X-ray-detected SNRs in nearby spiral galaxies: the case of M83

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Main Collaborators

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Overview

- Why
  - Best way to study SNRs as a class of objects
  - Snapshot of where SNe explode in a galaxy
  - Substantial fraction of the X-ray source
- M83 is important
  - Nearby 4.6 Mpc, High SF rate, low inclination, low NH
  - 6 SNe in the last century → more than 100 SNRs less than 2000 years old, more than 1000 less than 20,000 years old
- Datasets
  - Deep Ha, [SII], [OIII] and continuum imagery with Magellan
  - 729 ksec Chandra S-array exposure
  - New ATCA and EVLA radio imagery
  - New HST imagery
  - GMOS spectroscopy of 150 SNRs and candidates

Multi-wavelength Views of M83

Magellan 6.5m Imagery

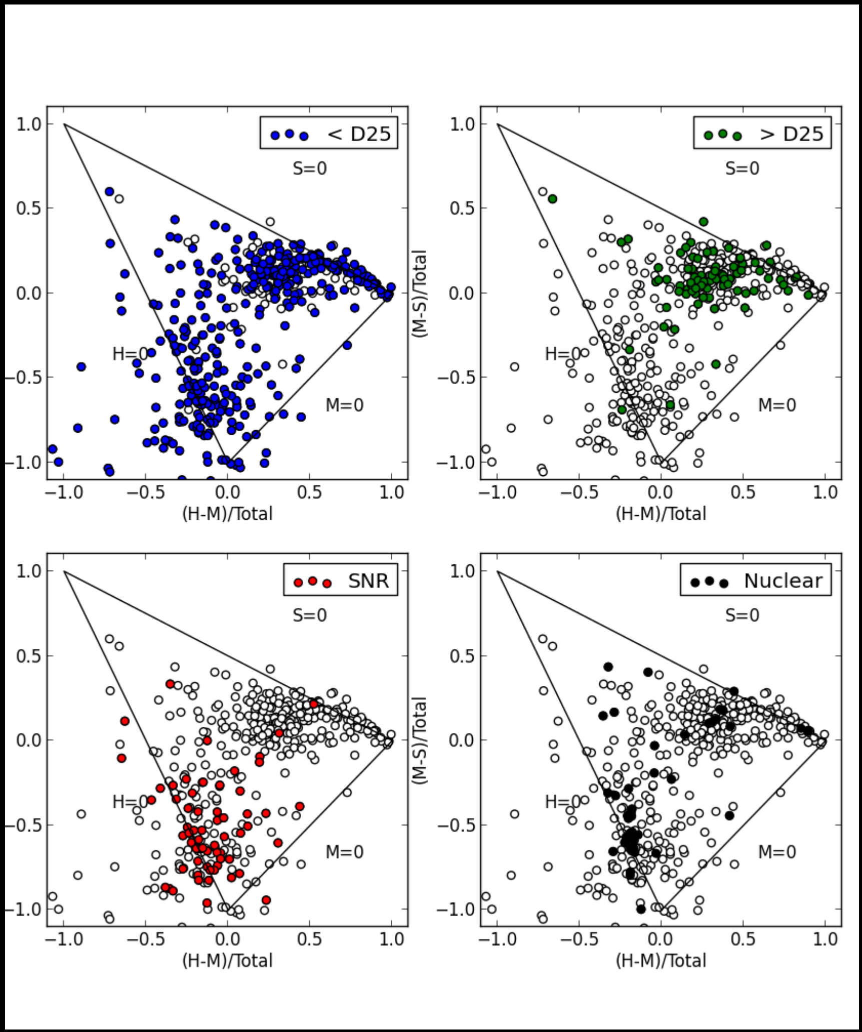
Red: Hα (w/stars)
Green: V-band
Blue: B-band

Chandra X-ray Observatory

Red: 0.5 – 1 keV (soft)
Green: 1 – 2 keV(med)
Blue: 2 – 8 keV (hard)

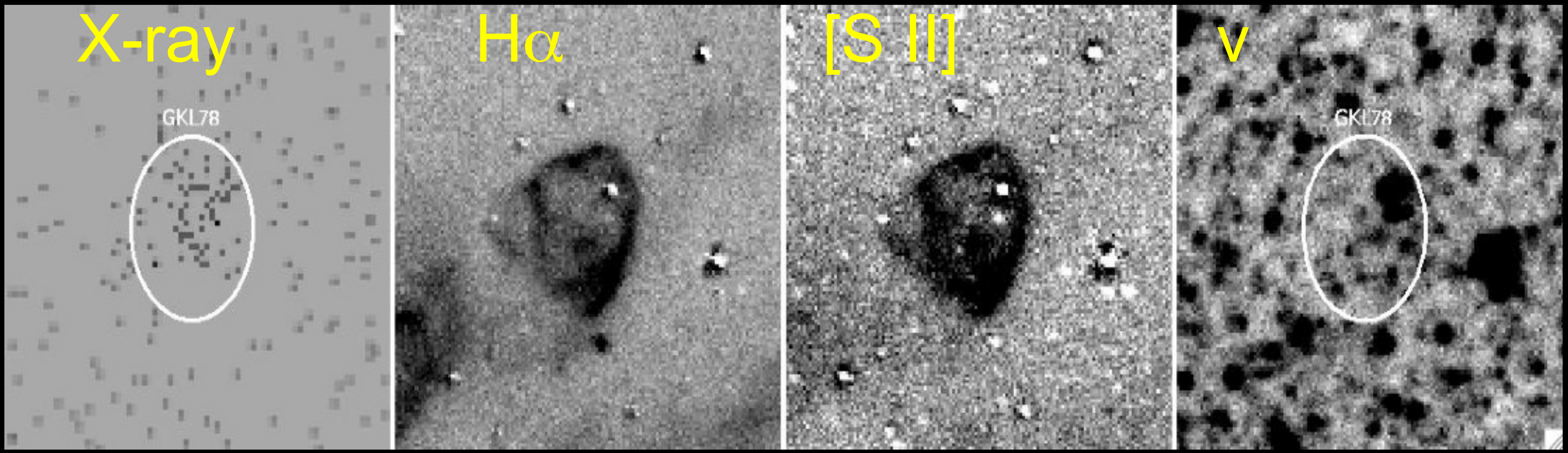
Chandra Large Program Summary

- 458 sources
- 378 within D25
- Highlights
  - Recovery of SN1957D in X-rays
  - New ULX
  - New micro quasar
  - 87 (mostly) soft X-ray sources identified as SNRs
- Tomorrow: Rob Soria will discuss entire survey
- Today: SNRs



