National Aeronautics and Space Administration

Exposing new views of a star's life cycle

This GALEX ultraviolet image shows the planetary nebula NGC 7293, also known as the Helix Nebula. It is the nearest example of what happens to a star, like our own Sun, as it approaches the end of its life, when it runs out of fuel, expels gas outward, and evolves into a much hotter, smaller, and denser white dwarf star.

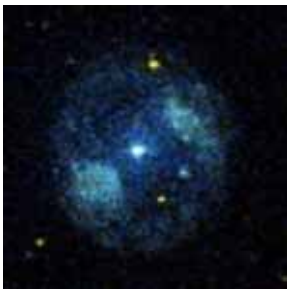
www.nasa.gov

GALEX Galaxy Evolution Explorer

The Helix Nebula: What is it?

The object shown on the front of this poster is the Helix Nebula. Although this object and others like it are called **planetary nebulae** (pronounced NEB-u-lee), they really have nothing to do with planets. They got their name when astronomers first saw them through early telescopes, because they looked similar to planets with rings around them, like Saturn.

A planetary nebula is really a shell of glowing gas and plasma from a star at the end of its life. The star has blown off much of its material and what is left is a very compact object called a **white dwarf.** For a while, the white dwarf is still hot and bright enough to make the material from the former star glow, and that is what we see as a beautiful nebula. Over 10,000 years or so, the gas will drift away and the white dwarf will cool so much that we can no longer see the nebula.



Planetary nebula JnEr1, as seen by GALEX.

This is what will happen to our Sun in about 5 billion years. What do you suppose our Sun's nebula will look like to some distant alien astronomers?

Planetary nebula A21, as seen by GALEX.

To understand what happens to a star at the end of its life, we need to know something about the rest of a star's life, from birth, through middle-age (our Sun's stage of life now), and into its last stage of life.

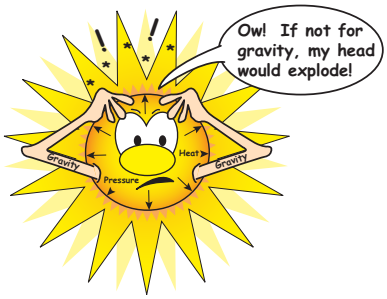
How Does a Star Form?

Stars are born where there are thick clouds of gas (mostly hydrogen) and dust in space. Gravitational attraction makes these materials clump together. The "clumped" object grows more and more massive as more and more gas gets pulled in by the growing gravitational force. As the object becomes more massive, squeezed by tremendous gravitational forces, it becomes more dense (compact). As it gets denser, it gets hotter and hotter. Eventually, if the giant gas ball gets massive enough and dense enough, the **atoms of hydrogen gas will begin to fuse together, creating helium** atoms and igniting the nuclear fires that make it a star.

This "Mountains of Creation" image was captured by the Spitzer Space Telescope in infrared light. It reveals billowing mountains of dust ablaze with the fires of active star formation. GALEX can see the new stars forming, because they glow brightly in ultraviolet (UV) light. However, the surrounding dust and gas clouds are cooler and not so visible to GALEX.

A Tug of War

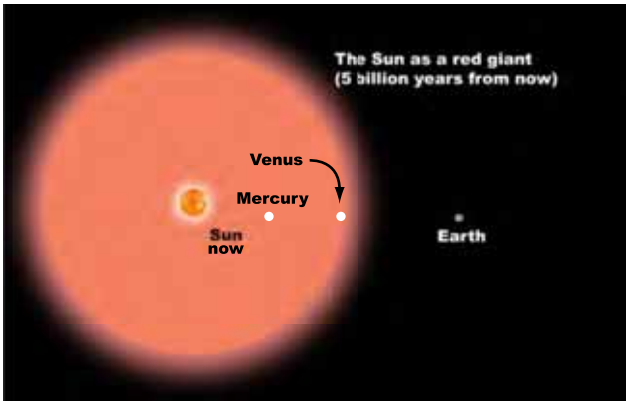
A star is an amazing balancing act between two huge forces. On the one hand, the crushing force of the star's own gravity tries to squeeze the stellar material into the smallest and tightest ball possible. But on the other hand, the force of the tremendous heat and pressure from the nuclear fires burning at the star's center tries to push all that material outward.



