G1.9+0.3 – The New Kid on the Block

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ABSTRACT

With an estimated age of 140 years, the supernova remnant (SNR) G1.9+0.3 is thought to be the youngest SNR within the Milky Way Galaxy. Through the use of the Chandra X-Ray Observatory and its archived data, an analysis of the emission from this object was conducted, coming to the conclusion that these emission are of a synchrotron origin, as opposed to a plasmatic one. Standard non-thermal models, such as power laws and synchrotron "cut-off" models, were used to fit extracted spectra across the whole azimuth of the SNR. Such spatially-resolved spectral analysis allows us to search for spectral and spatial variations in the properties of the X-ray shell of emission, particularly from the bright eastern and western rims. We will present the initial results from fitting these spectra using the power law and synchrotron cut-off models.

➔An Introduction to G1.9+0.3

When a star reaches the end of its life cycle, it dies in a violent explosion called a supernova. The remains of this star are then known as a *Supernova Remnant*, or "SNR" for short. Through the use of the Chandra X-Ray telescope and other technologies, astronomers have come to the estimation that SNR's are created up to three times a century within a galaxy (Borkowski 2010), and that G1.9+0.3 is the youngest known SNR in the Milky Way Galaxy.

G1.9+0.3 Specifics

.G1.9+0.3 is the youngest known SNR of the Milky Way, at 140 years old (Borkowski 2013, Borkowski and Reynolds 2010)

.This is a type 1A SNR, which means it displays reliable patterns in brightness, and that the cause of explosion was most likely the death of a white dwarf star (Dunbar 2015)

DATA REDUCTION

Data for this SNR was pulled from the Chandra archives and processed through the CIAO, a standard softare package for analyzing Chandra Data. Once the data was downloaded, Chandra repro was ran to get the latest calibration. From here the spec extract tool was used to extract the processed data.

