Detection of extragalactic Supernova Remnants

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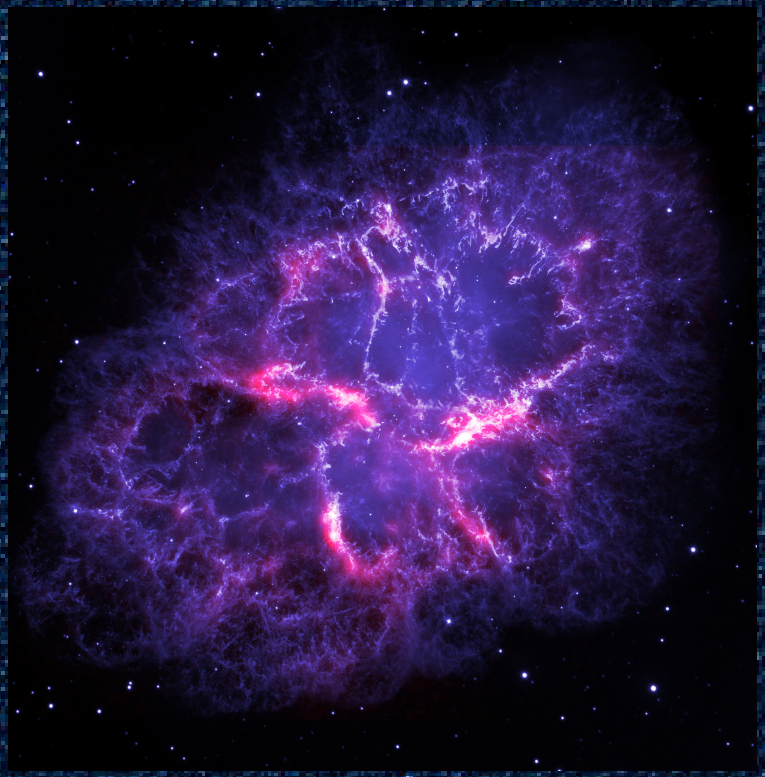
FORTH Foundation for Research & Technology - Hellas

erc European Research Council

Supernova Remnants



Crab Nebula

What is a supernova remnant?

- White Dwarf accreting material from a donor companion (Supernova Type Ia)
- Core-collapse of massive stars ($> 8\ M_{\odot}$) (Supenova Type II)

→ Propagation of shock wave

→ Interaction with the ejecta and circumstellar medium

→ Supernova Remnant (SNR)

Evolution of SNRs

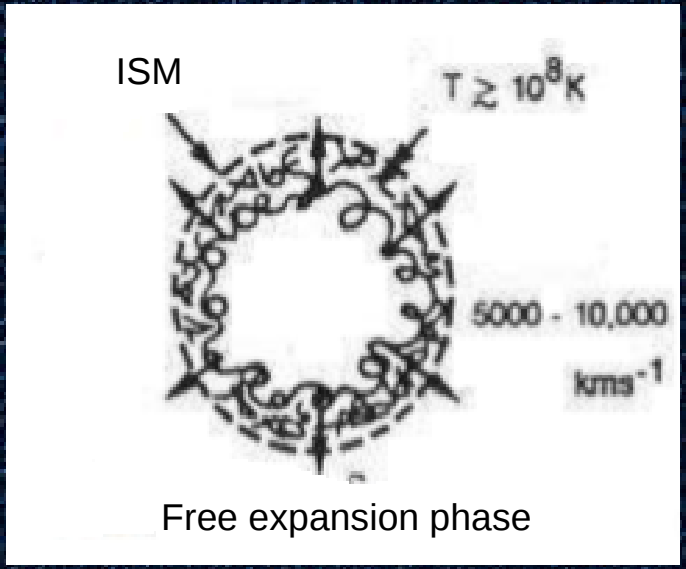
→ *Free expansion phase*

-Mo >> Ms

-Shock wave propagation without resistance

-uo > 10,000 km/s

-100-1000 years

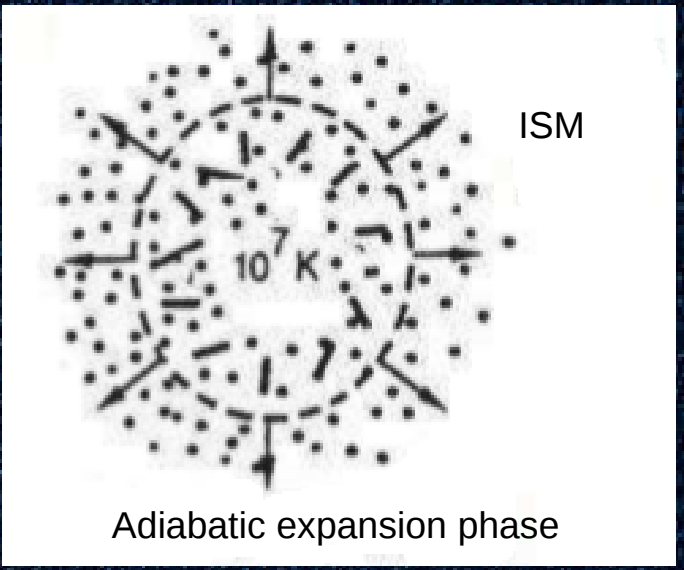


Free expansion phase

Evolution of SNRs

→ *Free expansion phase*
-Mo >> Ms
-Shock wave propagation without resistance
-uo > 10,000 km/s
-100-1000 years

→ *Adiabatic expansion phase*
-Mo < Ms
-Inverse shock wave
-Deceleration of front shock wave
-10,000 years



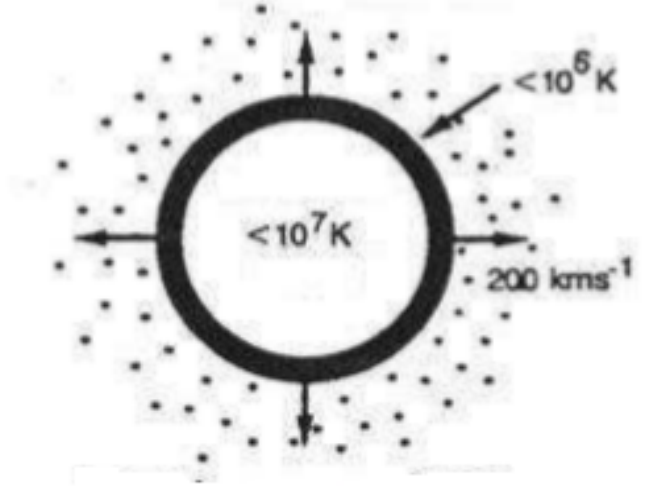
Adiabatic expansion phase

Evolution of SNRs

→ *Free expansion phase*
-Mo >> Ms
-Shock wave propagation without resistance
-uo > 10,000 km/s
-100-1000 years

