

PSR B1509-58: When the Galaxy Has a Question

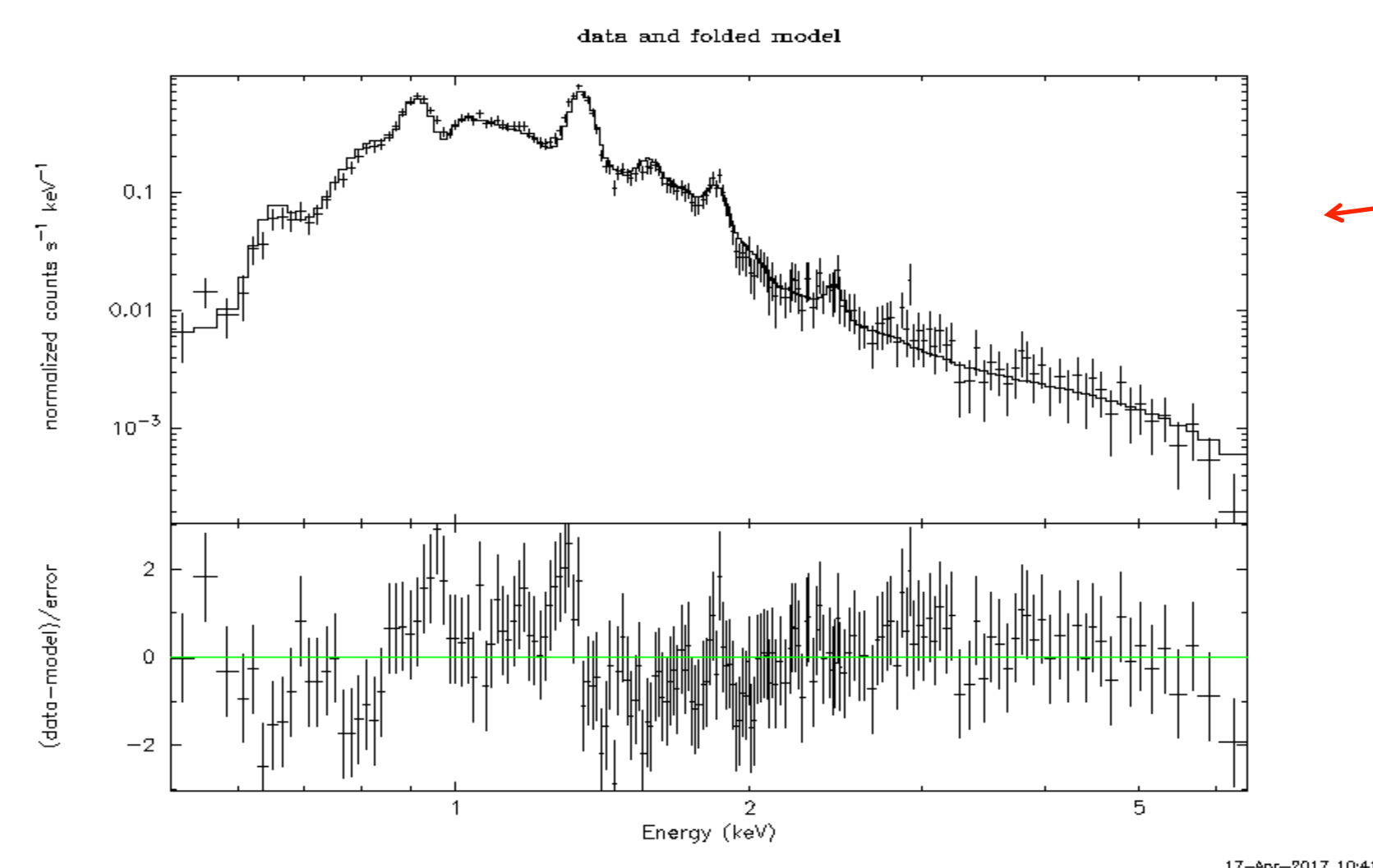
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Abstract

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.