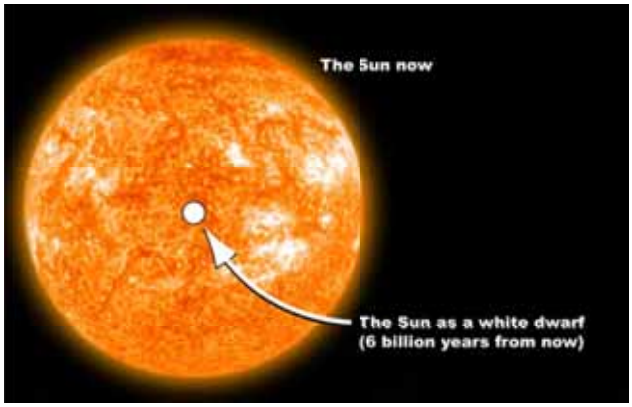
When the star has used up almost all of its hydrogen nuclear fuel (after several billion years), the outward pressure from the nuclear reactions is no longer able to counteract the gravity, and the core of the star collapses under its own weight, so to speak. As the core collapses, it gets even hotter. The outer layers of the star puff up from this increased heat, but as the star puffs up, the outer layers get cooler. The star is called a **red giant** at this point.

Our own Sun will become a red giant before it dies in about 5 billion years. It will be so large at this stage in its life that it will engulf the orbits of Mercury and Venus and maybe even Earth. Even if Earth remains outside the Sun, the oceans and the atmosphere will have boiled away and nothing will be able to live on what will be a burnt cinder of rock.

But even as the outer layers puff up, the core of a red giant continues to contract and get even hotter. When the core gets hot enough, the nuclear fires are once again lit, as the **helium atoms fuse into carbon and oxygen atoms**. It is in the cores of dying stars that much of the carbon and oxygen atoms in ours bodies were made!



In 5 billion years or so, the Sun will puff up and become a red giant star, swallowing up Mercury and Venus. In this picture, the orbits of Mercury, Venus, and Earth compared to the size of the Sun as a red giant are to scale, but the sizes of the planets and of the Sun now are not to scale. The Sun's diameter as a red giant will be about 80 times larger than it is now.



Eventually (after its red giant phase), the Sun will become a white dwarf, about the same size as Earth, but hundreds of thousands of times more dense. The Sun's diameter as a white dwarf will actually be about 110 times smaller than it is now.

A Fight to the Finish!

The nuclear reactions that are creating carbon and oxygen once again exert outward pressure and stop the collapse of the core. But this time, the nuclear reactions are very sensitive to temperature. If the temperature goes up just a little, the nuclear reactions happen a lot faster, releasing a lot more energy, making the temperature go up even more. The star becomes very unstable. It begins to pulsate violently, as the gravitational and nuclear forces fight to the death. Finally, the stellar atmosphere is blown into space.

As the gases are blown off, they form a cloud around what is left of the star. As more of the star's atmosphere blows away, deeper and hotter layers of the star's core are exposed. Finally, the surface of what is left of the star is so hot that it makes the cloud of gases around it glow. That glowing cloud of gas is what we know as a planetary nebula.

What is left behind at the center is called a white dwarf, made mostly of carbon and oxygen. It will eventually cool off and become more and more dense, because there are no more nuclear reactions pushing outward to counterbalance the gravitational forces that pull inward. Finally, the white dwarf may have half the mass of the Sun contained in an object with the volume of Earth. (Today the Sun has a volume more than one million times that of Earth!)

The white dwarf will eventually cool off so much that it will no longer illuminate the gases of the nebula. We are lucky to see planetary nebulae at all because they glow for only a few tens of thousands of years, compared with the lifetime of a typical star, which can be several billion years.

