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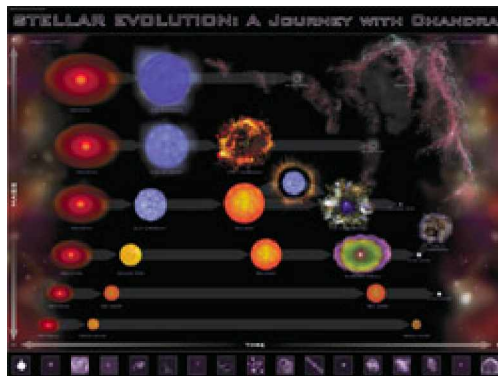
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Stellar Evolution



[Request a copy of the Stellar Evolution poster](#)

When the Universe came into existence ~14 billion years ago, the only elements were hydrogen, helium, and traces of lithium, beryllium, and boron. The heavier elements did not yet exist. Heavy elements are produced by nucleosynthesis - the fusion of nuclei deep within the cores of stars. At some point in time, the first stars were formed, and within their cores the fusion process created heavier and heavier elements; the most massive stars produced nuclei as heavy

as iron. When the stars used up their nuclear fuel, they started to evolve. The evolutionary processes of stars depend upon their initial mass. Mid-sized stars eject planetary nebulae, leaving a white dwarf core remnant. More massive stars explode as supernovae, leaving neutron stars or black holes at the centers of the supernovae remnants. The elements that were created within the cores of the first stars were ejected into space where they intermingled with the surrounding interstellar medium. This medium -- the gas and dust between the stars -- provides the raw material for the formation of new generations of stars. Eventually, these elements became incorporated into large clouds of gas and dust that condensed and formed protostars. And so the cycle of stellar formation and destruction continues - each new generation further enriching the interstellar medium with heavy elements that become incorporated into the next generation. We are just beginning to understand stellar formation and destruction - and how the Sun, Solar System and life on Earth are connected to this never-ending cycle.

- The Story of Stellar Evolution: Introduction and Background [html](#) | [pdf](#)
- [Interactive Guide to Stellar Evolution](#) (flash)
- [printable version available in pdf](#)
- [Our Cosmic Connections Activity & Webquest](#)
- [Stellar Cycles Post Assessment Activity](#)
- [Useful Resources](#)

Educators: Please note, the card sets for the Stellar Evolution module are available by [request](#).

More Interactive Features



Tour other areas of the Universe with these [interactive Flash features](#) from Chandra.



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Teacher's Guide

This guide has suggestions for the following stellar evolution activities: [Our Cosmic Connection](#), [Cosmic Webquest](#), and [Stellar Cycles](#).

Our Cosmic Connection:

The [Our Cosmic Connection](#) task is a sequencing activity using the set of 24 images provided. The purpose of the activity is to have students apply their knowledge of stellar evolution in a format that allows flexibility. The content that is necessary for the students to be successful is provided in [The Story of Stellar Evolution: Introduction and Background](#). All of the types of objects contained within the 24 images are discussed in the introduction and background. The entire image set can be provided to the students, or specific images can be selected and provided, depending upon the ability level of the classroom.

There are several ways that this activity can be used. [Image Set](#) can be arranged into three different types of sequences of stellar evolution: a mid-sized star, a massive star, and a Type Ia supernova event. Each student can arrange all three, or different students can present one of the sequences, or a group of students can work together to present either one or all three of the different types of stellar evolution. Students can either present their sequences in any format they or the teacher selects, or the [Templates](#) can be used. There is a Template for each of the three possible sequences. Each student will need several of the template sheets, and paste the images onto the sheets and write their description of each image in the space provided on the templates. Some of the images are used for all of the sequences so if a student, or group of students, is assigned more than one sequence they will need more than one set of the images. A description of what the images are is provided ([Image Description](#)), as well as a [Visual Answer Key](#). The visual answer key provides several different possible sequences for mid-sized, massive, and Type Ia. These are only some of the possible sequences. Most important are the student descriptions of the images and their defense of their sequences.

Cosmic Webquest:

The [Cosmic Webquest](#) is the internet version of the Our Cosmic Connection activity. This activity uses the same [Image Set](#) as Our Cosmic Connection 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 similar to each of the images. The students need to write down basic information about each of the images, (or the PDF version can be printed out) then they can use the [Templates](#) to paste the images and write a brief description about each of the images. Read the description in the paragraph above for some of the possible ways of using this activity. The [Visual Answer Key](#) will give you some of the possible sequences for mid-sized and massive stars, and Type Ia supernova events.