Long+2014

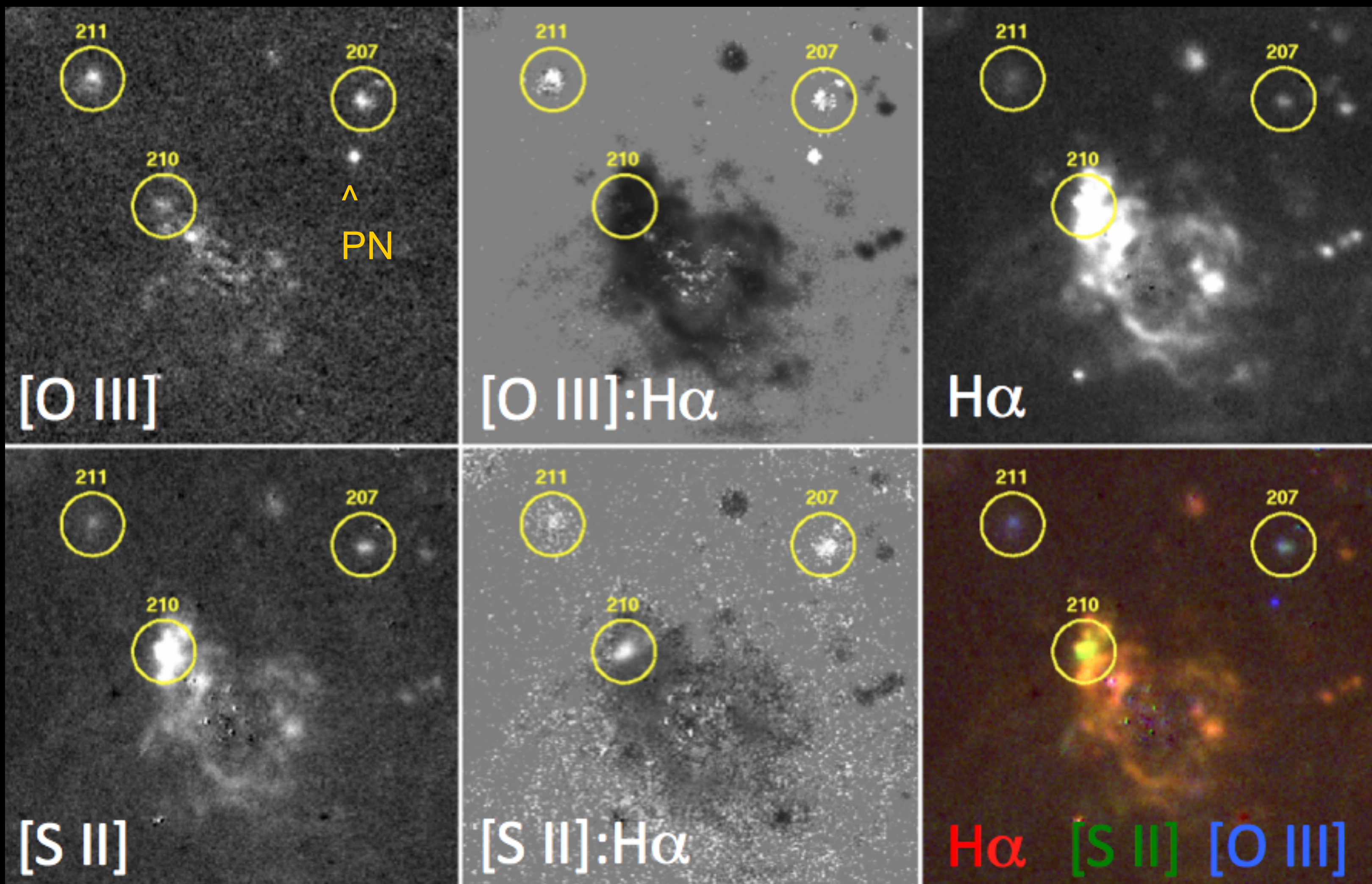
Identifying SNRs



- Optically, most SNRs are nebulae with [SII]:Hα ratios > 0.4. HII regions ~ 0.1
  - Confusion – Low surface brightness HII regions & DIG
- In X-rays, most SNRs are soft (thermal) X-ray sources
  - Confusion – Peaks in diffuse emission and SS sources
- At radio wavelengths, most SNRs are sources with steep spectral indices
  - Confusion – H II regions and background radio galaxies
- → Multi-wavelength confirmation is important

Magellan Data Example

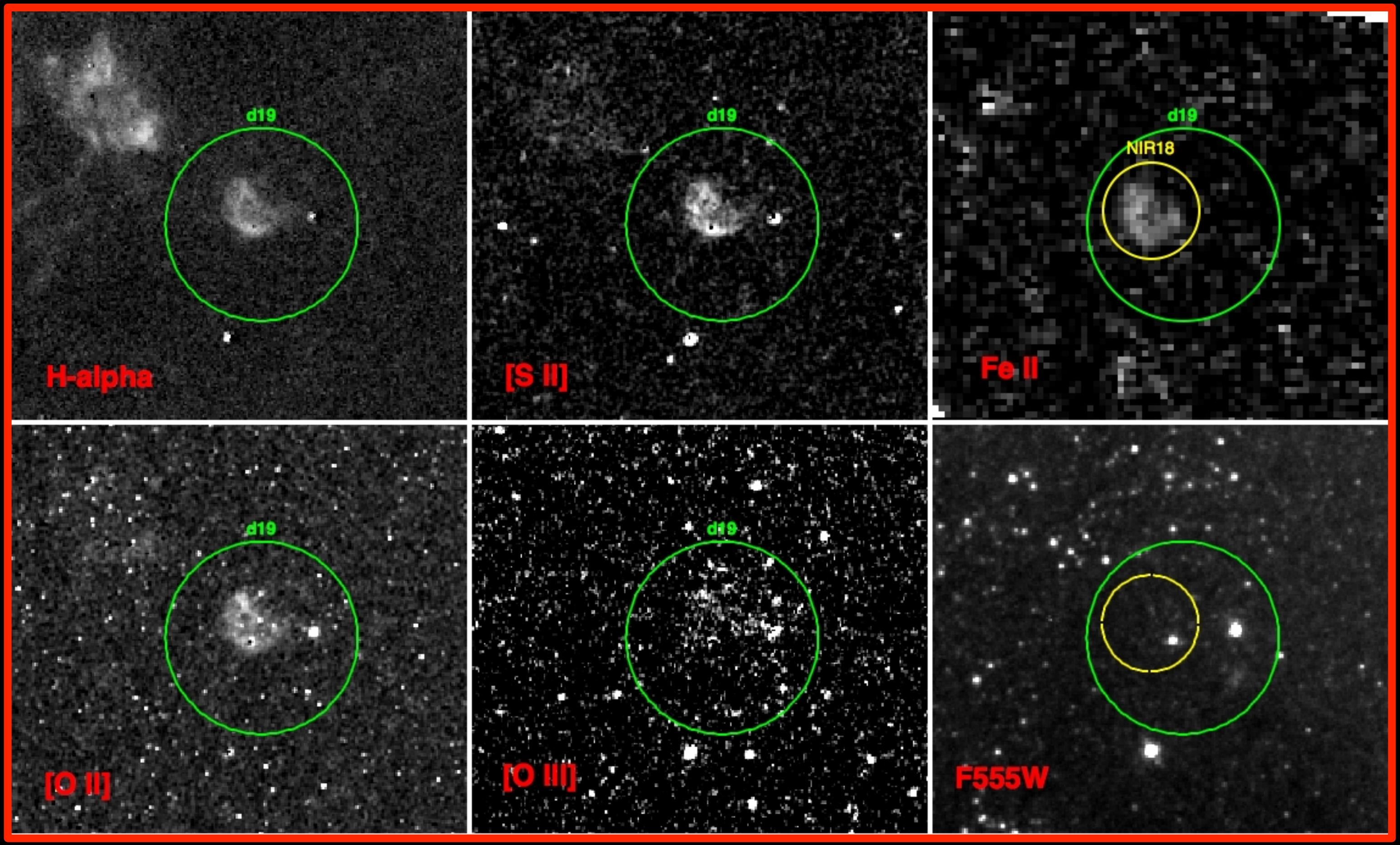
(27'' FoV)



