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"Revealing new optically-emitting extragalactic Supernova Remnants"

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I. Introduction

Why is it important to study the formation and evolution of SNRs?

✓ Investigate global properties of the galaxy's ISM as well as their local density and evolution (Blair & Long 2004)

✓ Can be used as proxies to measure the formation of massive stars.

✓ Can give information on star formation and stellar evolution

I. Introduction

Why do we need to perform a multiwavelength study of these sources?

- Different wavebands provide a picture of different evolutionary stages of the SNR populations

- SNRs properties depend on:

➔ *ISM (density, temperature)*
➔ *Progenitor properties (stellar wind density, mass loss rate, composition)*
➔ *Age*

The details of this connection are poorly understood.

I. Introduction

Sample

Our sample consists of six nearby galaxies (NGC 2403, NGC 4213, NGC4449, NGC3077, NGC 4395, NGC 5204) which fulfill the following criteria :

a) Late type (T > 4)

b) Distance < 5 Mpc, in order to minimize source confusion

c) Inclination < 60 degrees, in order to minimize internal extinction and projection effects

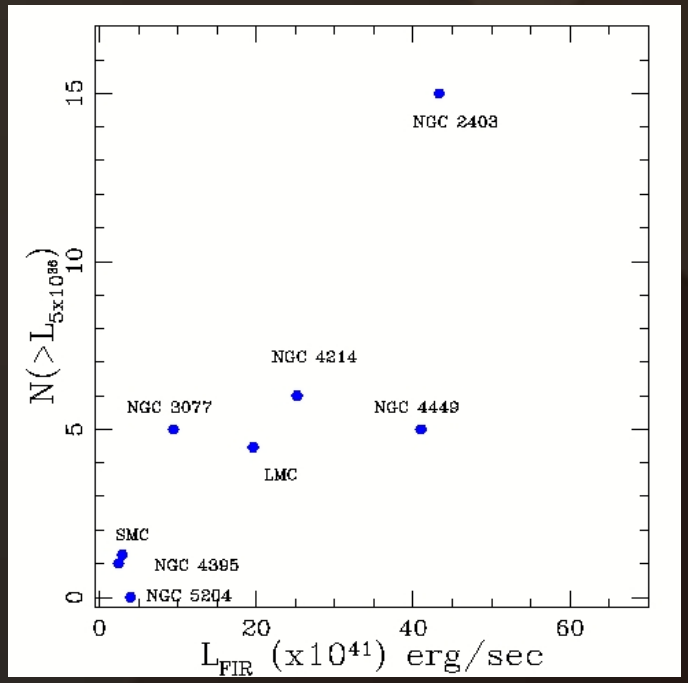
d) Exposure times long enough to achieve a uniform detection limit of ~10^{36} erg/sec.

II. X-ray SNR investigation

Using Chandra archival data for the six galaxies in our sample and based on their X-ray colors and spectroscopy, we concluded to

37 X-ray selected SNRs, 30 of which were new identifications

1) We examined the relation between the number of X-ray detected SNRs and the SFR.