Stellar Cycles:

[Stellar Cycles](#) is a performance task - an assessment tool to determine student understanding of stellar evolution. After students have had the background information, and used either the Our Cosmic Connection or Cosmic Webquest activities, Stellar Cycles can be used as an assessment. The [Image Set](#) is different than the image set used for the other two activities, and can be used in the same way - to arrange sequences of the evolution of mid-sized and massive stars. For those who present Hertzsprung-Russell diagrams (H-R diagrams) and/or light curves in the classroom, this image set includes both H-R diagrams and light curves that involve stellar evolution. [The Story of Stellar Evolution: Introduction and Background](#) includes the information necessary to include the diagrams and light curves, both in the classroom and in the assessment. And as for the Our Cosmic Connection activity, you may have students prepare one or more sequences. You can use the Templates and collect them to grade as you would a written exam, or elect to have the students present and defend their sequences before the class. A [scoring rubric](#) is provided to help grade the presentations. An [Image Description](#) is included, as well as a [Visual Answer Key](#) of some of the possible correct sequences. Three other activities that can be used as assessment tools are [The Crab Through Time](#), [The Universe - Rated R!](#) and [Portrait Gallery of the X-Ray Universe](#). These assessments are more in-depth and project oriented.

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Our Cosmic Connections Activity - Task Description

Scenario:

While you were absent from school with the flu, you missed the day you were presenting your project on stellar evolution in Earth Science class. In two days you are going on a class trip to the National Air and Space Museum in Washington DC, and the principal has decided that no one can go on the trip if they are missing any classroom assignments. Your teacher agrees to let you present your project to the class the following morning. The project consists of an oral presentation, and an organized portfolio of supporting materials. The presentation and portfolio is 20% of your grade for the quarter. Before you got the flu, you had searched the internet and downloaded several images representing the different stages of evolution for mid-sized and massive stars, and written a brief description for each image on index cards. All you need to do is review the images and descriptions. When you get home, you spread the materials out on the dining room table, and spend several hours arranging the images into different sequences and matching the images to the descriptions to prepare for your presentation. You decide that you will leave everything on the table and get up early to review the images and descriptions one last time. You stack the images and the descriptions in two separate piles, both in the order that you will present the evolutionary stages for the different mass stars from the stellar nursery to their final end products.

The next morning you go downstairs for your final review. You are completely shocked! You cannot believe the mess on the table! Your new puppy had jumped onto the table during the night, knocked the stack of images onto the floor, and chewed and mangled the index cards containing the descriptions.

Task:

There is no way you can tell your teacher that "the dog ate my presentation!" You only have one hour to quickly place the images back in order and write a description for each one.

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Our Cosmic Connections Activity



Lola Chaisson, Artist

Ever since the first stirrings of consciousness, humankind has lifted its eyes towards the mystery of the heavens and found solace in the contemplation of the seemingly peaceful and eternal panorama of the night sky. People of ancient cultures viewed the sky as the inaccessible home of the gods. They observed the daily motion of the stars, and grouped them into patterns and images. They assigned stories to the stars, relating to themselves and their gods. They believed that human events and cycles were part of larger cosmic events and cycles. The night sky was part of that cycle. The steady progression of star patterns across the sky was related to the ebb and flow of the seasons, the cyclical migration

of herds and the hibernation of bears, the correct times to plant or harvest crops. Everywhere on Earth people watched and recorded this orderly procession with symbols carved into bones and antlers, paintings on elk hide and rocks, and stone monuments and alignments. The motions of the Sun, Moon, stars and planets served as their calendar, clock, and compass.

We still have not lost our fascination for the night sky. The colored and twinkling display overhead causes us to pause and reflect, invoking the same deep stirrings that our ancestors felt when they looked towards the stars. When we look up we feel connected to the grandeur of the sparkling array above us; however we no longer view the sky as inaccessible.

Technological advances are taking us on a journey further and further into the universe - into the very hearts of stars - to listen to the rhythms of their pulsations, and begin to gain an understanding of the processes by which they evolve. We have discovered that the seemingly peaceful night sky is an illusion. Stars are not eternal - they are born of nuclear fires, they live, and ultimately die. Some stars die quietly, some literally tear themselves apart with violent explosions, while others undergo catastrophic collapse and disappear from the visible universe into extraordinarily dense black holes. We now have begun to understand that we are a part of that cycle, that Earth and life on Earth are connected to the lives of stars in the most profound and fundamental cycle of all - the continuous cycle of stellar birth, evolution, and death...and not only our origins lie within the stars - do does our future.



KPNO Horsehead Nebula Image

silicon, sulfur and iron. Elements heavier than iron were produced in the outer envelopes of the stars during the supernovae explosions and the resulting shock waves from the core collapse.

The shockwaves traveled through the remnants, carrying the heavier elements from the interior of the star into the surrounding interstellar medium, enriching the medium with the newly created elements. Some five billion years ago, the shockwave from a supernova event encountered a giant molecular cloud of gas and dust and triggered the fragmentation of the cloud. The collapse of one of these fragments condensed into the stellar nursery that gave birth to our Sun and the Solar System.



Dana Berry, Artist

This activity has been developed to assist students in acquiring a basic understanding and appreciation for the cosmic cycles of formation and destruction - and their connection to planet Earth.

