DOCUMENT RESUME

ED 314 240 SE 051 073

TITLE	The Death of a Star: Supernova 1987a. NASA Educational Briefs for the Upper Elementary-Level Classroom.
INSTITUTION	National Aeronautics and Space Administration, Washington, D.C.
REPORT NO	EB-88-2-(E)
PUB DATE	88
NOTE	5p.; Drawings may not reproduce well.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Astronomy; *Elementary School Science; Intermediate Grades; *Science Activities; *Science Materials; *Scientific Research; Space Exploration; *Space Sciences; Spectroscopy
IDENTIFIERS	National Aeronautics and Space Administration; Stars; *Supernova

ABSTRACT

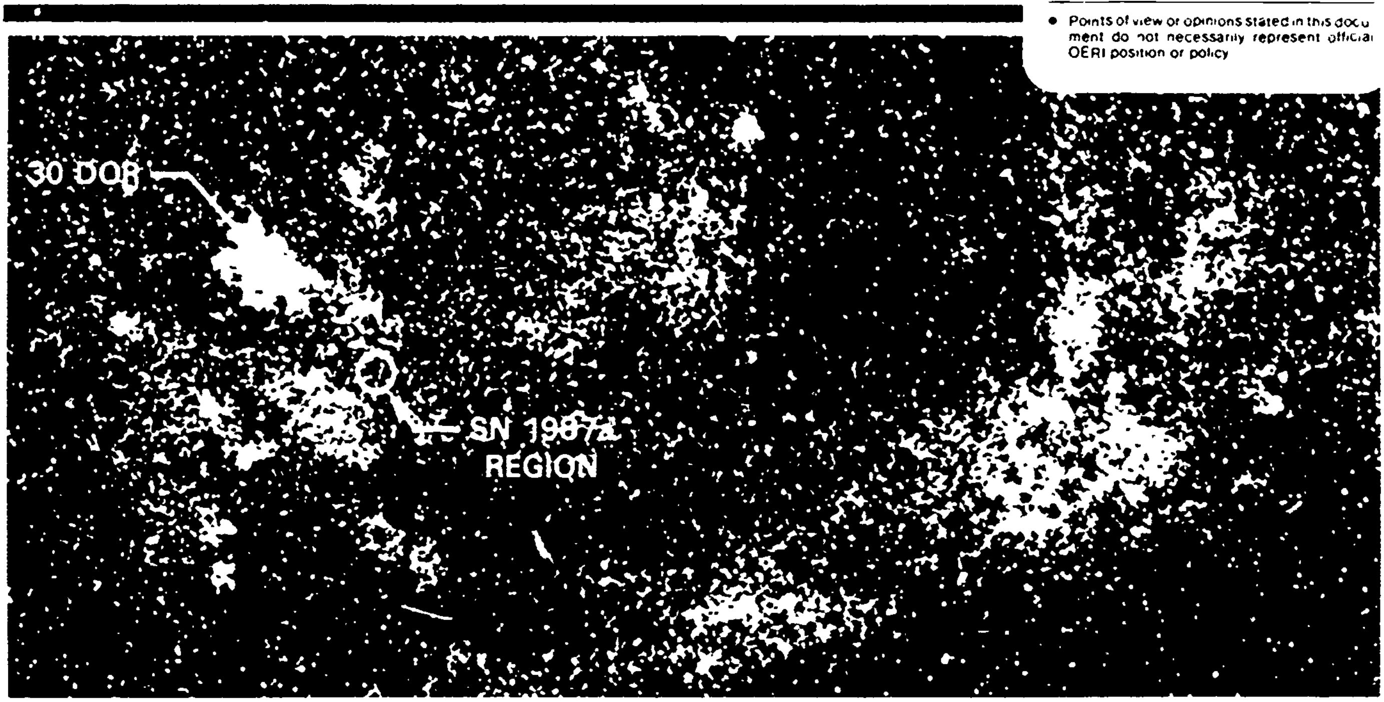
This material discusses supernova, the violent death of a massive star, at a level appropriate for upper elementary students. Background information on Supernova 1987a is presented. Observation techniques using visible light, ultraviolet waves, radio waves, neutrinos, X-rays, and gamma-rays are described. A vocabulary list, 11 questions, and 6 activities are provided for classroom use. Lists 11 references. (YP)

NASA Educational Briefs

An Educational Publication of the National Aeronautics and Space Administration

EB-88-2 (E)

For the upper elementary-level classroom



This telescope view of the Large Magellanic Cloud shows Supernova 1987a. The Large Magellanic Cloud is a neighbor galaxy to our Milky Way Galaxy.

