The X-ray Properties of Supernova Remnants in Nearby Galaxies

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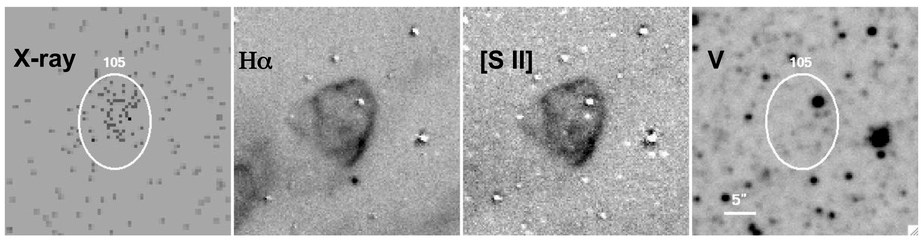
Abstract

More extragalactic SNRs have been detected in X-rays in nearby galaxies than in the Milky Way. Most of the X-ray detected SNRs were first identified optically, and then detected as soft X-ray sources in deep imaging observations with *Chandra* and in some cases XMM. Here, we discuss the large X-ray samples of SNRs in M33, M51, M83, and M101, with the goal of understanding which SNRs are detected in X-rays and which are not. Not surprisingly perhaps, most of the SNRs in these galaxies are middle-aged SNRs; very few analogs of Cas A or other young objects have been found. Trends of X-ray luminosity with diameter are absent, probably because the total amount of swept up material is the dominant factor in determining the X-ray luminosity of a SNR at a particular time. SNRs expanding into high density media evolve rapidly and have X-ray luminosities that peak at small diameters, whereas those expanding into lower density media evolve more slowly and have luminosities that peak later.

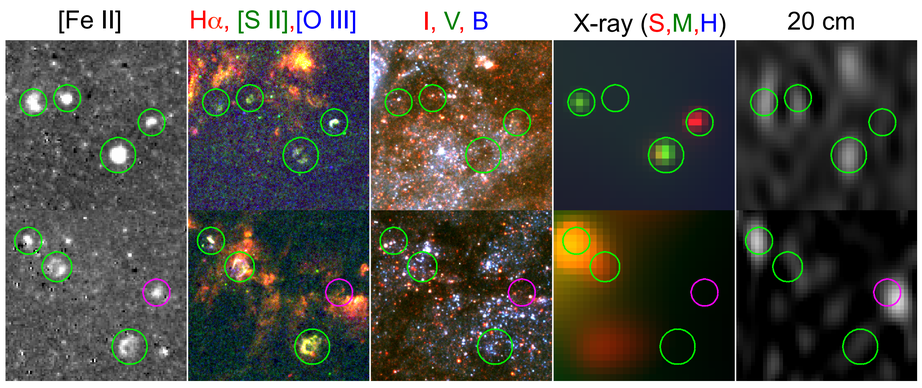
How are extragalactic SNRs identified

Most are identified optically, as emission nebulae with [S II]:Hα ratios that are higher (>0.4) than H II regions (<0.1).



A SNR in M33 first detected as an emission nebula with strong [S II] emission. Note the H II region that fades to almost nothing in the [S II] image. This SNR was detected in X-rays with *Chandra* (Long+10).

