X-Ray Spectroscopy of Supernova Remnants – a js9 activity

Purpose: To determine types of supernova events by examining Chandra X-ray Observatory images of supernova remnants (SNRs) and by identifying the elements in their energy spectra.
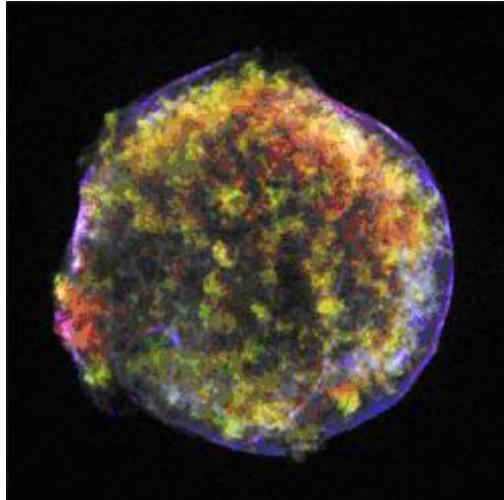

Figure 1. Tycho's SNR, Type Ia
Credit: NASA/CXC/Rutgers/J.Warren & J.Hughes et al.
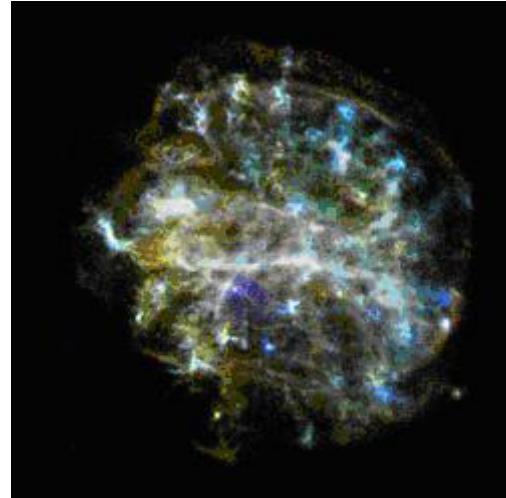
Figure 2. SNR G292.0+1.8, Type II
Credit: NASA/CXC/Rutgers/J.Hughes et al.

Tycho's Supernova Remnant
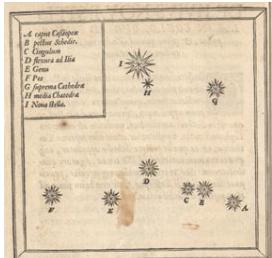
In the year 1572, the Danish astronomer Tycho Brahe observed and studied the sudden appearance of a bright "new star" in the direction of the constellation Cassiopeia. Now known as Tycho's supernova remnant, the event created a sensation in Tycho's time because until then stars were thought to be unchanging. Tycho's observations of this event marked the beginning of the study of astronomy as a science. This object is a Type Ia event - the thermonuclear destruction of a white dwarf. Information about this object is located at http://chandra.harvard.edu/press/05_releases/press_092205.html

SNR G292.0+1.8

The Type II core collapse of a massive star that produced this supernova remnant ~1600 years ago is located in the direction of the constellation Centaurus. SNR G292.0+1.8 is interesting because it is one of only a handful of oxygen-rich remnants. These types of objects are the primary sources of the heavy elements necessary to form planets and people. Although considered a "textbook" case of a supernova remnant, the intricate structure shown here reveals a few surprises. See more information at: http://chandra.harvard.edu/photo/2007/g292/

Tycho's Supernova Remnant (Type Ia) and SNR G292.0+1.8 (Type II) are representative of the two supernova types. Follow the procedure below to analyze their spectra and determine the elements present in the remnants and their relative abundances. The same procedure will be used to study other remnants, compare the results to Tycho and SNR G292.0+1.8, and determine if they are Type II or Type Ia supernova events.

Procedure:

1. Go to **https://chandra.si.edu/js9/** and **"File>close>this image"**

2. Click "The Unofficial Chandra Archive Search Page" button and type "115" in the ObsID box and click "Search."

3. Drag the link "ACIS OBSERVATIONS OF TYCHO AND KEPLER" to the js9 window. It may take a few minutes to appear. The image should now be in the js9 viewer.
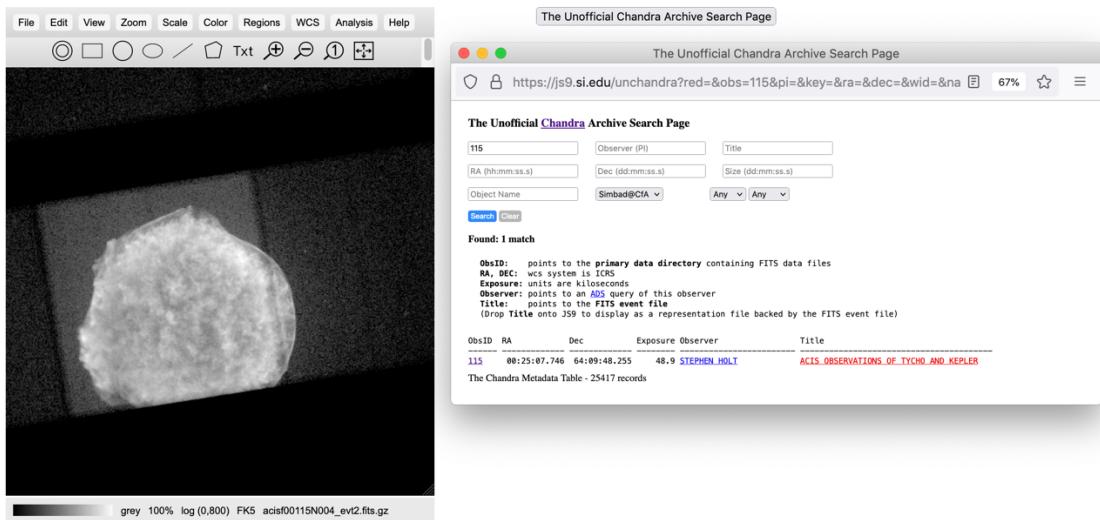
4. Go to **Zoom>zoom to fit** and then **Regions>circle**. Click on the circle that appears. You can move the center of the circle over Tycho's SNR by left clicking and holding in the center and moving it with your mouse. Resize this circle by left clicking on one of the corners of the square and dragging your mouse so that it encloses the SNR.