The Helix Nebula (also called NGC 7293) on the front of the poster is one of the largest and oldest planetary nebulae known. It is quite close to us in astronomical terms, at around 500 or 600 light years away. It is about 4 light years across, which is many times larger than our entire solar system.

How big do you think our Sun's planetary nebula will be?

Learn More About Galaxies, Ultraviolet light, and Nebulae

GALEX Website, http://www.galex.caltech.edu. See "Image Gallery."

Hubble Space Telescope Gallery of Planetary Nebula Images: http://hubblesite.org/newscenter/newsdesk/archive/releases/category/nebula/planetary.

The Space Place, http://spaceplace.nasa.gov. Under "Projects," see "Galactic Mobile" and "Galaxy Montage" activities. Under "Games," see "How old do I look?"

Universe by Robin Kerrod, DK EYEWITNESS BOOKS, 1st ed. (March 2003), ISBN: 0789492385 (ages 9-12).

Galaxies by Seymour Simon, Harper Trophy, Reprint ed., 1991, ISBN: 0688109926 (ages 9-12)

Our Galaxy and the Universe by Ken Gruan et al., Ken Press, 2002, ISBN: 1928771084 (ages 9-12).

Light, by David Burne. 1st ed., 2000, DK Publishing (DK Eyewitness Books). ISBN: 0789467097, ages 9-12.

Invisible Universe: The Electromagnetic Spectrum from Radio Waves to Gamma Rays : Grades 6-8, by Alan Gould and Stephen Pompea. Published by LHS GEMS; Teacher edition (August 1, 2002). ISBN: 0924886692.

Clues from Ancient Light

This activity introduces some important science concepts in simple language. The puzzle activity reinforces one aspect. Participants cut out the squares on the second page with the pictures of objects of different "ages," then rearrange them from oldest to youngest. A third page shows the pictures in the right order (allowing room for differing interpretation in a couple of cases), explaining a little about each picture. If desired, the puzzle page may be photocopied and glued to card stock or a manila folder before cutting out the squares.

GALEX Looks Back in Time

Like all telescopes that see far into space, GALEX is a time machine. As it peers into the distance, it is also peering into the past. That is because the light that GALEX detects has taken a long time to travel from its source (a galaxy, for example) to reach GALEX. Although light travels faster than anything else (300,000 kilometers or 186,000 miles per second, in round numbers), it does not travel infinitely fast. That means, while light travels, time passes. The farther it travels, the more time passes.

The distance light can travel in one Earth year is called a light year. A light year is a very long distance: around 9 trillion kilometers (6 trillion miles).

Light travels in waves, similar to the way water waves move through the ocean or sound waves move through the air. Next time a fire truck approaches with its siren blasting, listen closely. You will notice that the siren's note deepens a little just as the truck passes you. The note is lower because the sound waves are being stretched as the truck continues to move away from you.

The same thing happens to starlight. The galaxies are all moving away from us and each other because space itself is expanding. As the light waves move through expanding space, they get stretched out. The longer the light waves' journey through space, the more stretched out they become. Astronomers say this stretched out light is "red-shifted."

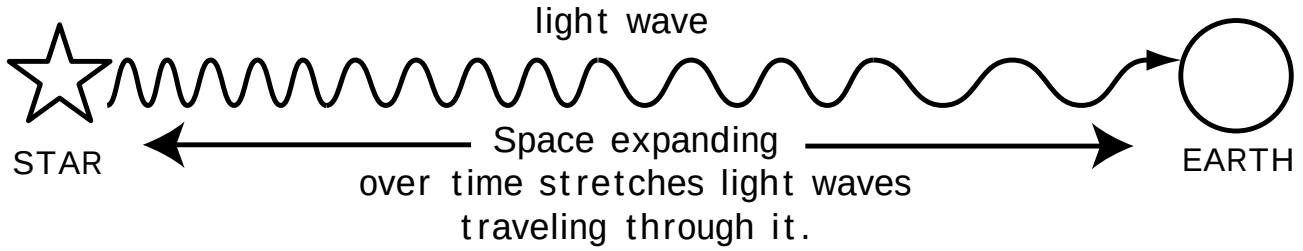
How Old Is the Starlight?