Examples of SNRs in M83

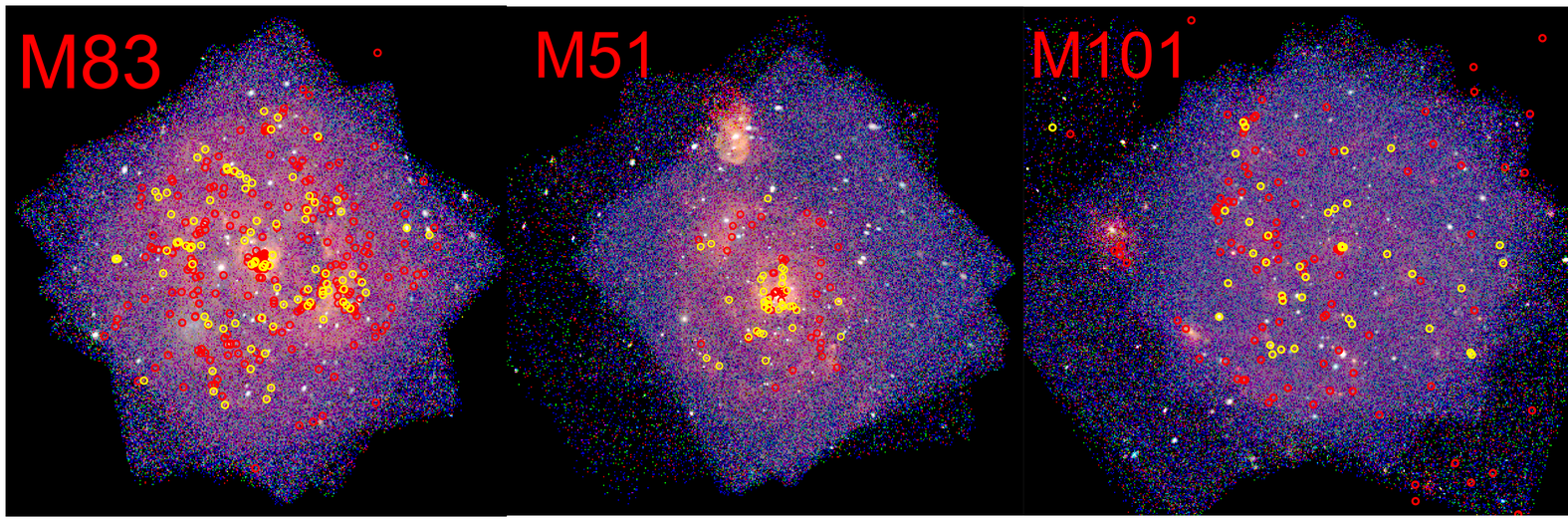


Two regions in M83 as observed in (from left to right) (1) [Fe II] 1.644 um, (2) Hα, [S II], [O III] (RGB) with stars subtracted, and (3) I,V,B broadband, all with HST/WFC3, (4) X-rays with *Chandra* (RGB=soft, medium, and hard) and (5) 20 cm radio with ATCA. SNRs identified on the basis of high [S II]:Hα ratios are indicated in green, with the smaller circles being 2" in diameter. Many of the SNRs in M83 are detected either as X-ray or radio sources as well. In the top panels, two SNRs apparently behind dust look harder (green) in the *Chandra* tile. A SNR identified on the basis of strong [Fe II] emission is indicated in magenta.

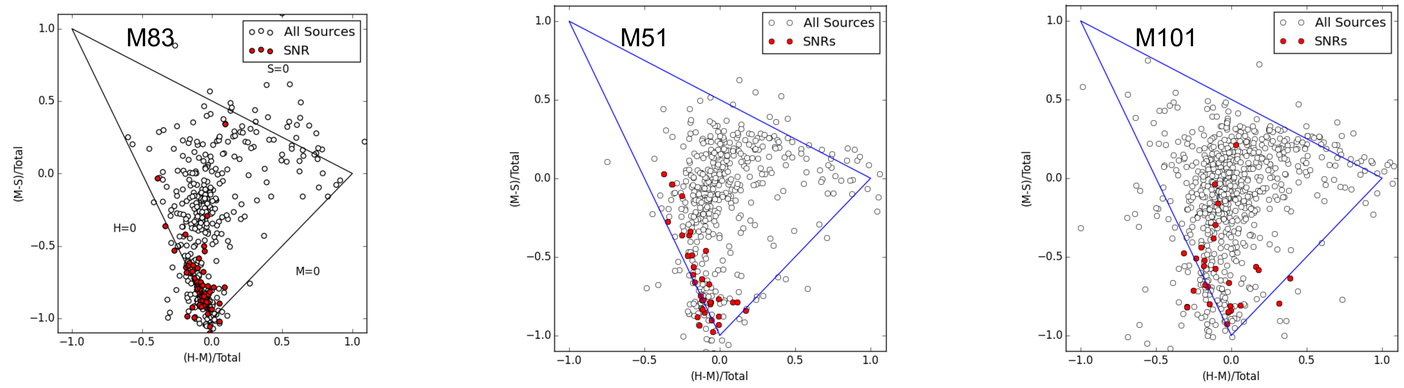
Deep X-ray observations with *Chandra* regularly detect SNRs in Nearby Galaxies

- M33
  - 88 of the 137 SNRs (known at the time) in M33 were detected in the 1.4 Msec *Chandra* ACIS survey (Long+10)
- M83
  - There are approximately 296 optically identified SNRs in M83
  - Of the 387 X-ray sources detected within the D25 diameter of M83 in deep 730 ksec *Chandra* observations, 87 aligned with SNRs (Long+14)
- M51
  - Prior to *Chandra* there was no optical SNR catalog for M51
  - HST observations conducted in concert with deep 850 ks Chandra observations reveal 80 optical SNR candidates
  - Of the 298 X-ray sources within the D25 diameter of M51 (NGC5194/5; Kuntz+16), 36 align with these candidates
- M101
  - There are about 149 optically identified SNR candidates in M101, as a result of a combination of ground based and new HST observations
  - Of these, about 40 are spatially coincident with *Chandra* X-ray sources