225 [SII] SNRs + 46 [OIII] candidates

Blair+2012

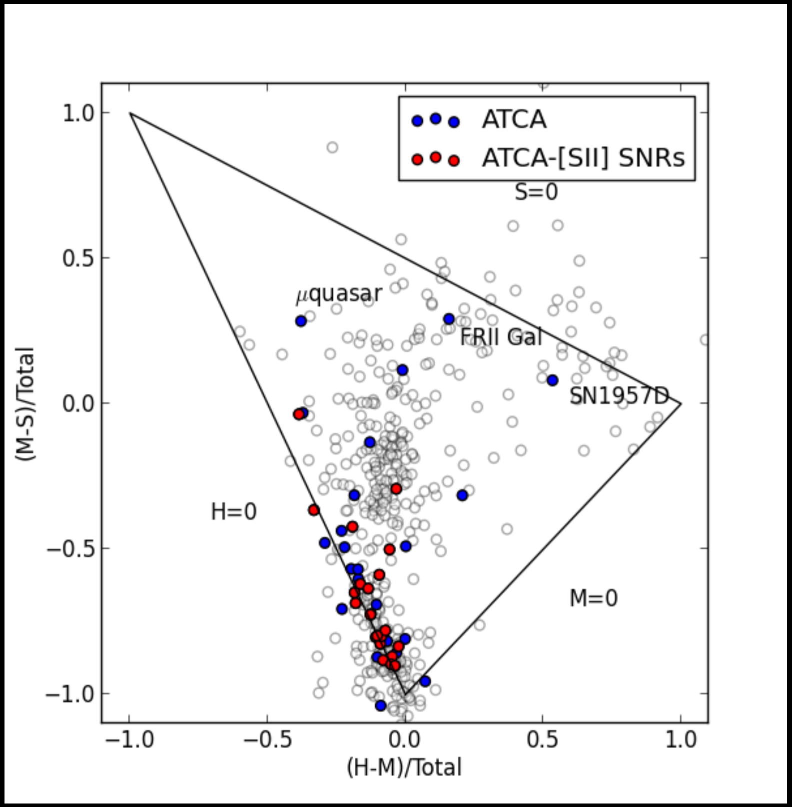
HST: more small SNRs and [Fe II]

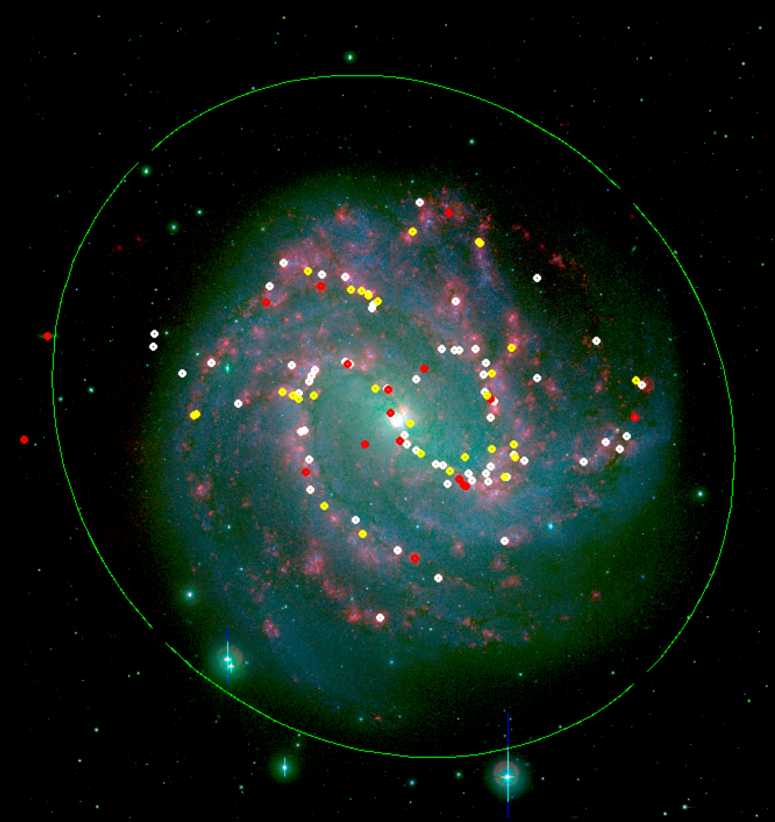


- In M83, we have identified about 20 SNRs in [Fe II]
- Some show strong [S II], others do not
- Some are X-ray sources, others not

Blair+2011, 2015

New ATCA radio survey

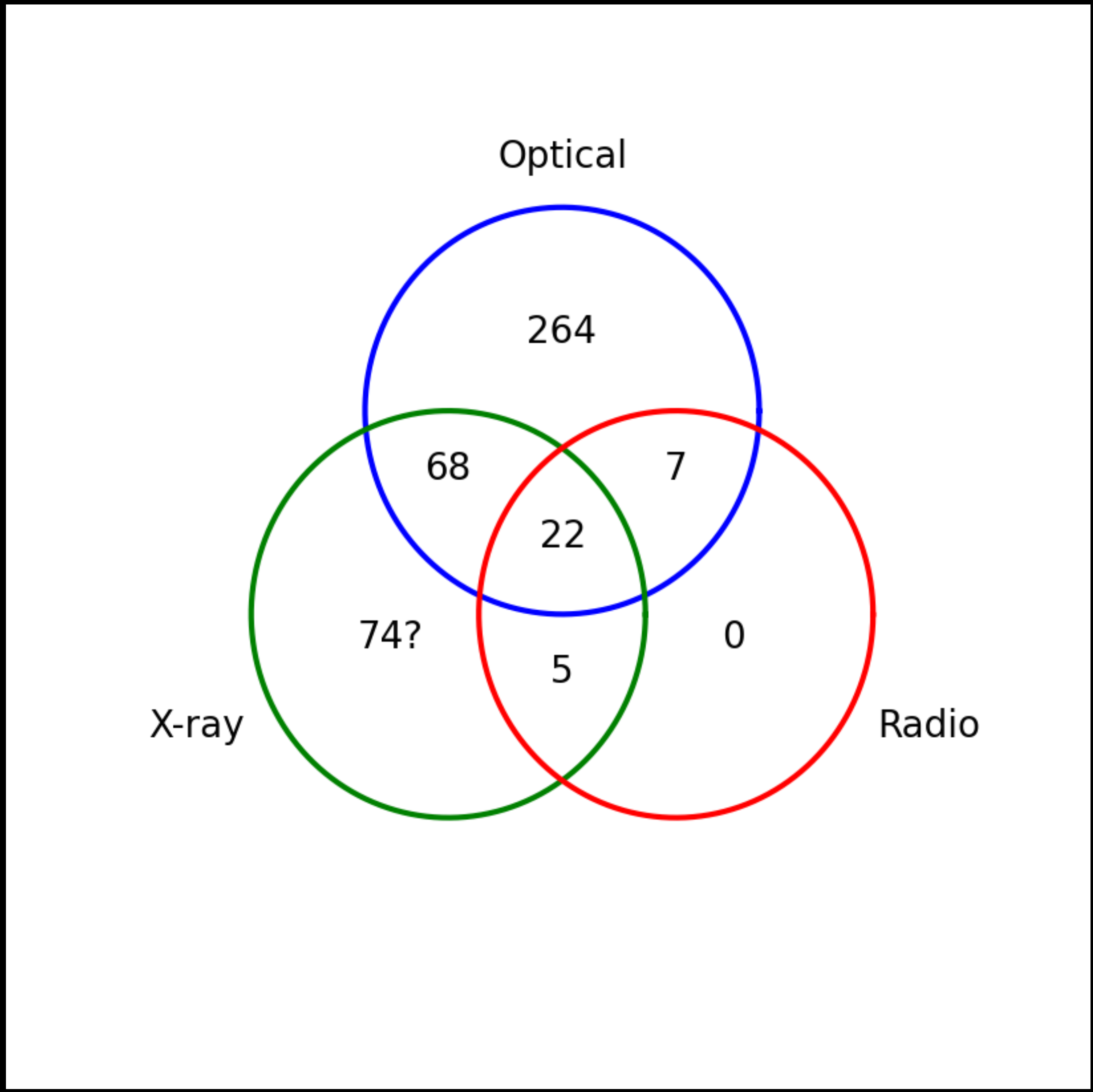




- 109 radio sources (like soft X-ray sources) concentrated in spiral arms, including 3 historical SNe
- 46 sources with X-ray counterparts,
  - 21 identified as optical SNRs
  - 7 of the others have soft X-ray hardness ratios and are likely SNRs
  - Others include micro-quasar, SN1957D, and background AGN
- 7 other radio sources coincident with optical SNRs not detected in X-ray

