Teacher Guide: Stellar Evolution: *Our Cosmic Connection* Classroom Materials

***Our Cosmic Connection* Activity Summary:**

The content focus of the Cosmic Connection materials is stellar evolution, and this activity has been developed to assist students in acquiring a general understanding and an appreciation for the cosmic cycles of stellar formation and destruction - and their connection to planet formation. The basic activity is a sequencing activity that uses the *Our Cosmic Connection* Image Set of different stages of stellar evolution. Multiple classroom sets of the *Our Cosmic Connection* Image Set can be requested from the Chandra website. There is also a flash version and a webquest version of the *Our Cosmic Connection* activity. This activity was constructed to use after the topic of stellar evolution has been presented in the classroom – this will be discussed in the "Using the Our Cosmic Connection Activity materials in the Classroom" section below. Also described below are the additional resources available to support *Our Cosmic Connection* – including background information in web, PDF, and flash formats, a second image set – *Stellar Cycles* – a similar sequencing activity that is more rigorous in content and includes images of the H-R diagram and light curves, a classroom activity that plots stars on the H-R diagram, posters, animations and podcasts. Using *Our Cosmic Connection* in the classroom does not require any prior knowledge, and has a lot of flexibility as there can be several scenarios that students present to demonstrate the process of star formation from stellar nurseries to their final end products.

Using the Background Information (13 pages):
http://chandra.harvard.edu/edu/formal/stellar_ev/story/

The background information – *Stellar Evolution – Cosmic Cycles of Formation and Destruction* – has been written specifically to support all of the activities and investigations on the Chandra website related to stellar evolution. It also addresses some specific concerns that teachers have for student misconceptions, and gives an overview of the basic transition stages of stars as they change over time – not so simple as to create or support misconceptions, and not too complicated for the intended audience of educators and students. Depending upon how the topic of stellar evolution is presented in the classroom, and the make-up of individual classrooms, the background content can be used only for teacher edification or as a student handout. Teachers may elect to print out the sections that are most directly related to the activity. The background contains more in-depth content than needed for *Our Cosmic Connection* and is not necessary to successfully complete the activity. There is also a simpler self-guided online stellar evolution tutorial flash version that teachers may prefer students to use as a content source before doing the *Our Cosmic Connection* activity in the classroom. These versions will be described in the following section.

Using the *Our Cosmic Connection* Activity Materials in the Classroom:

Background:
This activity was developed for use after the topic of stellar evolution has been presented in the classroom, and can be used either as a post assessment tool, a final class project, or a group discussion. It is assumed that the students have already encountered the content in the classroom. However, online content has been provided that teachers can use either for their own knowledge or as student handouts, depending upon each unique and individual classroom situation. The 17-page "Background Information" is appropriate for upper level students. For general students, an alternative more basic description of stellar

has been provided – as an online interactive flash version and as a PDF printout. The flash version is a self-guided tutorial that students can access that is based on the "Stellar Evolution: A Journey with Chandra" poster. If computer access is an issue, the tutorial has been converted to a 9-page PDF format that describes the stages of stellar evolution that are on the poster. The flash and associated PDF background information is at:
http://chandra.harvard.edu/edu/formal/stellar_ev/stellar_ev_flash.html
http://chandra.harvard.edu/edu/formal/stellar_ev/stellar_ev.pdf

Materials:
The *Our Cosmic Connection* task is a sequencing activity using a card set of 24 images that can be requested on the Chandra website. Educators can request as many card sets as they want. The cards are on heavy cardstock and do not need to be laminated; however, the four pieces of cardstock (6 images on each sheet) need to be cut out along the dotted lines into the 24 separates images. The number of sets needed depends on how the card set is used in the classroom – with individuals or groups. The card sets are also available in PDF and PowerPoint formats. Besides the card sets, students need the one-page task description for this activity. The task description is available in html and PDF formats. These materials are located at:
Image Set:
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/image_set.pdf
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/image_set.ppt
Request Form for the card sets on heavy cardstock:
http://chandra.harvard.edu/edu/request_special.html
Task Description:
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/task_desc.html
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/task_desc.pdf

A version of *Our Cosmic Connection* is also available in flash. To use the online flash version, the card sets are not necessary – only the task description. The flash activity contains the 24 images which the students drag and drop into sequences for mid-sized stars, massive stars, and a Type Ia supernovas. Space is provided for a brief description for each image. The sequences and descriptions can then be printed out. The flash version of *Our Cosmic Connection* is located at:
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/interactive.html

Educators may decide to have their students research the background content on the internet; therefore a webquest version of the activity is also available. With the webquest website option the students need either the webquest task description, a set of images, and the templates to attach the images to and write the description of the images – or the webquest website and the PDF printout of the website for students to write the descriptions on. The task description and templates are in html and PDF.
Task Description:
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/task_desc.html
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/task_desc.pdf
Webquest Website: (Described further below)
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/index.html
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/index.pdf
Webquest ULR list only:
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/url_table.html
Templates:
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/templates.html
http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/templates.pdf

Classroom Logistics:

There are several ways that this activity can be organized, depending on teacher preferences and individual classroom needs. Teachers can introduce stellar evolution with their own materials, or elect to use the background information provided on the Chandra website – either as classroom handouts, or by using the self-guided tutorial either online or as a handout. The self-guided tutorial can either be an individual student assignment, or an exercise involving the entire class.

