An Analysis Of Galactic Supernova Remnant G340.6+0.3

Author: Walker Hartman
Mentor: Dr. Thomas Pannuti
Department of Earth and Space Science, Morehead State University

Abstract: Pointed observations of Galactic supernova remnants (SNRs) as conducted at multiple wavelengths and with leading observatories (such as the Chandra X-ray Observatory and the Spitzer Space Telescope) have revealed many new insights into both SNRs themselves and the interstellar medium (ISM) with which these sources are interacting. We are currently investigating the multi-wavelength (chiefly X-ray and radio) properties of poorly studied SNRs that have been readily detected in the infrared to help improve understanding of how SNRs and their surrounding ISM interplay. to demonstrate this, we present an analysis of an archival pointed observation of the Galactic SNR G340.6+0.3 with the Chandra X-ray Observatory. The high angular resolution image reveals shell-like morphology that similarly matches the radio morphology of the SNR. In addition, spatially-resolved spectroscopy of the SNR using standard thermal plasma models reveals an asymmetry in the spectral properties of the rim. While enhanced (relative to solar) abundances of elements such as silicon are indicated from fits to the spectrum of the X-ray luminous northeastern rim (indicating that X-ray emitting plasma at this site is ejecta-dominated), the measured elemental abundances at other locations of the SNR are consistent with solar, indicating that those sites' plasma is dominated by swept-up ISM. From spectral fits and our adopted distance to this SNR of 15 kiloparsecs, we estimate a median electron number density for X-ray-emitting plasma to be 0.20 per cubic centimeter and the swept-up X-ray emitting mass of the plasma to be approximately 50 solar masses. Further results will be presented.

Background and Motivation:

- Few Galactic supernova remnants (SNRs) have been studied extensively at multiple wavelengths (such as X-ray, radio and infrared)
- Further detailed multi-wavelength analyses of Galactic SNRs will better our understanding of SNRs and SNR-related phenomena with general and individual Galactic SNRs in specific.
- G340.6+0.3 is a poorly-studied Galactic SNR that has been targeted by multiple telescopes in various wavelengths, but the observations made haven't been thoroughly analyzed.
- Multiple distances estimations have been made for G340.6+0.3 (such as the 16.8kpc estimation made by Caswell et. al. (1983)), but we adopt a distance of 15kpc based on The estimation from Kothes & Dougherty (2007)

Spectra of SNRs at X-ray energies:

- Bremsstrahlung radiation (Figure 1.1): electrons emit photons as they pass nuclei and they are accelerated.
- G340.6+0.3 emits X-rays through the thermal bremsstrahlung process and fits to the extracted spectra with thermal plasma models indicate that the temperature of the plasma is kT = X keV (where X is the kT value from the fitted region)
- Detailed analysis of extracted X-ray spectra from SNRs can determine which process is producing the observed emission (based on slope of spectrum)

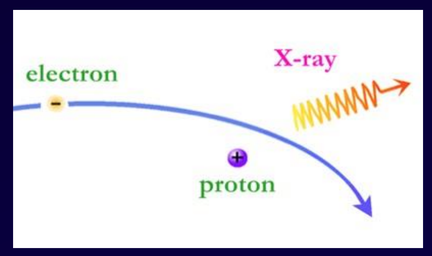

Figure 1

G5.9+3.1

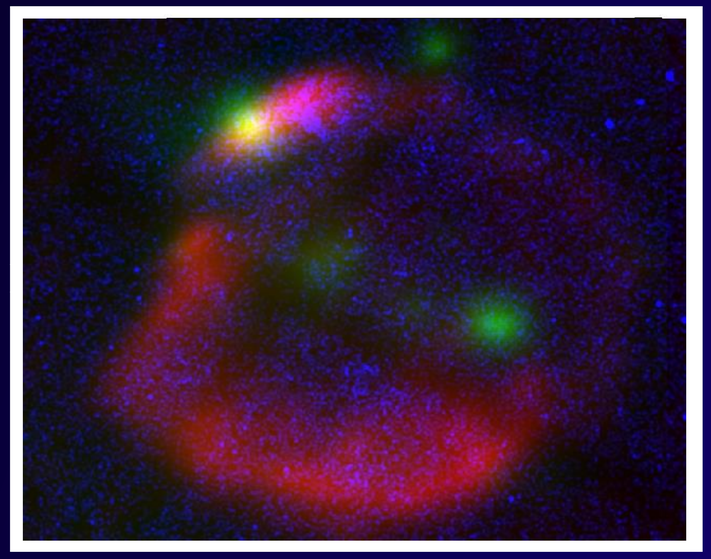

Figure 2: Exposure-corrected and adaptively-smoothed True-Color RGB image of G340.6+0.3, where Red represents radio emission data from the *RACS* 887MHz observation, Green corresponds to the Infrared 22Microns *WISE* observation and the Blue is X-ray emission from the *Chandra X-ray* observation. The Northeastern rim displays emission in all 3 different spectrums. Throughout the SNR's shell, there is a geometric overlap between the Radio and X-ray emission in G340.6+0.3.

Parameter	Southern Rim	Joint Fit
N_H (10^{22}cm^{-2})	$7.42\pm^{0.90}_{1.01}$	$1.14\pm^{0.35}_{0.33}$
kT (keV)	$0.78\pm^{0.13}_{0.084}$	$0.89\pm^{0.10}_{0.13}$
Normalization (cm^{-5})	$1.29\text{x}10^{-2}$	$8.75\text{x}10^{-3}$
χ^2/Degrees of Freedom (DOF)	127.05/128	285.5/254
$\Delta\chi^2$	0.99	1.12

Table 1: Summary of parameters of fit to spectra extracted for the different rims of G5.9+3.1 using the TBABSxAPEC model. The spectra have been fit simultaneously such that the temperatures and the normalizations of the three individual spectra were allowed to vary while the column density was tied together. Note the range of values in temperatures and electron number densities.