Long+2014

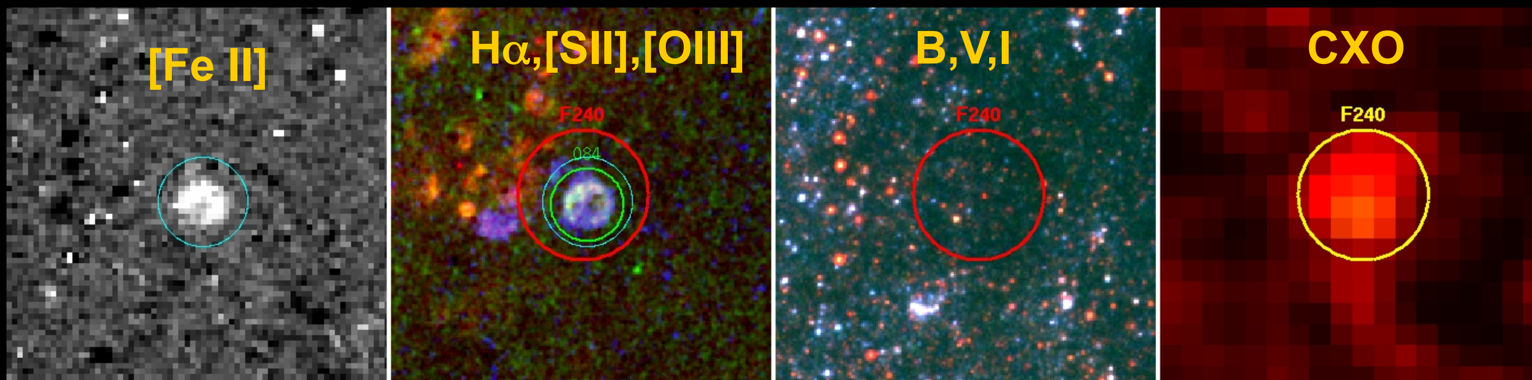
The M83 SNR sample today



Updated from Long+2014

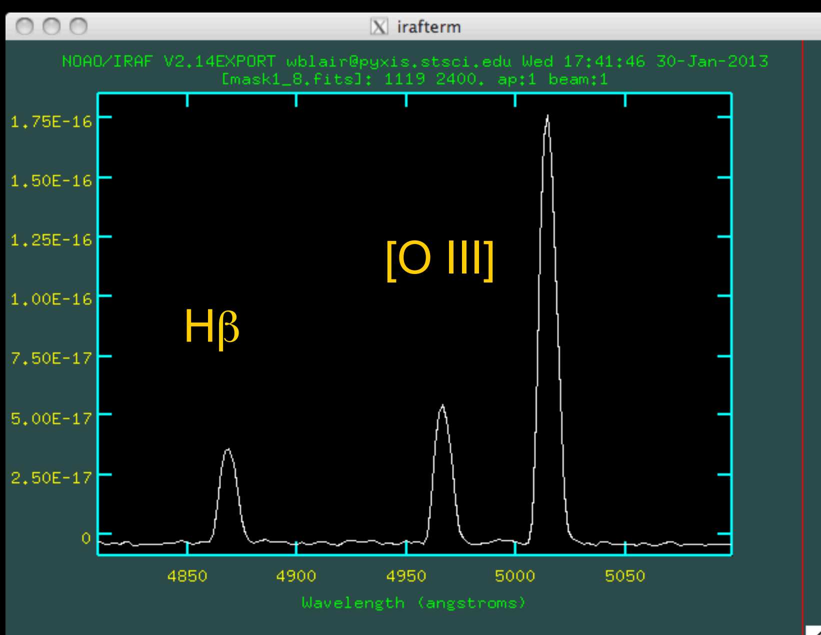
Most SNRs appear evolved

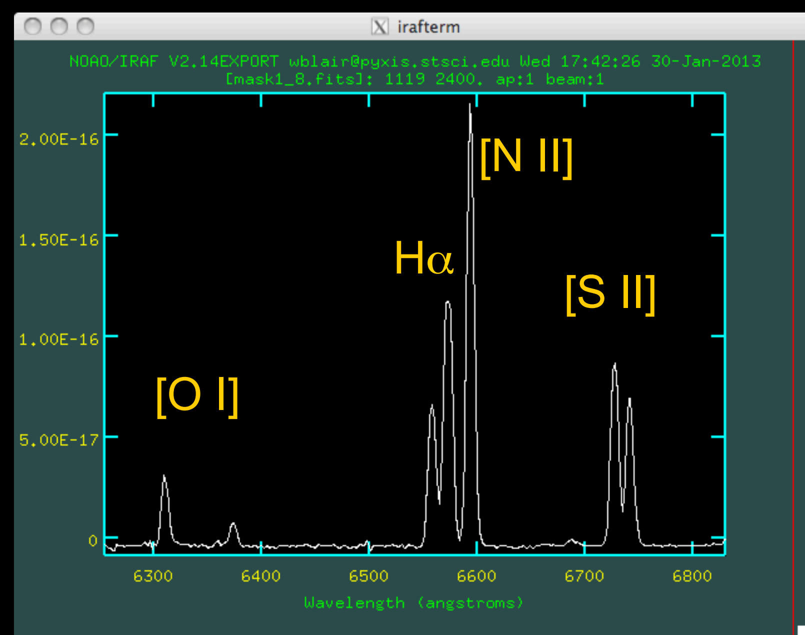
(B12-84, similar in size to the Cygnus Loop)



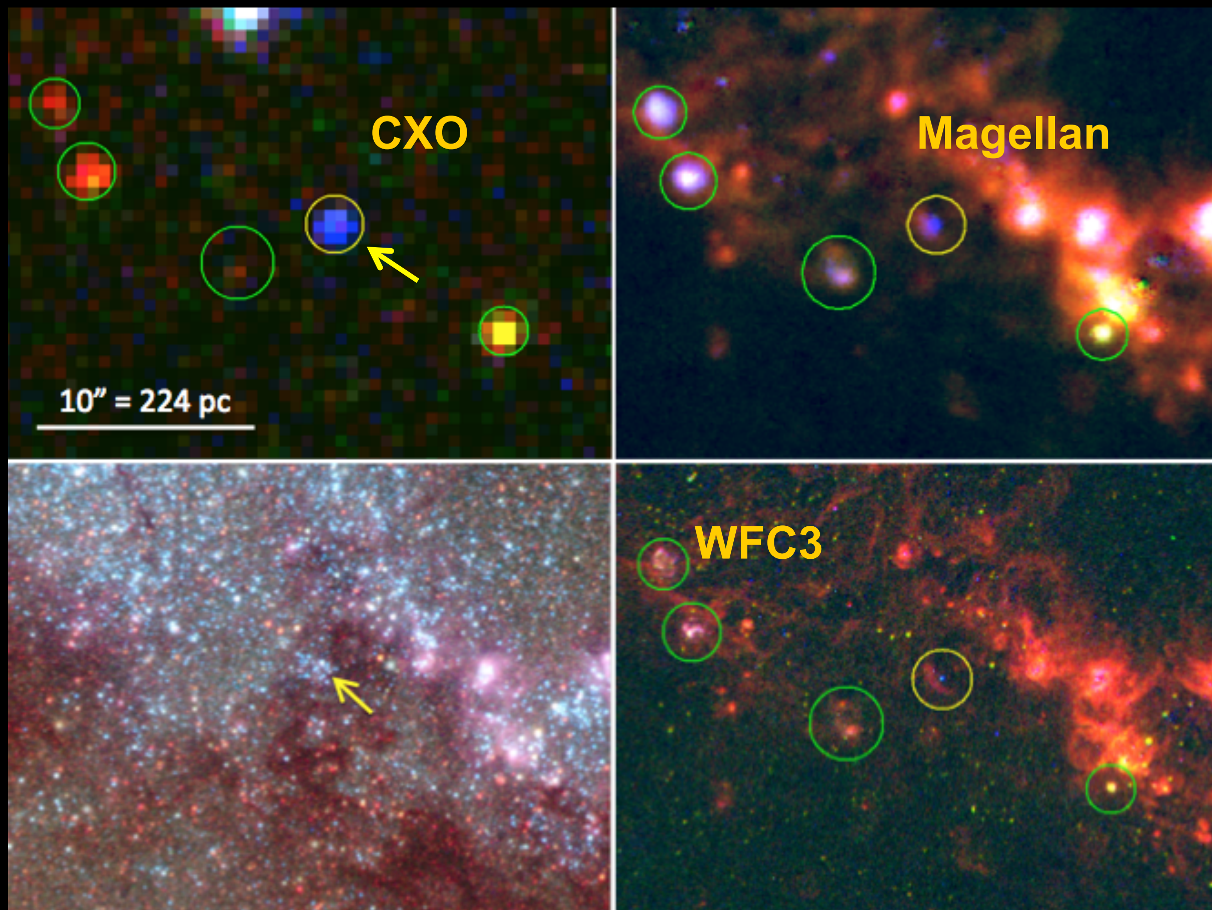
(Large circle is 3”)