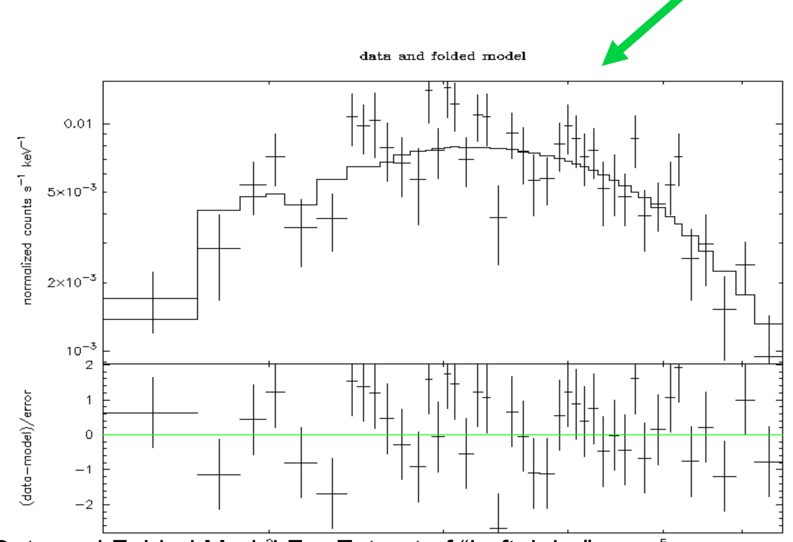

Figure 1. Data and Folded Model For Extract of "Left John" Region

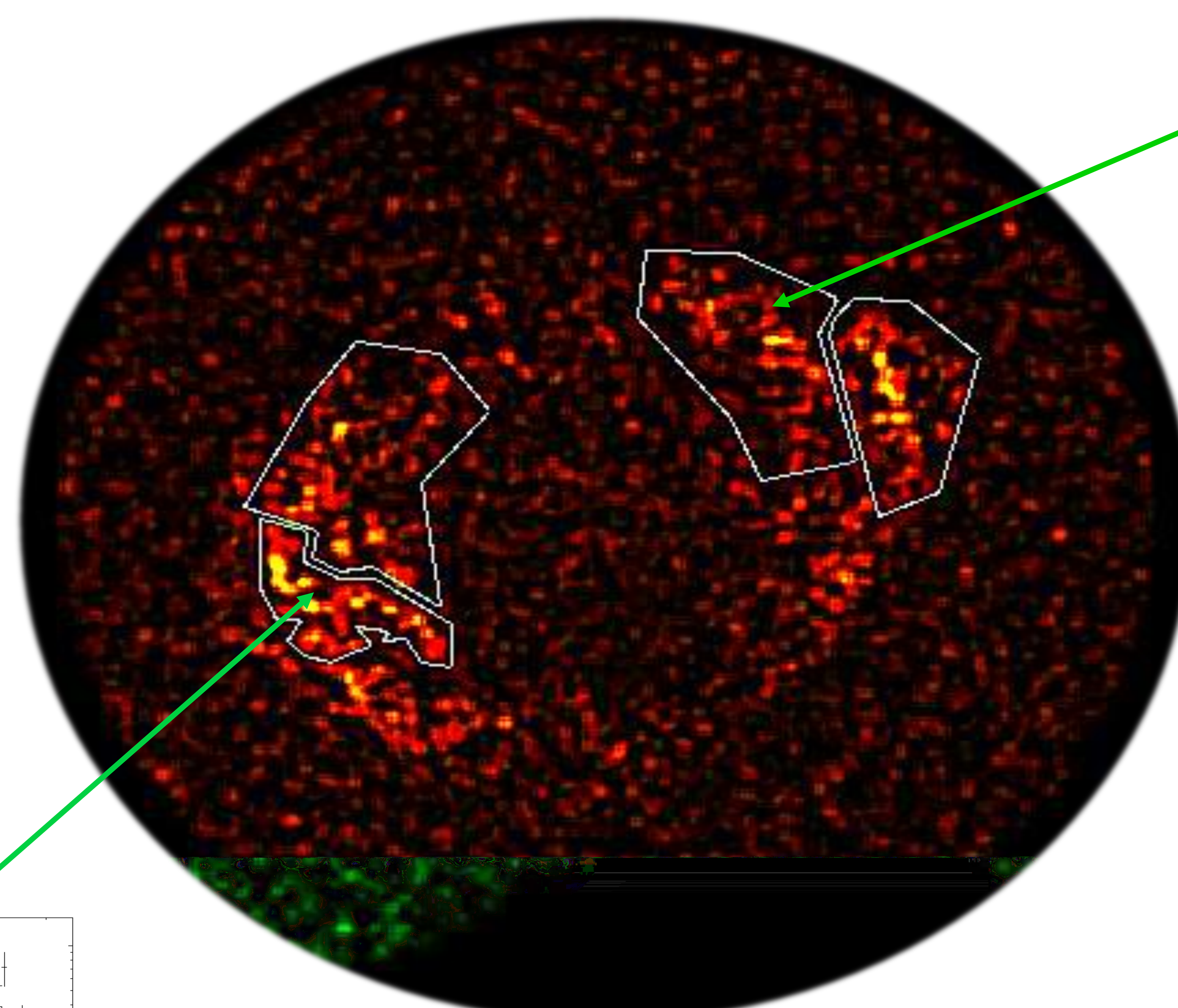

Image 1. An X-Ray Image of SNR G1.9+0.3. This image includes 4 regions of extract.