G340.6+0.3

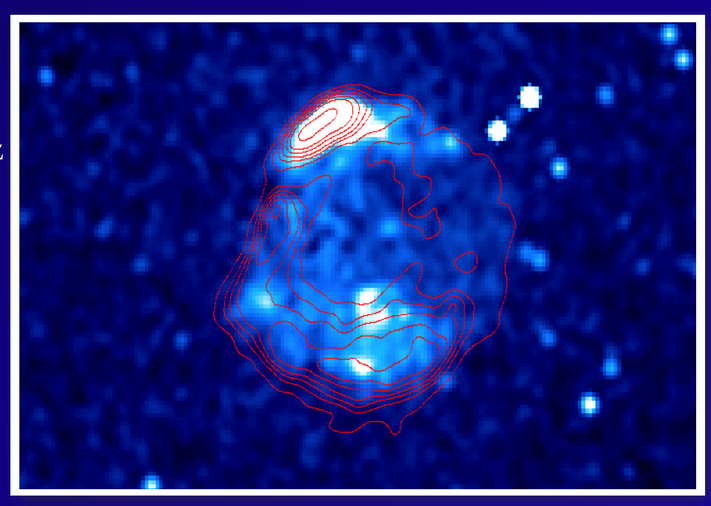

Figure 3: Exposure-corrected and adaptively-smoothed *Chandra X-ray* Broadband Flux image (0.5keV to 7.0keV) of G340.6+0.3 overlaid with contours from the RACS 887MHz observation of the remnant, with contour parameters ranging from 1.0E-8keV to 4.5E-7keV (relative to the radio). It appears that the Northeastern rim of the SNR contains a large amount of both radio and X-ray emission at the same location. The southern rim displays some overlap between them , but overall appears to be mainly ISM dominated.

Spectra of Southern Rim of G340.6+0.3 (TBABS*VNEI model)

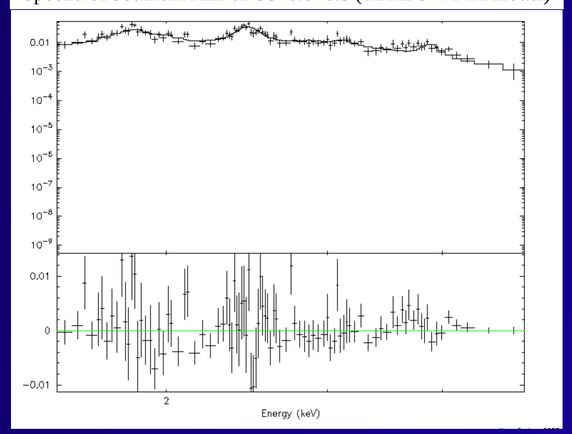

Figure 4: *Top Panel* – The extracted X-ray spectrum of the ISM-dominated Southern rim of G340.6+0.3 as fit with the TBABSxVNEI model using the parameters listed in Table 1 as well as elemental abundances.
Bottom Panel – Residuals to the fit.

Table of Spectrum of NE Rim Fit with TBABS*VNEI model

Parameter	Northeastern Rim	Whole SNR
N_H (10^{22}cm^{-2})	$6.69\pm^{0.94}_{1.03}$	$8.75\pm^{1.17}_{0.93}$
S (relative to solar abundances)	$4.81\pm^{2.35}_{1.39}$	$1.61\pm^{0.49}_{0.32}$
Normalization (Photons keV^{-1} cm^{-2} s^{-1} at 1 keV)	$1.63\text{x}10^{-3}$	$8.75\text{x}10^{-3}$
χ^2/Degrees of Freedom (DOF)	258.5/251	285.5/254
$\Delta\chi^2$	1.03	1.12

Table 2: Summary of parameters of fit to spectra extracted for the ejecta dominated northeastern rim of G340.1+0.6 using the TBABSxVNEI model. The fitted value of the elemental abundance of Sulfur for the Northeastern rim is nearly 3 times as much as the rest of the SNR and almost 5 times more than the amount of Sulfur in the sun.

Spectrum of NE quadrant of G340.6+0.3+0.1 with TBABS*VNEI model

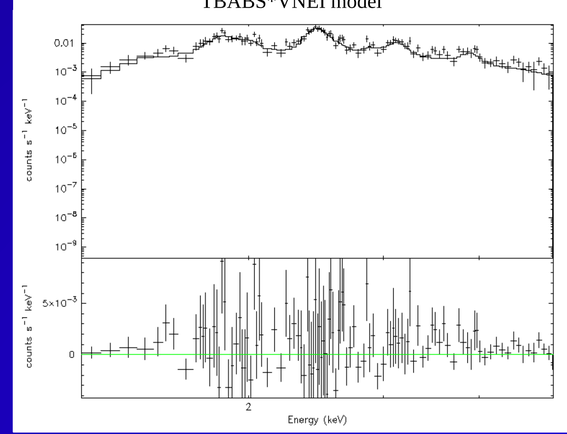

Figure 5: *Top Panel* – The extracted *Chandra X-ray* spectra, with the solid black line denoting the best fit for the data gathered from Xspec.
Bottom Panel – The residuals of the fit at that location along the line.