The Death of a Star: Supernova 1987a

Nothing like it had been seen on Earth for nearly 400 years. A supernova—the violent death of a massive star—is, as one scientist describes it, "the largest explosion in nature except for the Big Bang itself."

In 1987, astronomers got a rare chance to watch the death of a nearby star when a supernova appeared as a bright "new" object in the heavens. Not since the invention of the telescope almost 400 years ago has a star exploded this close to us.

On February 23, the new object was discovered in a fuzzy patch of light called the Large Magellanic Cloud, which is actually a neighboring galaxy visible only from the Southern Hemisphere. Supernova 1987a (so named because it was the first supernova discovery of the year) was reported by astronomers observing with telescopes located below the equator, at the Las Campanas Observatory in Chile.

Compared with other galaxies, the Large Magellanic Cloud is right next door to us—only 170,000 light years (or about 1,000,000,000,000,000,000 miles) away, less than twice the distance across our own Milky Way galaxy. In 1519, it appeared to the Portuguese explorer Ferdinand Magellan as a wispy cloud. Today we know that the galaxy shines with the diffuse light of billions of stars. The fact that the supernova—a single star—can be seen with the naked eye, outshining all those billions of suns, shows the great power of a supernova explosion.

Because the light from Supernova 1987a traveled 170,000 years to get here, astronomers know that the actual explosion took place long in the past. At the same time that the supernova actually exploded, Homo Erectus was chipping flaked stone tools and wouldn't learn the art of cave painting for another 140,000 years. In one second, 1,700 centuries ago, the exploding star released more energy than our Sun will during its entire ten billion-year lifetime. By comparison, the Sun puts out the amount of energy contained in all the world's nuclear weapons in only ten millionths of a second.

Scientists believe that a supernova of this type occurs when the core of a massive star–one with at least a dozen times as much material as our Sun–collapses on itself after burning up all the nuclear fuel that is its power source. When the outward pressure of nuclear fusion energy no longer can withstand the inward pull of gravity, the star becomes unstable and collapses in a single catastrophic moment. The shock wave rebounding from this collapse causes the gaseous outer layers of the star to be blown out into space with fantastic energy.

The core of the original star is made of iron. During and after the explosion, iron and other elements in the star's outer layers are fused together by the tremendous heat and energy to form new elements. A significant proportion of all atoms heavier than iron are thought to be created in supernova explosions. When the star explodes, the newly formed atoms and molecules are blasted out into space, where they provide the material from which new stars and planets are formed. Many of the atoms that make up our own Earth—and the life that inhabits its surface—originated in the cosmic furnace of some supernova.

When astronomers discovered Supernova 1987a, one of their first tasks was to identify which star had exploded. After studying old photographic plates of that region of the sky, a little-known star called Sanduleak -69 202 was identified as the missing star that had "gone supernova." (The star got its name from an astronomer named Nicholas Sanduleak, whose catalog of unusual stars lists this as the 202nd object in the 69th degree south of the celestial equator.)

Sanduleak -69 202 is thought to have had a mass 15 to 20 times that of the Sun before its explosion. Astronomers were at first surprised that this hot blue star could cause a supernova of the type seen in 1987. Previously, these "Type II" supernovas had been seen only in larger "red supergiant" stars; theorists have since proposed that the Sanduleak star was a red star that had turned blue before it exploded.