→ Adiabatic expansion phase
-Mo < Ms
-Inverse shock wave
-Deceleration of front shock wave
-10,000 years

→ Radiative phase
-Mo << Ms
-uo ~200 km/s
-Radiation in the optical
- ~50,000 years



Radiative phase

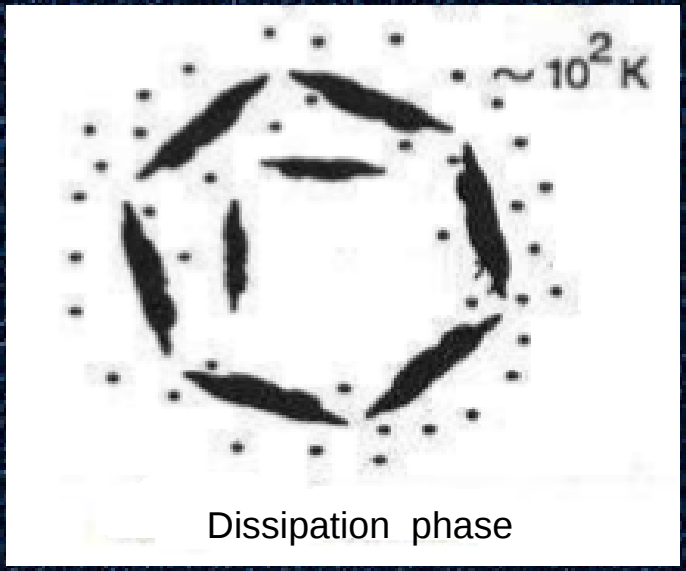
Evolution of SNRs

→ *Free expansion phase*
- *Mo >> Ms*
- *Shock wave propagation without resistance*
- *uo > 10,000 km/s*
- *100-1000 years*

→ Adiabatic expansion phase
- *Mo < Ms*
- *Inverse shock wave*
- *Deceleration of front shock wave*
- *10,000 years*

→ Radiative phase
- *Mo << Ms*
- *uo ~200 km/s*
- *Radiation in the optical*
- *~50,000 years*

→ Dissipation phase
- *Assimilation with ISM → Dissipation*

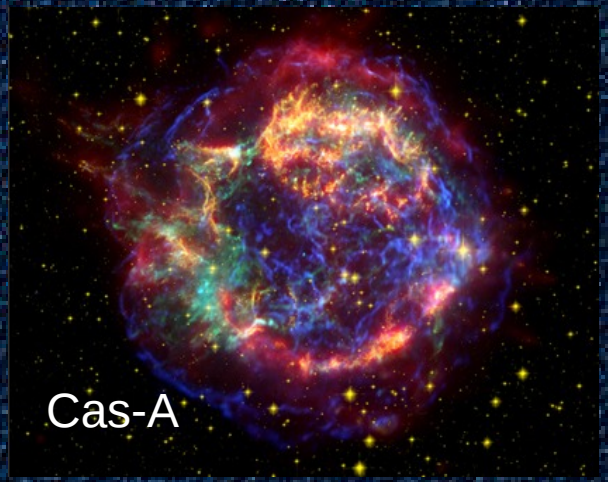


Dissipation phase

Classification of SNRs

Based on morphology

Shell-like



Plerions or Crab-like

Composite

Classification of SNRs
Based on optical spectral properties

→ Balmer-dominated

Intense hydrogen lines

Faint (or absent) forbidden lines

[O III], [S II], [N II]

→ Rich in Oxygen

Intense forbidden lines [O III]

Faint (or absent) hydrogen lines

Importance of studying SNRs

→ Enrich the interstellar medium (ISM) with heavy elements

→ Trigger star formation

→ Yield information about the interplay between ISM, stars and SFR (density, chemical composition, temperature)

→ Information about stellar evolution and star formation rate

Study of extragalactic SNRs

Pros	Cons
Wider sample & larger numbers	Large distances:
Low extinction	-unresolved structures
Known distance	-difficulty in the study of nebular physics

Multiwavelength study of Supernova Remnants in nearby galaxies

In Northern Hemisphere:

(Leonidaki et al. 2010, Leonidaki et al. 2013)

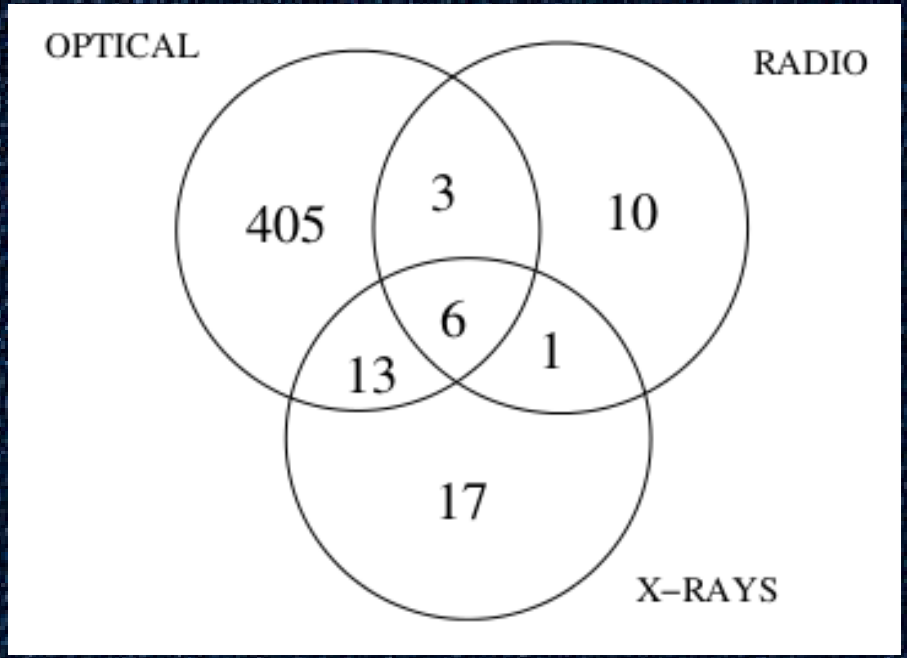
NGC 2403, NGC 3077, NGC 4214,

NGC 4395, NGC 4449, NGC 5204

In X-rays: 37 detected SNRs

In the optical:

67 spectroscopically confirmed SNRs (out of 95 photometrically detected SNRs



Leonidaki et al. 2013

Subject of the study

Detection of SNRs in nearby galaxies

Galaxy	RA	DEC	Distance (Mpc)	Dimensions (arcmin)
NGC 45	00:14:03.99	-23:10:55.50	6.8	8.5×5.9
NGC 55	00:14:53.60	-39:11:47.90	2.0	32.4×5.6
NGC 1313	03:18:16.05	-66:29:53.70	4.1	9.1×6.9
NGC 7793	23:57:49.83	-32:35:27.70	3.7	9.3×6.3

Observations

→ Blanco 4-meter telescope
CTIO (Cerro Tololo Inter-American Observatory), in Chile

→ Mosaic II camera
field of view: 36'x36',
Pixel scale: 0.27 arcsec/pixel

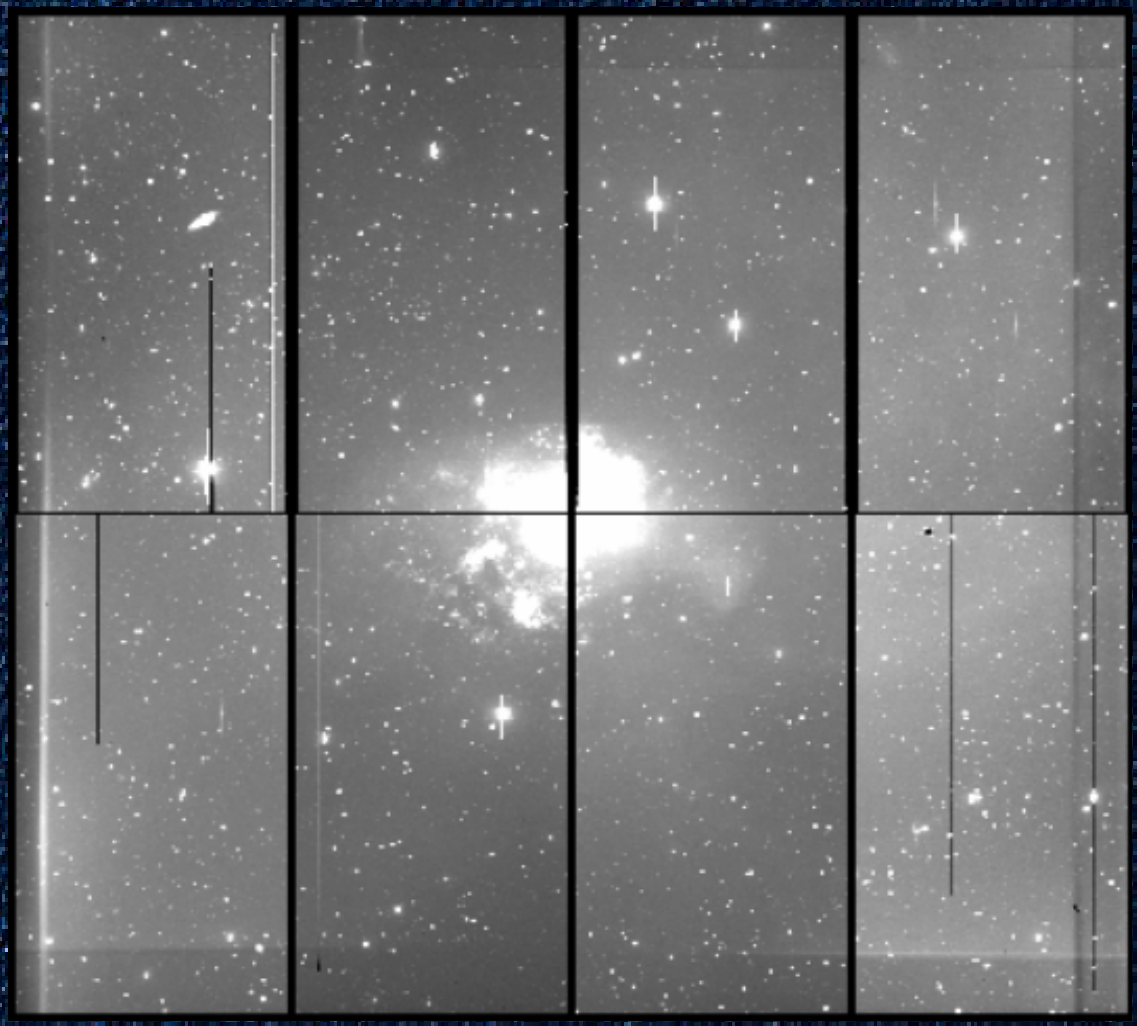
→ Hα (narrow band) 3600 sec
(FWHM: 80Å, CWL: 6563Å)

→ [S II] (narrow band) 7200 sec
(FWHM: 80Å, CWL: 6725Å)

→ R (broadband) 900 sec
(FWHM: 1510Å, CWL: 6440Å)

→ A. Zezas, P. Boumis, I. Leonidaki
November, 2011

Indicative image
(NGC 1313-Ha image)