GALEX sees starlight that has been traveling for just a few years from stars that are "only" a few tens of trillions of kilometers away. But it also sees really stretched out "red-shifted" starlight that has been traveling over 10 billion years! That is more than two-thirds of the age of the whole universe! So GALEX is seeing faraway galaxies as they were a very long time ago when they gave off the light, as well as nearby galaxies as they looked just a few hundred thousand years ago.

Just as old photographs show how people looked decades ago, GALEX sees pictures of galaxies when the universe was much younger than now. So astronomers can look at the galaxy pictures from far away—and long ago—compare them with pictures of galaxies nearby—very recent—and see how galaxies and their stars are born, age, and die over time. They can learn how galaxies evolve.

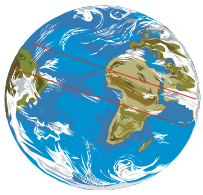
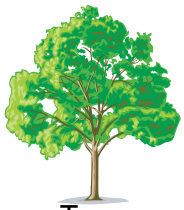
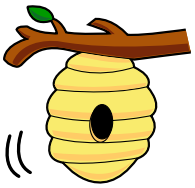
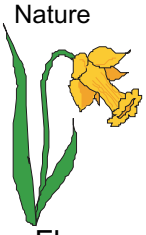
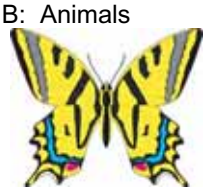
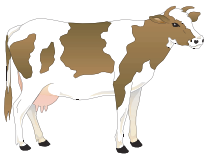
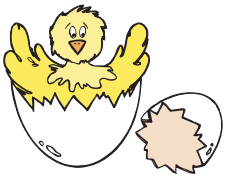
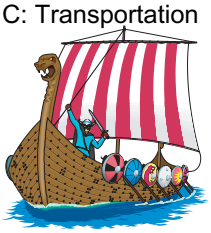
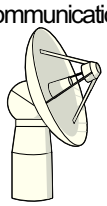
How Old Do I Look?

Can you tell how old something is just by looking at it? The squares on the next page contain pictures of old things, new things, and every age in between things. Cut out the squares. For each row (A – F) of six pictures from a single category, like nature or animals, arrange the objects by age, oldest on the left, youngest on the right. Some things may be a little hard to compare, but make a good guess anyway. At least be able to explain why your arrangement by age could be right! Compare your best guesses to ours on the answer page.

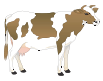
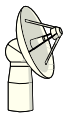


Light travels in waves, just as energy traveling through the ocean pushes the water into waves. But as light waves travel through space, they gradually get stretched out. That is because, along with the universe, space itself is expanding and stretching the distances between things.

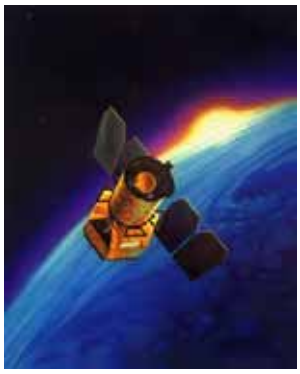
CUT OUT SQUARES. IN EACH ROW, ARRANGE OLDEST TO NEWEST (LEFT TO RIGHT).