Gemini-S GMOS Spectra





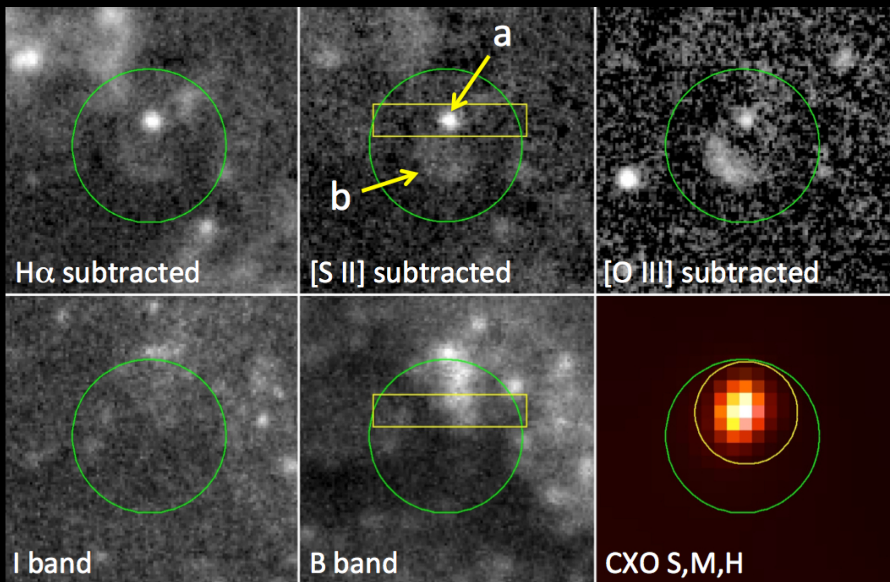
X-ray & Optical Counterpart of SN 1957D
(A very young SNR)



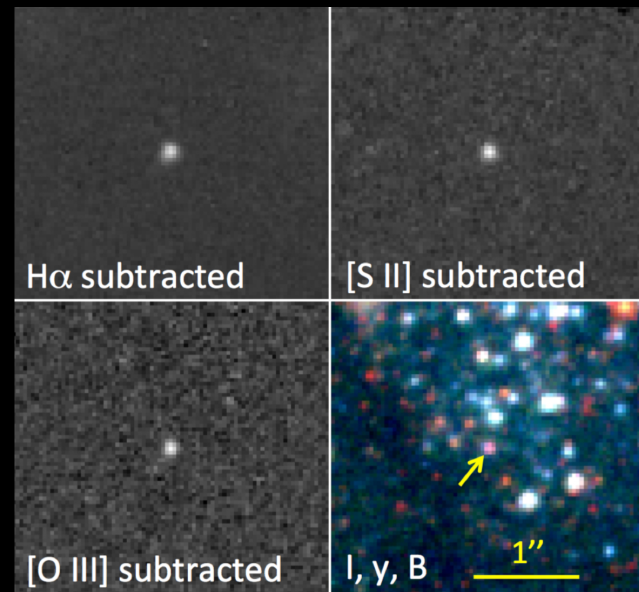
- Recovered in X-rays
- Hard X-ray spectrum suggests the X-ray emission is pulsar powered

Long+2012

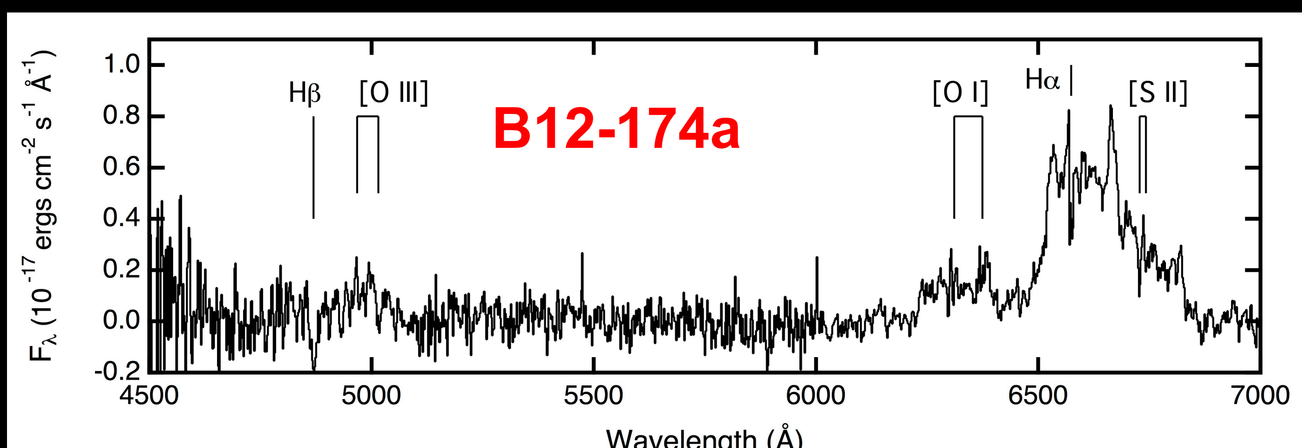
Only one SNR with broad emission lines so far



