

Teacher Guide and Overview for 3-Color Composite Images:

Overview:

Satellite and spacecraft images are not photographs but pictorial presentations of measured data. Satellite systems measure electromagnetic radiation in different bands of the electromagnetic spectrum (i.e. radio, infrared, visible, ultraviolet, X-ray, gamma ray). The detectors on spacecraft such as Chandra and Hubble, Earth orbiting satellites and ground-based telescopes do not take color images. Color images are assembled from separate black & white images taken through colored filters. To produce one colored image, three separate images are collected through a red, a green, and a blue filter. The three images are then combined with image analysis software into one color image.

Astronomical images are not “true color” images – they do not represent visually accurate color – they use “false” colors or more accurately “representative” colors. True color would be an attempt to reproduce a visually accurate color. False color is an arbitrary selection of colors to represent some characteristic in the image, such as photon intensity, energy, temperature and chemical composition/distribution, or features such as shock waves and magnetic fields.

Computer aided data collection and processing is an essential facet of research using space and ground-based telescopes. Every 8 hours, the Chandra X-Ray Observatory downloads millions of pieces of information to Earth. To control, process, and analyze this flood of numbers, scientists rely on computers, not only to do calculations, but also to change data into images. Although computers are used extensively, scientists and programmers go through painstaking calibration and validation processes to ensure that computers produce technically correct images. The process of producing the computer-generated images from X-ray data collected by Chandra requires the use of representative or “false” colors.

Composite images that combine the data from different wavelengths, such as Chandra (X-ray), Hubble (optical) and Spitzer (infrared) provide an even more comprehensive analysis of the processes taking place within astronomical objects such as stars, galaxies and nebulas.

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. Ds9 allows the user to download a toolbox and remotely access dedicated Linux servers which process the analysis commands and return the results to the user. The introduction 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. The download instructions are located at: http://chandra-ed.cfa.harvard.edu/install_2014.html.

NOTE: It is not necessary to read the tutorial before beginning the ds9 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 and investigations. 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/or rulers. The 3-Color Composite Image activity does not have a pencil and paper version; it requires a computer.

Teacher Guide for 3-Color Composite Images:

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. The student handout contains a brief introduction and background for composite images, download instructions for both the ds9 (Chandra) and ImageJ (NIH) software – both free – and a step by step guide to use the software to produce a composite image of the Cassiopeia A (Cas A) supernova remnant (SNR). An extension at the end of the activity gives students the opportunity to produce composite images for two more supernova remnants. These can also be used as an assessment tool.

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

Prior to using the 3-Color Composite Image activity in the classroom, you may want your students to have a basic idea of how the ds9 software works before they use the software. The activity Decoding Starlight: from Pixels to Images located at <http://chandra.harvard.edu/edu/formal/imaging/highIndex.html> (high school version) guides students through the basic steps of data and image processing with actual data from the Chandra X-Ray Observatory without using the ds9 software – it is a pencil and paper activity. In the activity students bin and assign colors to photon intensity data based on the Cas A supernova remnant and then produce a more artistic public release image based on their results. The Decoding Starlight and 3-Color Composite Images together are constructed to address the common student misconception that spacecraft and telescopes simply “take a picture”. The 3-Color Composite Images answer key (pdf download) shows the red, blue and green filter images of Cas A as well as the merged composite image.

Extensions & Resources:

1. A follow-up to the 3-Color Composite Images activity would be to show the students a 3-D visualization of the Cas A supernova remnant. This activity uses ImageJ, an image processing program developed by the National Institutes of Health. ImageJ is used to solve many image processing and analysis problems, such as three-dimensional live-cell imaging. Using biological software with astronomical data is not uncommon. One of the software programs used to construct the 3-D visualization of Cas A is from the Astronomical Medical Project at Harvard. Both the medical and the astronomical

communities have the same problem – analyzing huge data sets to determine patterns. This is an excellent example to show students that software from different disciplines can be adapted to create models. The Cas A 3-D visualization can be accessed from the Chandra Photo Album, and contains complete explanations of the project and the 3-D view of the Cas A remnant. It is located at: <http://chandra.harvard.edu/photo/2009/casa2/>

