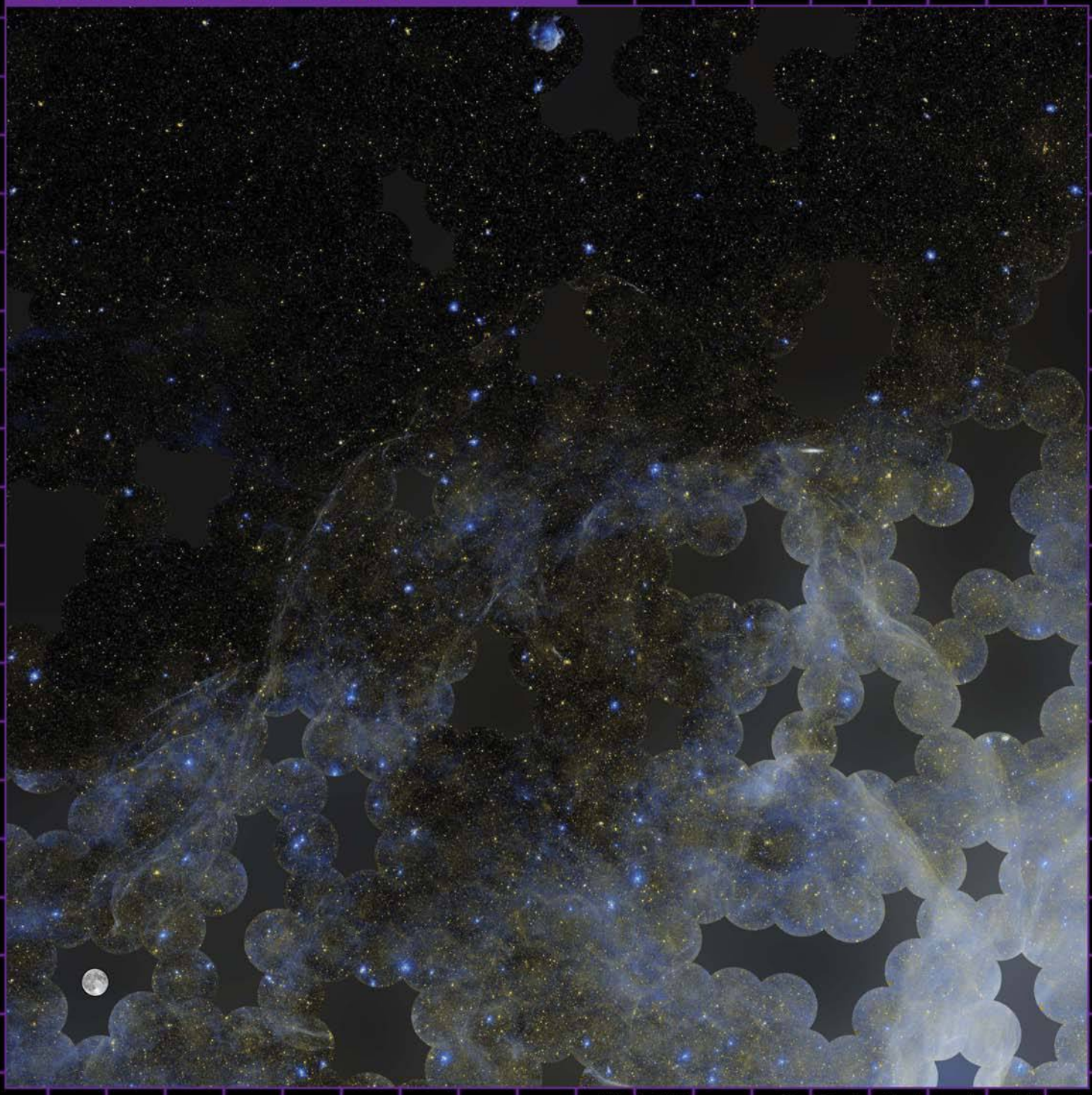
National Aeronautics and Space Administration

GALEX

Galaxy Evolution Explorer

Census in Ultraviolet



This ultraviolet image covers a 20° x 20° region of the sky, near the constellations of Puppis and Vela. This mosaic of 400 separate images represents only 1% of the All-sky Imaging Survey that is the primary mission of the Galaxy Evolution Explorer. The filamentary structure is part of the Gum Nebula, a million-year-old supernova remnant. The filaments illustrate the interaction of the nebular material with the gas and dust in our Milky Way galaxy. An image of the full Moon is added to show scale.