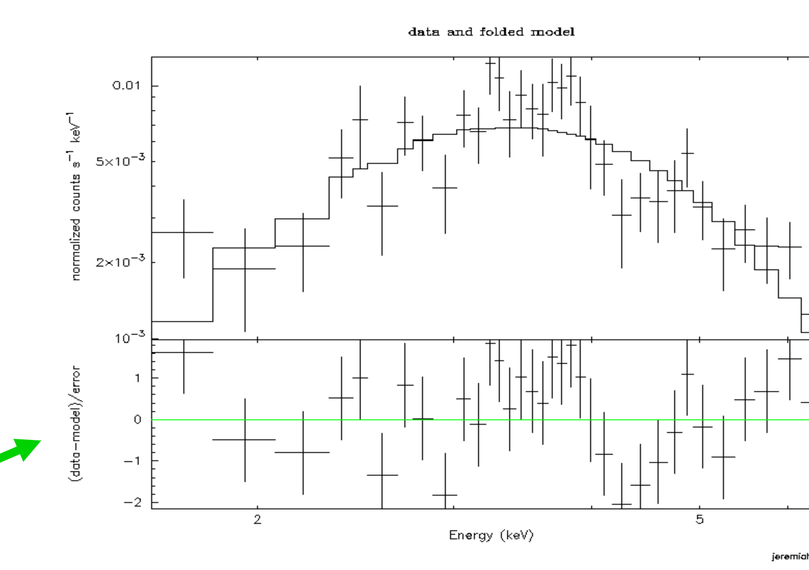

Figure 2. Data and Folded Model For Extract of "Right Upper Cleft" Region

	Left Upper Cleft	Right Curve	Left John	Right Upper Cleft
N_H	5.59 (-1.17 , 1.41)	12.57 (-3.59 , 4.76)	10.48 (-2.23 , 2.74)	5.67 (-1.39 , 1.70)
Γ	2.19 (-0.54 , 0.59)	2.74 (-0.83 , 0.98)	2.46 (-0.60 , 0.67)	2.11 (-0.60 , 0.67)
Norm	5.2×10^{-4}	1.2×10^{-3}	7.5×10^{-4}	3.5×10^{-4}
X^2/DF	49.70 / 39	40.17 / 31	29.08 / 32	30.85 / 29
Red X^2	1.274	1.296	0.909	1.064

Table 1. Column Density, Photon Index, Normalization, Chi^2/degrees of freedom, and reduced Chi^2 values for each region of extract

Results

The results from fitting the extracted X-Ray spectra has determined that, within the error bounds of the photon index calculated from each region, the same type of energy is being emitted across the board: Synchrotron radiation. This research confirms the standing ideas and research of other astronomers. Though there may be slight variations in emissions from the left and right side of this SNR, thus demonstrating its asymmetrical nature, the photon index of each region is congruent with that of other SNR's emitting synchrotron radiation.

Further Research

In this study several other regions of this SNR were observed and processed, however due to size limitations, they were not included on this presentation. Adding these additional numbers and figures would be the first step towards furthering this study. Changing the size and shapes of our regions and re-processing them would also be beneficial as would comparing the emissions of this SNR to others that have shown signs of synchrotron radiation emissions.

References

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Reynolds, S., Borkowski, K., Green, D., Hwang, U., Harrus, I., & Petre, R. (2008). The Youngest Galactic Supernova Remnant: G1.9+0.3

PSR B1509-58: When the Galaxy Has a Question

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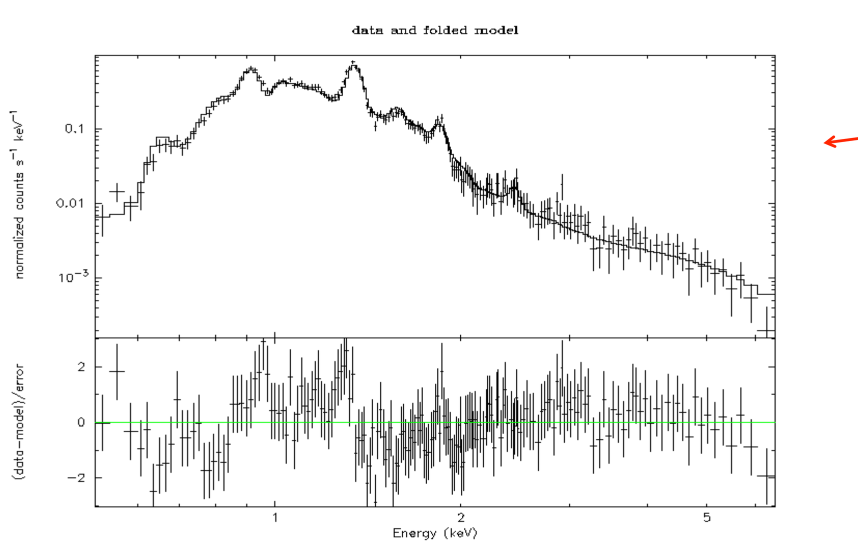
Abstract

We have conducted a spectral analysis of an archival observation made of the Galactic pulsar wind nebula (PWN) PSR B1509-58 using the Chandra X-ray Observatory. This PWN is famous for its striking resemblance to an extended hand-like structure: its age and distance are estimated to be approximately 1700 years and five kiloparsecs, respectively. The combination of the rapid rotation of the neutron star and its ultra-strong magnetic field makes B1509-58 one of the most powerful electromagnetic generators in the Galaxy. Spectra were extracted from the bright “palm” (which is associated with the central neutron star of the PWN and its trailing wind structure) and the “fingers” using the Chandra Interactive Analysis of Observations (CIAO) software package and fit using the software package XSPEC.