The purpose of the task description and image set is for students to arrange the cards into reasonable sequences of stellar evolution – the cards allow the opportunity for three different sequences – mid-sized stars, massive stars, and sequences resulting in Type Ia supernova events. Students do not have to work with the entire image set at the same time. Teachers can select only a few of the images and have students arrange the designated images into a sequence. For example, if the teacher wants the students, either individually or working in groups, to arrange a sequence of stellar evolution for a massive star, the following set of images would one possibility: 4, 5, 9, 12, 15, and 24. Each student can arrange all three sequences, or different students can work with one of the sequences, or groups of students can work together to present either one or all three of the different sequences of stellar evolution. This activity can also be assigned as a final exam, an enrichment activity, or a final class project: students can use the task description and card set as a basis to put together a portfolio, or a PowerPoint presentation.

The descriptions of the 24 images in the Our Cosmic Connection card set are located at: http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/image_desc.html

NOTE:

This activity has been presented at numerous NSTA conferences for the past several years. The format used to present *Our Cosmic Connection* works well for a large group within a 1-hour time limit. It is presented as a PowerPoint – with the first slide the *Stellar Evolution: A Journey with Chandra* illustration from the poster. The slide is used to give a general overview of the stages of stellar evolution. The participants work in groups and each group has a card set. The participants are then told to select certain numbered cards from the set, and place them in a sequence; first for mid-sized stars and then for massive stars. There is usually enough time for the Type Ia supernova sequence also. With each sequence, the participants are asked which image would be first, and after there have been a few responses, the PowerPoint is used to show what the first image should be. Presenting the activity with an entire group evokes a lot of discussion, it is fun, and by the end of the hour participants are having no trouble putting together more complex sequences. The slide set is animated so go through the entire set to understand how the slides were put together. This would work well in the classroom also – so the PowerPoint presentation is included as another option for teachers to use the image set in the classroom. The last three slides (7-9) contain the visual answer keys. It is located at: http://chandra.harvard.edu/edu/formal/stellar_ev/story/cosmic_connections.ppt

Webquest Version:

The *Cosmic Webquest* is the internet version of the *Our Cosmic Connection* activity. This activity uses the same images as *Our Cosmic Connection* in an online format and can be used in a variety of ways: computer lab assignment, make-up lesson, enrichment activity, and individual or class project. In this version, the students are sent to websites to gather information about each of the images (with the exception of the image of Earth). The websites have an image and description of an object that is in the same stage of stellar evolution as each of the images in the card set – but not the same object in the image set. This gives students two objects in the same evolutionary stage to view as similar stellar stages can look different. The students write a brief description of the stage of evolution

for each of the images either directly on the PDF printout from the website (color or black and white), or on the set of provided templates. If the templates are used, there is a template for each of the three possible stellar evolution sequences and each student or group of students will need 12 copies of the template and one set of images for each of the three sequences. The PDF image set can be printed in either color or in black and white and cut into the separate images to attach to the templates. Students then cut each template sheet into individual images and arrange the images into appropriate sequences.
Website: http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/index.html
Website PDF: http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/index.pdf
Templates: http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/templates.pdf
Images: http://chandra.harvard.edu/edu/formal/stellar_ev/webquest/image_set.pdf

ANSWERS & RESULTS:
The intent of this activity is to gain a basic understanding of the formation, evolution, and destruction of mid-sized and massive stars and the end products of stellar evolution. There is more than one possible arrangement of the cards – and sometimes the cards are more appropriately arranged not in a straight line, but in a circle representing the continuous cycle. Sometimes there are 2 or more images that represent something that is happening more or less simultaneously or two of the images are different end products for the same event – so some of the images may be arranged not only in a straight line, but with some of the images above or below each other for an either/or situation. The important outcome is that students gain knowledge of stellar evolution – so if they incorrectly describe an image of a supernova remnant as a stellar nursery – that is not as important as knowing the correct sequence of events. Students may have unexpected sequences that are just as "accurate" as the expected ones if they are explained logically with no obvious misunderstanding. So there is room for flexibility with responses – after all, we have little understanding of the complex processes involved in stellar evolution. Theories are constantly being challenged and redefined by ongoing observations.