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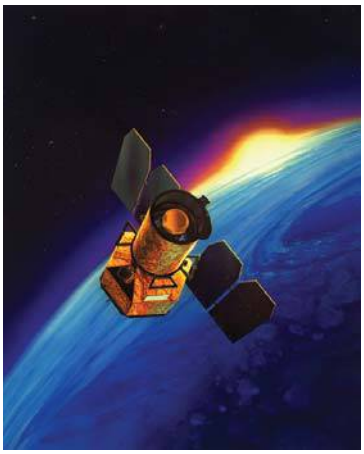
Census in Ultraviolet



The Galaxy Evolution Explorer, or GALEX, 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.

A Telescope for the Big Picture

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 very distant 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.

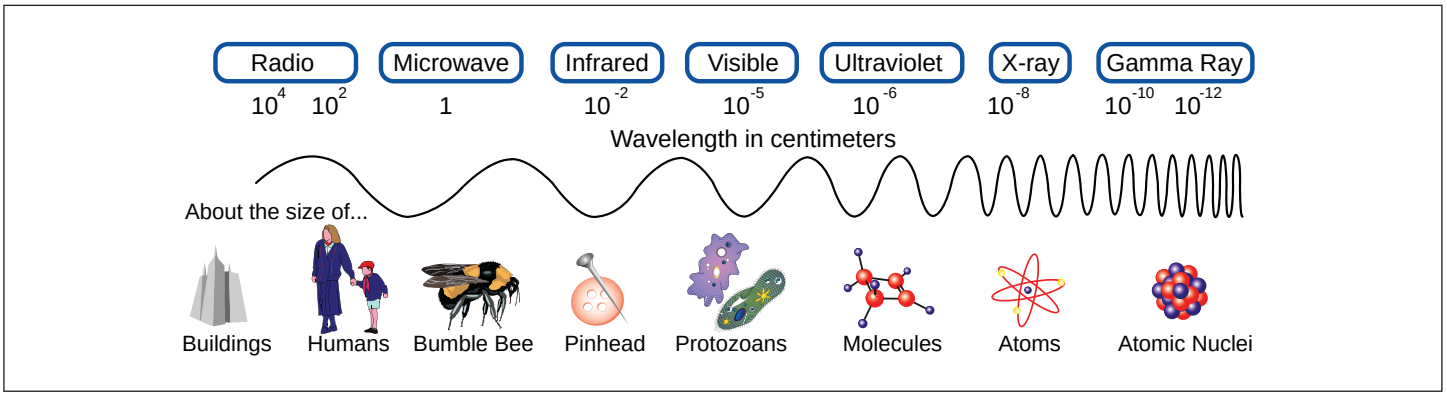
GALEX is especially good at finding star nurseries—places where new stars are forming inside galaxies. GALEX can see these hot, baby stars well, because they shine brightly in ultraviolet light. And because GALEX does not see visible light, it is not confused by the larger number of older stars. By studying 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.

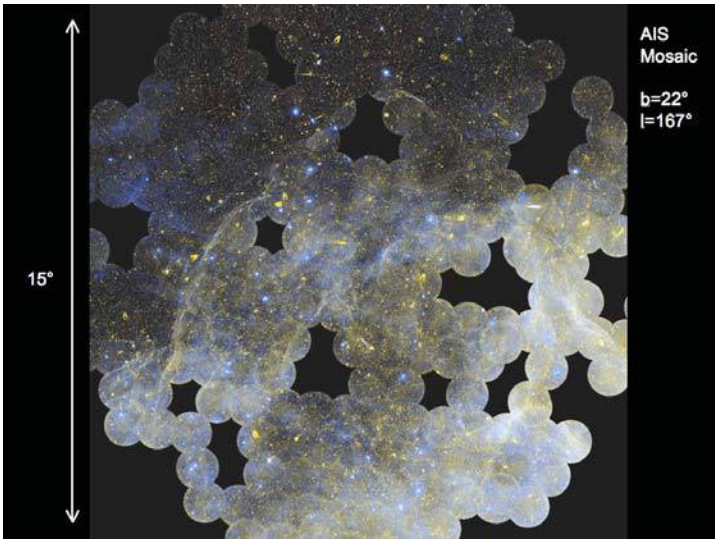
GALEX can detect stars and galaxies that are about 40 million times fainter than ones we can see with our unaided eyes from even the darkest skies here on Earth. GALEX is the first mission to map most of the sky in UV light at a great enough distance to survey galaxies outside our own galaxy. Its all-sky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

The GALEX mission is managed by the Jet Propulsion Laboratory and the California Institute of Technology.