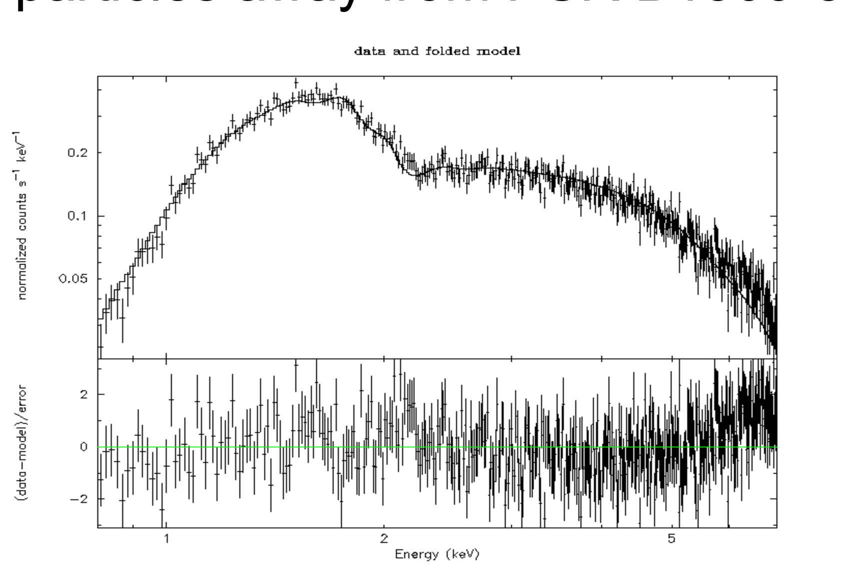
Introduction: Pulsar Wind Nebula

- A pulsar is a spinning neutron star with a strong magnetic field. Pulsars are also surrounded by pulsar wind nebulae which are composed of charged particles that have been accelerated to very high energies (nearly the speed of light).