5. Go to **Analysis>Energy Spectrum**. To get the energy in electron volts (eV) of each emission line, create a zoom box on the graph by holding the left mouse button down and dragging a box around the area of the emission line (peak). To return to the original graph click the blue ⤡ arrows in the upper left corner.

6. Record the energies and identify the elements for each X-ray emission line/peak in the Data section below and on your printed graph, using Table 1. If you have lines whose energy is not close to that of one of the elements in the chart, leave those lines unidentified.
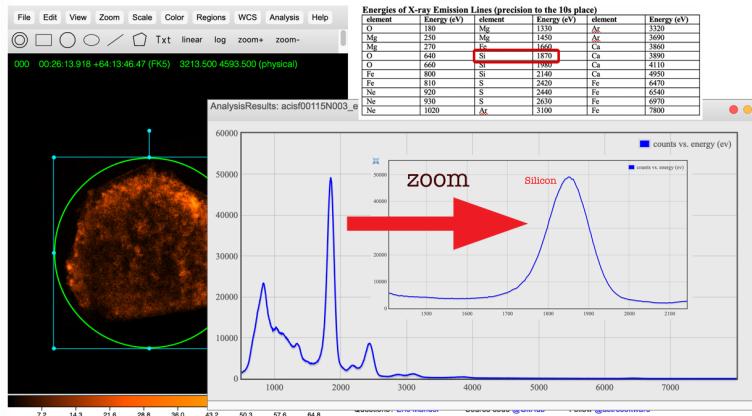
7. Go to **File>close>proxy file** and then repeat steps #1-6 for **G292.0+1.8.** Its ObsID is 126.

Table 1. Energies of X-ray Emission Lines (multiply by 1000 to get eV).

element	Energy (Kev)	element	Energy (Kev)	element	Energy (Kev)
O	0.18	Mg	1.33	Ar	3.32
Mg	0.25	Mg	1.45	Ar	3.69
Mg	0.27	Fe	1.66	Ca	3.86
O	0.64	Si	1.87	Ca	3.89
O	0.66	Si	1.98	Ca	4.11
Fe	0.80	Si	2.14	Ca	4.95
Fe	0.81	S	2.42	Fe	6.47
Ne	0.92	S	2.44	Fe	6.54
Ne	0.93	S	2.63	Fe	6.97
Ne	1.02	Ar	3.10	Fe	7.80

Data:

Tycho's SNR (Type Ia)		SNR G292.0+1.8 SNR (Type II)	
Energy of emission line (eV)	chemical symbol of element	Energy of emission line (eV)	chemical symbol of element

Conclusions and Analysis:

1. What are the similarities and differences between these two spectra?

2. From your analysis of Tycho's SNR and SNR G292.0+1.8, what elements are more predominant in a Type Ia supernova? Which are more predominant in a Type II? Are there elements present in one that are not in another?

3. Explain how you might be able to classify a supernova event as type Ia or type II from its spectrum based on your observations of Tycho's SNR and SNR G292.0+1.8. Sometimes, due to interstellar absorption, emission lines less than 1.5 KeV are not seen. How could this affect your classification of a supernova remnant?

Extensions:

1. Analyze the spectra of any three of the following SNRs using the same procedure as Tycho's SNR and G292.0+1.8. Construct your own data tables.

   a. **Obs ID 117 – ACIS OBSERVATIONS OF W49B**
   b. **Obs ID 116 – Kepler's SNR**
   c. **Obs ID 2758 – SNR 0103-72.6: AN UNSUALLY BRIGHT REMNANT IN THE SMC ALTERNATE TARGET**
   d. **Obs ID 775 – A SYSTEMATIC STUDY OF LMC SNRS WITH AXAF** (this is the SNR called **DEM L71**)
   e. **Obs ID 114 – ACIS OBSERVATIONS OF CAS A**

2. From your analyses, classify these SNR by type. What is the basis for your conclusions? How sure are you of your classifications? What features of the spectra helped with your classifications? What features made it difficult to classify these SNR?

3. Look up these supernovas in the Chandra Supernova Photo Album. How do your results compare with the information in the Photo Album?
   http://chandra.harvard.edu/photo/category/snr.html

Partial Answer Key

There is no full answer key for this investigation. In the conclusions and analysis section of the investigation, students are asked to discuss the spectral and elemental composition differences and/or similarities of two representative SNR spectra, one type Ia and one type II. Using these as a guide, students can then do analysis on other SNR to determine if they are type 1a or type 2. In general,

- Type Ia remnants (from white dwarfs) should have relatively strong Si, S, Ar, Ca, and Fe, and weak O, Ne, and Mg
- Type II (from massive stars) generally have the reverse pattern.
- Sometimes, due to interstellar absorption, emission lines less than 1.5 KeV are not seen. This could make a type 2 more difficult to identify, as the strong oxygen, neon and magnesium lines may be missing. In this case students could use other evidence, such as changing scales and contrast and bias in the js9 image to look for a stellar core remnant which would be present in a type II and not a type Ia

Samples showing identified elements.