Our Cosmic Connection Activity

- ⌘ Task Description [html](#) | [pdf](#)
- ⌘ Set of Images [pdf](#) | [ppt](#)
- ⌘ Teacher Guide and Answer Key [html](#) | [pdf](#)
- ⌘ Alignment to Standards [html](#) | [pdf](#)

Cosmic Webquest

- ⌘ Task Description [html](#) | [pdf](#)
 - Webquest Activity [html](#) | [pdf](#) | [flash](#)
 - Table of URL's [html](#) | [pdf](#)
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Our Cosmic Connections Activity - Image Descriptions

The name and type of object and/or artist illustration for each of the images is listed below. The stage of stellar evolution is indicated by the bold type. The URL for each of the deep sky objects is listed. For more specific information concerning the sequencing or selection of the images please refer to the [Teacher Guide and Answer Key](#).

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1. Planet Earth

[NASA image]

2. Sirius B (bright object in foreground) is a **white dwarf** in a binary system with Sirius A (dim object in the background) - a 2 solar mass main sequence star.

[Chandra X-Ray Observatory image]

<http://chandra.harvard.edu/photo/2000/0065/index.html>

3. DEM L71 is a **Type Ia supernova remnant** in the Large Magellanic cloud. It is the remains of a supernova explosion that destroyed a white dwarf star.

[Chandra X-Ray Observatory image]

<http://chandra.harvard.edu/photo/2003/deml71/>

4. Betelgeuse is a **red supergiant** in the constellation of Orion.

[Hubble Space Telescope image]

<http://antwarp.gsfc.nasa.gov/apod/ap990605.html>

5. The Orion Nebula is a **stellar nursery**.

[Canada-France-Hawaii Telescope - CFHT image]

<http://antwarp.gsfc.nasa.gov/apod/ap040315.html>

6. V838 Mon is basically still a mystery. It is a star slightly more massive than the Sun which dramatically brightened and faded. Though its' evolutionary stage is not known, it is **might be somewhere between the main sequence and early red giant** branch.

[Hubble Space Telescope image]

<http://antwarp.gsfc.nasa.gov/apod/ap040305.html>

7. The Sun is a **mid-sized main sequence** star. [Solar and Heliospheric Observatory (SOHO) image]

<http://antwarp.gsfc.nasa.gov/apod/ap981212.html>

8. Close-up of **stellar nursery** in the Eagle Nebula (M16).

[Hubble Space Telescope image]

<http://antwarp.gsfc.nasa.gov/apod/ap010812.html>

9. Eta Carina is a 100 solar mass star that will end its life in a **Type II supernova explosion in the near future**.

[Hubble Space Telescope image]

<http://antwrp.gsfc.nasa.gov/apod/ap041128.html>

10. Artist William Hartmann's illustration of a **proto-planetary system**.

<http://www.psi.edu/hartmann/>

11. **A new white dwarf**, NGC 2440.

[Hubble Space Telescope]

<http://antwrp.gsfc.nasa.gov/apod/ap040111.html>

12. **Cas A is a Type II supernova remnant** with a neutron star core.

[Chandra X-Ray Observatory image]

<http://chandra.harvard.edu/photo/2002/0237/index.html>

13. The Eight Burst Nebula (NGC 3132) is a **planetary nebula** with a white dwarf core. The white dwarf is the dim star just above and to the right of the bright foreground star.

[Hubble Space Telescope image]

<http://antwrp.gsfc.nasa.gov/apod/ap030913.html>

14. This **proto-planetary disk** is located within the Orion Nebula stellar nursery.

[Hubble Space Telescope image]

<http://antwrp.gsfc.nasa.gov/apod/ap950911.html>

15. **Massive blue stars**, the Pleiades open cluster.

[David Malin, Anglo Australian Observatory]

<http://antwrp.gsfc.nasa.gov/apod/ap031227.html>

16. Artist Illustration of **black hole**.

[Chandra X-Ray Center, M. Weiss]

17. **Expanding supernova remnant** from Cas A supernova event.

[Hubble Space Telescope image]

<http://antwrp.gsfc.nasa.gov/apod/ap030830.html>

18. Artist illustration of **red giant and white dwarf** in binary system.

[NASA artist]

19. Artist Dave Shaver's illustration of a supernova explosion.

<http://thatfish.com/tf/Studio/Adobe/Tutorials/Supernova/SuperNova300x300.jpg>

20. Artist illustration of a **white dwarf** core remnant.

[University of Leicester, UK image]

21. **T-Tauri** star.

[Hubble Space Telescope image]

<http://antwrp.gsfc.nasa.gov/apod/ap000921.html>

22. Artist Dana Berry's illustration which is used to represent a **Type Ia supernova** explosion in this activity.

23. Artist Jeff Bryant's illustration of **red giant** stage of a star similar to the Sun. <http://members.wri.com/jeffb/vistapro/>

24. The Crab pulsar.

[Chandra X-ray Observatory image]

http://chandra.harvard.edu/press/99_releases/press_092899.html

Illustrations from artists William Hartmann, Dana Berry, Dave Shaver and Jeff Bryant are included with this activity by special permission from the artists.

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