The Ultraviolet All-sky Imaging Survey

The primary mirror on GALEX is only 20 inches in diameter, not much bigger than a backyard telescope, but GALEX has a wide field of view. Each image "tile"—or GALEX single field-of-view image—covers a circular patch of the sky with a diameter of 1.2°. Such a wide-angle view is necessary for a telescope whose job is to survey the entire sky. However, most of the images so far published have been a single tile or less. The largest previously published image was seven tiles, covering about 2.5° by 3.5°.





This section of the GALEX mosaic of the Gum Nebula represents an angular view of 15° of sky.

The image on this poster is the first image released to the public of the GALEX all-sky survey, this one made up of nearly 400 tiles. This image covers about 20° x 20° of the sky. It includes 1% of the all-sky survey images. For reference, the Moon subtends about ½°. So this area of the sky is 1600 times larger than the area of the sky covered by the Moon.

This mosaic image is a good example of how the view changes as you move away from the plane of the Milky Way. The bottom right of the image looks toward the plane of the galaxy, while the upper part looks above the plane of the galaxy. It is in these parts of the sky that other galaxies become visible.

The wispy white filaments seen in this image are parts of the Gum Nebula, the supernova remnant that is closer to us than any other. It ranges from 450 light-years away at its "front" edge to 1500 light-years away at its "back" edge, and spans 40 degrees of the sky, near the southern constellations of Puppis and Vela. It was discovered by and named for Australian astronomer Colin Stanley Gum (1924-1960). The nebula is thought to be about one million years old.

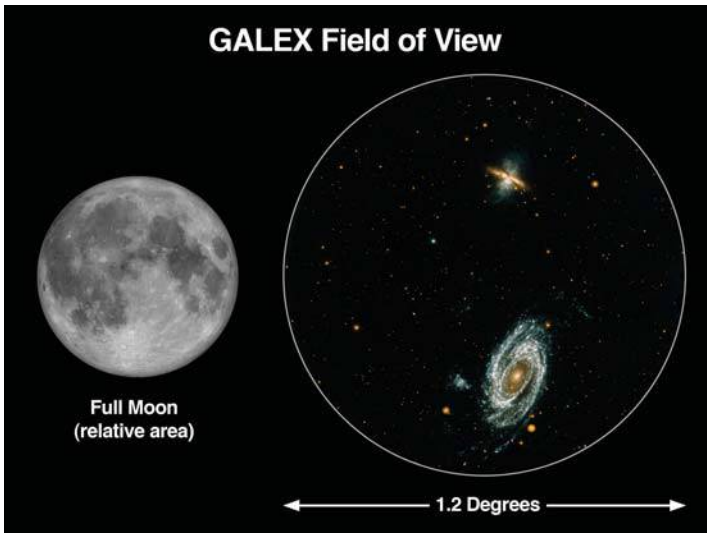
Because this nebula is so close, we can see the structure well in this GALEX image. We can see the filaments that show how the material was pushed by the supernova blast. To the right and left of the gap just below the center of the image are some white lines that could possibly be the edges of bubbles created by more recent supernova explosions that pushed the older and larger supernova remnants around.

The white line to the right of center is a galaxy. The Hydra Cluster of galaxies is visible to the left of center.

GALEX image of Jupiter's Ghost, the planetary nebula visible as a small, blue smudge at the top of the mosiac image on the front of the poster.

The planetary nebula called Jupiter's Ghost is the blue smudge at the very top of the image on the poster front. The Moon is superimposed on the image at lower left for scale.

The first all-sky survey, from which this image is taken, covered 65% of the sky, using short exposures. This survey represents only 20% of the total exposure time for the mission. Other parts of the mission have the telescope performing long-exposures, looking deep into space and far back in time. As a matter of fact, the entire exposure time of all the tiles in this poster image is less than for any one of GALEX's deep exposure image tiles. Now that the primary survey is complete, another all-sky survey is underway, using longer exposures.



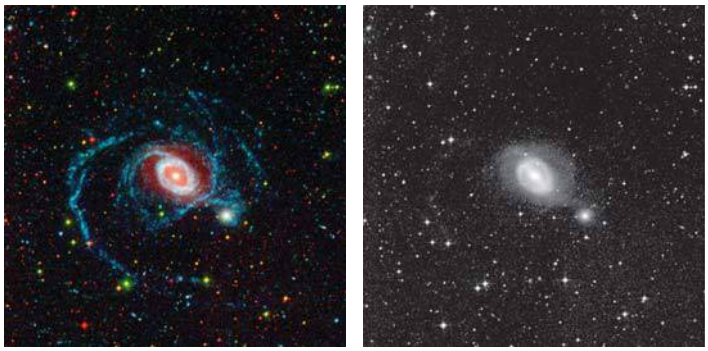
GALEX has a field of view of 1.2° of the sky, which is about four times as big as the Moon appears.