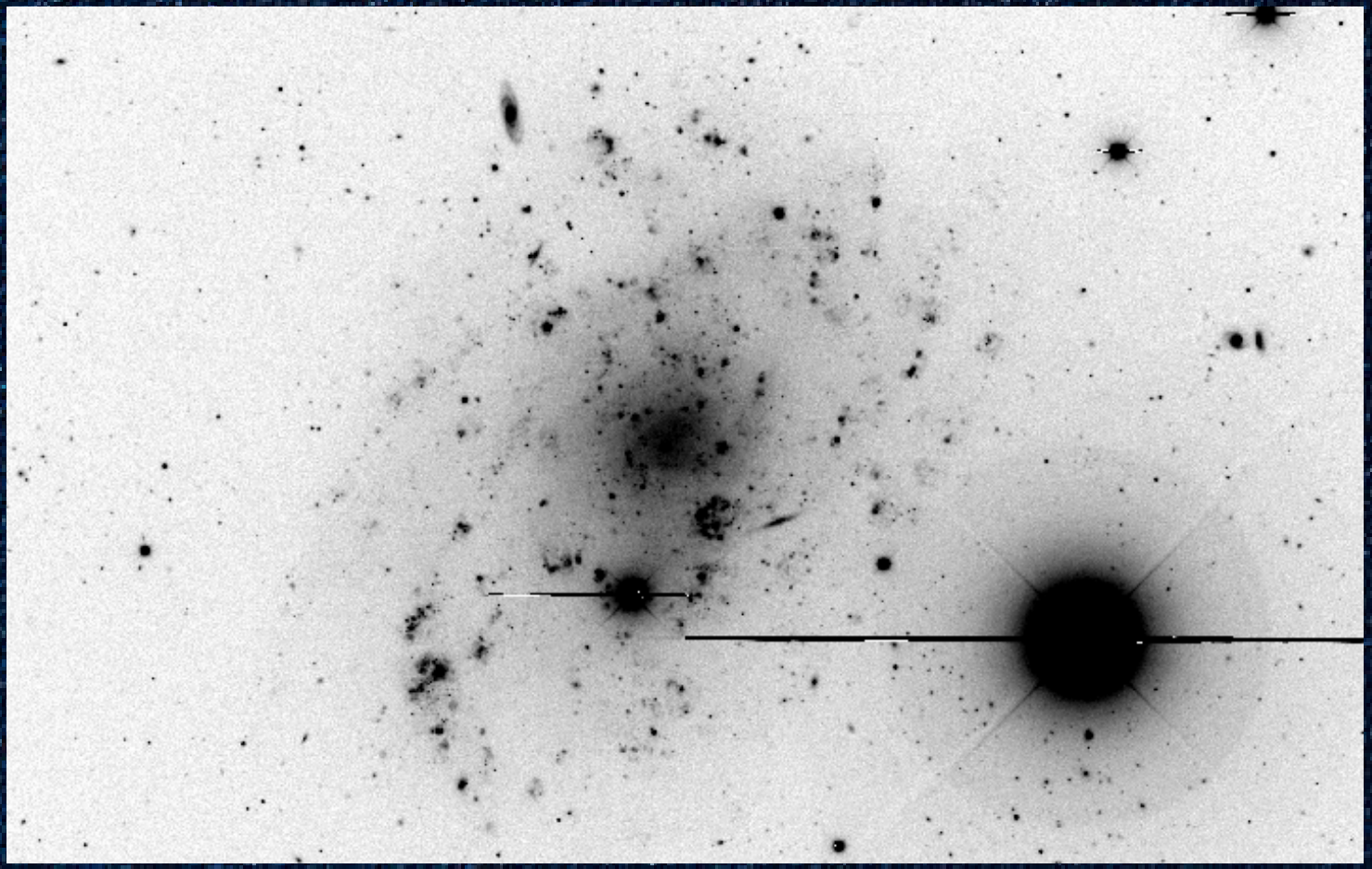


36' x 36'