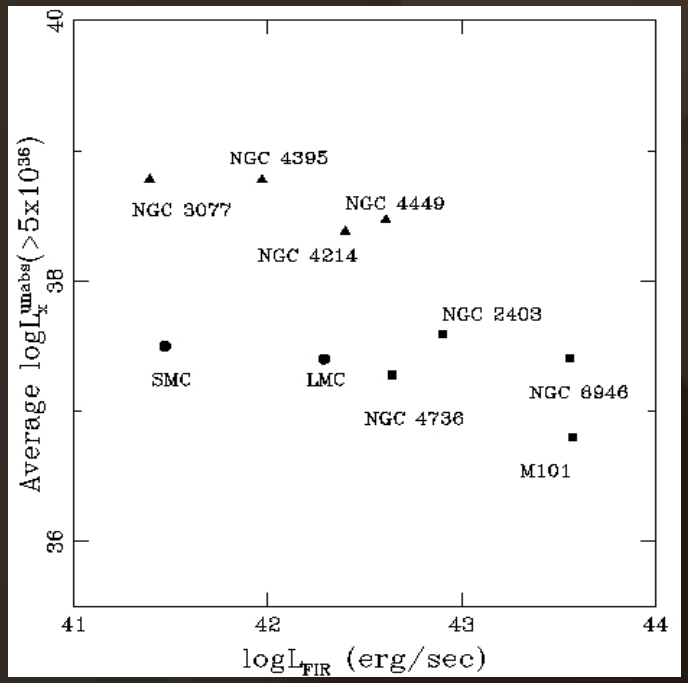


Evidence for a linear correlation between the number of luminous SNRs and SFR.

(Leonidaki et al. 2010)

II. X-ray SNR investigation

1) In order to investigate any connection between the properties of SNRs and the star-formation mode of the galaxies as indicated by their SFR, we plot the average SNR X-ray luminosity against the FIR luminosity.



- No clear correlation between average Lx of SNRs and FIR luminosity.
- Distinction between SNRs in the spiral and irregular galaxies.

1) We find that the numbers of SNRs in irregular galaxies are more consistent with an MC-like SNR X-ray luminosity function, while those of spiral galaxies are more consistent with the SNR-XLF of the spiral M33.

(Leonidaki et al. 2010)

III. Optical SNR investigation

a. Photometric probe : Preliminary SNR identification

We obtained optical images through [S II] 6716 & 6731 Å and Hα filters using the 1.3m Skinakas (Crete, Greece) and 1.2 FLWO (Arizona, USA) telescopes.

- Initial cleaning of the data (bias, flat fielding, sky background subtraction, continuum subtraction) using the IRAF package.
- Source detection in Halpha, [S II] images.
- Photometry

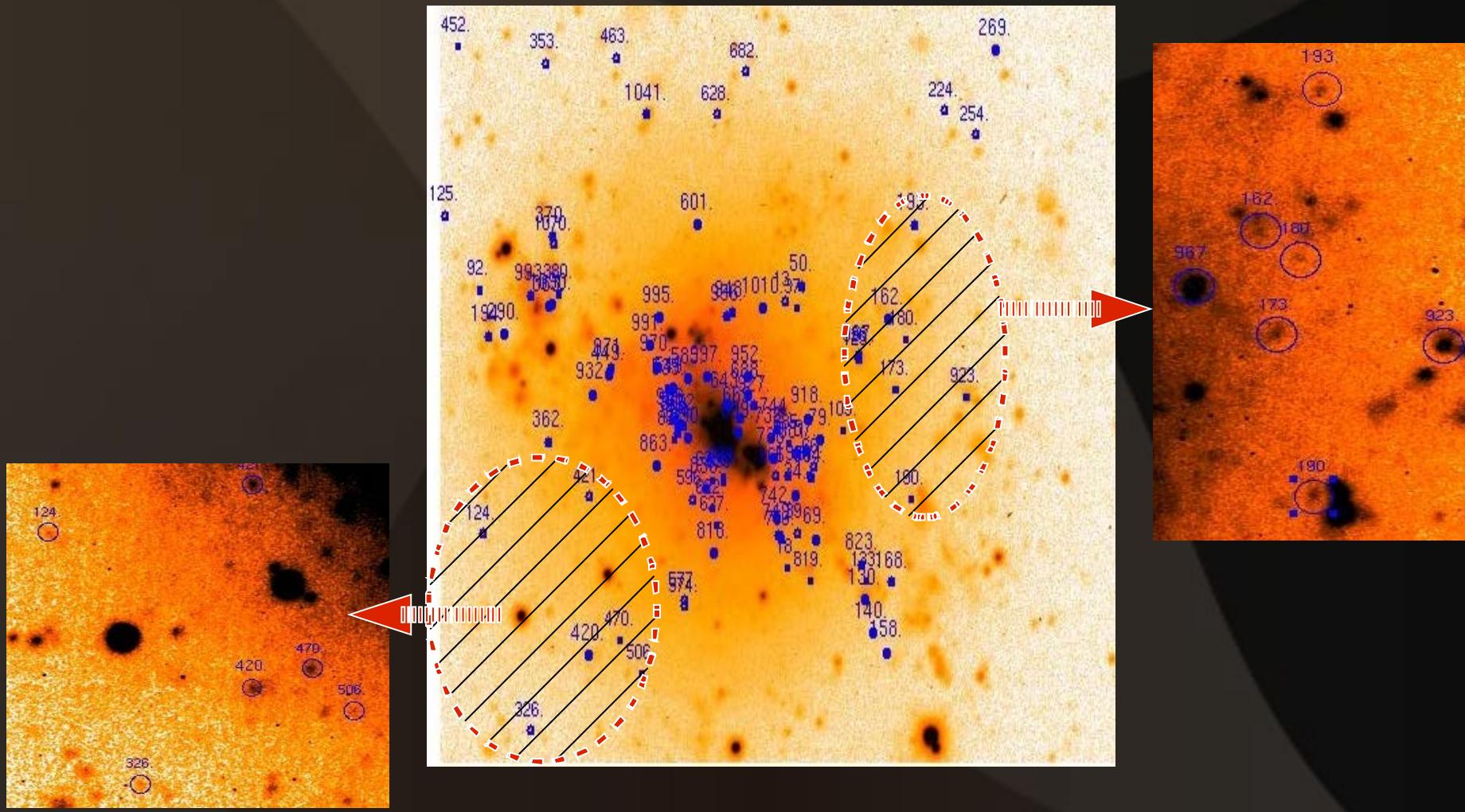
Diagnostic tool for identifying optical SNRs:

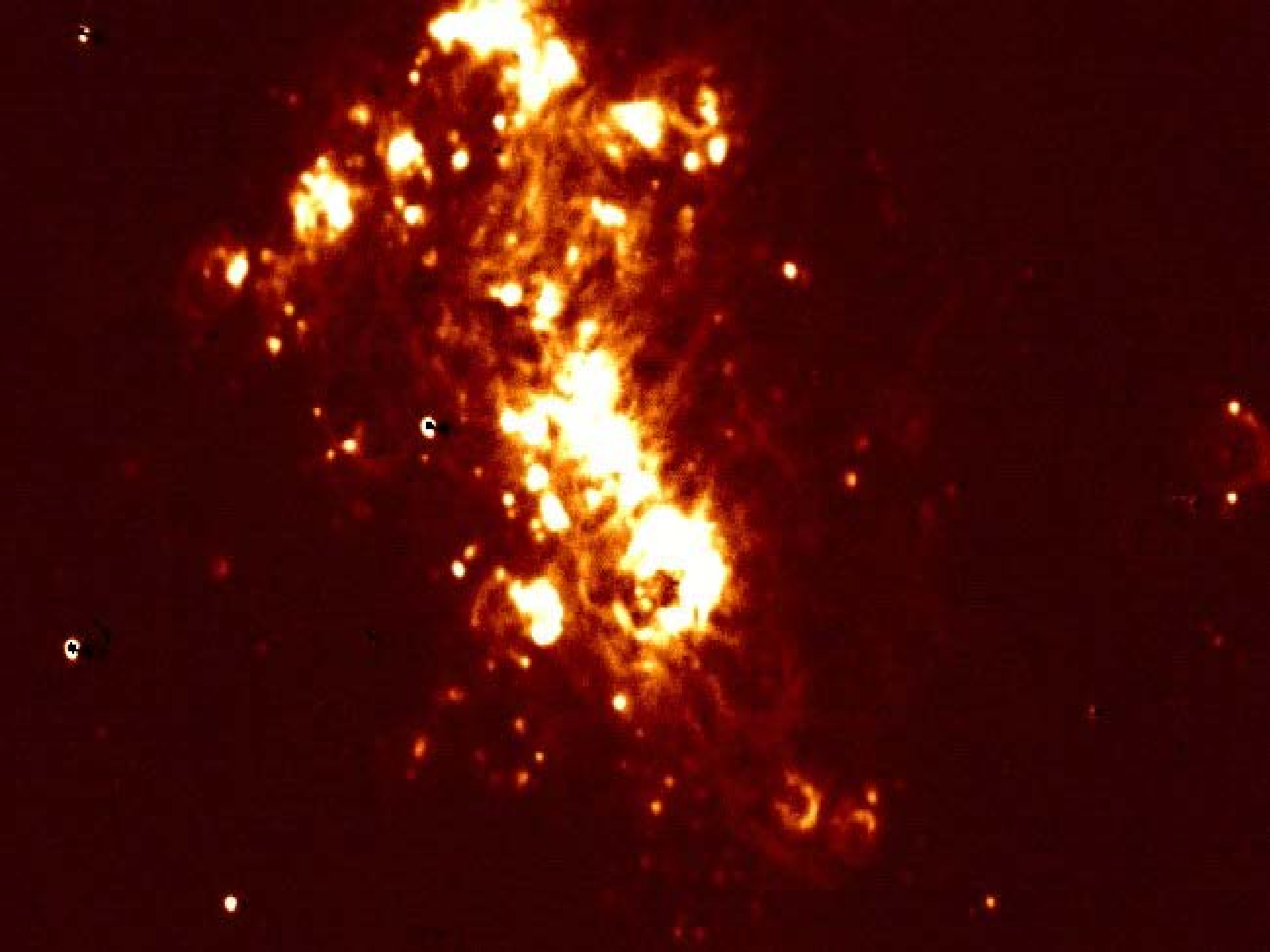
Sources with flux ratio **[S II] / Hα ≥ 0.4**

