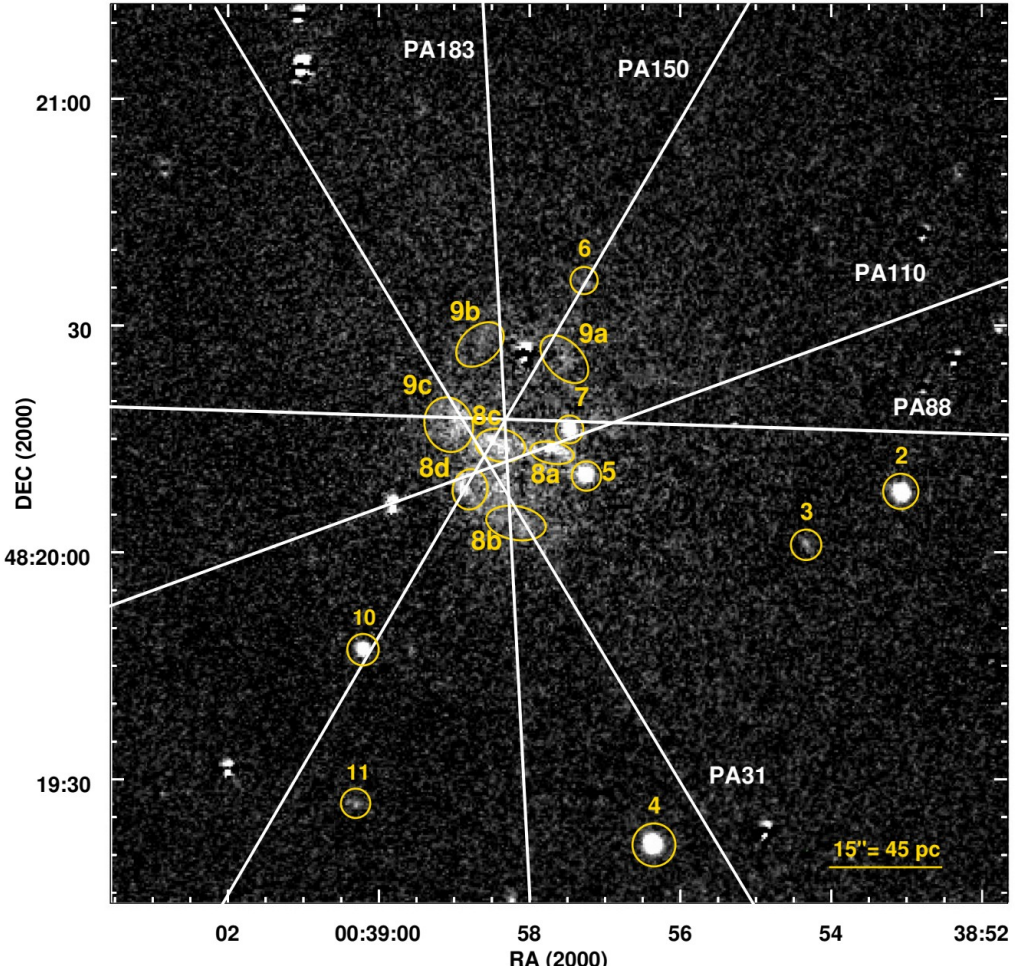
Optical photometry

- **2m telescope** at National Astronomical Observatory **Rozhen**, Bulgaria
- Hα, [SII] and cont. narrow filters (3 nm FWHM)
- 80 mins exposure
- 6 PNe (1, 2, 3, 4, 5, 10)
- 1 symbiotic star
- **1 HII region!!** (7)
- **2 SNR candidates** (8, 9)
- 1 PN with shocks? (6)