2. The Cool Cosmos website has an excellent multiwavelength overview of the Cas A supernova remnant, including X-ray (Chandra), visible (DSS), visible (Robert Fesen), near/mid-infrared (Spitzer), mid-infrared (ISO), far infrared (IRAS) and radio (NRAO). The site includes a brief explanation of the processes and features displayed in each of the images; it is located at:

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/casA.html

3. openFITS – Create Images from Raw Data:

This is an excellent extension of the 3-Color Composite Images activity. This program allows students to create their own images of 22 different astronomical objects from the Chandra observation archive. With the basic understanding of astronomy data and image processing that students have acquired from the 3-Color Composite Images and/or Decoding Starlight, they can create their own astronomy images from FITS (Flexible Image Transport System) files. FITS is the digital file format used mainly by astronomers. Students can download FITS files and construct their own versions of the 22 images provided in this activity located at <http://chandra.harvard.edu/photo/openFITS/>

In the 3-Color Composite Images activity students simply merge three images taken through different colored filters into one composite image. In the Create Images from Raw Data activity, students learn how to smooth the data, remove artifacts, and use colorize, hue and color curves tools to produce their own unique images of any of the 22 objects they are assigned. The objects range from pulsars, to supernovas to galaxies, to Sagittarius A – the black hole in the center of the Milky Way Galaxy. The students are performing basic image analysis with actual X-ray data.

Assessment:

If the two objects listed under **Extension** in the 3-Color composite image activity are not used in the classroom (Obs ID 7639 and Obs ID 115) they can be used as a follow-up assessment, or just to reinforce the skill of using the ds9 software.

The openFITS – Create Images from Raw Data activity is also an excellent assessment tool. There are 22 different objects to select; if all of the students have been assigned the same object as a class assignment that leaves 21 other objects that can be used to assess student understanding of image processing. The following rubric can be used to measure the degree of understanding. It is important for students to present and describe the process they used; especially since they will have different results for the same image. This provides an opportunity to discuss how images based on the same data and analyzed with the same tools can look different due to individual “tweaking” when utilizing the software tools. This is exactly how the public release images in the Chandra Photo Album were produced – by “tweaking” the data until a visually appealing image was

created that also prominently displayed the most scientifically interesting features and/or processes. The following rubric is an assessment for the openFITS – Create Images from Raw Data activity. The rubric is based upon each student being assigned 4 different objects; the actual number assigned depends upon the individual teacher.

Task Specific Scoring Rubric for openFITS – Create Images from Raw Data

Content Understanding	Communication
<p>4pts- Students have used all of the image analysis tools in the correct sequence for all of the images they have been given. The purpose for each tool is described completely, accurately, and in detail.</p>	<p>4 pts- Students describe each tool in detail using correct terminology. Information is clearly understood by the listener or reader and does not sound as if it was merely copied off the web site.</p>
<p>3 pts- Students have used all of the image analysis tools for all of the images they have been given. Each stage is described completely and accurately.</p>	<p>3 pts- Students describe each tool using correct terminology. 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.</p>
<p>2 pts- Students have used all of the image analysis tools in the correct sequence for half of the images they have been given. All of the tools used are described, but there may be incomplete information and/or some inaccuracies.</p>	<p>2 pts- Students describe each tool but some terminology may be incorrect. Information may be unclear to the listener or reader and may sound as if it was copied from the web site.</p>
<p>1 pt- Students have used some of the image analysis tools for at least one quarter of the images they have been given. Not all of the tools are described and information is incomplete and/or there are many inaccuracies.</p>	<p>1 pt- Students describe some tools 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.</p>
<p>0 pts- Incomplete or missing</p>	<p>0 pts- Incomplete or missing</p>

Connections to the Standards:

Below are the connections for the 3-Color Composite Images 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-PS4-5: 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:

Developing and Using Models

Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (**HS-ESS1-3**)

Disciplinary Core Ideas:

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:

Systems and System Models:

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions – including energy, matter, and information flows – within and between systems at different scales. (**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. 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.

Content Standard E – Science and Technology:

1. Understandings about science and technology: Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.

Benchmarks for Science Literacy Project 2061 (Grades 9-12)

<http://www.project2061.org/publications/bsl/online/index.php?home=true>

The Universe: 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**