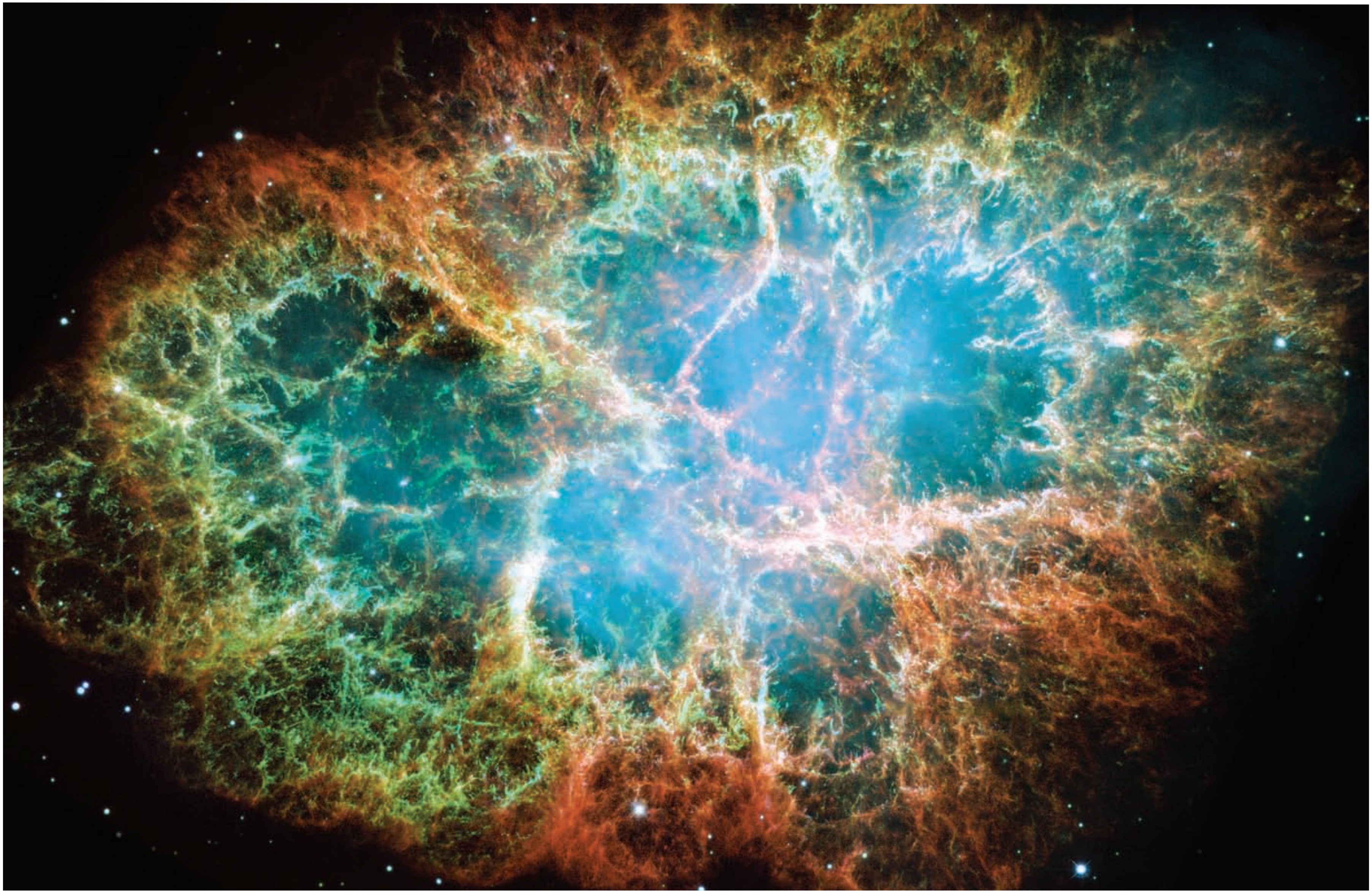
National Aeronautics and Space Administration



The Crab Nebula (M1)

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Celestial Fireworks

Americans celebrate Independence Day by peppering the sky with fireworks. Nearly a thousand years ago, on July 4, 1054, a more powerful explosion brightened the heavens.

Chinese astronomers witnessed the debut of a bright star appearing in the sky within the constellation Taurus. They described the “guest star” as about as brilliant as the full Moon. This star was so bright that people saw it during the day for almost a month. The star remained visible in the evening sky for more than a year before fading from sight.

More than 700 years later, while hunting for comets, Charles Messier spotted an interesting fuzzy object in the same area of the sky as the Chinese guest star. He noted that it was not a star, nor a comet, and placed it on his list of objects that comet hunters should avoid. It became well known to astronomers as the first entry in Messier’s catalogue, published in 1774.