News from the Universe

In the years the Galaxy Evolution Explorer (GALEX) has been on the job, it has offered up many surprises. Scientists have seen familiar objects in brand new ways, understanding them as never before. Scientists have seen phenomena they knew existed, but had never before actually witnessed, like the earliest phases of a supernova explosion and a black hole gobbling up a star.

Here are a few examples of some of the more surprising findings from images made by the Galaxy Evolution Explorer.

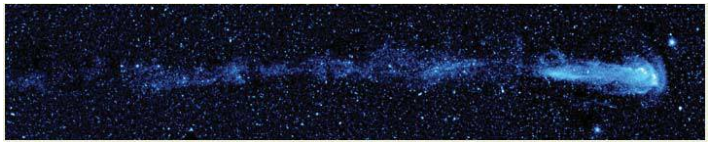
Invisible Spiral Arms



In the GALEX image of galaxy NGC 1512 on the left, red represents its visible light appearance, the glow coming from older stars, while the bluish-white ring and the long, blue spiral arms show the galaxy as the Galaxy Evolution Explorer sees it in ultraviolet, tracing primarily younger stars. The image on the right is the same galaxy in visible light only. (Credit: NASA/JPL-Caltech/DSS/GALEX).

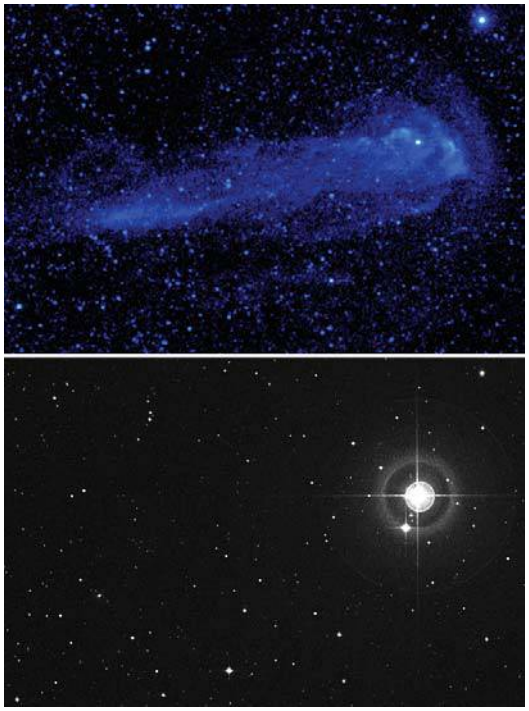
NASA's Galaxy Evolution Explorer has revealed that roughly 20 percent of nearby galaxies have spiral arms that extend far beyond the galaxies' apparent edges. Some of these galaxies are more than three times larger than they appear in images taken by ordinary visible-light telescopes. These "invisible arms" are made of mostly young stars shining brightly at UV wavelengths. The discovery of these extended arms provides fresh clues for scientists about how some galaxies form and evolve.

UV surprise



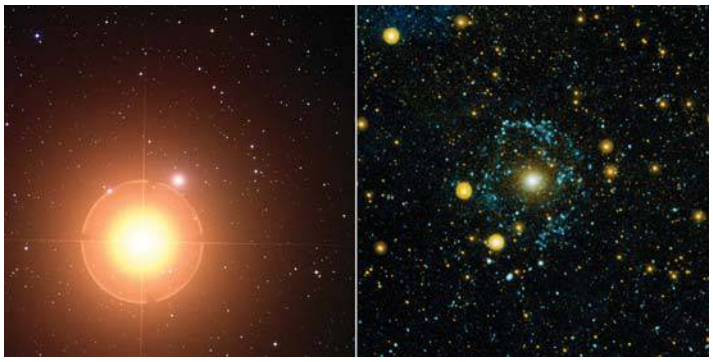
Astronomers were surprised to discover in images from the Galaxy Evolution Explorer a 13-light-year long tail on Mira, a star that has been extensively studied for 400 years.