A: Nature  Earth	A: Nature  Tree	A: Nature Galaxy	A: Nature  Bee hive	A: Nature Mountain	A: Nature  Flower
B: Animals/ Baby	B: Animals  Butterfly	B: Animals  Milk cow	B: Animals Old man	B: Animals Giant tortoise	B: Animals  Baby bird
C: Transportation Pegasus rocket (launched GALEX space telescope)	C: Transportation Covered wagon	C: Transportation First metal bike	C: Transportation  Viking ship	C: Transportation Wright brothers' airplane	C: Transportation Volkswagen Beetle
D: Communication Telephone (rotary dial)	D: Communication Cell phone	D: Communication Telephone (separate ear & mouth pieces)	D: Communication Telephone (combined ear & mouth pieces)	D: Communication  GALEX ground station antenna	D: Communication Smoke signals
E: Gone quickly Cloud	E: Gone quickly Soap bubble	E: Gone quickly Birthday candle flame	E: Gone quickly Flower	E: Gone quickly Lightning	E: Gone quickly Leaf
F: "Imagers" GALEX space telescope	F: "Imagers" Box camera	F: "Imagers" Isaac Newton's Telescope	F: "Imagers" 35-millimeter film camera	F: "Imagers" Digital camera	F: "Imagers" Cave painting

ANSWERS!

A This galaxy, M81, is over 10 billion years old. Picture taken by the GALEX telescope.	A Earth is about 4-1/2 billion years old.	A Mountains can be almost as old as Earth itself. Some are just a few million years old.	A Trees can be hundreds of years old. This one looks at least a few years old.	A This beehive is likely to be at least a few days old. It could be older than the tree though!	A This daffodil looks very fresh, probably just a day or two old.
B Giant tortoises can live from 150-200 years! This one may not be that old, but it might be over 100.	B This man looks about 80 or 90 years old.	B  Cows must bear a calf before they can give milk. They are usually at least two years old.	B This baby is crawling, so he is probably between six months and one year old.	B Butterflies we see are in the last part of their life cycle. This phase usually lasts only about one week.	B This little chick has just hatched and is still in his shell. It may be only a few minutes old.
C This ship might have been used by the Viking warriors more than 1000 years ago.	C Covered wagons were used by the settlers of the western U.S. during the 1800s.	C The first all-metal bicycle appeared in 1870. Covered wagons were still in use though!	C Wright brothers' airplane flew successfully in 1903.	C The last Volkswagen Beetle "love bug" was made in 1978.	C The Pegasus rocket was first launched from a big airplane in 1990. It launched GALEX in 2003.
D Native Americans "talked" by smoke signals long before Europeans arrived in the 1600s.	D This kind of telephone appeared during the early 1900s.	D This later model has a rotary dial. The ear and mouth pieces can be held in one hand.	D This kind of rotary phone appeared in the late 1950s.	D This cell phone is one of the newest models. May be newer than GALEX ground antenna.	D  GALEX ground stations in Hawaii and Australia began operating in 2002.
E This leaf (if it is still on the tree) could be several days or weeks old.	E This dandelion doesn't last long before it turns to a puff of fuzzy seeds that blow away.	E How old is a cloud? Clouds are always changing. But maybe it will look the same to you for a few minutes.	E This candle is very small so the flame will burn for only a couple of minutes.	E A bubble floating in the air is fragile and usually pops in a few seconds.	E Up to 18 lightning bolts can strike in one second, so this one must be very young indeed!
F Cave paintings date from over 15,000 years ago.	F Isaac Newton designed the first reflecting telescope in 1672.	F This box camera was probably made in the 1950s.	F This "look through the lens" camera is most likely newer than the box camera.	F Digital cameras like this are the latest advance in photography. First sold in the 1990s.	F GALEX space telescope, launched in 2003, has very advanced imaging instruments.

GALEX: The Galaxy Evolution Explorer



GALEX (short for Galaxy Evolution Explorer) is a space telescope orbiting Earth since 2003. GALEX observes galaxies in **ultraviolet** (UV) light. Because Earth's atmosphere blocks most UV light, GALEX must be above the atmosphere.

GALEX is looking at tens of millions of galaxies spanning much of the universe. A **galaxy** is a grouping of stars, gas, dust, planets, moons, and various strange objects such as black holes all held together by gravity. All but a few stars in the universe live in galaxies. Our Sun is just one of at least 200 billion stars in our own Milky Way Galaxy. The entire universe probably contains over 100 billion galaxies.