There are several possible evolutionary sequences for the images in the card set for mid-sized and massive stars and Type Ia supernovas. So a visual answer key has been provided in a PowerPoint format which shows some of these sequences. Remember that the scenarios presented are not necessarily the only ones or the "most correct" ones – they are just some of the possibilities and the results depend on which images the teacher has given the students to use. The visual answer key is located at:
http://chandra.harvard.edu/edu/formal/stellar_ev/cosmic/vanswer_key.pdf

After completing this activity students should understand that:

1.) Stellar evolution is not equivalent to biological evolution – it is a series of changes of physical properties and forces of gravity within a star over time.
2.) Stellar evolution creates the elements and provides the conditions that are necessary for the formation of new stars and planetary systems.
3.) Massive stars evolve at faster rates than less massive stars, expediting elemental production and evolution by making available more complex elements – the building blocks for planets as well as life, on a more rapid time scale than would otherwise be possible.
4.) Because of the different rates of stellar evolution, all stages of stellar changes can be detected, from embryonic and protostars with infrared and optical telescopes, to pulsars and black holes with X-ray telescopes. **NOTE**: The images in the card set include radio, infrared, optical, UV, X-ray, and composites from different missions to help students understand the importance of multiwavelength observations. The artist illustrations help students understand the importance of art to science in explaining complex concepts and systems.

5.) Similar to cycles on Earth – the rock cycle and the water cycle – stellar evolution is also a cycle – a continuous cycle of change on a cosmic scale.

If *Our Cosmic Connection* activity is used as a performance task, post-assessment or as a presentation, then a scoring rubric is an appropriate assessment of student performance. An example scoring rubric which emphasizes the purpose of this activity is shown below:

Content Understanding	Communication
4pts- Student has the correct sequence for all of the images they have been given. Each stage is described completely, accurately, and in detail. 3 pts- Student has the correct sequence for three quarters of the images they have been given. Each stage is described completely and accurately. 2 pts- Student has the correct sequence for at least half of the images they have been given. All of the stages are described, but there may be incomplete information and/or some inaccuracies. 1 pt- Student has the correct sequence for at least one quarter of the images they have been given. All of the stages are described, but information is incomplete and/or there are inaccuracies. 0 pts- Incomplete or missing	4 pts- Student describes each stage 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. 3 pts- Student describes each stage 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. 2 pts- Student describes some stages 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. 1 pt- Student describes some stages 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

Supporting Classroom Activities, Materials, and Resources:

Stellar Cycles Image Set:
The *Stellar Cycles* Image Set is different than the image set used for *Our Cosmic Connection*; however, it is used in the same way - to arrange sequences of the evolution for mid-sized and massive stars and Type Ia supernovas. For teachers who present the topics of Hertzsprung-Russell (H-R) diagrams and/or light curves in the classroom, this image set includes images of stages of stellar evolution, light curves and H-R diagrams. (HTML, PDF and PowerPoint (PPT) versions) Educators can request as many classroom sets of the Stellar Life Cycle cards as necessary. The Stellar Cycles materials and card sets are available at: http://chandra.harvard.edu/edu/formal/stellar_cycle/

Plotting Variable Stars on the H-R Diagram Activity*:*
Students plot pulsating variable stars on an H-R diagram. The diagram has several bright and nearby stars plotted to show the locations of the main sequence, giant, supergiant and dwarf branches. Students plot both maxima and minima with corresponding stellar

classifications for several variables, and then identify the type of variability – Cepheid, RR Lyrae, Mira or Semiregular. The investigation includes extensive background information, student worksheets and answer keys in HTML and PDF. This activity works well for upper level students.
Student Activity:
http://chandra.harvard.edu/edu/formal/variable_stars/plot.html

Multimedia:
Stellar Evolution: A Journey with Chandra Poster Request Form:
http://chandra.harvard.edu/edu/request.html
Locating Historic Supernovas in the Milky Way Galaxy:
http://chandra.harvard.edu/resources/flash/locate_milkyway.html
Podcasts by Category, Including: White Dwarfs, Supernovas, Neutron Stars, and Black Holes:
http://chandra.harvard.edu/resources/podcasts/

NEXT GENERATION SCIENCE STANDARDS (NGSS):
http://www.nextgenscience.org/

Performance Expectations:

HS-ESS1 Earth's Place in the Universe

HS-ESS1-1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.

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-ESS1-1**)

Obtaining, Evaluating, and Communicating Information
Communicate scientific 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-ESS1-3**)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars
The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (**HS-ESS1-1**)

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (**HS-ESS1-2**), **(HS-ESS1-3**)

Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (**HS-ESS1-3**)

Cross Cutting Concepts

Scale, Proportion, and Quantity
The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. (**HS-ESS1-1**)

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. Formulate and revise scientific explanations and models using logic and 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.

2. Recognize and analyze alternative explanations and models: This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations.

3. 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 B – PHYSICAL SCIENCE:

Structure of atoms: The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.

CONTENT STANDARD D – EARTH AND SPACE SCIENCE:

1. The Origin and Evolution of the Earth System: The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today.

2. The Origin and Evolution of the Universe:

- The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.
- Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in 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. 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.

CONTENT STANDARD G – HISTORY AND NATURE OF SCIENCE:

1. Science as a human endeavor:

- Scientists strive for the best possible explanations about the natural world.
- Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public. Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific.
- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest.

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)

THE UNIVERSE

- The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements found on earth and behave according to the same physical principles. 4A/H1a
- 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