(Mathewson & Clarke 1973).

III. Optical SNR investigation

Ha image of NGC 4214 with candidate SNRs overlaid





Reading the SNR spectrum...

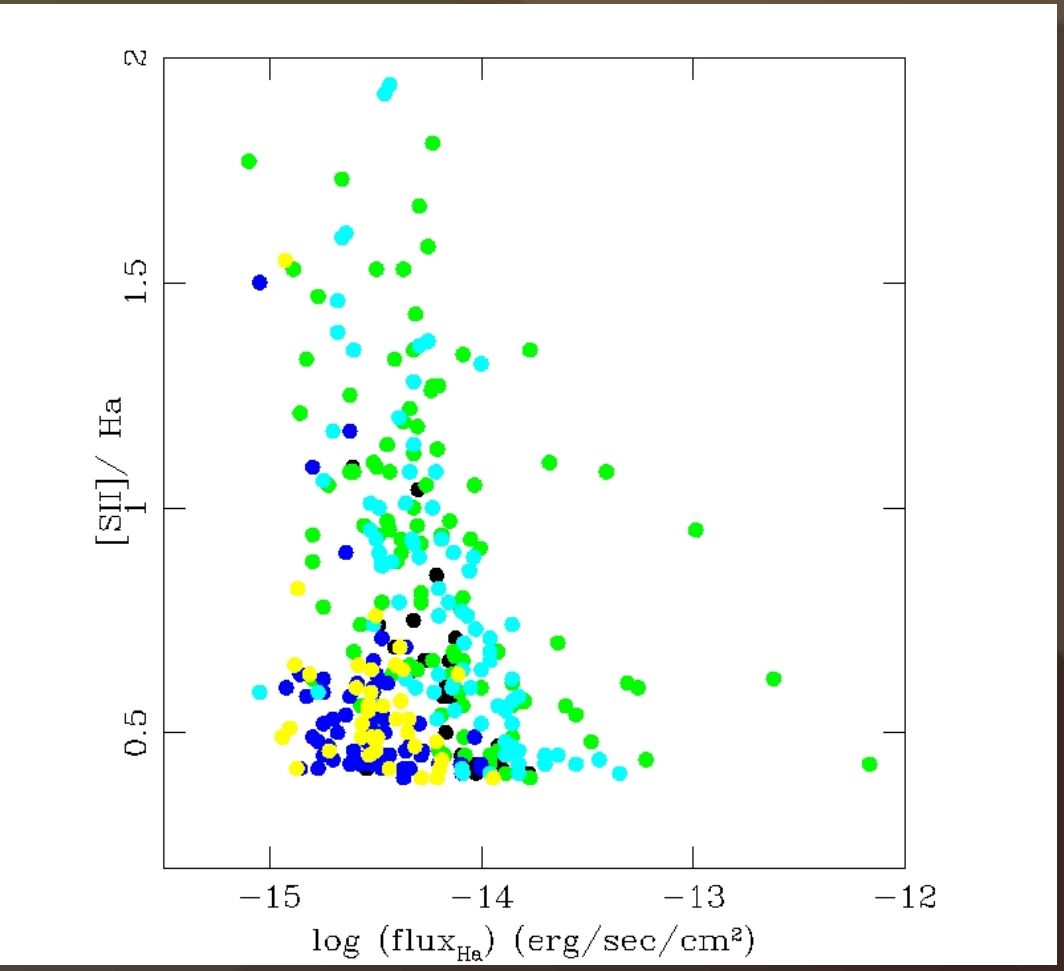
- Collisionally ionized species (e.g. [S II], [N II], [O I]) as well as hydrogen recombination emission lines are signatures of shock-heated gas.