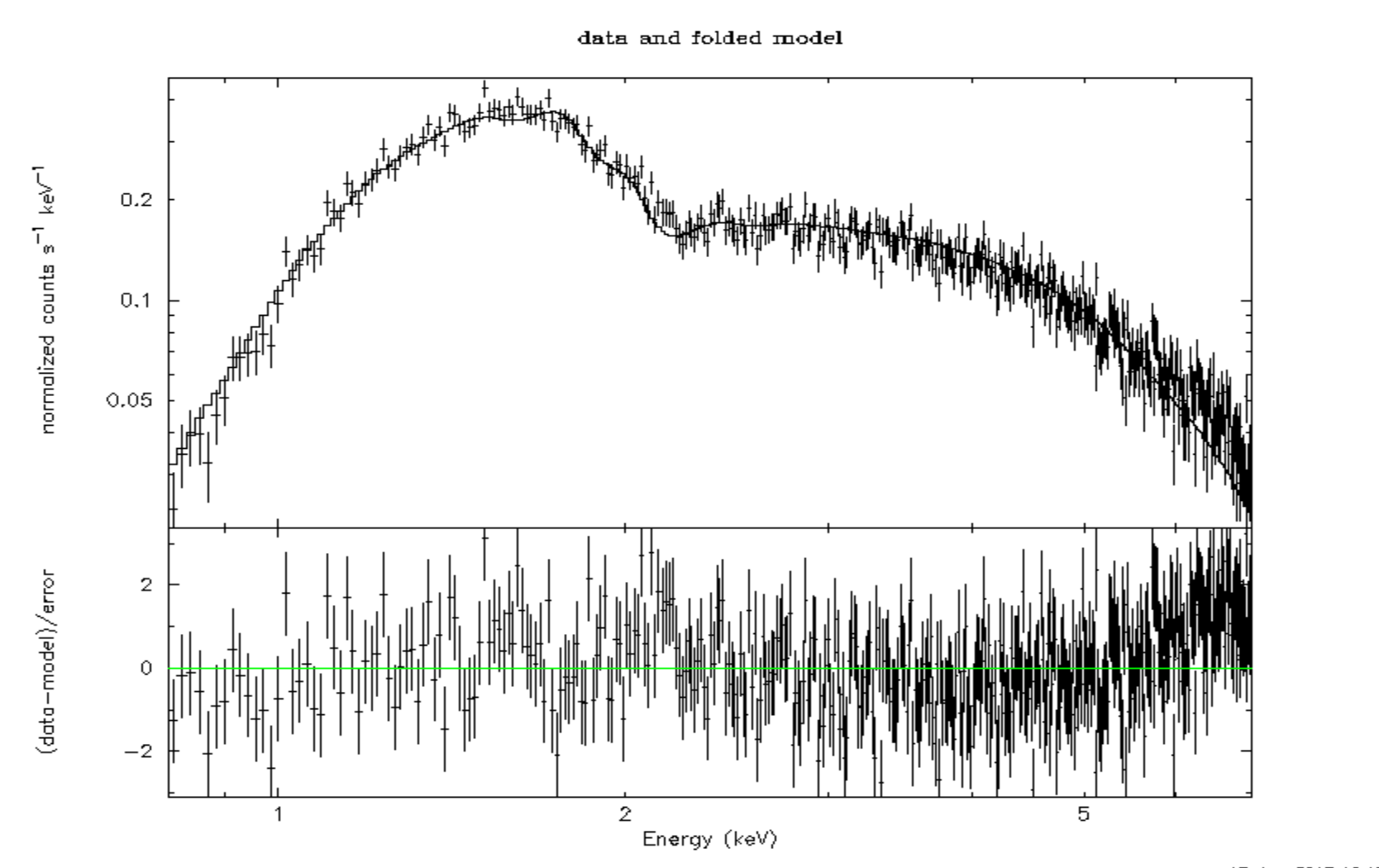
Introduction: Pulsar Wind Nebula

- 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).