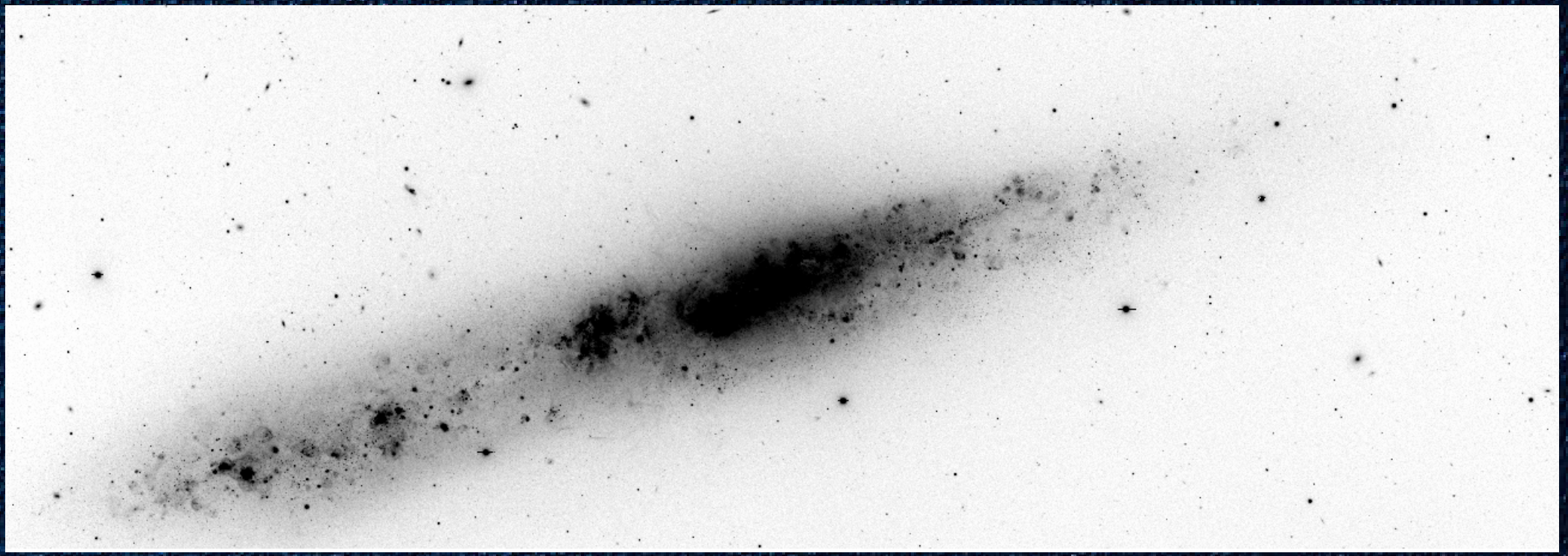
Data reduction

→ Bias, Flat-fielding correction
→ Astrometry (2MASS Catalog)
→ Final images

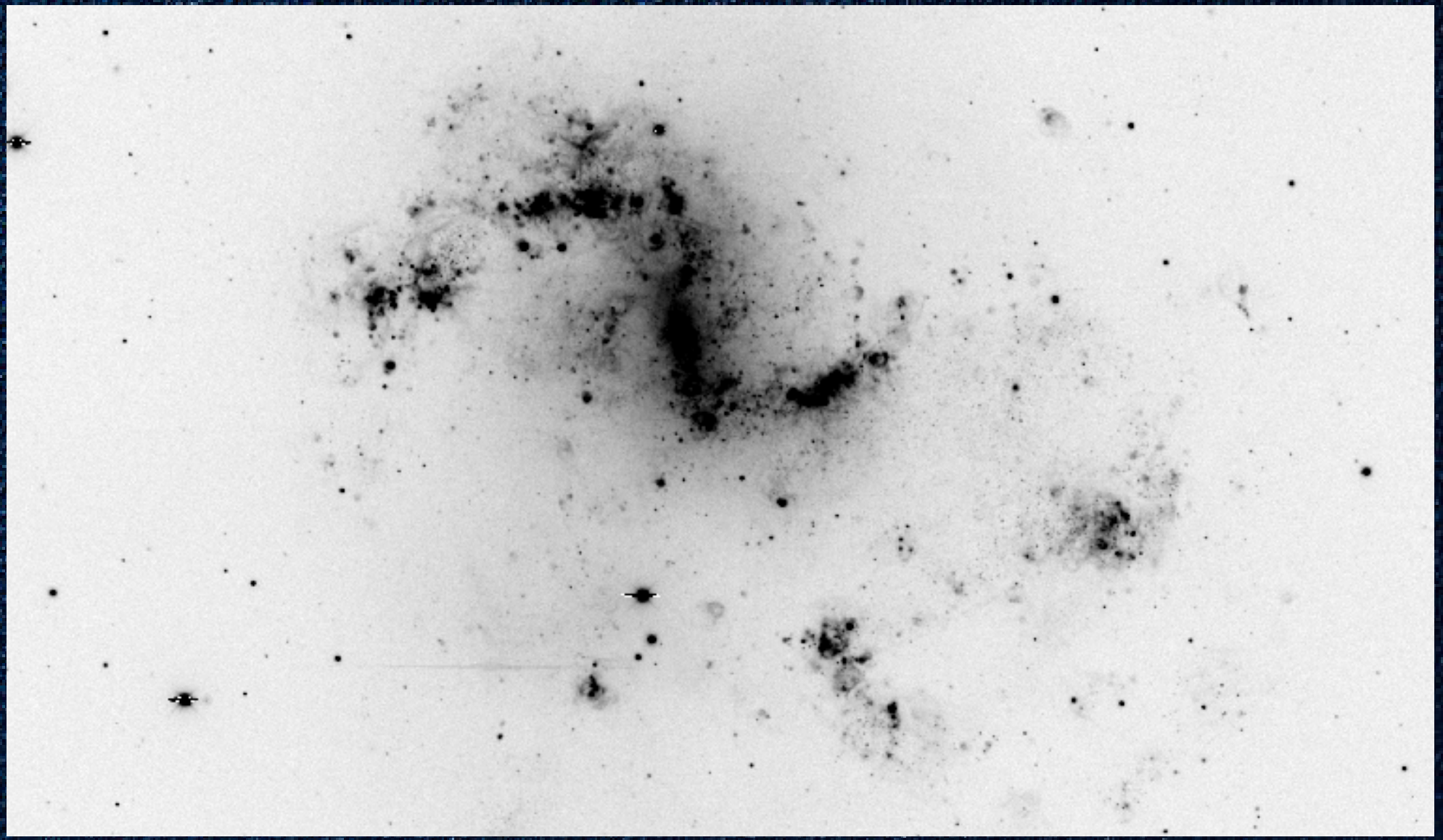
NGC 45



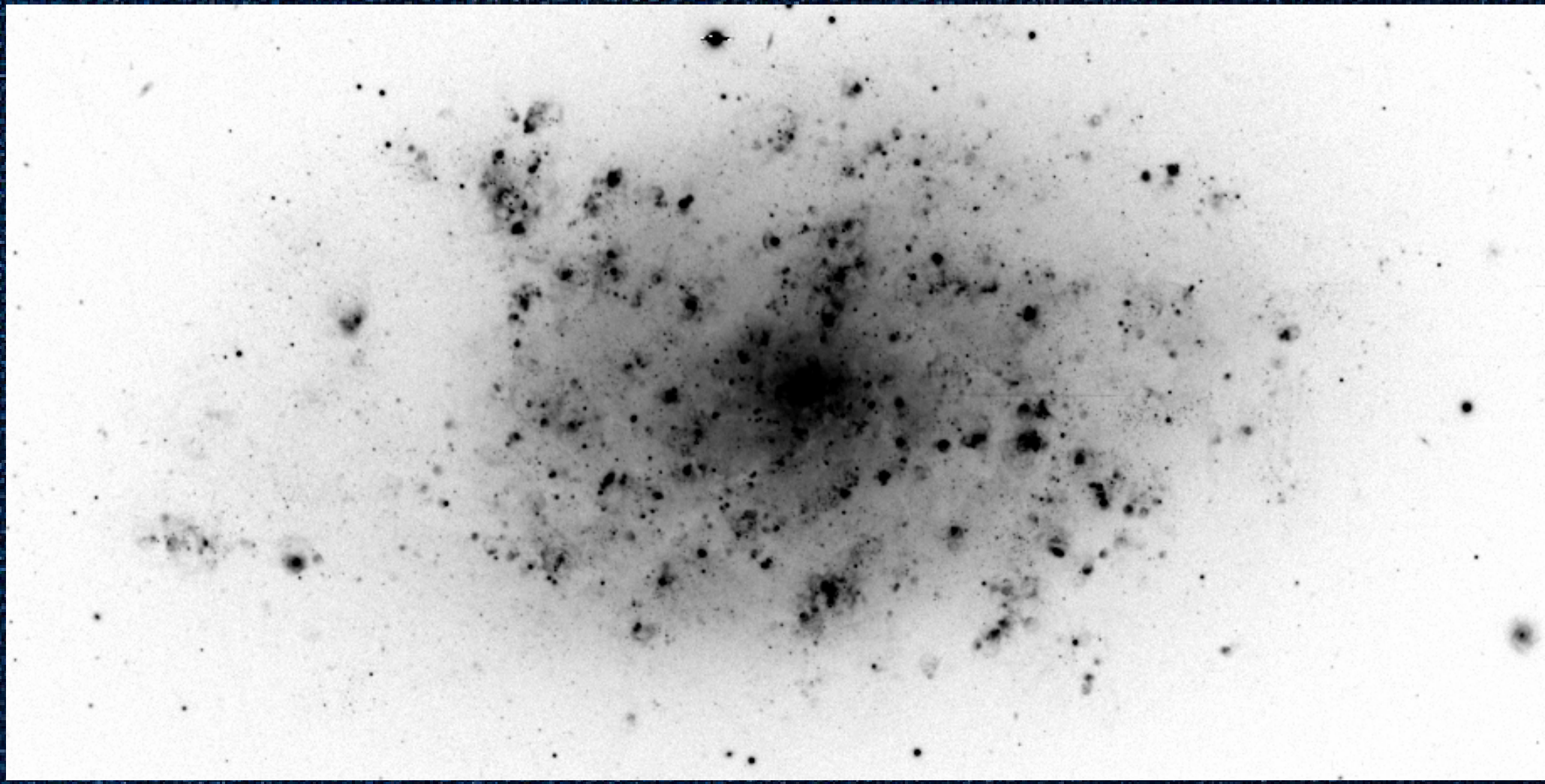
NGC 55



NGC 1313



NGC 7793



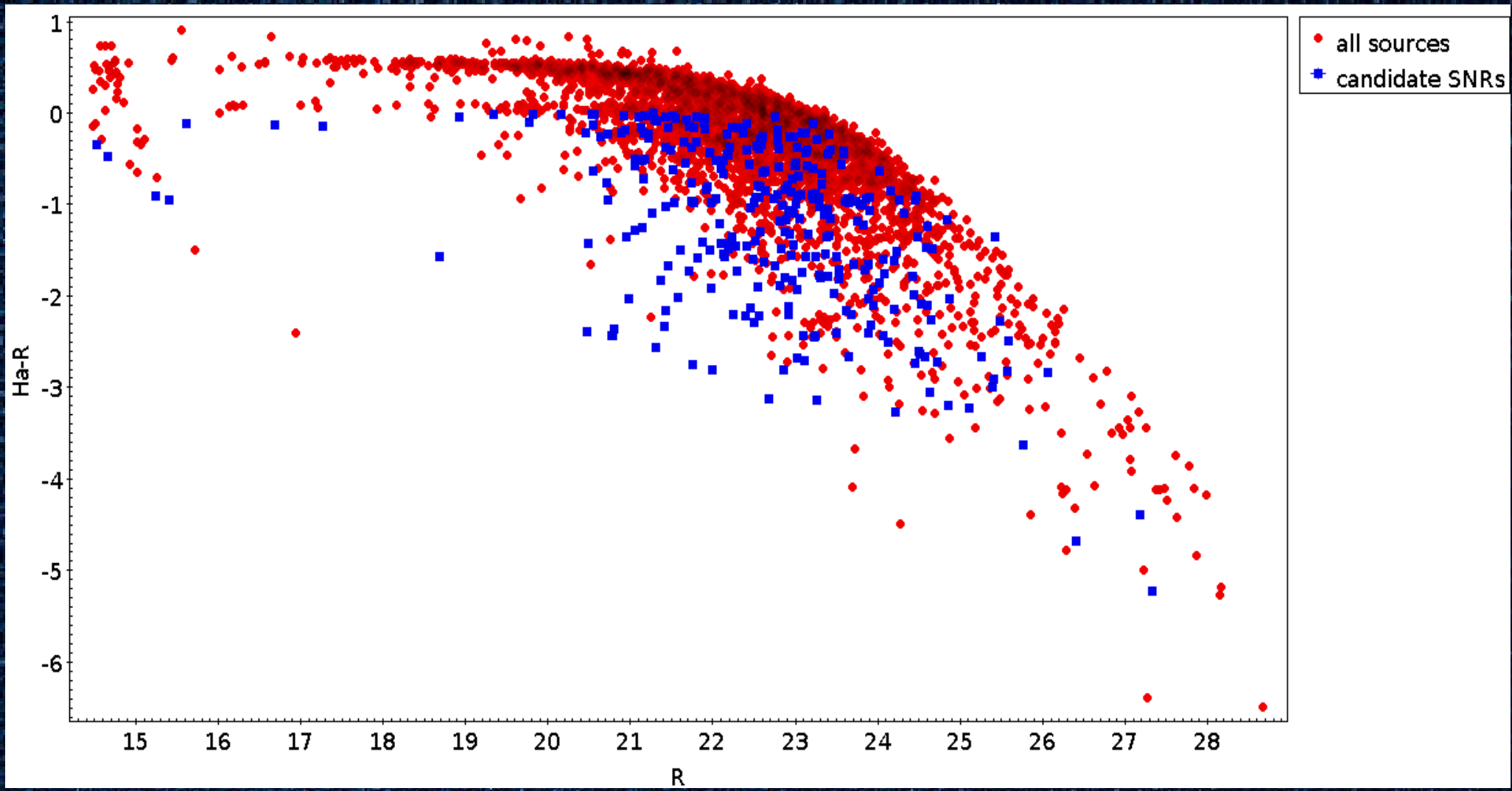
Detection - Photometry - Flux calibration

- SExtractor for the detection
- IRAF (Image Reduction and Analysis Facility) for photometry
- standard stars (Massey, P. et al. , 1988)

SNR selection criteria:

- $Counts\, H\alpha > 3\sigma$
- $\frac{[S\,II]}{H\alpha} > 0.4$ (Mathewson & Clarke, 1973)
- Hα excess-magnitude diagram to distinguish stars from candidate SNRs