- The absence of [O III] emission lines possibly denotes slow shocks propagating into the interstellar clouds (shock velocities < 100 km/sec; eg Hartigan et al. 1987).

- SNRs with [SII] (6717) / [SII] (6731) > 1 are believed to be old SNRs (Stupar & Parker 2009).

Some interesting results...

~500 photometric SNRs have beed detected, 475 of which are new identifications (65 spectroscopically identified SNRs).

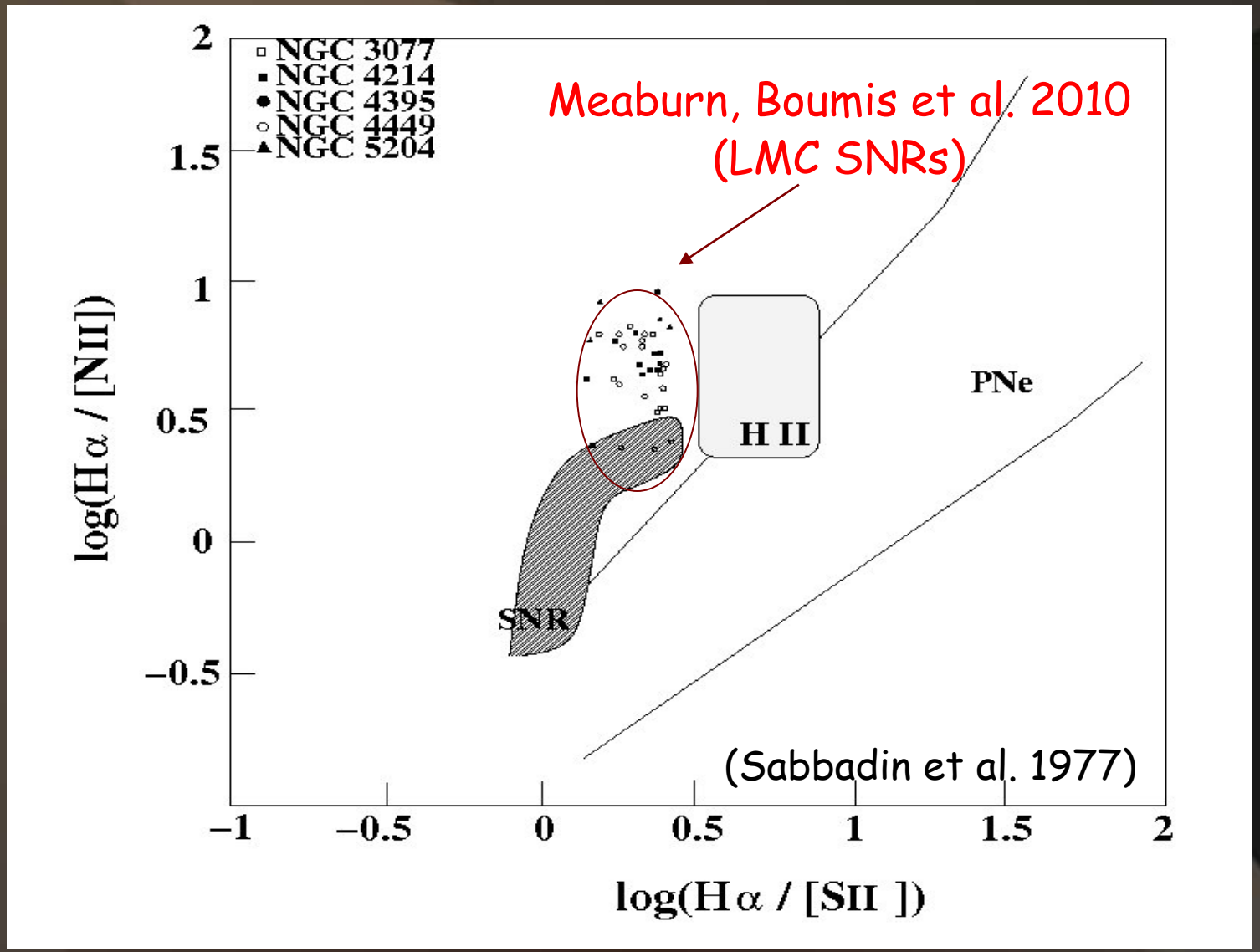


Photometric SNRs reach Ha limiting fluxes down to 10^{-15} erg s^{-1} cm^{-2}.

(Leonidaki et al. 2011, to be submitted)

Diagnostic ratio plots

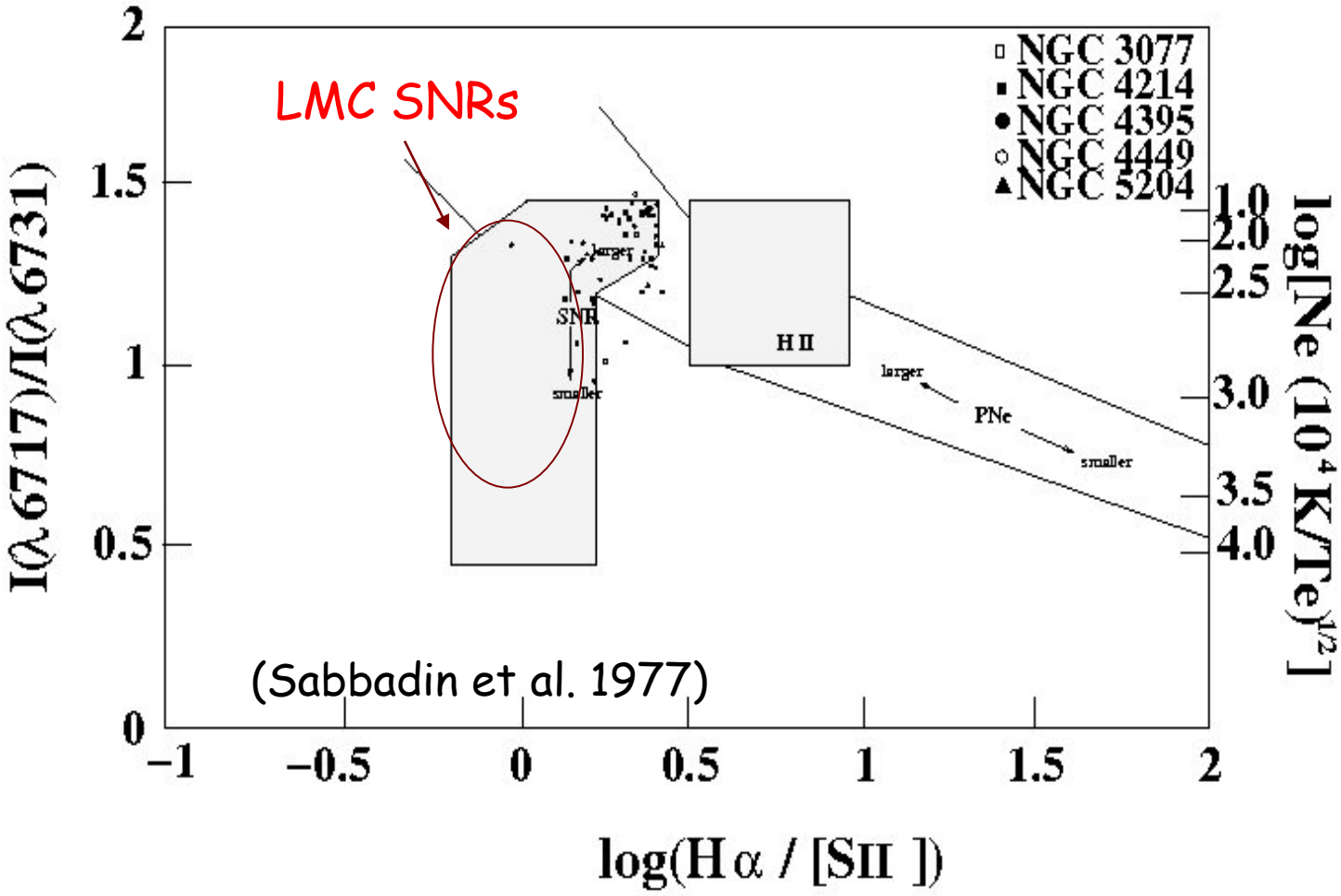
a. Ha / [S II] vs Ha / [N II]