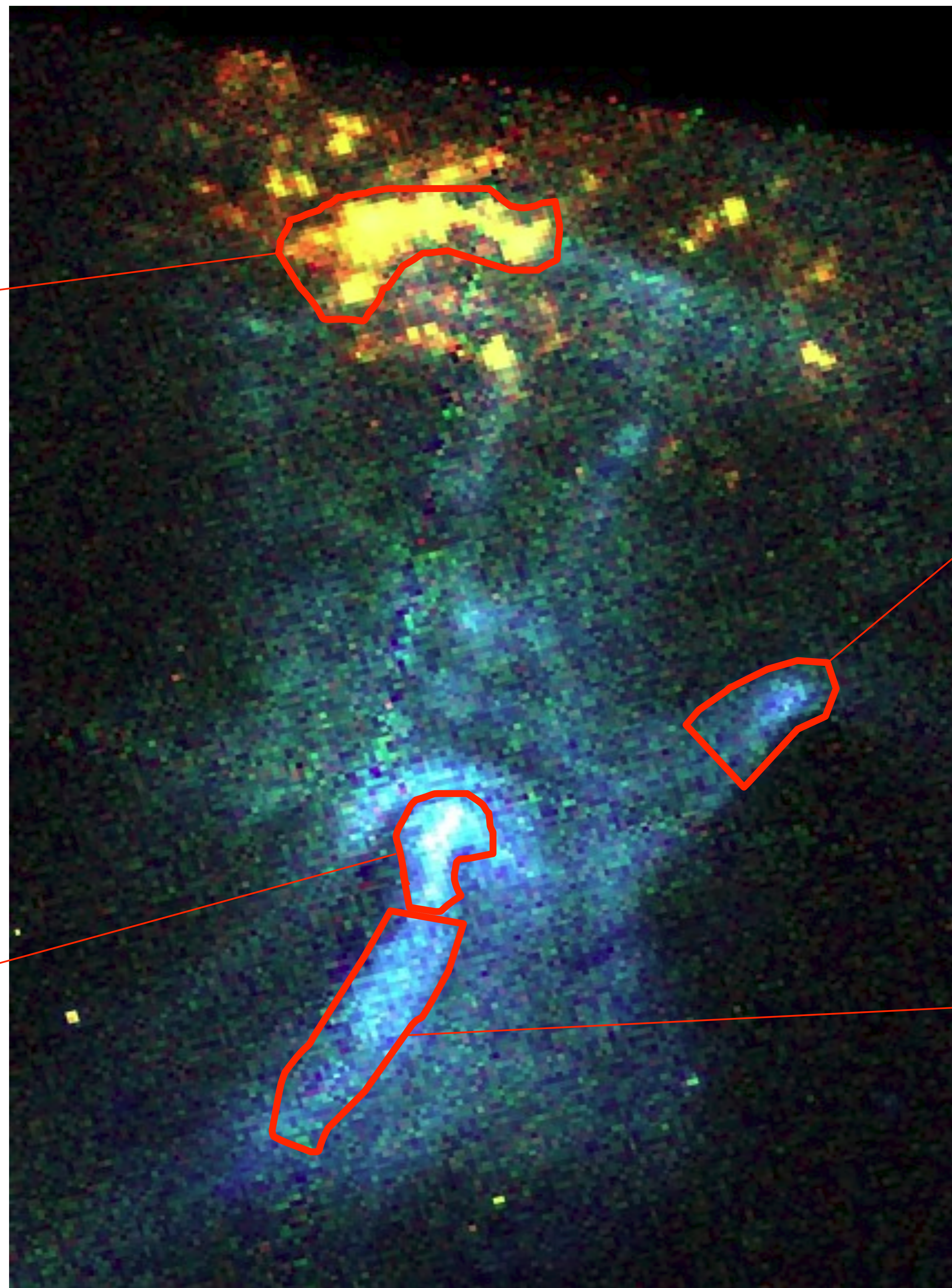
PSR B1509-58

- 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.