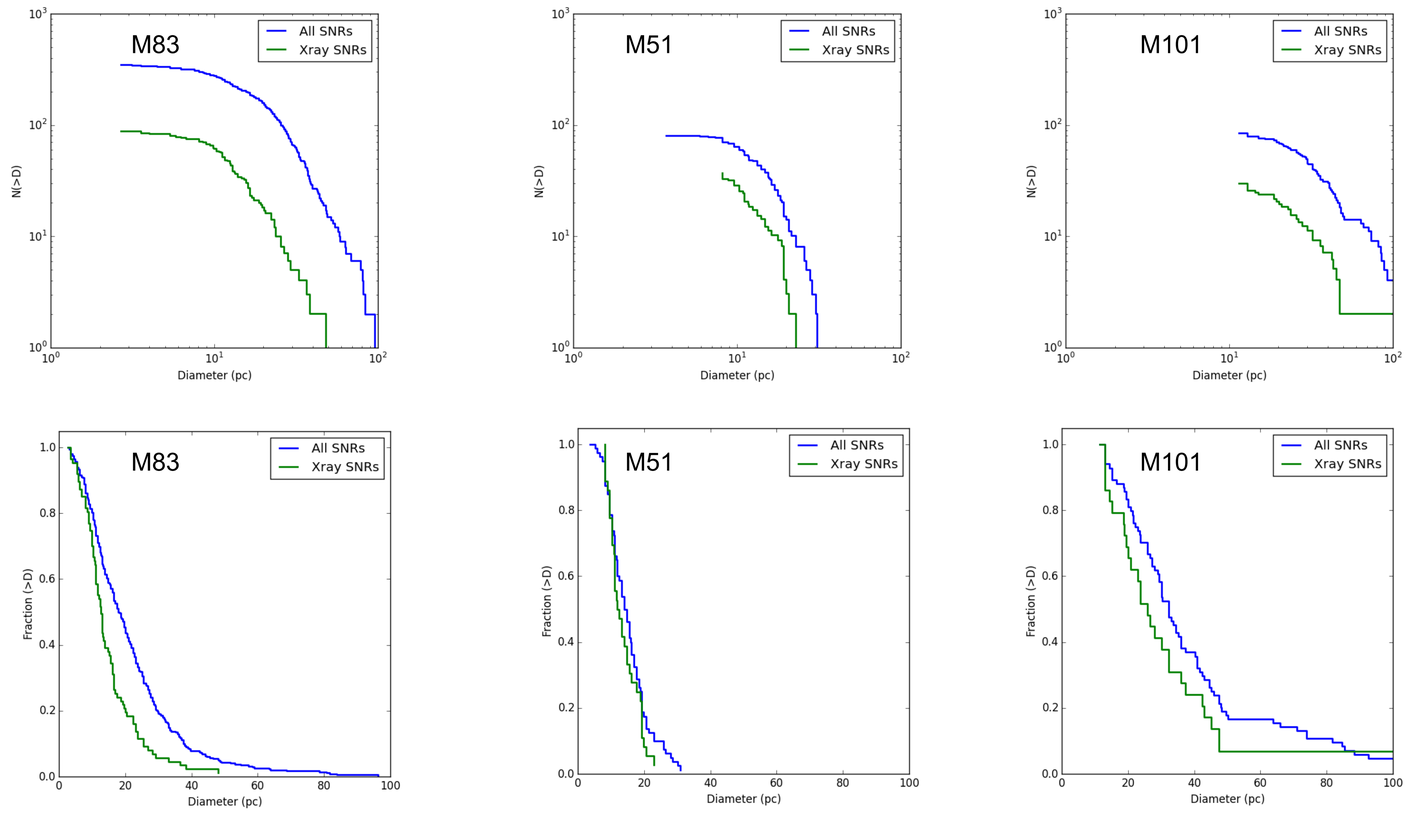
Although a few new extragalactic SNRs have been identified with *Chandra*, most X-ray SNRs are so faint that direct X-ray identifications can generally not be made.



X-ray images of M83, M51 and M101 with SNRs overlayed. Those detected in X-rays are in yellow; the remainder are in red.



Hardness ratios of SNRs compared to total population of X-ray sources in the fields of M83, M51, and M101. For M51, the SNRs shown are all in regions covered by HST observations.



The size distributions of SNRs in M83, M51, and M101. In M83 and M101, the X-ray size distributions are more concentrated at small diameters than the optical size distribution. In M51 they are similar, but this may be because lower surface brightness optical SNRs have not been identified in M51, since the only SNR catalog is derived from HST observations.

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