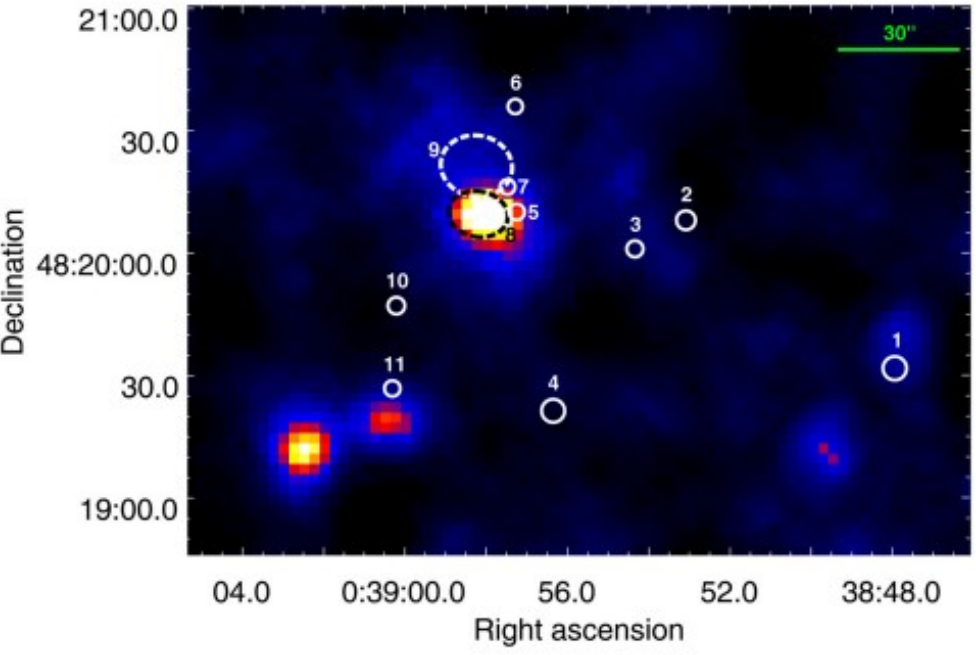
Optical spectroscopy

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

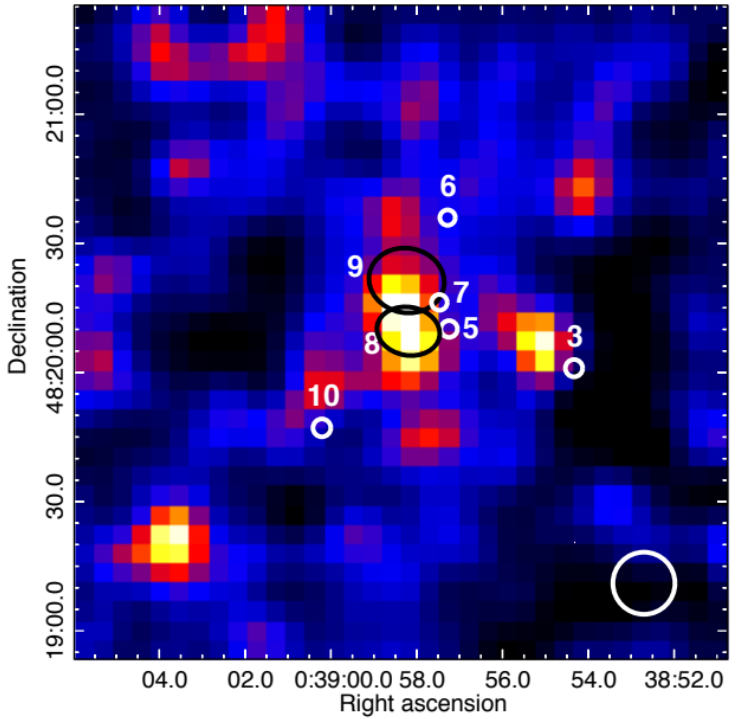


Archival data – XMM-Newton & VLA

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

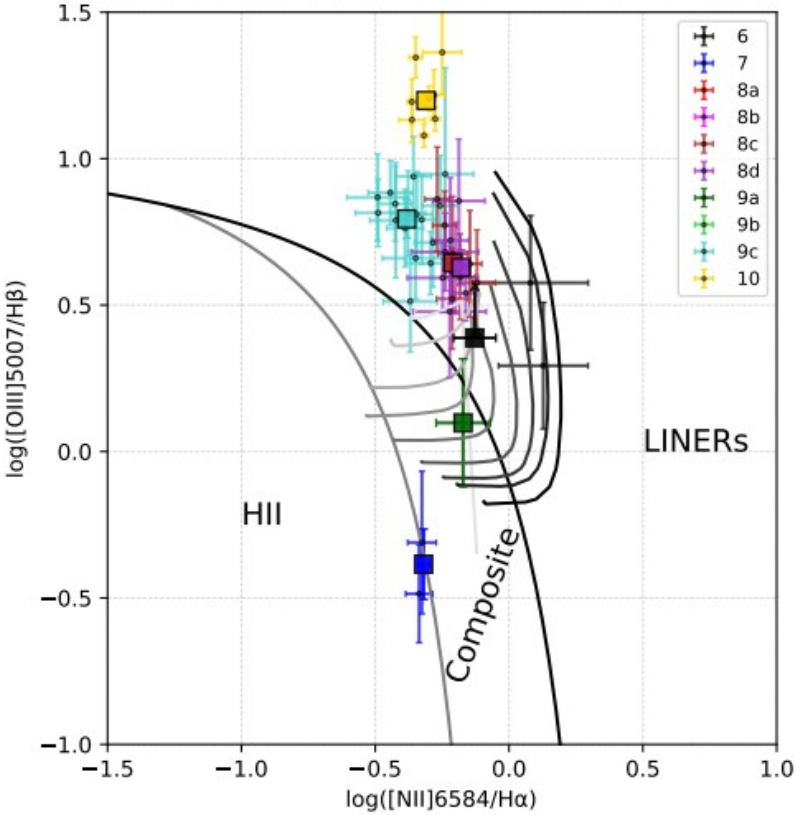


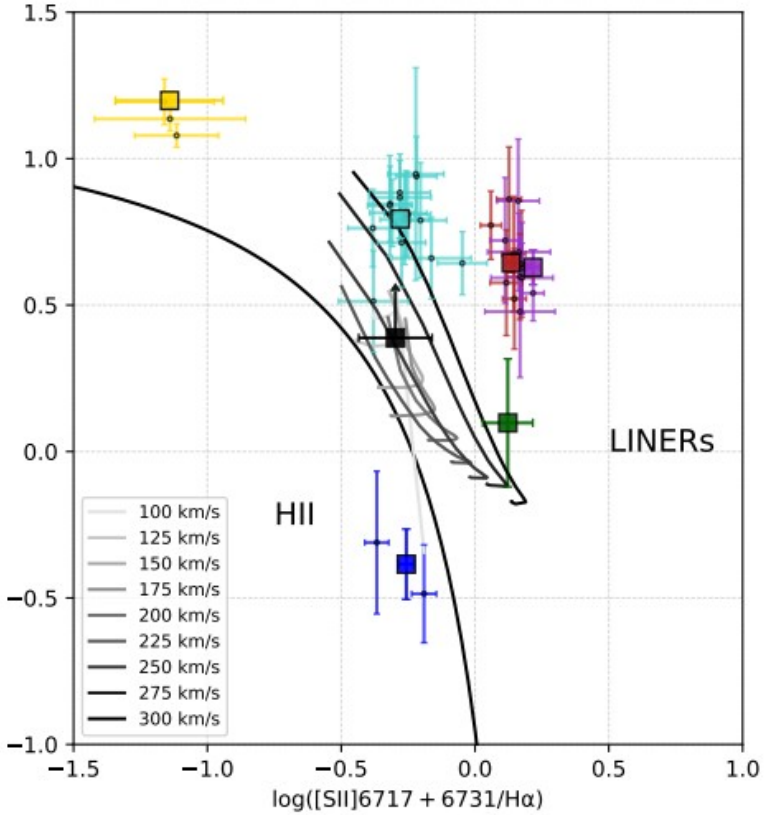
-beam size 14.4”, 1.4 GHz
- indication of the diffuse radio continuum emission
-flux of SNR 8 ~1.4 mJy