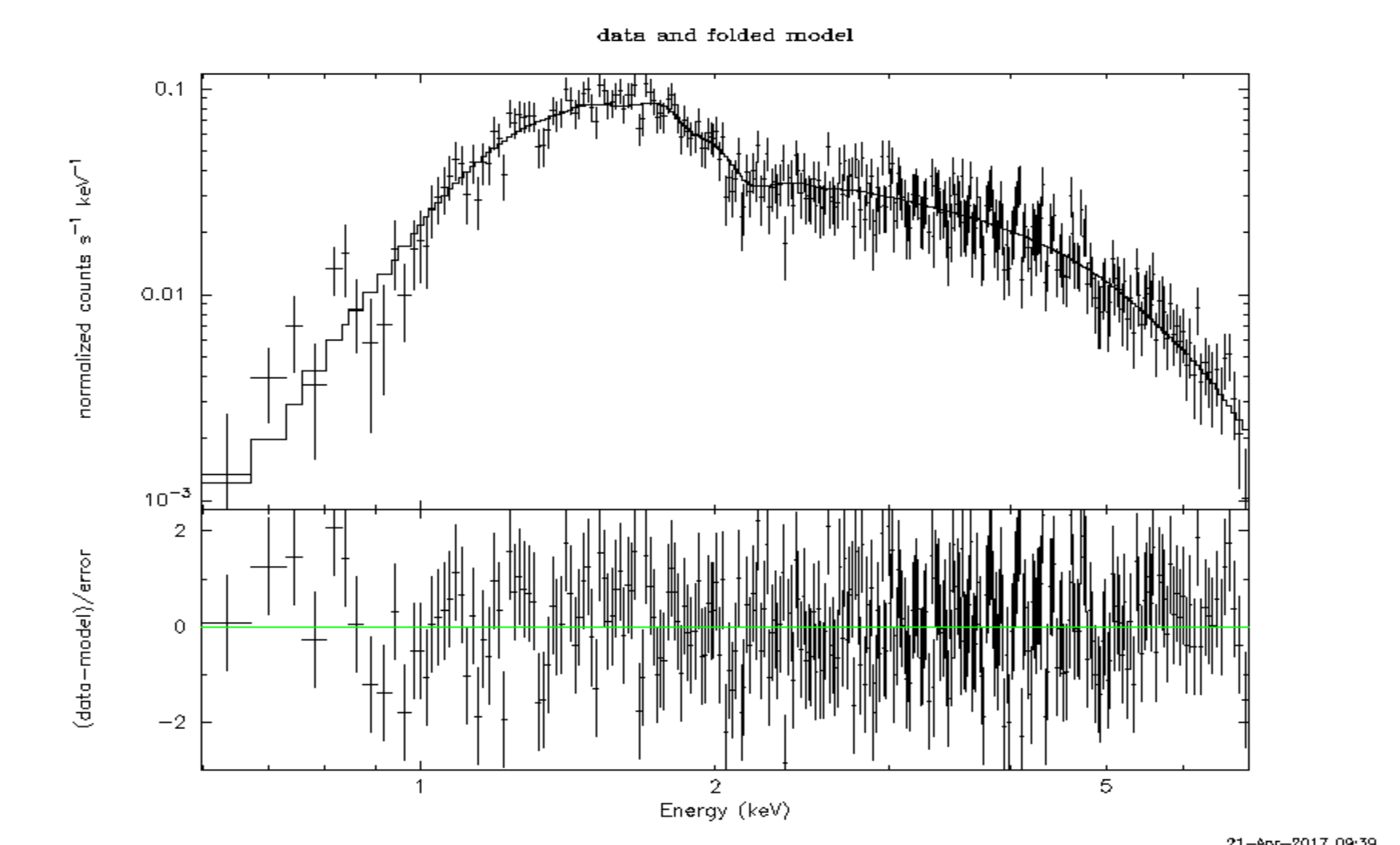


Summary of Fit Parameters

	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)
PhIndex	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	0.28 (-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)	...	...	...

