Teacher Guide for X-Ray Spectroscopy of Supernova Remnants:

Overview:

X-Ray Spectroscopy of Supernova Remnants is an investigation that guides students through the process of examining the spectra of several supernova remnants; determine the elements that are present and their relative abundances, and decide if each remnant is from a Type II core collapse event or the Type Ia thermonuclear destruction of a white dwarf. This investigation uses ds9 – a Chandra X-Ray Observatory image analysis software package. Ds9 allows the user to download a toolbox and remotely access dedicated Linux servers which process the analysis commands. There is also a pencil and paper version of this investigation.

Supernova events have a profound impact on the surrounding interstellar medium (ISM), including the distribution of the heavy elements that were synthesized during the event. The interaction of the resulting shockwave moving through the ISM produces emission lines from the elements. By studying the presence and distribution of specific elements, scientists can gain insight into both the progenitor star that was destroyed in the collapse (Type II) or explosion (Type Ia), and the mechanics of the event. Spectroscopy – analyzing the radiation emitted from supernova remnants (SNRs) – is one of the tools used by scientists to determine the type of each event. Students will study the distribution of important signature elements involved in supernova collapses and/or explosions – including oxygen, silicon, neon, iron, nickel, and magnesium – in two different types of supernova remnants, and determine both their elemental abundances. This information, along with the geometry and spatial distribution of the elements and the stellar core left behind in the center of the remnant can determine the type of supernova event. Type II core collapses of massive stars leave behind stellar cores (white dwarfs, neutron stars, pulsars, black holes) and Type Ia supernova events leave no stellar core, as they are the thermonuclear destruction of a white dwarf. Utilizing the ds9 image analysis software with actual supernova X-ray spectra will involve students in an investigation designed to show how scientists analyze supernova SNRs and their stellar cores.

The Chandra ds9 image analysis software allows educators and students to perform X-ray astronomy data analysis using data sets from the Chandra X-ray Observatory, and the ds9 image display program and software analysis tools. The program uses the same analysis process that an X-ray astronomer would follow in analyzing the data from a Chandra observation. The download instructions to install the ds9 toolbox are located at http://chandra-ed.cfa.harvard.edu/install_2014.html. The introduction at http://chandra-ed.harvard.edu/learning_ds9overview.html describes the overview and purpose of the software and gives a short summary of the Chandra mission. The tutorial for using the ds9 software is located at http://chandra-ed.harvard.edu/learning_ds9.html.

NOTE: It is not necessary to read the tutorial before beginning the activities and investigations. All ds9 educational activities are constructed to use one or two specific software tools, and complete instructions to use the tools are given within the individual activities. Since computers are not always available as an option, a paper and pencil version of each activity and investigation is also provided that include screen shots of the necessary images from ds9. The only additional materials required are pencils and rulers.

Teacher Guide:

The X-Ray Spectroscopy of Supernova Remnants investigation is completely self-contained. The student handout contains a brief introduction to the Tycho and G292.0+1.8 supernova remnants (SNRs), download instructions for the ds9 software, and a step by step procedure to produce spectral plots and identify the elements for the two remnants.

As stated in the overview, students do not need to read the ds9 tutorial or have any prior knowledge of the ds9 software to use this activity. All necessary instructions are within the activity, including downloading the software. The software is downloadable to desktops and laptops in either a Windows or Mac environment.

If you want your students to have some prior knowledge of the ds9 software, you may consider the three following basic activities which introduce the software.

The Decoding Starlight: From Pixels to Images High School Version is a pencil and paper activity that uses Chandra data from Cas A to give students an idea of how photon intensity is converted into images and does not use ds9.
http://chandra.harvard.edu/edu/formal/imaging/highIndex.html

The 3-Color Composite Images activity is a short, completely self-contained activity that guides students through the process of merging 3 images (red filter – soft X-rays, green filter – medium X-rays, blue filter – hard X-rays) into one composite image.
http://chandra.si.edu/edu/formal/age_snr/3color_ds9.html

In the openFITS Create Images from Raw Data activity, students learn how to smooth the data, remove artifacts, and use colorize, hue and color curves to produce their own unique image of any of the 22 objects they choose. The objects range from pulsars, to supernovas to galaxies, to Sagittarius A – the black hole in the center of the Milky Way Galaxy. http://chandra.harvard.edu/photo/openFITS/

If computers are not an option, this investigation also has a pencil and paper version that incorporates screen shots from the ds9 software. Students will perform the same calculations and answer the same questions with either version of this investigation. If the pencil and paper version is used, students will need rulers. For students to appreciate what the ds9 software is accomplishing, it would be beneficial to have the class work through Tycho's SNR and/or SNR G292.0+1.8 with the pencil and paper version before moving on to ds9. This would also help ensure that all students start the remainder of the investigation with the same skill and knowledge level.

Ds9 Version: http://chandra.harvard.edu/edu/formal/snr/ds9.html
Pencil & Paper Version: http://chandra.harvard.edu/edu/formal/snr/paper.html

http://chandra.harvard.edu/edu/formal/snr/bg.html is a separate 6-page introduction and background for this investigation and contains a basic description of Type II and Type Ia supernovas, as well as X-ray radiation and spectroscopy. It is an informational handout for student use.

Assessment:

There is no 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 the two SNR spectra, and use that information to determine if Tycho and G292.0+1.8 are Type II or Type Ia remnants. The Chandra Photo Album supernovas category can be accessed and students can read about the two objects. There are 5 separate Tycho image releases, the earliest observation release is located at: http://chandra.harvard.edu/photo/2002/0005/. There are 3 images releases posted of G292.0+1.8, the earliest is located at: http://chandra.harvard.edu/photo/2001/0112/

The following rubric can be used to assess student understanding of the X-Ray Spectroscopy of Supernova Remnants investigation.