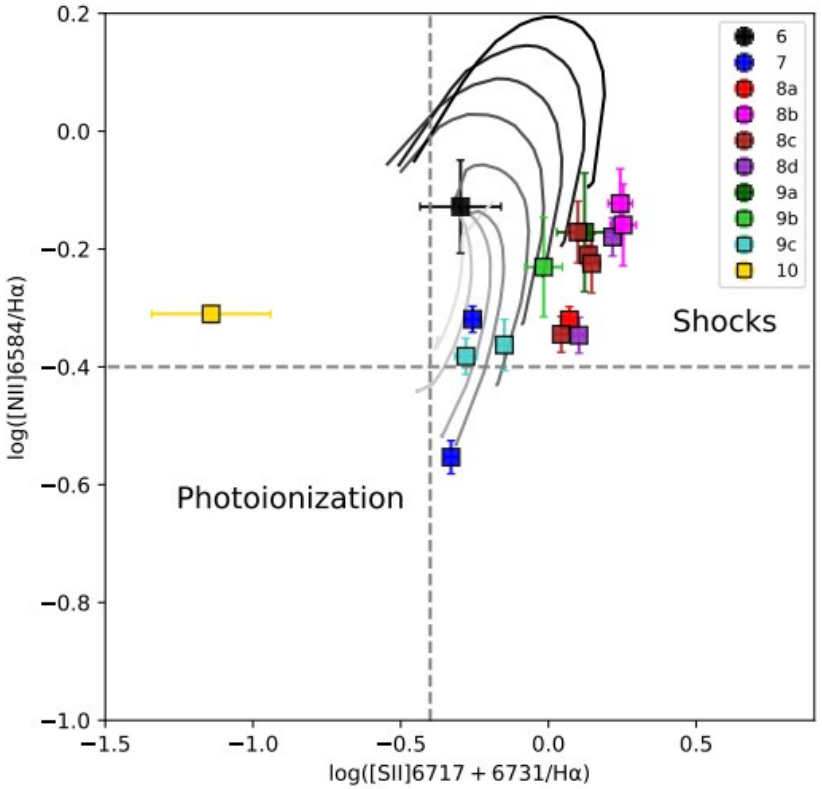
BPT diagrams

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



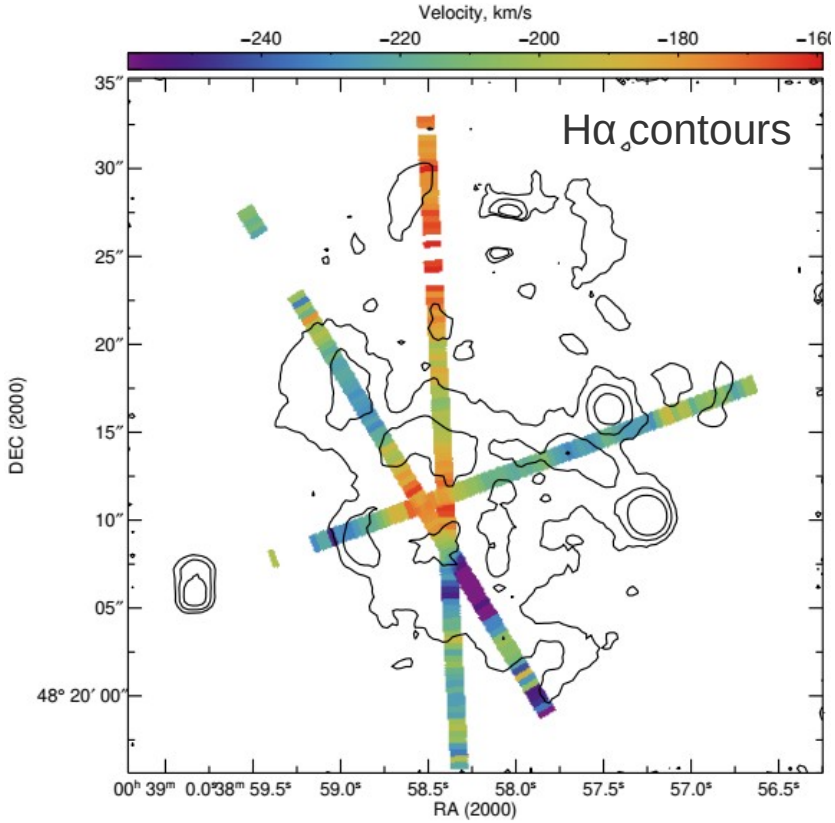


Diagnostic diagram

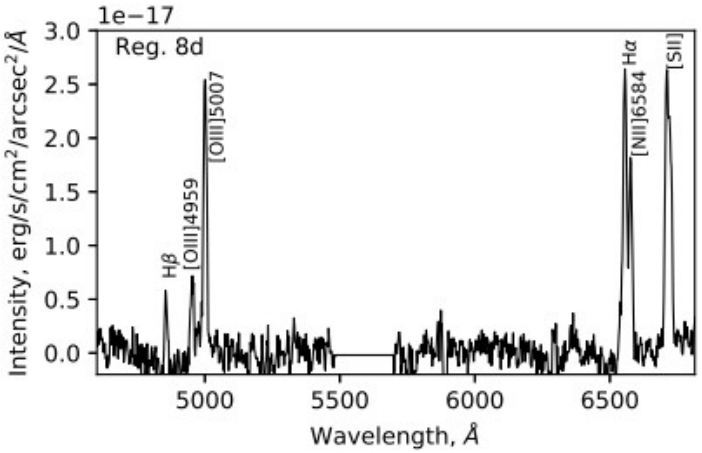


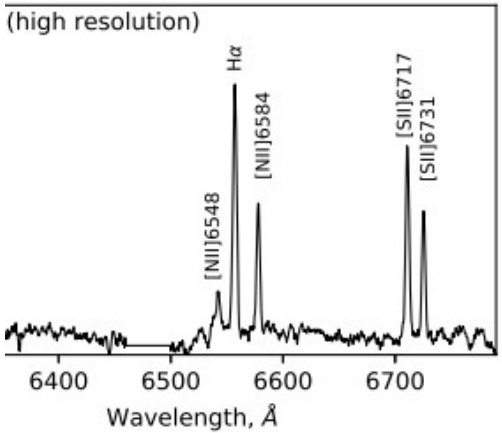