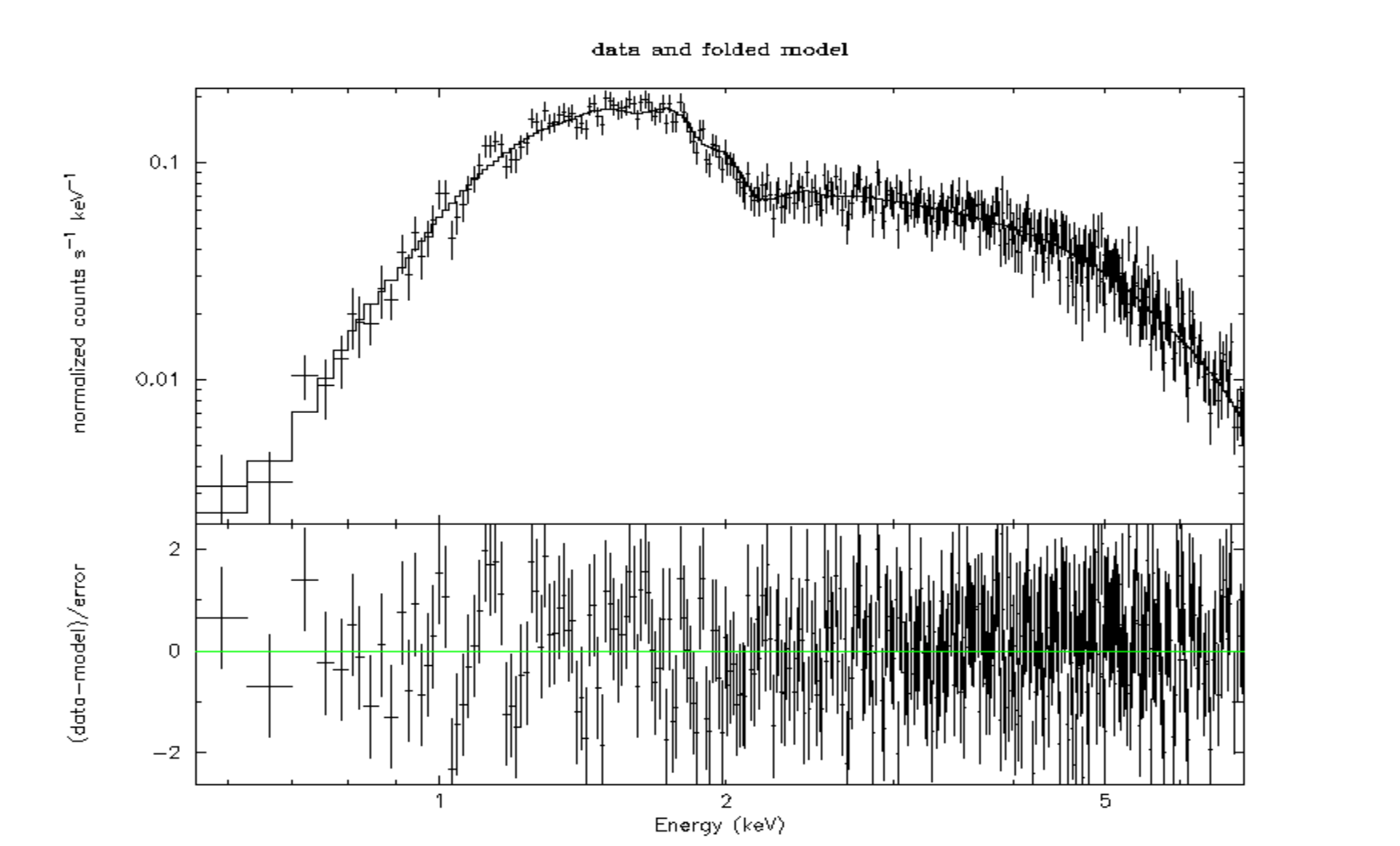
Results

- 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/>