(Leonidaki et al. 2011, to be subm)

Diagnostic ratio plots

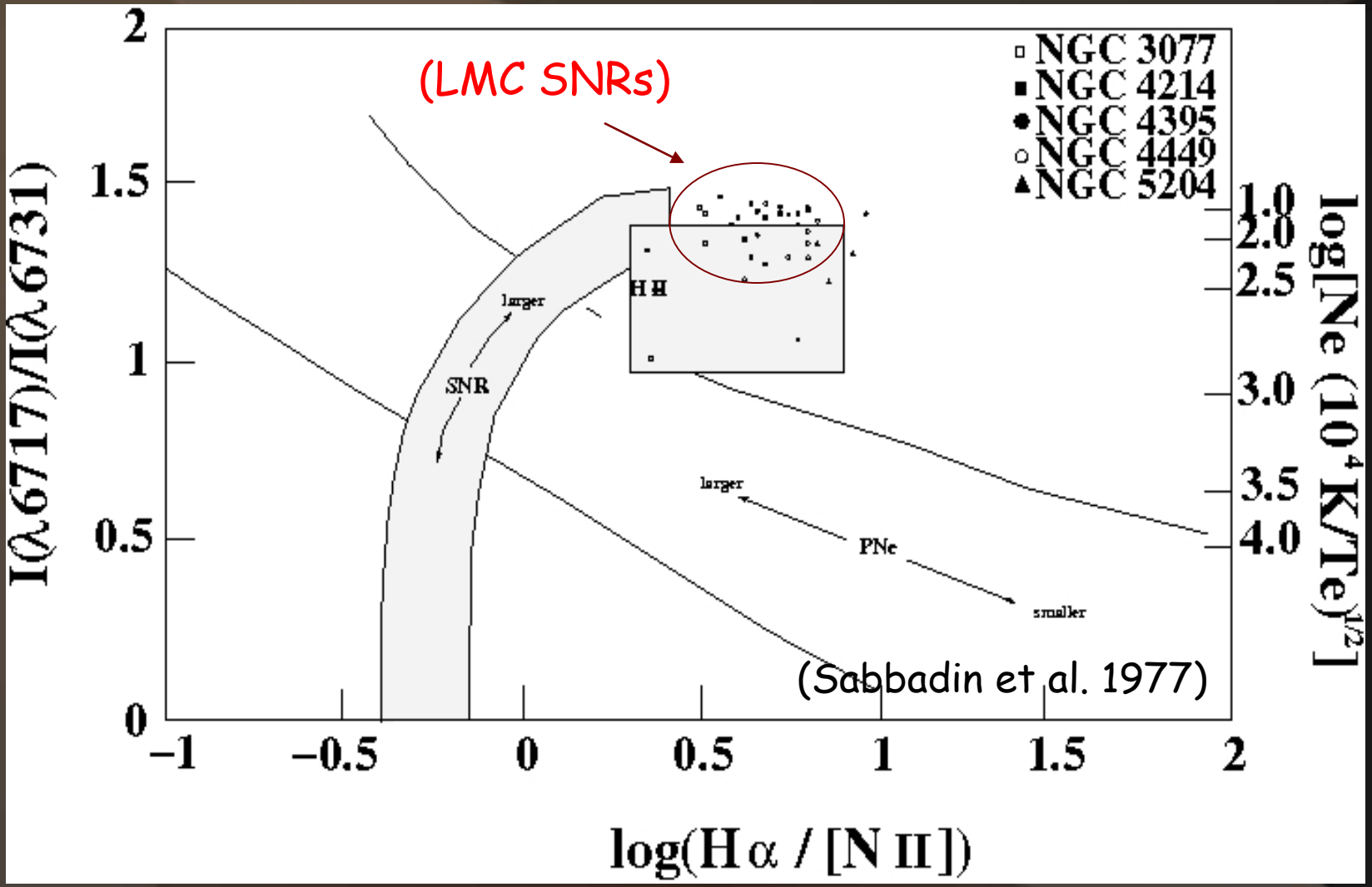
b. Ha / [S II] vs electron density



(Leonidaki et al. 2011, to be submitted)

Diagnostic ratio plots

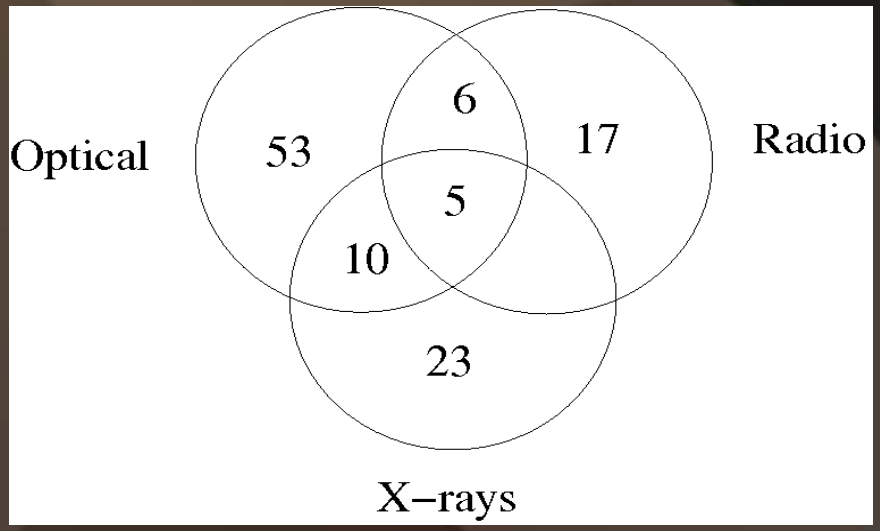
c. Ha / [N II] vs electron density



(Leonidaki et al. 2011, to be submitted)

Multi-wavelength SNR associations

Venn diagram for all spectroscopically observed SNRs in our sample of galaxies.



Comparison of the emission of SNRs in different wavebands can provide information about the evolutionary stage of the sources and/or can illustrate selection effects.

To conclude...

i) Our final results give us confidence that photometric method used for the preliminary identification of SNRs is robust.

ii) We have created the deepest census of spectroscopically classified SNRs in nearby galaxies.

iii) Our sample of galaxies present lower [NII] metallicities than the Milky Way, at least by a factor of 2.

iv) The extracted spectra can give us an estimation about shock velocities (can be used to probe the interaction with the ISM).

•v) The measured electron density of the shock-heated gas (from the [S II](6716)/(6731) ratio) denotes that most of our detected SNRs are old (and therefore larger in size).

vi) A comparison of the number of SNRs detected in different wavebands can give us information about the evolutionary stages in the life of a remnant.