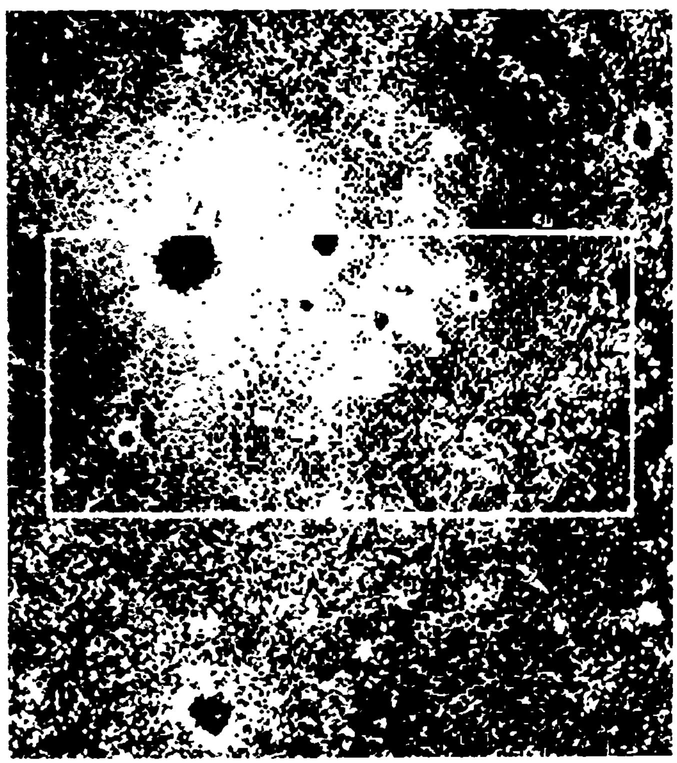
Since the day the supernova was discovered, astronomers around the world have been using telescopes, satellites, high-flying airplanes, large radio antennas, rockets, balloons, and instruments mounted on orbiting space platforms to observe the "new" star in different wavelengths of the electromagnetic spectrum. Each type of light reveals a different process going on inside the exploding star.

In the early stages of a supernova, high-energy radiation such as X-rays and gamma-rays— produced deep inside the core—cannot penetrate the expanding cloud of gas and dust produced by the explosion. But by studying the supernova in visible light, astronomers can tell how fast the exploding atmosphere of the star is moving, what its temperature is, and what it is made of. Visible wavelength studies are possible from observatories located in the southern part of the world. Infrared light tells what is happening to the dust shell now enveloping the remnant star.

Ultraviolet observations also help scientists to understand this outer "surface" of the expanding shock wave of gas and dust. Within a day of the supernova's initial sighting, the International Ultraviolet Explorer satellite in Earth orbit was commanded (by technicians on the ground) to turn its attention toward the newly discovered object. The ultraviolet observations also have been used to help establish how the supernova's brightness and color change with time. These brightness measurements were important facts assisting the theorists who have been trying to predict the supernova's next behavior.

Radio observations using large dish antennas on Earth are also used to study the expanding gases from the explosion. These investigations tell astronomers about the interactions between the explosion and the material that already existed around the star.

Most of the energy from a supernova, however, is given off in the form of very small, almost massless particles called neutrinos. These particles are able to pass through solid matter almost undisturbed. Therefore, special underground water tanks have been built with instruments that record the very rare "hits" between neutrinos and the water particles inside the tank.

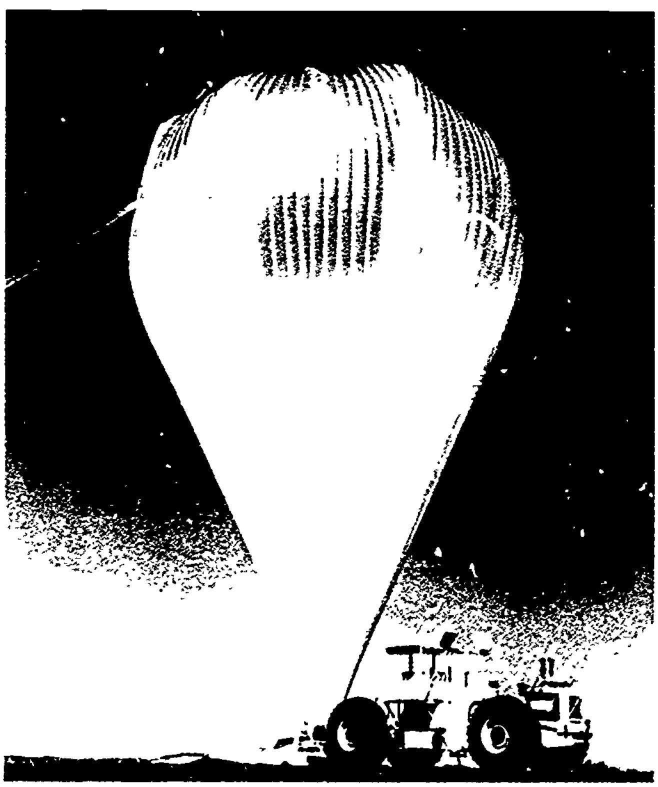


The Japanese Ginga X-ray satellite took this view of Supernova 1987a, which appears inside the box.