Magellan images, 10” FoV

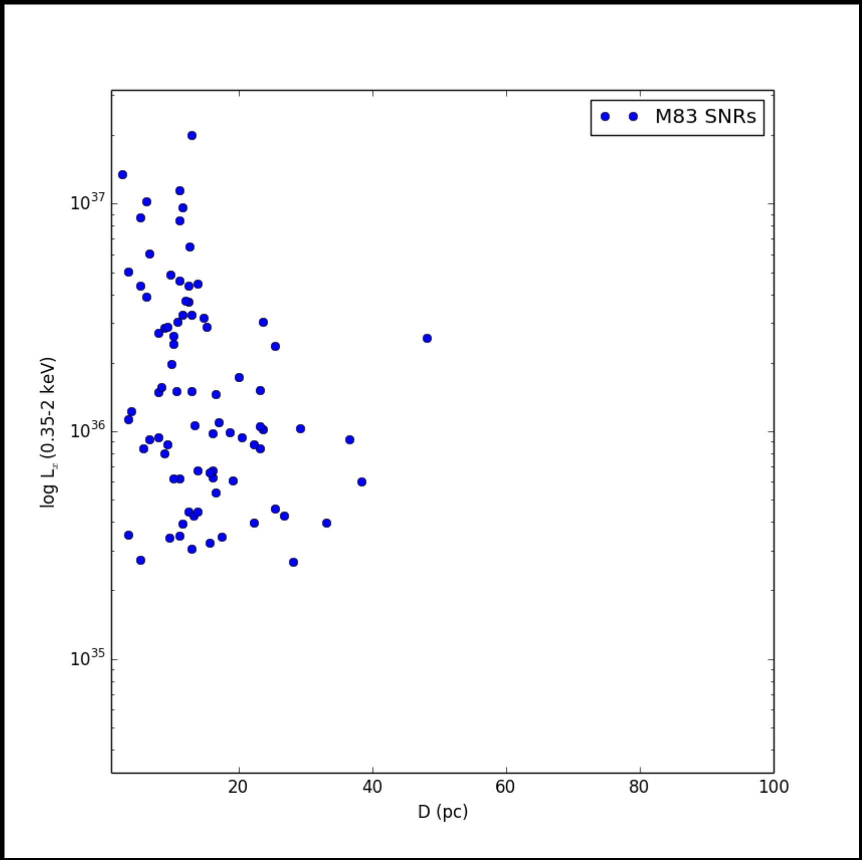


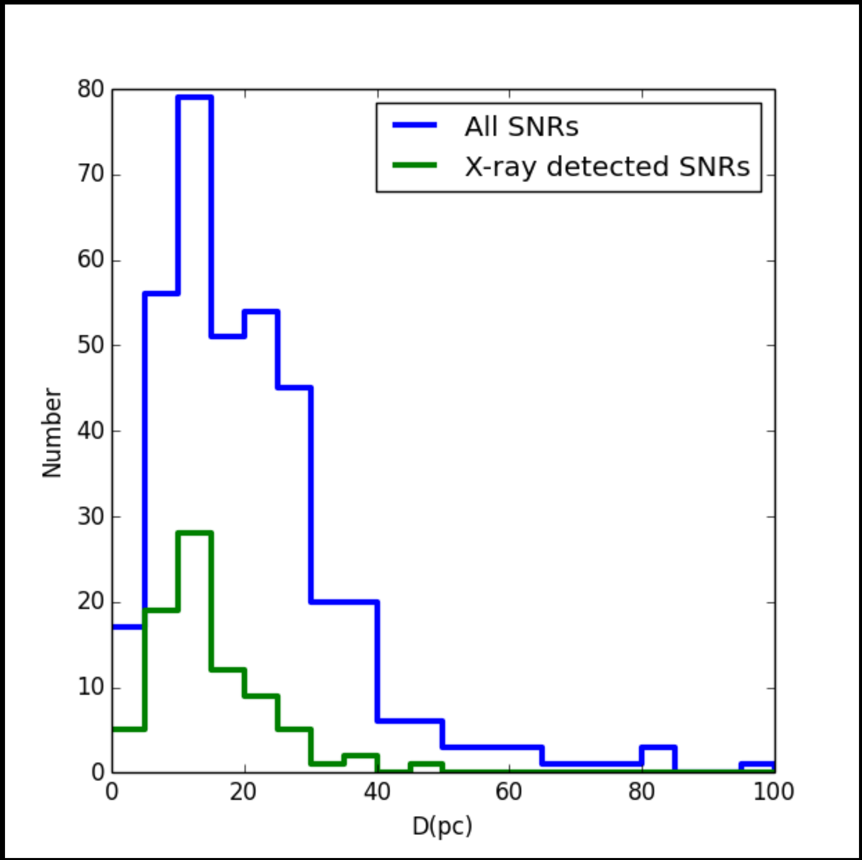
HST WFC3 images, 3” FoV



Blair+15

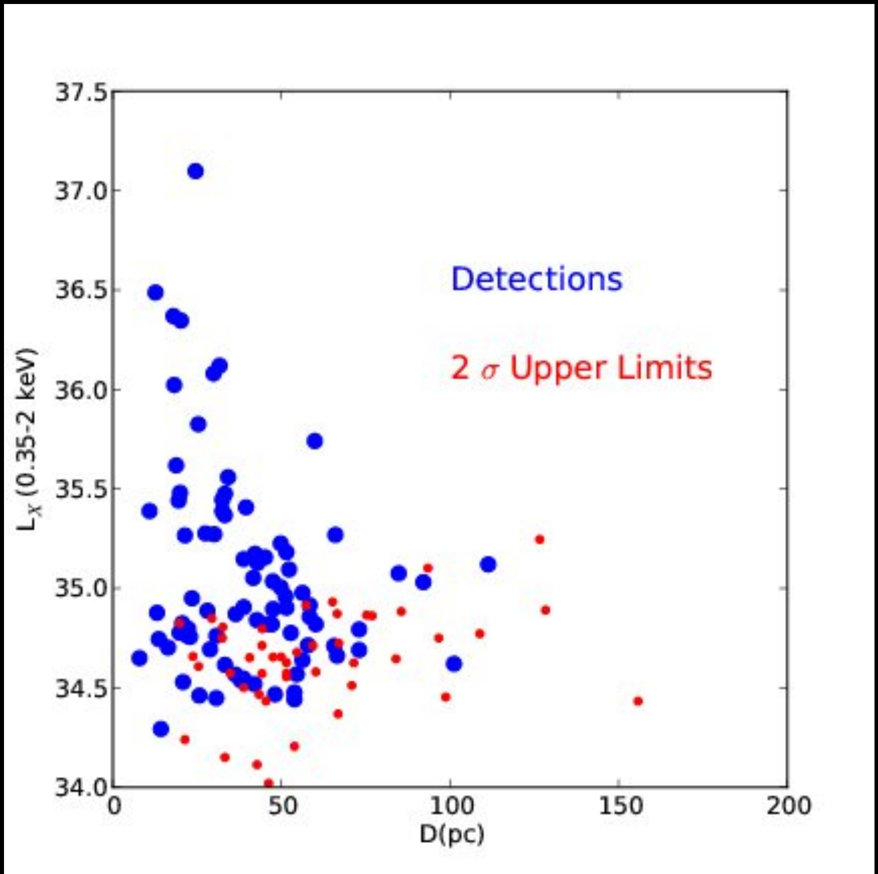
Diameter distribution in M83

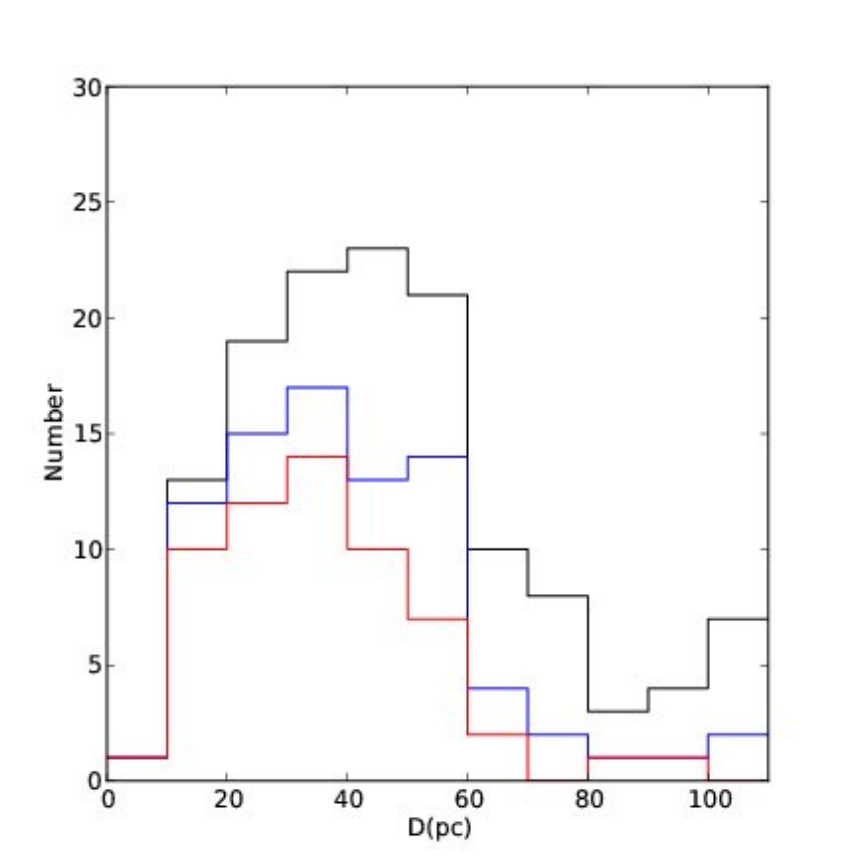




- 73 SNRs with D < 10 pc and 24 of these detected in X-rays
- Median D of all SNRs is 18.1 pc vs. 12.6 pc for X-ray-detected SNRs

Diameter Distribution in M33





- Median D is 44 pc for all SNRs, 32 pc for X-ray-detected SNRs

Simple Interpretation

Just the Facts

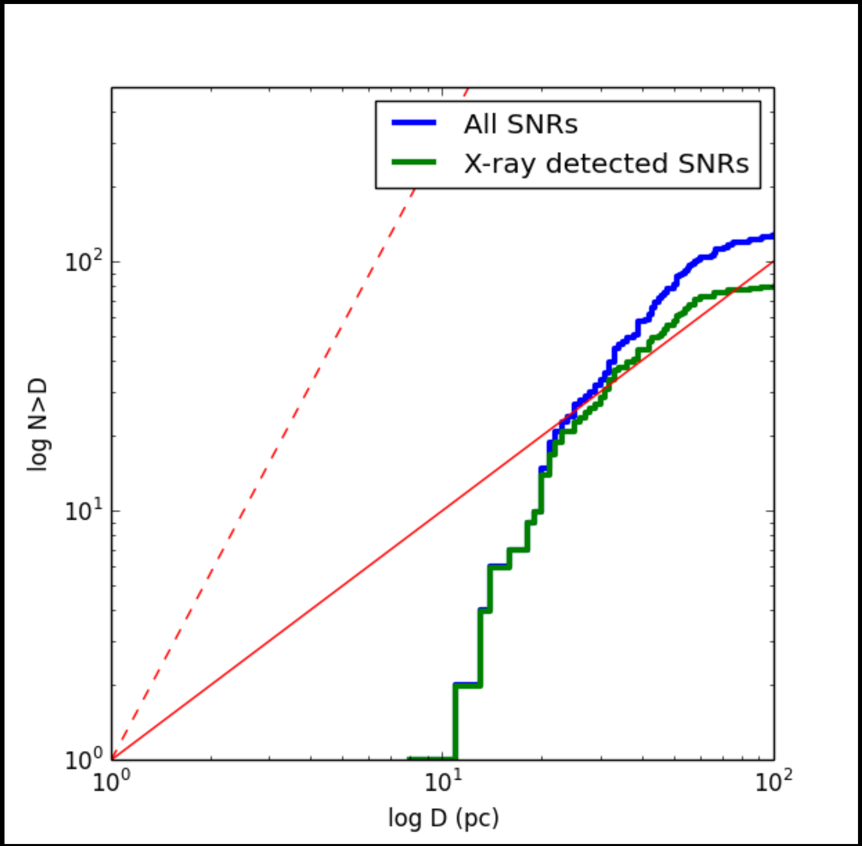
- About 25% of optically identified SNRs are detected in X-rays in M83