Stars, planets, galaxies, clouds of dust and gas, and other matter in space are sending out energy all the time. This energy, called **electromagnetic energy**, travels in **waves**. Like waves traveling through the ocean, electromagnetic waves can be very long, very short, or anything in between.

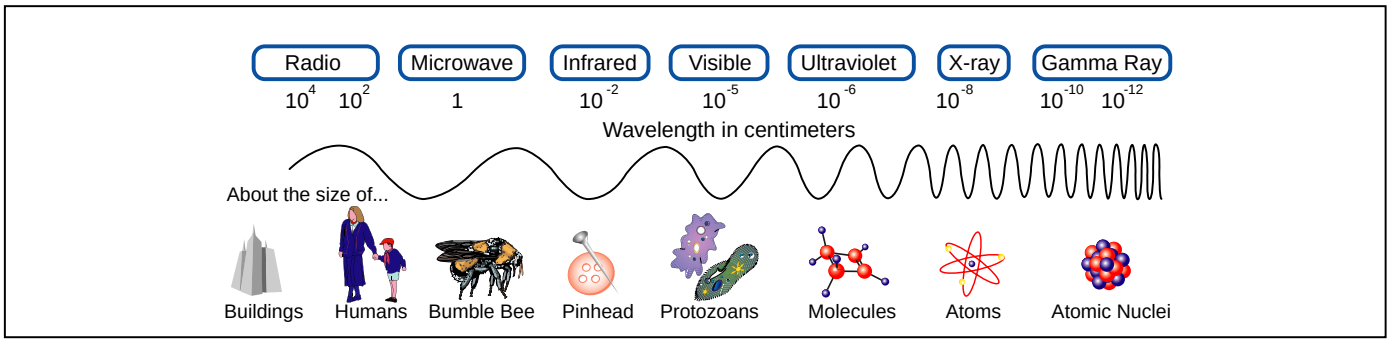
Therefore, the light we see from the Sun and other stars—the visible light—tells only a small part of the story of the stars. To get the complete picture, we must extend our vision to include other wavelengths or energies of light. That is why scientists and engineers have invented different kinds of telescopes. For example, we have special telescopes for the long radio waves; special telescopes for the infrared waves that we cannot see but rather feel as heat; and we have special telescopes such as GALEX for detecting invisible ultraviolet waves.

GALEX detects the UV light coming from nearly the farthest parts of the universe. Some of this light is almost two-thirds as old as the universe itself, having taken billions of years to reach us from the galaxies that were its source.

GALEX is especially good at finding star nurseries—places where new stars are forming inside galaxies. GALEX can see these hot, baby stars well, because they shine brightly in ultraviolet light. And because GALEX does not see visible light, it is not confused by the larger number of older stars. By studying galaxies near and far away, especially those that glow strongly in ultraviolet, scientists can understand better where and how stars are formed, how galaxies come to be, and how galaxies change over cosmic time.

The beautiful ***Andromeda Galaxy*** (or M31) is the nearest large galaxy to our own ***Milky Way Galaxy***. On the left is Andromeda as it appears through a visible light telescope (at a bit smaller scale). The image on the right was made by GALEX, capturing Andromeda's UV light. The star-forming regions in the spiral arms are quite clumpy compared to the vast regions of old stars. (Visible light image courtesy of John Gleason.)

GALEX can detect stars and galaxies that are about 40 million times fainter than ones we can see with our unaided eyes from even the darkest skies here on Earth. GALEX is the first mission to map most of the sky in UV light at a great enough distance to survey galaxies outside our own galaxy. Its all-sky map will also help astronomers find the most interesting looking galaxies for future study in detail using other telescopes.



This material was contributed by the Jet Propulsion Laboratory, California Institute of Technology, reflecting research carried out under a contract with the National Aeronautics and Space Administration.