Seventy years later, British astronomer Lord Rosse used the largest telescope of his day to spy Messier’s fuzzy object. The object consisted of glowing strings of gas and dust, called a nebula. He christened it the “Crab” because its tentacle-like structure resembled the legs of the crustacean.

The Crab Nebula is actually the glowing remains of a star. In 1054, a star about 10 times the mass of our Sun reached the end of its life and exploded as a supernova. The gas in the nebula represents the outer layers of the star, blown across interstellar space at several million miles per hour. The colors in the filaments and outer regions of this Hubble image, taken in visible light, represent the elements oxygen and sulfur. They were created in the star during its life and were expelled by its explosive death.

The development of telescopes that detect other wavelengths of light, such as radio waves and X-rays, allowed astronomers to see features in the Crab Nebula that cannot be seen in visible light. In 1968, they uncovered a rapidly spinning neutron star — the dense, compact core of the exploded star — at the nebula’s center. Only about six miles (10 kilometers) across, the neutron star would fit inside a small city. Radio astronomers observed bursts of radio waves 30 times a second and called it a pulsar. These radio outbursts are caused by twin searchlight beams that sweep across our viewpoint, making the neutron star appear to blink on and off. The Crab Pulsar was the first pulsar discovered. Electrons whirling at nearly the speed of light within the neutron star’s intense magnetic field create abundant high-energy X-ray emissions. The same process powers the nebula’s eerie interior bluish glow seen in this Hubble image.

Due to its relative proximity to Earth and energetic emissions at many wavelengths, the Crab Nebula is one of the most studied objects in space. It has revealed intricate details of the death throes of massive stars. Eventually, the elements created in this supernova explosion will be recycled through interstellar gas clouds and will become part of the next generation of stars.

Credits for Hubble image: NASA and ESA.

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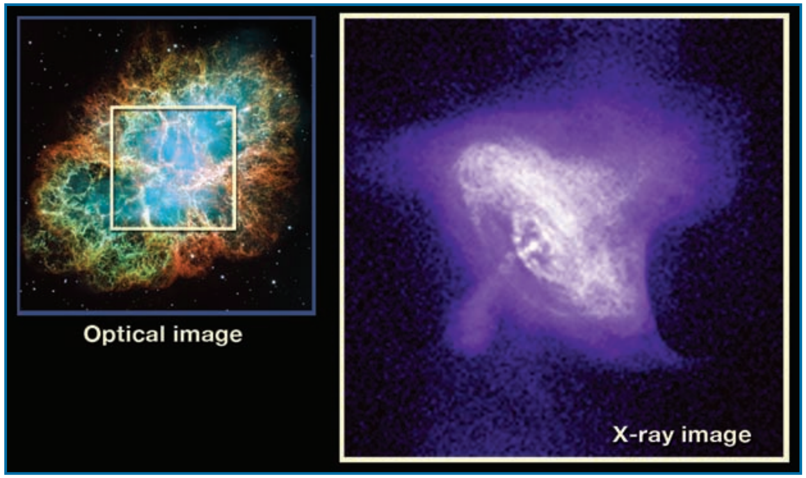

Buried deep within the Crab Nebula is the powerhouse creating the high-energy fireworks detected by astronomers. The image on the left, taken in visible light by the Hubble telescope, shows the pulsar’s location at the heart of the nebula. The pulsar cannot be seen in visible light.

The X-ray image on the right, taken by the Chandra X-ray Observatory, shows two rings of material around the Crab Pulsar. Winds from the central pulsar slam into the surrounding material, creating knots and clouds of energetic X-ray–emitting particles. The pulsar also powers two turbulent jets shooting off perpendicular to the rings at half the speed of light.

Credits for Chandra X-Ray Telescope image: NASA and ESA.

FAST FACTS / VOCABULARY

Location: Constellation Taurus

Distance: 6,500 light-years away

Neutron star: A neutron star is the collapsed remnant of a massive star after a supernova. A neutron star is one of the few possible endpoints of a star’s life.

You can get images and other information about the Hubble Space Telescope on the World Wide Web. Visit **http://www.stsci.edu/outreach** and follow the links.

The corresponding classroom activity for this lithograph can be found at: **http://amazing-space.stsci.edu/** or may be obtained by contacting the Office of Public Outreach at the Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218.

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In Search of … Supernova Remnants

Description

Using the "Crab Nebula (M1)" lithograph, engage your students in a Level One Inquiry activity to investigate supernova remnants. A Level One Inquiry activity can help prepare students to be more independent thinkers. Students conduct research to answer questions they have about how massive stars end their lives.

Grade Level

High school: grades 9–12

Prerequisites

Students should know that stars vary in brightness, color, age, temperature, and mass, and that mass determines a star's fate. Students should also be aware that normal stars, like the Sun, fuse hydrogen in their cores. The depletion of this fuel source initiates the final stages in the lives of stars, resulting in supernovae for massive stars.