- Middle age SNRs dominate detections (and sample)
- L_x at a single diameter is highly variable
- Very large objects are always faint

It's the environment, stupid!

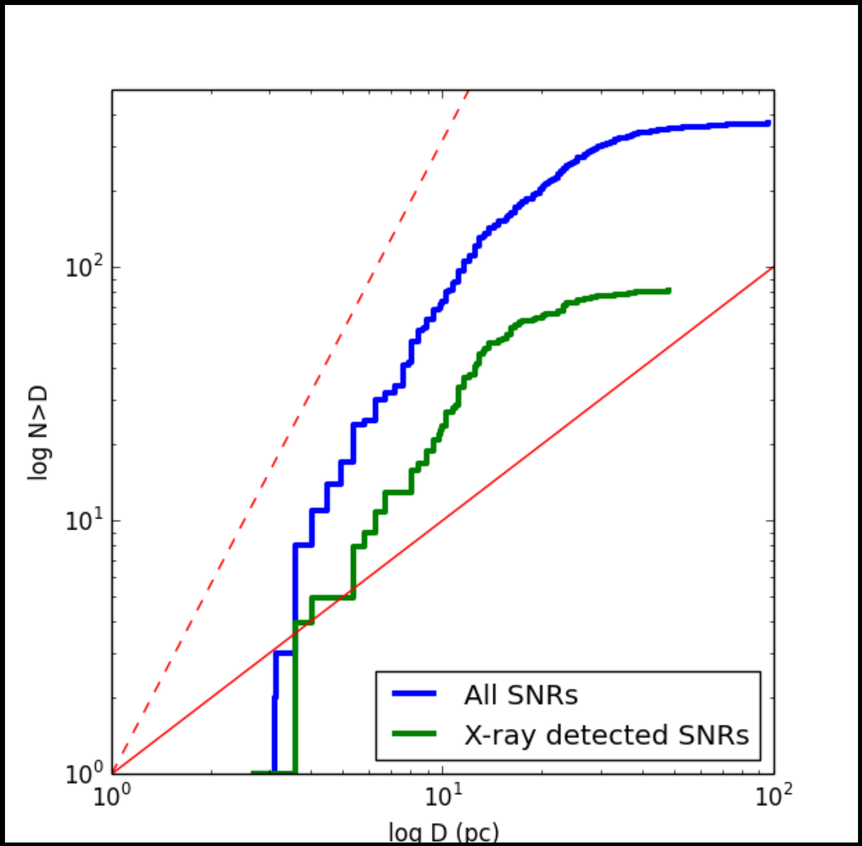
- $L_x \sim \eta\, n^2 R^3$
- η (0.35-2 keV)
  - ~ constant for kT>0.3 keV
  - drops rapidly for kT<0.3 keV
- T inversely proportional to swept up M
  - $M(M_o) = 83\ T(keV)^{-1}\ E_{51}$
- Implications
  - Small diameter objects are faint
  - Large diameter($R_{max} \sim n^{1/3}$) are faint
  - L_x of intermediate diameter objects strongly dependent on density (n^2)