In the ten seconds after the first light from the supernova reached our planet, a trillion neutrinos passed through every square centimeter on Earth. A mere handful of these caused collisions that were detected in observatories in Japan and Ohio. But these were enough to prove for the first time that neutrinos are produced by stars other than our Sun.

Many of the most important supernova observations are made from above Earth's atmosphere, which absorbs many kinds of incoming radiation. NASA's Kuiper Airborne Observatory (KAO), an airplane equipped with infrared-sensitive instruments, has studied the dust surrounding the star as well as the chemical processes going on inside the core, where heavy elements such as nickel and cobalt are being created. The infrared studies also give information on the dust that surrounded the star before it exploded, and on how newly created materials are spread out into space.

X-rays from the supernova were first detected by a Japanese satellite and by a Soviet space station experiment in August 1987. Small NASA sounding rockets also carried X-ray detectors above the atmosphere for short periods. X-rays indicate very high temperatures. The formation of heavy elements in a supernova produces gamma-rays. Collisions between these gamma-rays and material inside the expanding supernova causes the gamma-rays to lose energy becoming X-rays. The X-rays, in turn, give clues to events which have occurred to the star remnant.



This NASA balloon helps astronomers in their work. It will carry its payload at a "float" altitude of 1,000,000 feet.

Gamma-rays give the most direct evidence of the creation of new elements in a supernova. Gamma-ray observations are made using detectors carried to altitudes above 100,000 feet by scientific balloons, and by satellites. The first gamma-rays from Supernova 1987a were detected by a satellite in November 1987.

These high-energy observations provide new information about the strange processes going on in the center of the exploded star and confirm existing theories about the creation of new matter–nucleosynthesis–in a supernova. The gamma-rays are produced in the decay of radioactive nickel and cobalt produced when the star's iron core collapsed.

According to theory, a supernova of this size leaves behind either a neutron star at its core–an extremely dense remnant made of compressed atoms–or a pulsar, a neutron star which is spinning rapidly and producing X-rays.

As the dust from the stellar explosion clears, the mysteries at the center of Supernova 1987a will become more visible in all wavelengths, and astronomers will be able to continue their study of this most spectacular event in nature well into the next century. At some point, perhaps ten years from now and perhaps 100 years from now, the expanding shell of material exploded away from the supernova's progenitor star will become a visible nebula. Depending on what it looks like this nebula will be named and will join the lore of astronomy.

For the Classroom

Vocabulary

neutrino
nuclear
wavelength
Sanduleak -69 202
Large Magellanic Cloud
supernova
electromagnetic spectrum
light year

Find the meaning of the italicized parts of the following words:

*infra*red
super*nova*
*ultra*violet

Questions

1. How long ago did the supernova explode? How do we know? What was happening on Earth when the star exploded?

2. Why can't students in the United States see the supernova? Where would they have to go to see it?

3. Magellan was the first European to describe the Large Magellanic Cloud, which he saw during his voyage around the world in the 16th century. Why do you think no one had discovered it before?

4. Where does a star's energy come from?

5. Was the star that exploded larger than our own Sun?

6. What color do astronomers think the supernova star was when it exploded?

7. How did the supernova get the name Sanduleak -69 202?

8. Who names stars?

For Further Research

1. How will our own Sun die? When do astronomers think it will happen?

2. What elements are contained in the Sun? Find a table of the elements. Which elements are heavier than iron? How and where are they created?

3. How does studying old photographic plates of the region of the sky where the supernova is tell astronomers which star exploded? (See photo)

Activities

Make a chart of the electromagnetic spectrum. Which types of radiation have the highest energy? Which ones have the lowest?

Using glitter (to represent stars), a glue stick and a piece of paper, make a two-dimensional model showing the starry spirals of our own Milky Way galaxy. If the Milky Way is 100,000 light years across and the Large Magellanic Cloud is 170,000 light years away from the Milky Way, how far away should a second piece of paper representing the Large Magellanic Cloud be placed? Stick a pin in the Milky Way "map" to represent the Sun (on an outer spiral arm) and another pin in the Large Magellanic Cloud "map" to represent the supernova. (Note: the Large Magellanic Cloud is only 2/5 the diameter of the Milky Way.)

The Crab Nebula in the constellation Taurus is made of leftover material from a supernova explosion that occurred in this galaxy in 1054. Using a small telescope, find the Crab Nebula in the night sky.

On an astronomical globe, find the Large Magellanic Cloud in the southern constellation Dorado.

In the night sky, try to identify stars of each of the following colors: red, blue, and yellow. What does color tell you about the star?

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