LOS velocity map

$V_{NGC185} = -203.8$ km/s

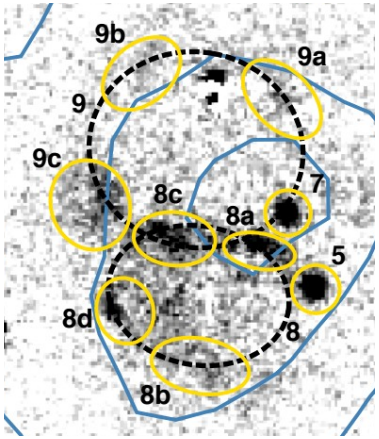


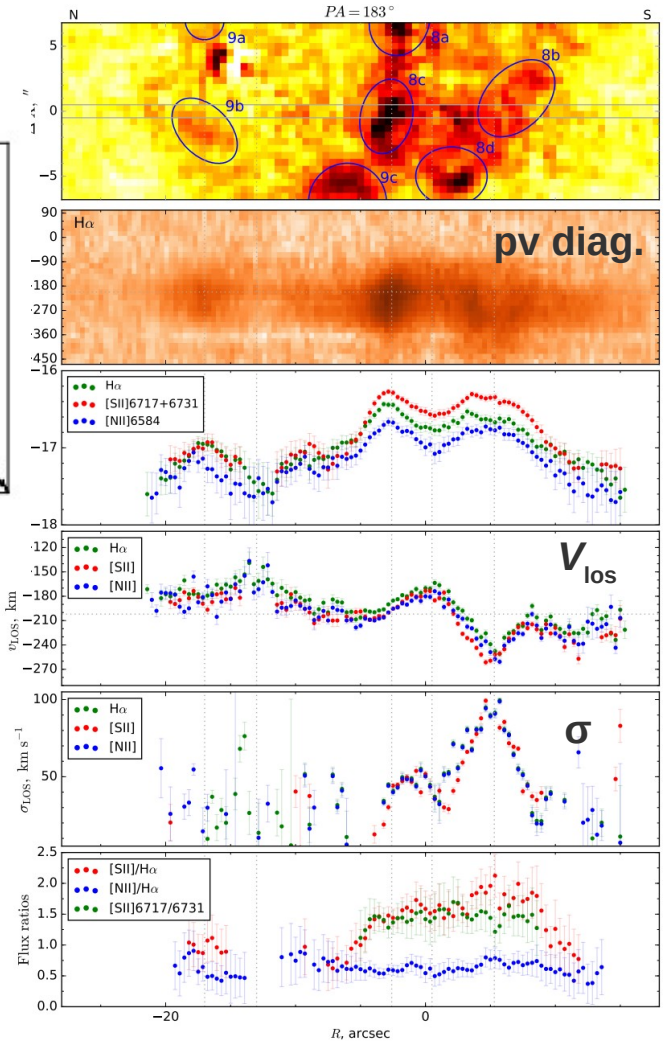
Obiect 8 - SNR





-[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, being faint in radio-domain?