Number Diameter Relation

M33

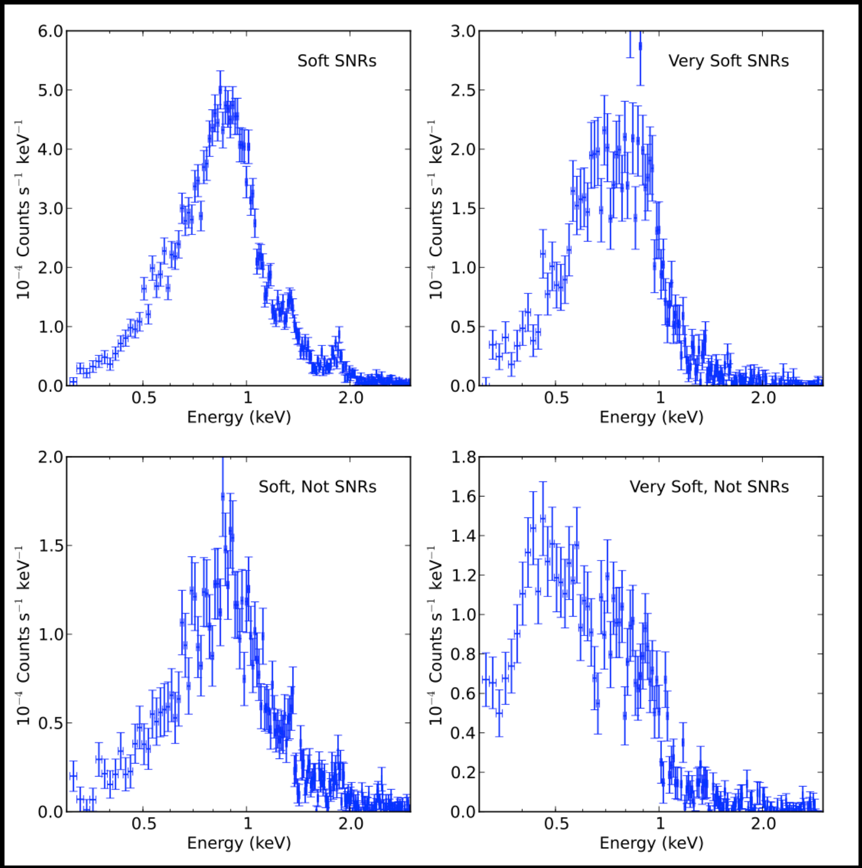


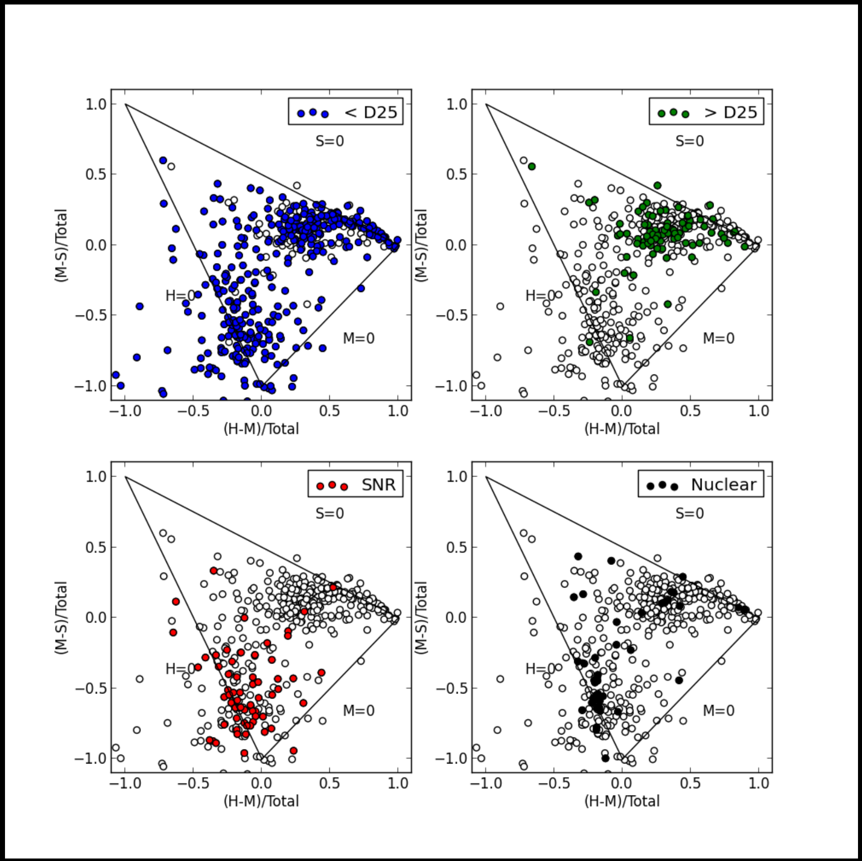
M83



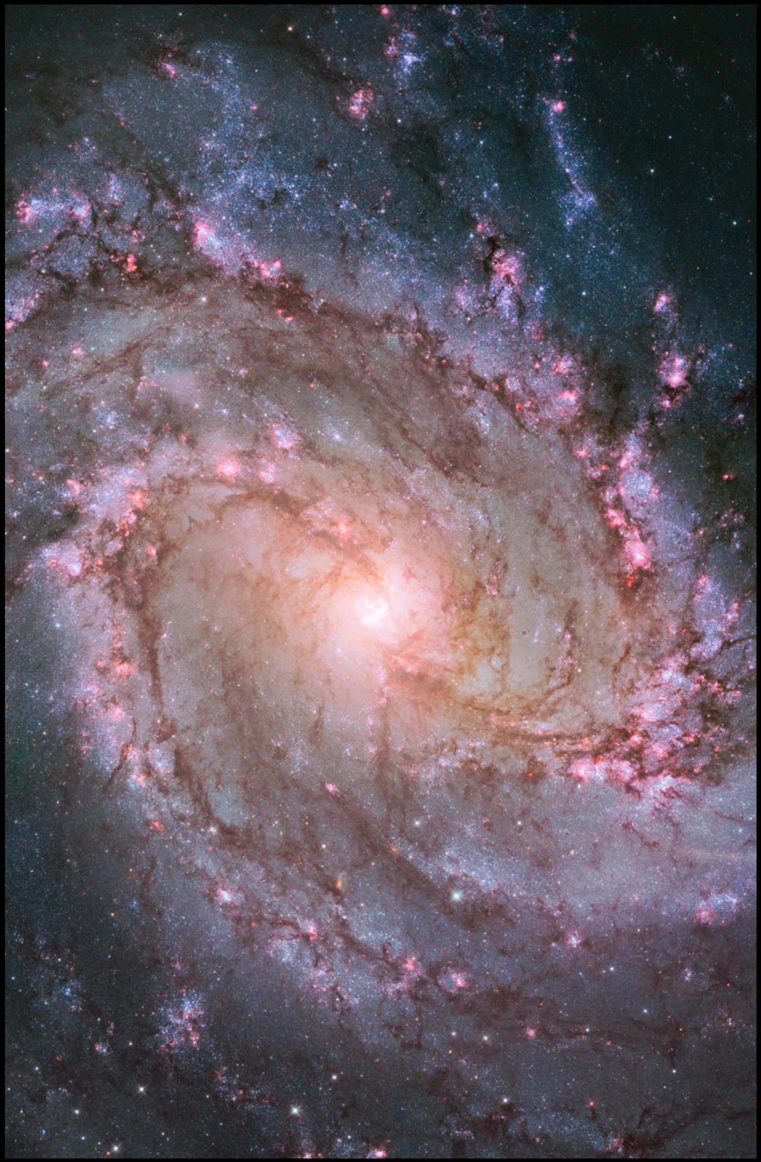
- The N-D slopes closer to Sedov than free expansion
- Difference between M83 and M33 is likely associated with a denser ISM in M83

More SNRs in X-rays ?





Summary



- As expected from observed SN rate, there are LOTS of SNRs in M83!
- *Chandra* and *HST/WFC3* have allowed us to uncover the young SNR population in M83
- 87 → 93, plus as many as 74 more if all soft sources are SNRs
- 73 SNR candidates with diameters below 10 pc.
  - 37/73 were previously known SNR candidates but there small sizes were unknown prior to HST.
  - 36/73 were newly discovered with HST.
  - 24 have *Chandra* X-ray counterparts.
- But very few appear to be obviously in the ejecta-dominated state.
- Most probably reason for this
  - Rapid evolution due to higher density/ pressure in the general ISM