Hα excess-magnitude diagram



Results

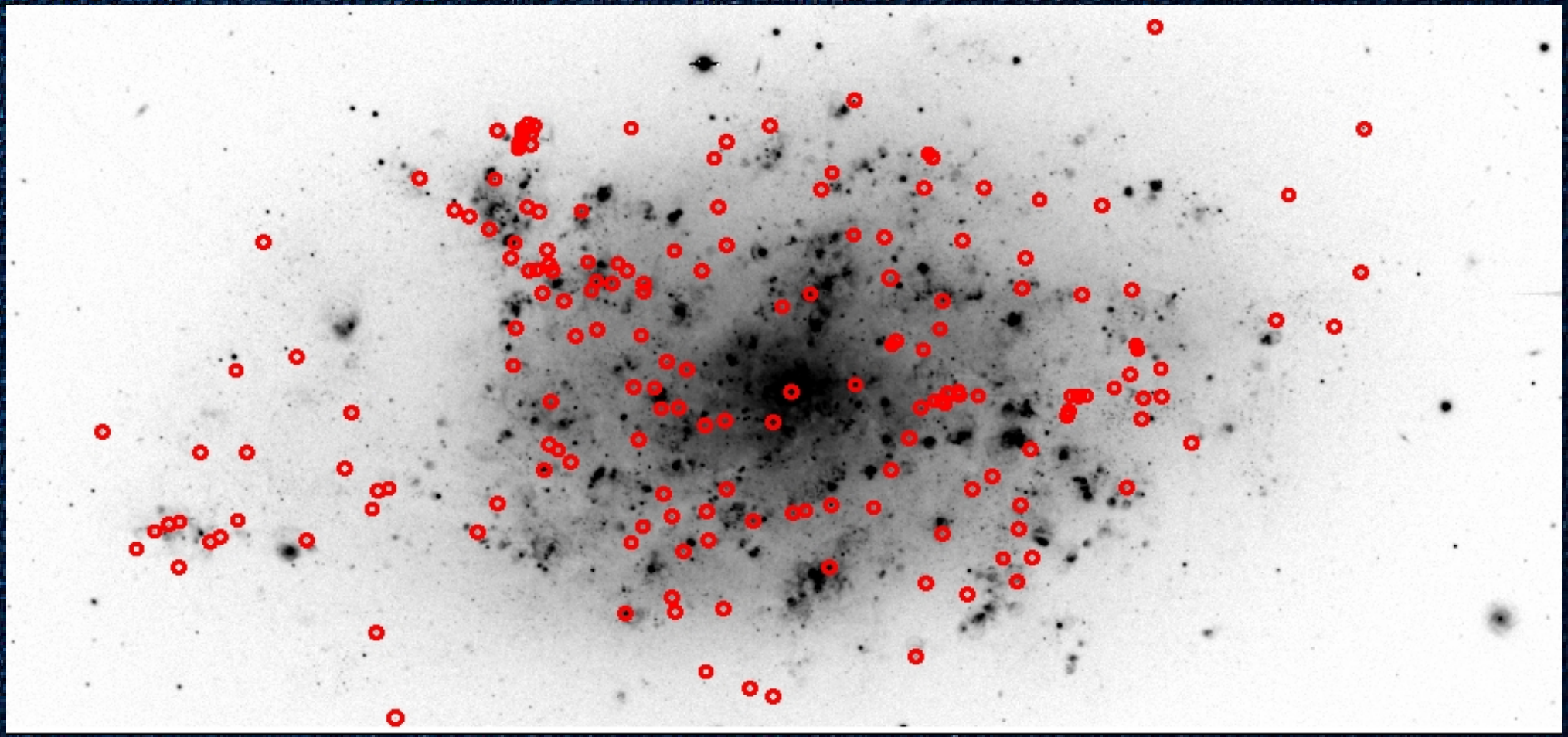
In total 295 candidate SNRs

NGC 45 → 16

NGC 55 → 72

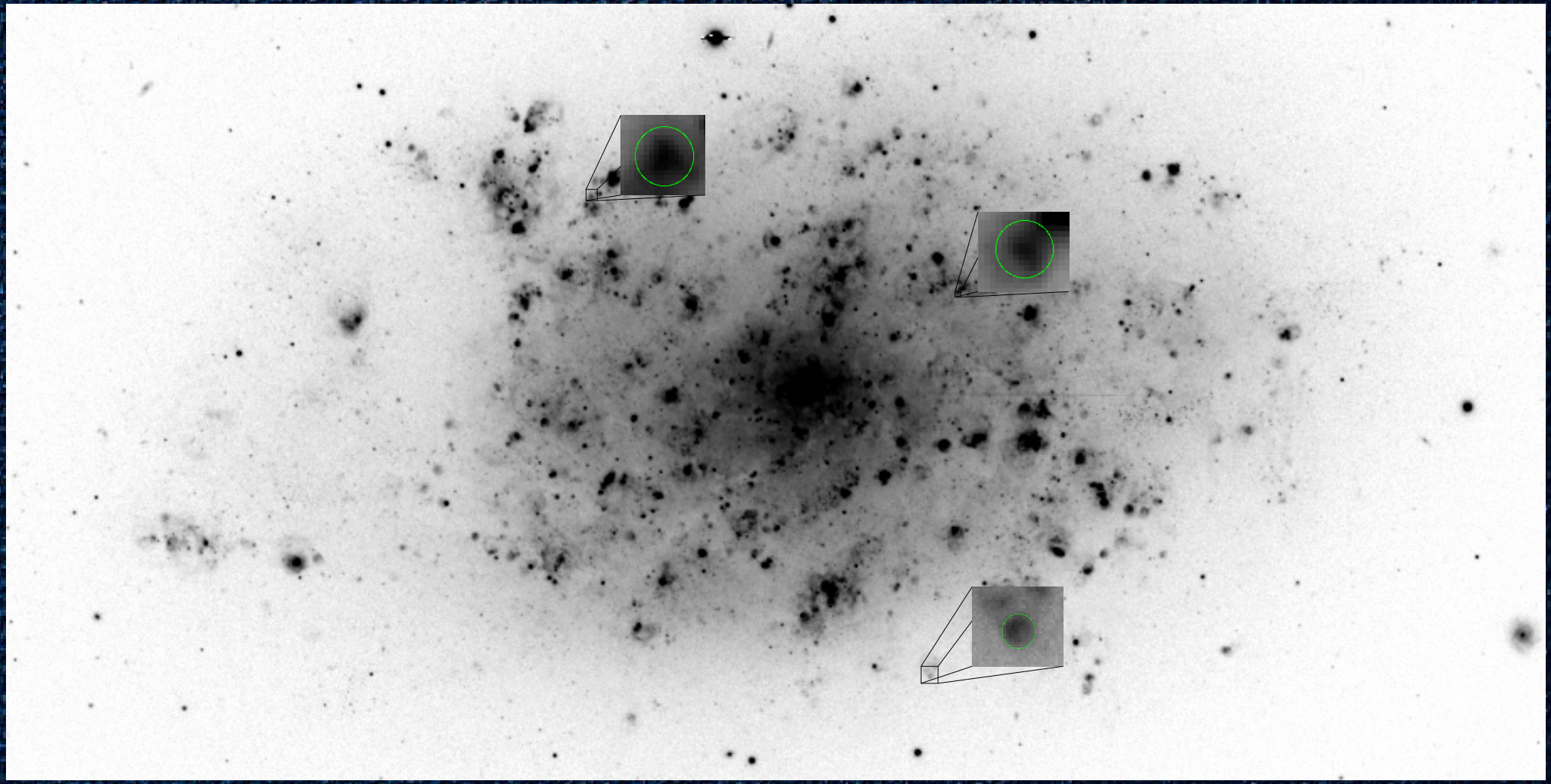
NGC 1313 → 28

NGC 7793 → 179

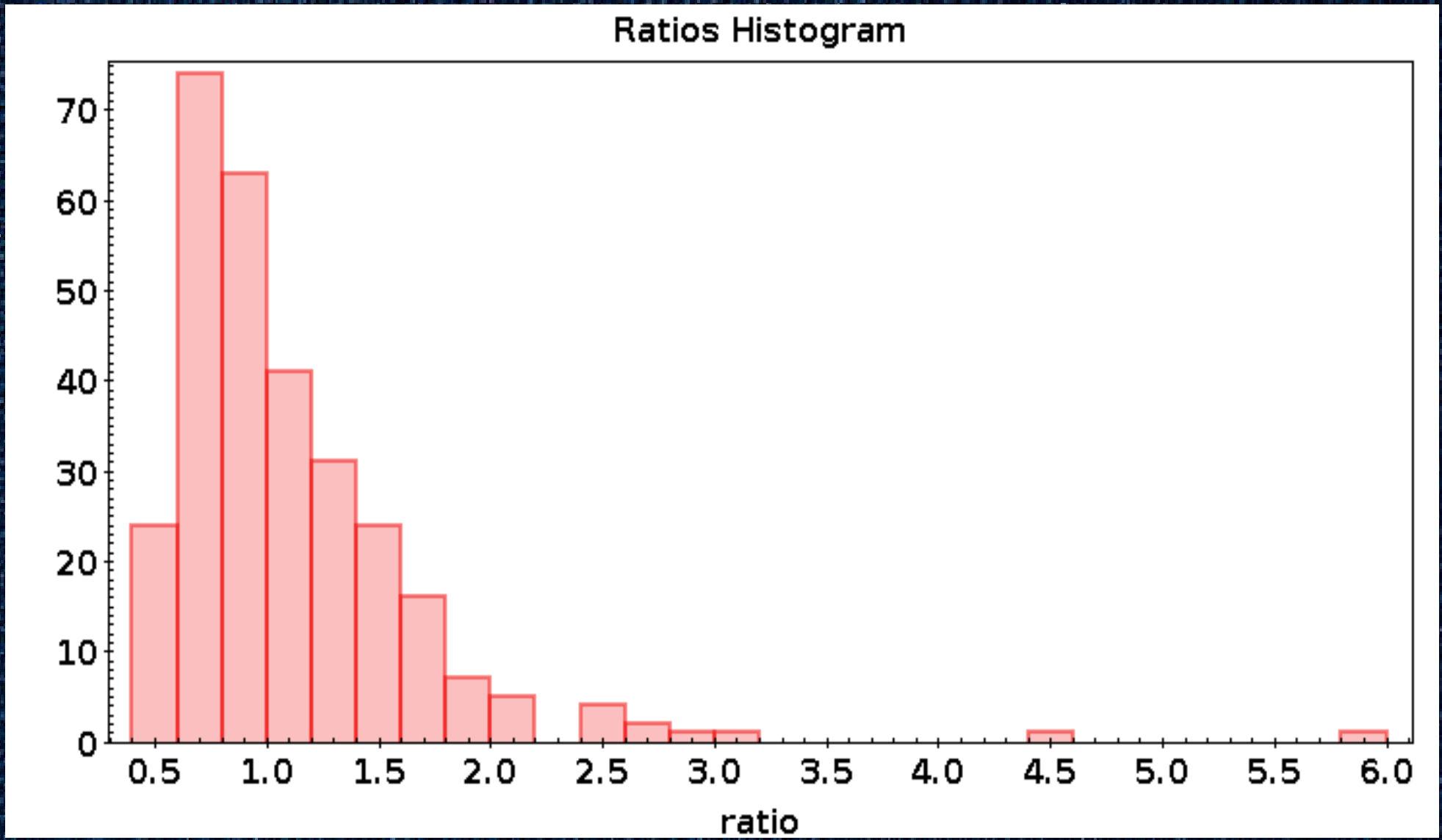


NGC 7793

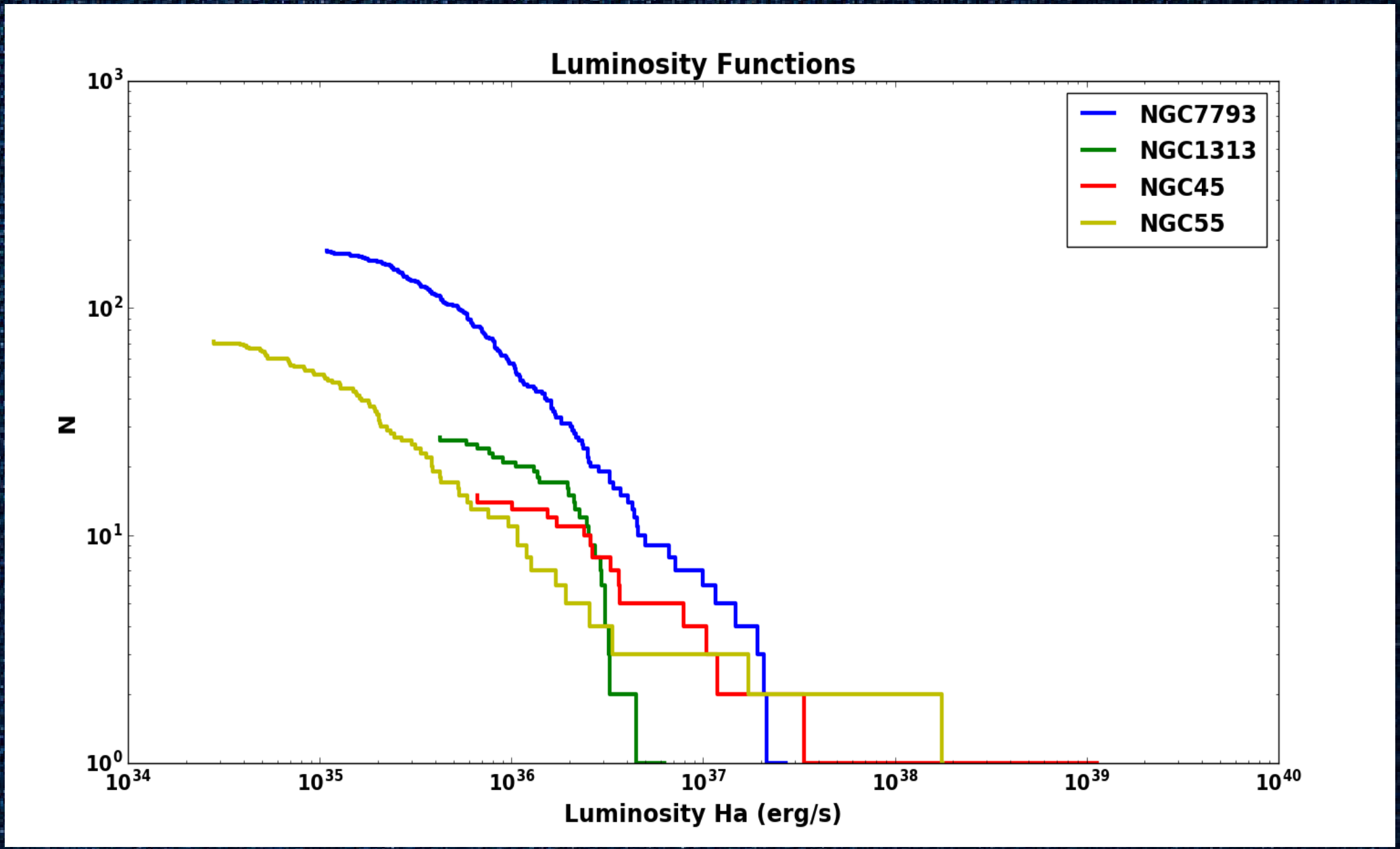
NGC 7793



$\frac{[S\,II]}{H\alpha}$ ratios histogram



Luminosity Functions



Future goals

- Investigate the correlation between SNR populations and types of galaxies.
- Spectra for:
  - Verification of shock excited nature of SNRs spectroscopically.
  - Shock velocity diagnostic [S II]/Hα vs [O III]/Hβ (Allen et al. 2008)
  - Electron density [S II](6716Å)/[S II](6731Å)
  - Electron temperature [O III](4959,5007Å)/[O III] (4363Å)
- Extend our sample to more galaxies.

Thank you....