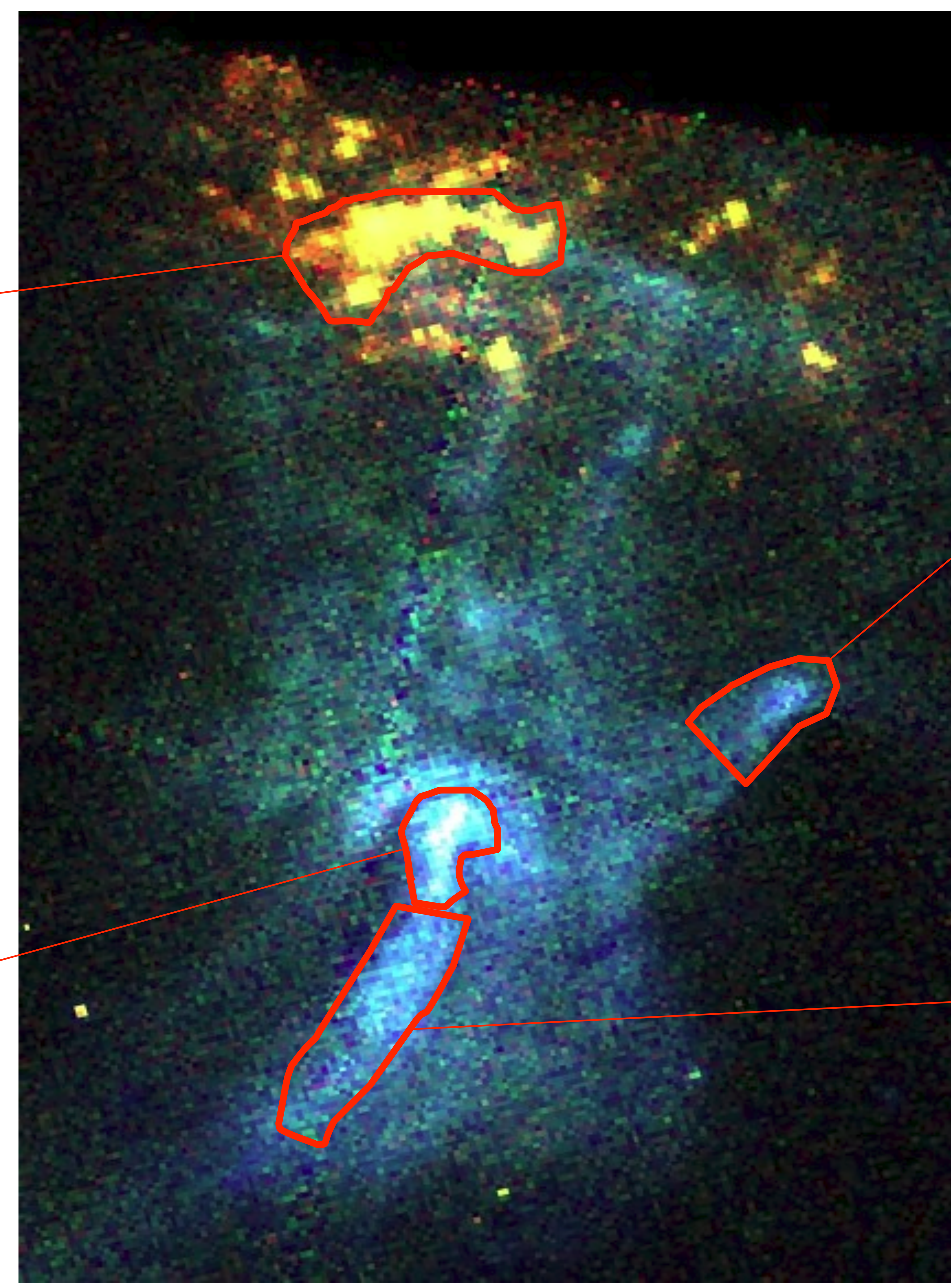
PSR B1509-58

- Astronomers think that PSR B1509-58 is about 1700 years old as measured in Earth's time-frame and is located about 5 kiloparsecs away (see figure – red, green and blue are low, medium and high energy X-ray emission, respectively).
- The combination of rapid rotation and ultra-strong magnetic field drives a wind of particles away from PSR B1509-58.



Data Reduction

- Downloaded dataset for observation of PSR B1509-58 from the on-line *Chandra* X-ray Observatory data archive. Used standard tools in CIAO software package to analyze the data.
- Used CIAO tool **chandra repro** to apply basic calibration tasks.
- Used DS9 to choose regions for extraction of source and background spectra.
- Used CIAO tool **specextract** to extract spectra for all source (“finger,” “palm,” “palmtail,” and “thumb”) and background regions.
- Fit the spectral files from the regions using XSPEC.

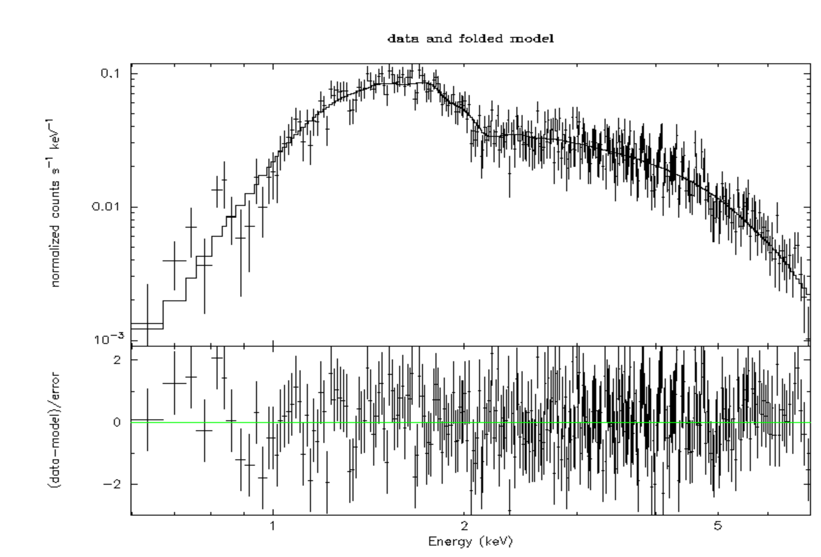


Summary of Fit Parameters

	Finger	Palm	Palmtail	Thumb
nH (10E22 cm^-2)	1.08 (-0.02, +0.05)	0.82 (-0.02, +0.02)	0.87 (-0.02,+0.02)	1.12 (-0.02,+0.02)
PhoIndex	1.25 (-0.55, +0.48)	1.32 (-0.02,+0.02)	1.69 (-0.02,+0.02)	2.06 (-0.02,+0.02)
Norm (Power Law Component)	3.49	2.49E-3	1.48E-3	1.11E-3
Norm (Thermal Component)	4.06	…	…	…
Chi Squared/Degrees of Freedom	169.72/167	538.14/421	364.65/375	297.54/301
Reduced Chi Squared	1.02	1.28	0.97	0.99
kT (keV)	0.39 (-0.04, +0.05)	…	…	…
Mg	0.73 (-0.07, +0.08)	…	…	…
Si	0.26 (-0.06, +0.07)	…	…	…
S	0.43 (-0.30, +0.42)	…	…	…
Fe	0.19 (-0.05, +0.05)	…	…	…
Tau (cm^-3 s)	1.29E+11 (-0.52E+11, +0.76E+11)	…	…	…