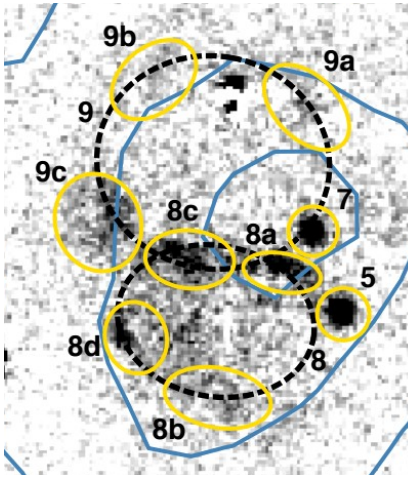
Object 9 - SNR

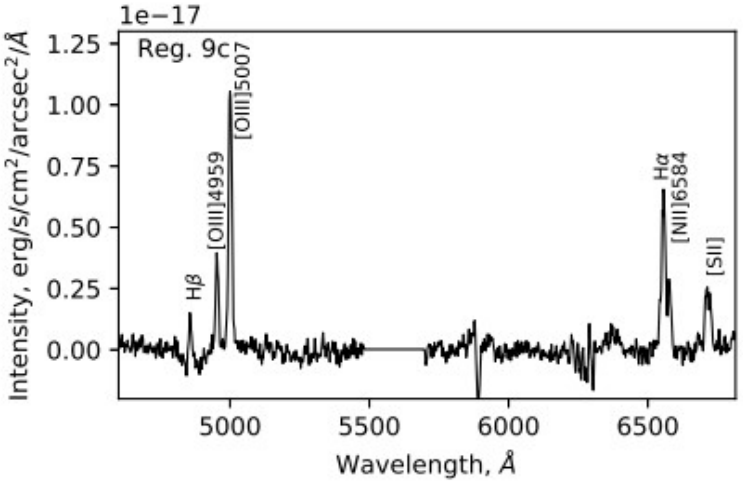
-[SII]/Hα 0.7-1.2

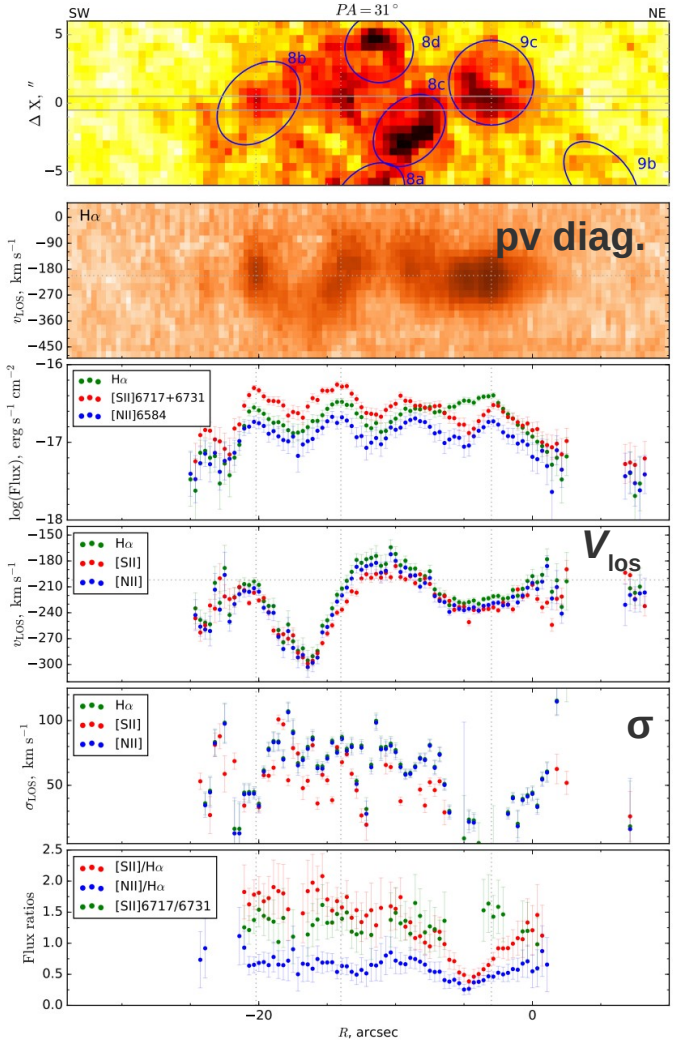
-diameter 50 pc

-expansion velocity ~30 km/s

-age ~3.5-6 x10^5 yrs

