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)
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 abundances
Diagnostic diagram

Velocity map

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

Shocks

Photoionization

Hα contours
Object 8 - SNR

- $[\text{SII}]/\text{H}\alpha \sim 1.5-2.0$
- diameter 45 pc
- expansion velocity $\sim 90$ km/s
- $n_e \sim 200$ cm$^{-3}$
- age $\sim 1 \times 10^5$ 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/s
-age ~3.5-6 x10^5 yrs
Object 7

- $[\text{S}II]/\text{H}$α $\sim 0.5$
- diameter $< 6$ pc
- faint $[\text{O}III]$ 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 **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?
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
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 $\sim 50 – 90 \text{ km s}^{-1}$)

- 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

- VLA radio data: weak and unresolved, diffuse radio continuum emission in the center of NGC 185

- ...and we need more data

THANK YOU!