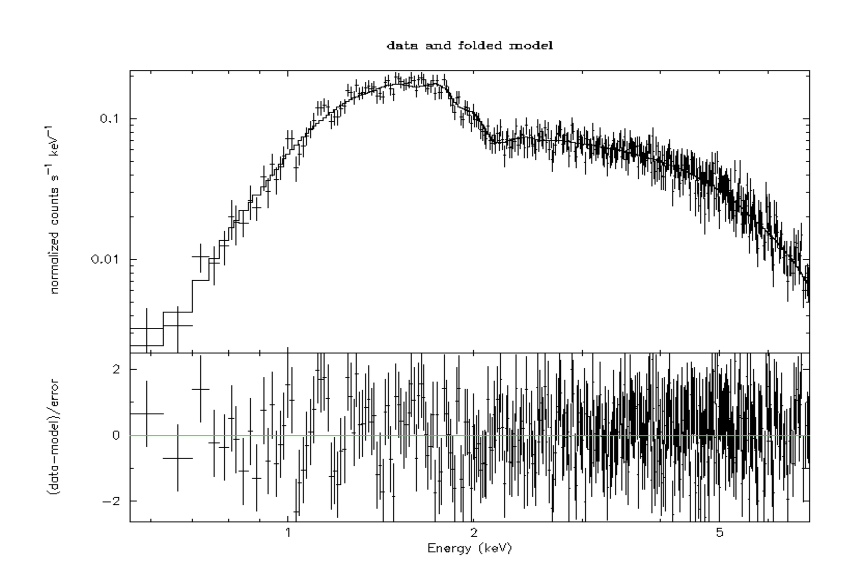
Results

- We find variations in the fitted values of the photon indices across the whole “hand,” indicating variations in energy distributions of the accelerated particles in the pulsar wind nebula.
- One region has a strong thermal component that probably originates from shock-heated interstellar material.



Further Research

- We will extract spectra from other regions to search for more variations (if present) in the spectral properties (like the photon index) of different regions of the “hand.”
- We will apply more sophisticated models to the spectra to see if these provide better fits.



References

- Pulsar Wind Nebulae. (2016, November 04). Retrieved April 21, 2017, from https://www.cfa.harvard.edu/news/su201643
- (n.d.). Retrieved April 21, 2017, from http://chandra.harvard.edu/photo/2009/b1509/

Analyzing Thermal and Non-thermal X-ray Emission from Supernova Remnant RCW 86

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Abstract

We present an analysis of two pointed observations made of the Galactic supernova remnant RCW 86 with the Chandra X-ray Observatory. These two observations targeted the bright SW and NE rims and the total exposure time of the two observations was 164 kilo seconds. RCW 86 is significant in that it is believed to be associated with a historical supernova observed in 185 A.D. There is still debate about the type of stellar progenitor that produced this SNR, whether the progenitor was a massive star or a white dwarf star in a binary system. To investigate the nature of the stellar progenitor of RCW 86 we are performing spatially-resolved spectroscopy of the x-ray emission from this remnant at different portions along the rims with the intent of measuring iron abundances relative to oxygen. We are also analyzing the non-thermal x-ray emission detected from RCW 86 that appears to be synchrotron radiation.

Introduction

Supernova remnants are the result of spectacular explosions of white dwarf and stars far bigger than our sun that occur very often in our galaxy and the universe itself. These explosions disperse gases that contain elements that made up those stars. Some produce neutron stars while others, produce pulsars. These supernova remnants can be observed through X-ray, optical and radio telescopes.