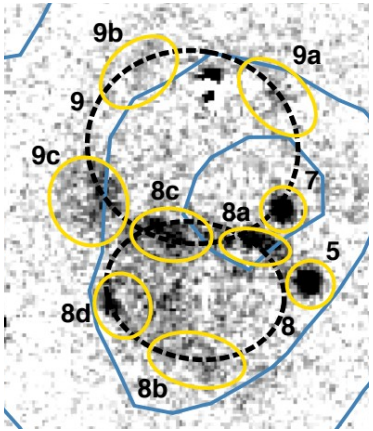


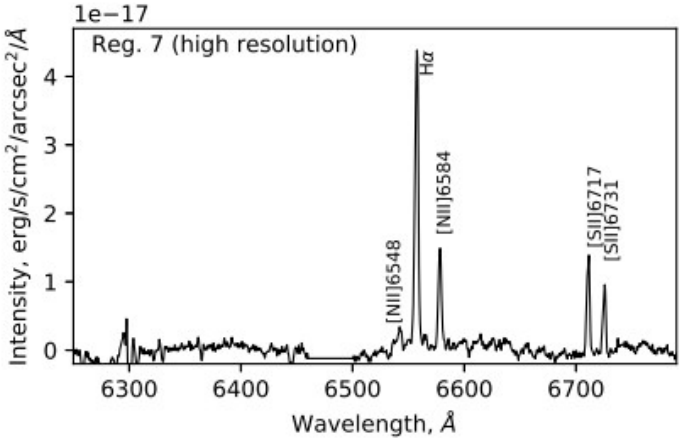


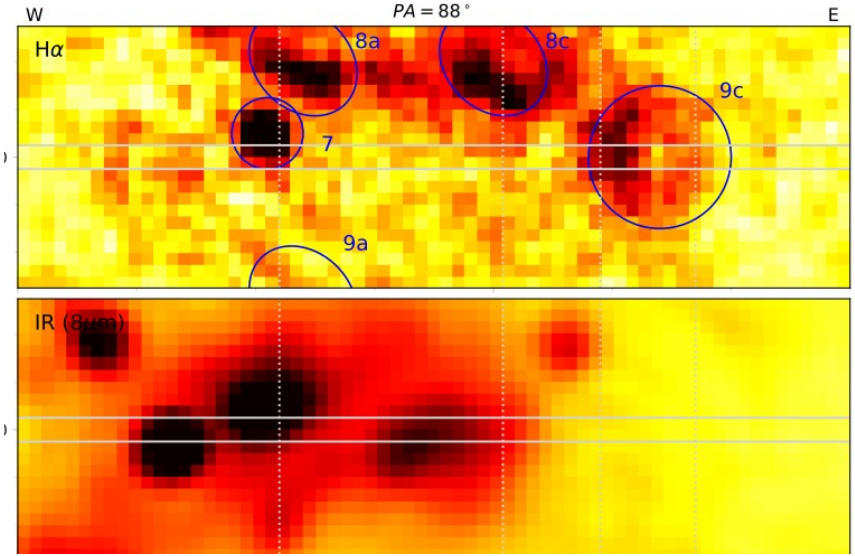


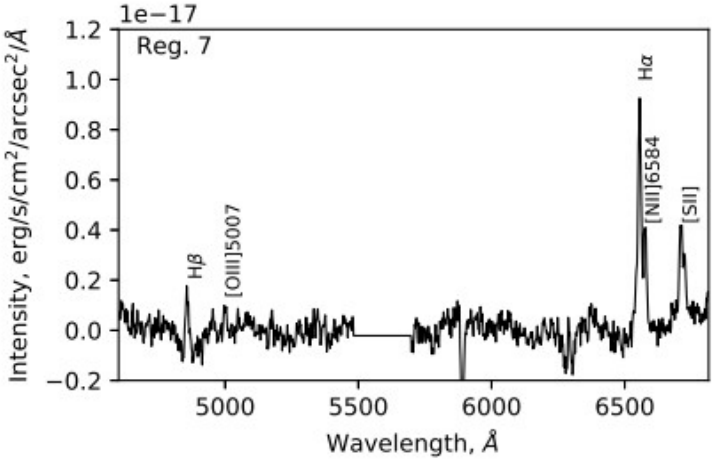
Object 7

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