Misconceptions

Teachers should be aware of the following common misconceptions and determine whether their students harbor any of them. Students may have misconceptions regarding the evolution and fate of stars. Students may think all stars end their lives the same way — as supernovae. Whether a star becomes a planetary nebula or a supernova depends on its original mass.

Students may think that stars don't change. Stars, in fact, evolve over billions of years. Most stellar changes, such as the birth of a star, occur over many human lifetimes.

Purpose

The purpose of this activity is to use the image and text on the lithograph to introduce the last stages of massive stars. Students formulate questions about supernovae and their remnants, use the Internet to search for answers, and then demonstrate an understanding of the topic by presenting a report of their findings. Students are also asked to reflect on their learning by checking whether they had answered their original questions through their research and/or whether they had generated any new questions.

Materials

- "Crab Nebula (M1)" lithograph
- Computer with Internet connection for researching

Instructions for the Teacher

Preparation

- Obtain a lithograph for each student. Lithographs are available as PDF files at: http://amazing-space.stsci.edu/eds/tools/type/pictures.php.
- Familiarize yourself with the evolution of massive stars using a current astronomy textbook or the AstroFile, "A History of the Crab Nebula": http://hubblesite.org/newscenter/newsdesk/archive/releases/1996/22/astrofile/
- Bookmark or identify as favorites the following suggested Websites and/or prepare a list of Websites that students can access to obtain additional information about supernovae:
  - STScI News Releases about Stars that form Supernovae: http://hubblesite.org/newscenter/newsdesk/archive/releases/category/star/supernova/
  - STScI News Releases about Nebulae classified as Supernova Remnants: http://hubblesite.org/newscenter/newsdesk/archive/releases/category/nebula/supernova%20remnant/
  - STScI: Hubble Supernova 1987A Scrapbook (1994-2003): http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/09/image/b
  - STScI: Kepler's Supernova Remnant: Images from Chandra, Hubble, and Spitzer: http://hubblesite.org/newscenter/newsdesk/archive/releases/2004/29/text/

Procedure

Evaluate your students' misconceptions about stars by having them write down anything they know and understand about stars. Have students volunteer their ideas about stars. From those ideas, identify their misconceptions and discuss them with the class. Or, collect the papers containing their ideas about stars. From those ideas, compile a list of their misconceptions about stars and discuss them with the class.

Ask students to look at the image of the Crab Nebula on the front of the lithograph and the close-up image on the back. Then tell them to write down three questions they want answered about supernova remnants. Compile a list of students' questions and pick out common themes. Set up groups of students based on those themes. Ask students to read the information on the back of the lithograph, noting if any of their questions were answered. Allow students to refine their questions by discussing them with their groups. Ask students to use the Internet to research their questions. The Internet sites listed above can provide a starting point for their research. Instruct students on how to access other Websites that may be appropriate.

Ask students to prepare a report in which they explain how supernova remnants form. This report could be in the form of a slide show, a skit, a story, a graphic organizer, a Power Point presentation, or a written report — anything that conveys their understanding of the topic to another student, a group of students, or the entire class. Ask students to review their original questions to see if they were answered. Then ask them if they have any additional questions.

Instructions for the Student

Your teacher will ask you to write down things you know and understand about supernovae. You may be asked to share this information with the rest of the class. Study the images of the supernova remnant, and write down three questions about what you see in the images. Then read the back of the lithograph, noting if any of your questions were answered.

Your teacher will assign you to a group that will research the answers to your questions on Internet sites provided. To demonstrate your understanding, your teacher will ask you to give a report that explains some aspect of supernova remnants, or how the remnants form. This report could be a slide show, skit, story, graphic organizer, Power Point presentation, or whatever you think communicates what you learned about supernova remnants. You may be allowed to work individually or in small groups, and make your presentations to another classmate or group of students, or the entire class.

Education Standards

Benchmarks for Science Literacy

American Association for the Advancement of Science:
http://www.project2061.org/tools/benchol/bolframe.htm

Grades 9–12:

4. The Physical Setting

A. The Universe

By the end of the 12th grade, students should know that:

• On the basis of scientific evidence, the universe is estimated to be over 10 billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. **The process of star formation and destruction continues.**

McREL Language Arts Standards and Benchmarks
http://www.mcrel.org/compendium/browse.asp

Science Standard 3: Understands the composition and structure of the universe and the Earth's place in it.

Level 4 (Grade 9–12)

Benchmark 3

1. **Knows the ongoing processes involved in star formation and destruction** (e.g., stars condense by gravity out of clouds of molecules of the lightest elements; nuclear fusion of light elements into heavier ones occurs in the stars' extremely hot, dense cores, releasing great amounts of energy; **some stars eventually explode, producing clouds of material from which new stars and planets condense**).

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