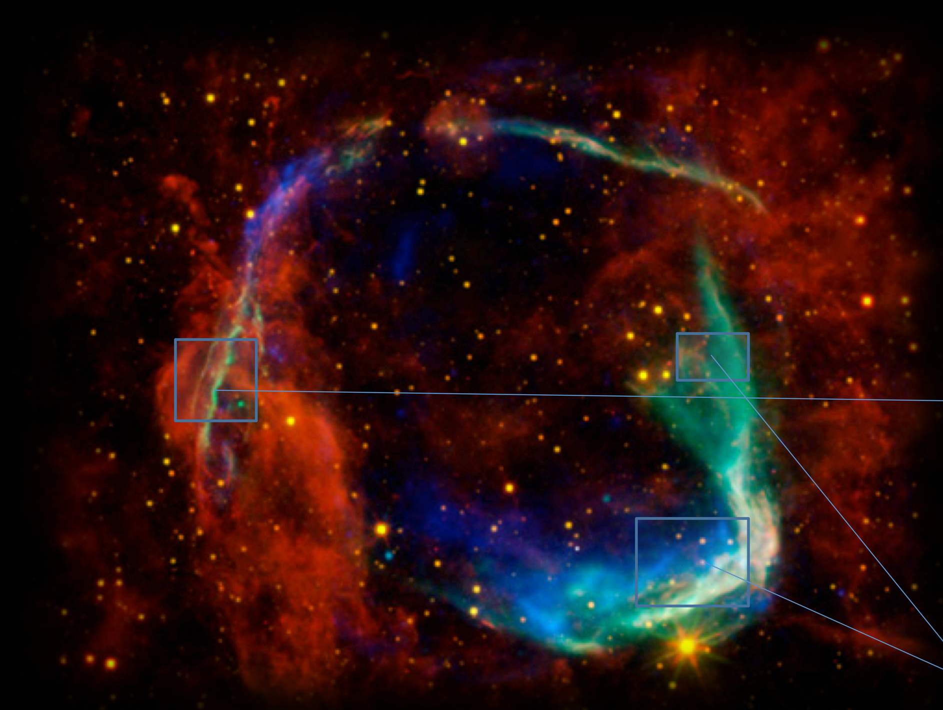


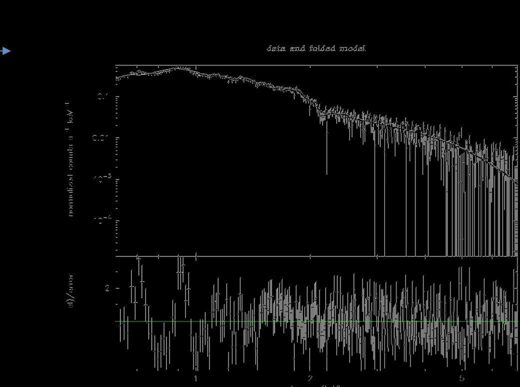
Image of X-ray and infrared emission from RCW 86. (Image Credit: *Chandra* X-ray Observatory.

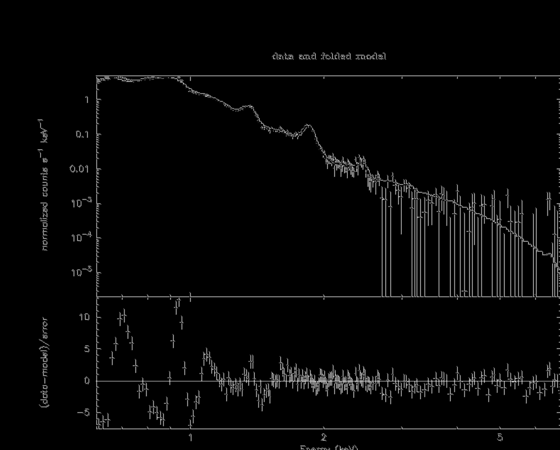
SNR RCW 86

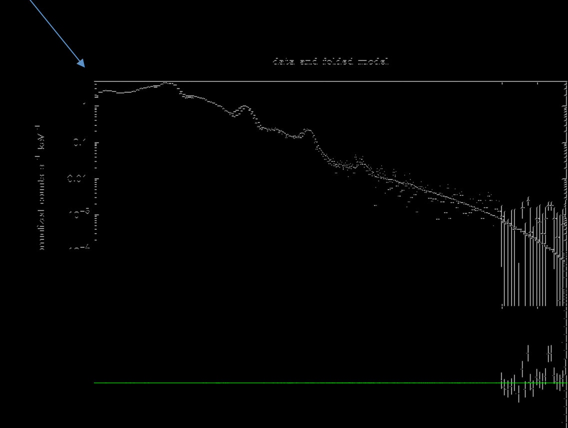
Supernova remnants are one of the greatest discoveries in the history of astronomy. We consider here one of the oldest known historical Galactic remnants, RCW 86. This source is associated with a supernova observed in 185 A.D by a Chinese astronomer that noticed a new star that appeared and remained in the sky for months. The distance of this remnant is roughly 8,000 light years away from our planet and is nearly 2,000 years old. RCW 86 resides in the southern constellation of Circinus.