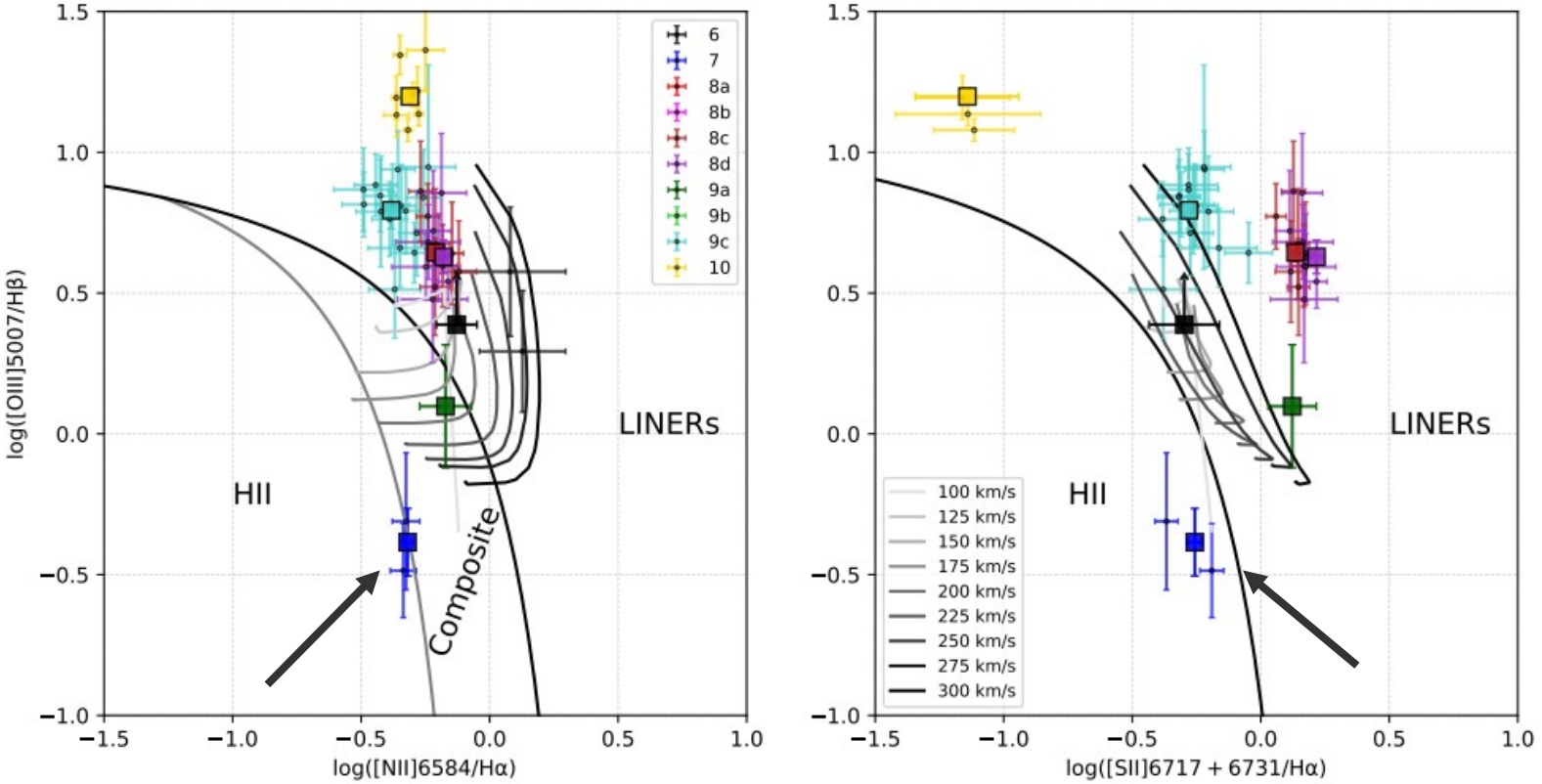






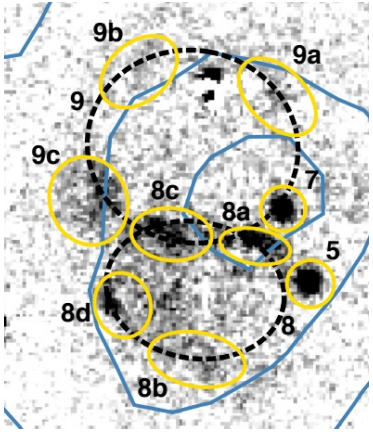


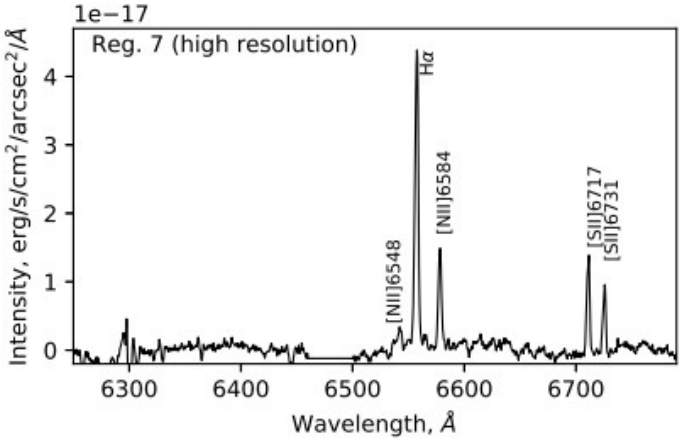
Object’s 7 position on BPT



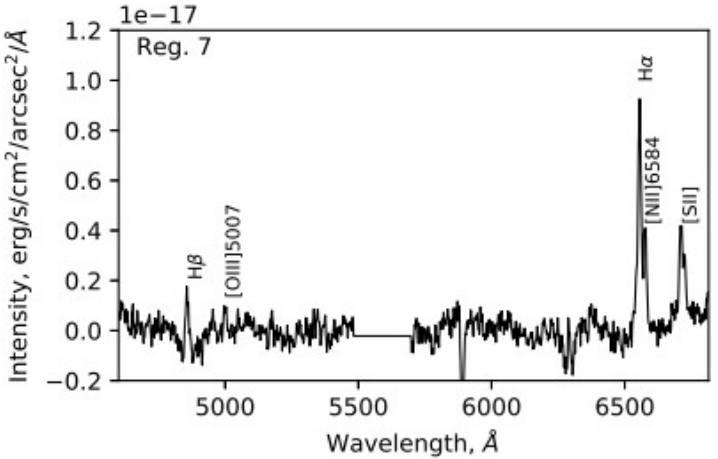
Object 7- ?