Task Specific Scoring Rubric for X-Ray Spectroscopy of Supernova Remnants

Content Understanding	Communication
4pts- Students have a detailed spectrum for the Tycho and G292.0+1.8 SNRs and correctly determined that Tycho is a Type Ia event and G292.0+1.8 is a Type II event. The spectral differences are described completely and accurately. 3 pts- Students have a less detailed spectrum for the Tycho and G292.0+1 SNRs, and correctly determined that Tycho is a Type Ia event and G292.0+1.8 is a Type II event. The spectral differences are described completely and accurately. 2 pts- Students have a basic spectrum for the Tycho and G292.0+1 SNRs, but incorrectly determined whether the SNRs were Type II or Type Ia. There may be incomplete information and/or some inaccuracies. 1 pt- Students have a basic spectrum for at least one of the SNRs. The type of supernova event was not determined. Information is incomplete and/or there are inaccuracies. 0 pts- Incomplete or missing	4 pts- Students describe spectral analysis and results in detail and accurately. Information is clearly understood by the listener or reader and does not sound as if it was merely copied off the web site. 3 pts- Students describe spectral analysis and results in detail and accurately. Information can be understood by the listener or reader and in most cases, does not sound as if it was merely copied off the web site. 2 pts- Students describe spectral analysis and results but some of analyses or terminology is incorrect. Information may be unclear to the listener or reader and may sound as if it was copied from the web site. 1 pt- Students describe some of the analysis and results but much of the terminology is incorrect. Information is vague and/or confusing to the listener or reader and may sound as if it was copied from the web site. 0 pts- Incomplete or missing

Extensions and Additional Resources:

The investigation lists 5 more SNRs which students can download into the ds9 program for spectral analysis to determine the type of supernova event. The first two – Tycho and G292.0+1.8 are Type Ia and Type II respectively. Some of the other objects selected are more problematic! One type can spectrally resemble the other due to interstellar absorption of some of the lower energy emissions. The objects are all in the photo album so students can compare their results.

Located at http://chandra-ed.harvard.edu/casa/index.html#section_1 on the Chandra-Ed website are a contextual narrative and a set of 6 activities that utilize ds9 and Chandra data to explore the science of the Cassiopeia A (Cas A) Type II supernova remnant. The purpose of this set of basic activities is for students to learn a few of the ds9 tools.

Connections to the Standards:

Below are the connections for the X-Ray Spectroscopy of Supernova Remnants activity to the Next Generation Science Standards (NGSS), the National Science Education Standards (NRC), and Benchmarks for Literacy Project 2061.

Next Generation Science Standards (NGSS)
http://www.nextgenscience.org/search-standards-dci

Performance Expectations:

HS-PS4: Waves and their Applications in Technologies for Information Transfer

HS-PS4-2: Evaluate questions about the advantages of using a digital transmission and storage of information.

HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

HS-ESS1: Earth's Place in the Universe

HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Science and Engineering Practices:

Obtaining, Evaluating, and Communicating Information:
Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
(**HS-PS4-5**)

Engaging in Argument from Evidence:
Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (**HS-PS4-5**)

Disciplinary Core Ideas

PS4.A: Wave Properties
Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (**HS-PS4-2**), (**HS-PS4-5**)

PS4.B: Electromagnetic Radiation
Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (**HS-PS4-5**)

PS4.C: Information Technologies and Instrumentation
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (**HS-PS4-5**)

ESS1.A: The Universe and Its Stars
The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (**HS-ESS1-3**)

Cross Cutting Concepts:

Cause and Effect:
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (**HS-PS4-5**)

National Science Education Standards (Grades 9-12)
http://www.nap.edu/openbook.php?record_id=4962&page=173

Content Standard A – Science As Enquiry:

1. Use Technology & Mathematics to Improve Investigations and Communications:
A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

2. Formulate and Revise Scientific Explanation and Models Using Logic & Evidence
Student inquiries should culminate in formulating an explanation or model. Models

should be physical, conceptual, and mathematical. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.

3. Understanding about Scientific Enquiry: Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories. Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

4. Communicate and Defend a Scientific Argument
Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

Content Standard D – Earth and Space Science

1. The Origin and Evolution of the Universe
Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

Content Standard E – Science And Technology:

1. Communicate the Problem, Process and Solution:
Students should present their results to students, teachers, and others in a variety of ways, such as orally, in writing, and in other forms—including models, diagrams, and demonstrations.

Benchmarks For Science Literacy Project 2061 (Grades 9-12)
http://www.project2061.org/publications/bsl/online/index.php?home=true

1. The Nature of Science
- Science is based on the assumption that the universe is a vast single system in which the basic rules are everywhere the same and that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. **1A/H1***
- In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to a better understanding of how things work in the world but not to absolute truth. **1A/H3bc***
- Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible, practical, or ethical, they try to observe as wide a range of natural occurrences as possible to discern patterns. **1B/H3***

• Scientists often cannot bring definitive answers to matters of public debate. There may be little reliable data available, or there may not yet be adequate theories to understand the phenomena involved, or the answer may involve the comparison of values that lie outside of science. **1C/H9**** (**SFAA**)

2. The Universe

• Eventually, some stars exploded, producing clouds containing heavy elements from which other stars and planets orbiting them could later condense. The process of star formation and destruction continues. **4A/H2ef**

• Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and X-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle data and complicated computations to interpret them; space probes send back data and materials from remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. **4A/H3**