Data Analysis

- Data analysis of RCW 86 was done with CIAO 4.8. Light curve analysis was done on observation ID 1993 of RCW 86 to create event files suitable for analysis.
- A three color (RGB) image was produced depicting detected X-ray emission in the low, medium and high energy ranges as red, green and blue, respectively.
- Created regions for spectral extraction as well as corresponding background spectral regions.
- Observations were combined to create exposure-corrected images for the whole SNR.
- Contours depicting radio emission (corresponding to synchrotron emission) were placed on the merged X-ray image to search for spatial correspondences.







Data Results

- The parameters of these fits are different.
- For the southwest part of the remnant the majority parameters have a reduced chi-squared of less than 1.2
- The parameters for the northeastern part of the SNR vary widely compared to southwestern portion of SNR.
- For the radio and x-ray contours the southwest region of RCW 86 seem to correlate much more than the northeastern portion of the SNR.

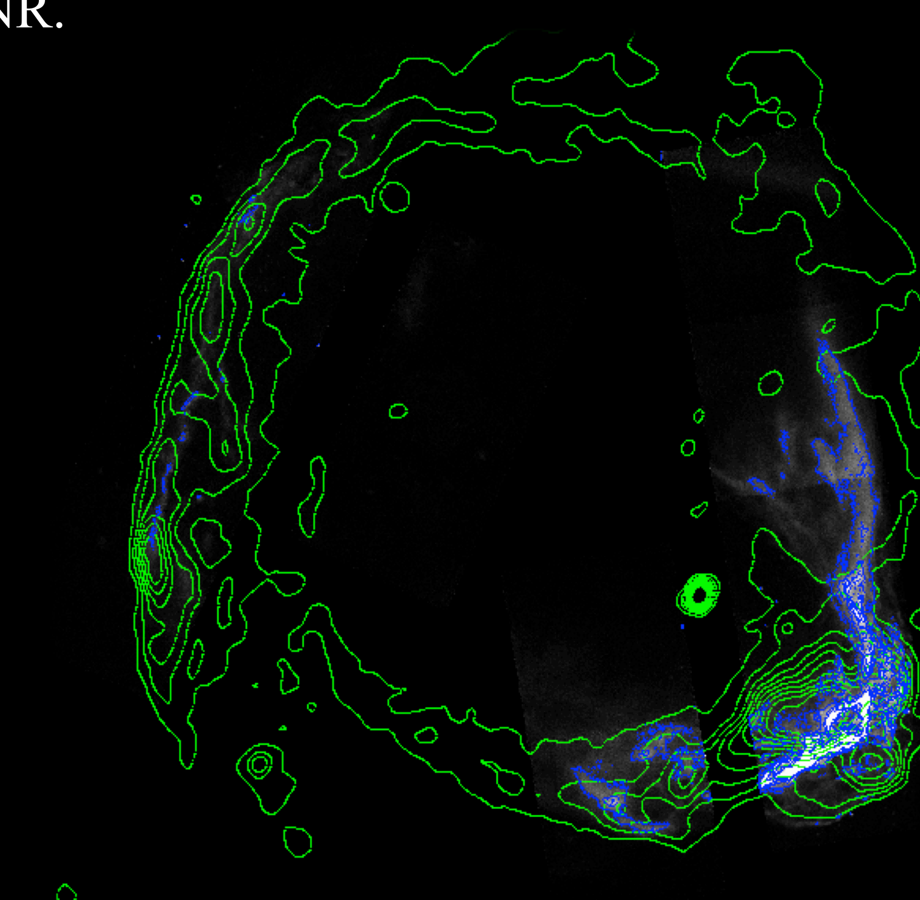
References

http://cxc.harvard.edu/ciao/threads/

http://chandra.harvard.edu/photo/2011/rcw86/

Future Research

- Continuing spectral analysis by extracting spectra from regions across the whole SNR.
- Attempt to characterize the SNR progenitor based on measured elemental abundances.
- Characterizing distribution of different emission processes (thermal and nonthermal) across the whole SNR.



This is the combined Chandra X-ray image of the SNR (northeastern and southwestern rims) with radio contours overlaid. Radio contours trace synchrotron emission from supernova remnants, so inspection of this image reveals regions where X-ray emission and radio emission coincide and thus possibly indicate synchrotron emission at X-ray energies from this SNR. Synchrotron emission at X-ray energies is produced only by very energetic particles that have been accelerated to nearly the speed of light.

Chandra Observations of RCW 86

Date	Observation ID	Observation Time (ks)
01/02/01	1993	2600
01/01/02	1993	93600
15/05/04	4611	10020
03/02/13	14890, 15608, 15609	104220