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



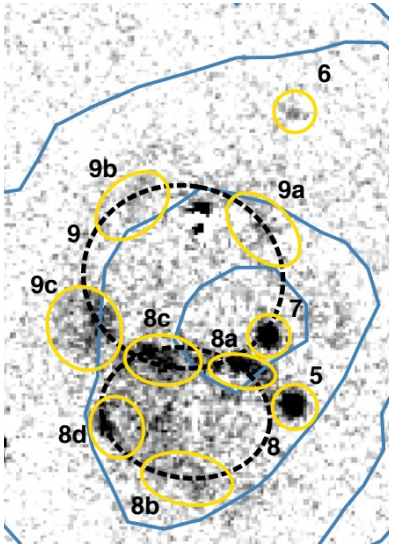


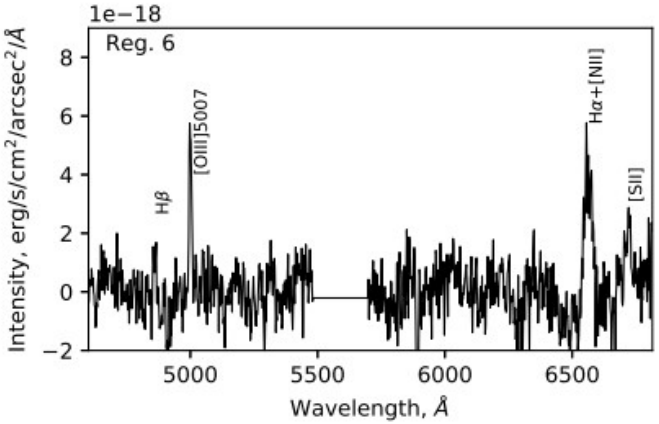
Two possibilities:
- (i) a compact **HII region** with overlaped shock-ionize gas from objects 8 or 9 (or both),
-(ii) a **part of the old evolved SNR** - object 8 or 9, encountering an ISM condensation

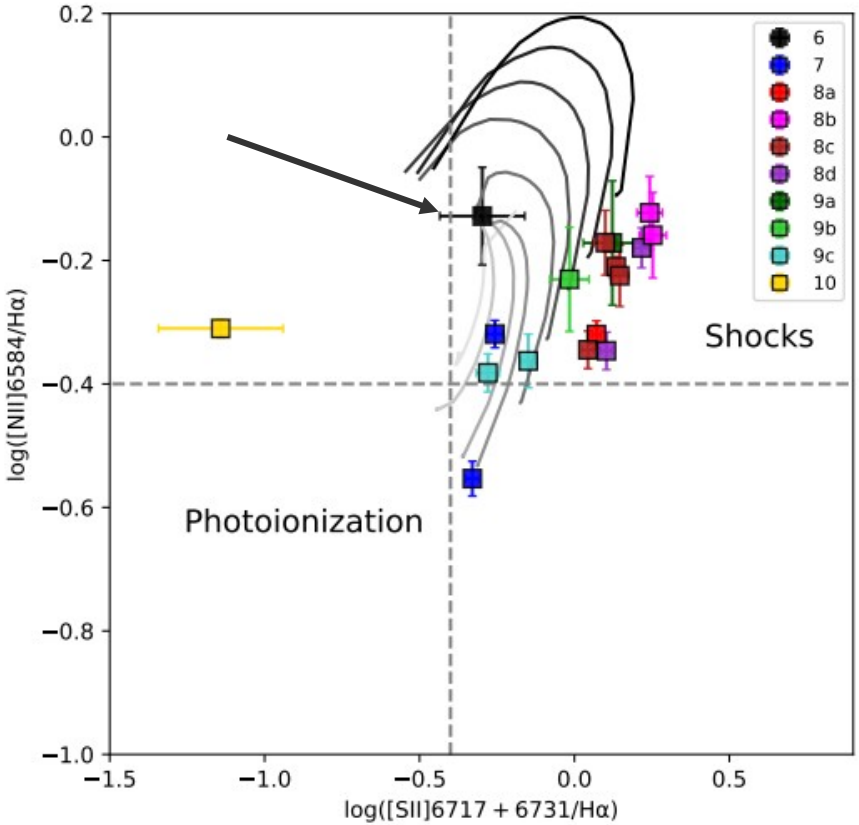


Object 6 - ?

-[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?**







Summary

- Hα and [SII] 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 **HII region**)
- Spectroscopic observations confirmed 2 SNRs and HII region
- High-resolution spectra showed complex kinematics of the extended emission with filaments of high expansion velocities (~50 – 90 km s^{-1})
- The estimated electron density of emission nebulae is **~200 cm^{-3},** which is somewhat higher than expected in elliptical galaxy
- Archival XMM-Newton observations indicate the presence of an extended source in projection of our SNR candidate 8
- Archival VLA radio data indicate weak and unresolved, diffuse radio continuum emission in the center of NGC 185

Next steps

- VLA observations last week (DDT proposal) at 1.4 GHz in A configuration (1-2” resolution)
- X-ray observations: *Chandra* or *e-Rosita*

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Thank you for your attention!