Mira is a pulsating star monitored carefully by astronomers for more than 400 years. Yet until GALEX examined Mira, no one would have guessed that Mira possesses a comet-like tail 13 light-years long. After accounting for the published motions of Mira and the motion of our own Sun, Mira was calculated to be moving at well over 800 miles per second through our galaxy. This fast motion, combined with the fact that Mira is literally shedding its atmosphere, as many old stars do, produces the bow-shock and tail that had previously gone undetected.



Mira's tail is visible only in ultraviolet light (top), and does not show up in visible light (bottom).

Galactic Surprise



The "Ghost of Mirach" galaxy, NGC 404, appears as a whitish spot in the center of both these images—in visible light on the left, ultraviolet as seen by GALEX on the right. In ultraviolet light, this galaxy comes to "life," revealing a never-before-seen ring containing new stars. (Visible light image credit National Optical Astronomy Observatory.)

Mirach is a red giant star that looms large in visible light. Because NGC 404 is lost in the glare of this star, it was nicknamed the Ghost of Mirach. As revealed by GALEX in ultraviolet light, the ring of young and new stars in the NGC 404 image was a big surprise considering that the galaxy was thought to be dead.

Some of the discoveries of GALEX will change our understanding of how galaxies develop and when, where, and why stars form in galaxies. Scientists have been surprised to find many newborn stars in the outer parts of old, mature galaxies. Scientists had assumed that as a galaxy ages, the clouds of gas needed to form new stars in these outer reaches either got used up or blown away. Finding so many new stars in these regions of old galaxies shows that, apparently, they were wrong.

A New View of Andromeda

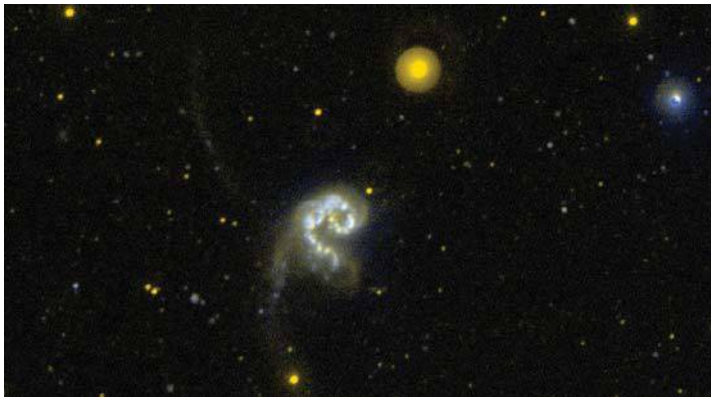
The GALEX telescope took this UV image of the Andromeda galaxy (M31), revealing a surprising shape not apparent in visible light.

At 2 million light-years away, Andromeda is the nearest big galaxy to the Milky Way. Astronomers know it better than any other. Or so they thought. GALEX has captured a new and different view of Andromeda. According to GALEX, Andromeda is not a spiral but a ring.

GALEX's sensitivity to UV is why Andromeda looks different. To GALEX, Andromeda is defined by its youngest, hottest stars. They are concentrated in the galaxy's core and scattered around a vast ring some 150,000 light years in diameter. Looking at familiar galaxies with a new wavelength, scientists are gaining a better understanding of the processes affecting their evolution.

A Great Big Wreck

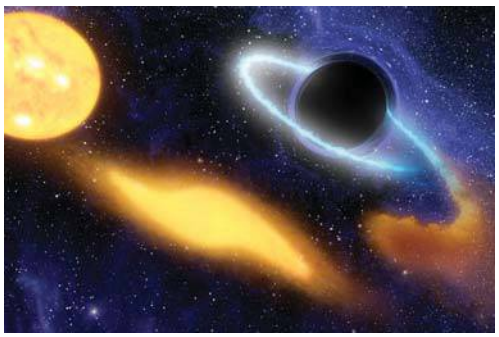
Galaxy collisions aren't as bad as you might think. A typical spiral galaxy contains a hundred billion stars, yet when two such galaxies run into each other, there is so much space between the stars that they seldom collide. The two colliding galaxies of the Antennae system are about the same size and type as Andromeda and our own Milky Way, also on a collision course.



This GALEX UV image of the colliding Antennae Galaxies shows areas of active star formation, which is not in the tidal tails as one might expect.

The true violence of colliding galaxies is star formation. While individual stars rarely collide, vast interstellar clouds of gas do smash together. These clouds collapse. Gravity pulls the infalling gas into denser knots until, finally, new stars are born. Surprisingly, star formation rates are low in the tidal tails, several times lower than what we experience here in the Milky Way. The merging cores of the Antennae, on the other hand, are sizzling with new stars, ready to explode.

Caught in the Act



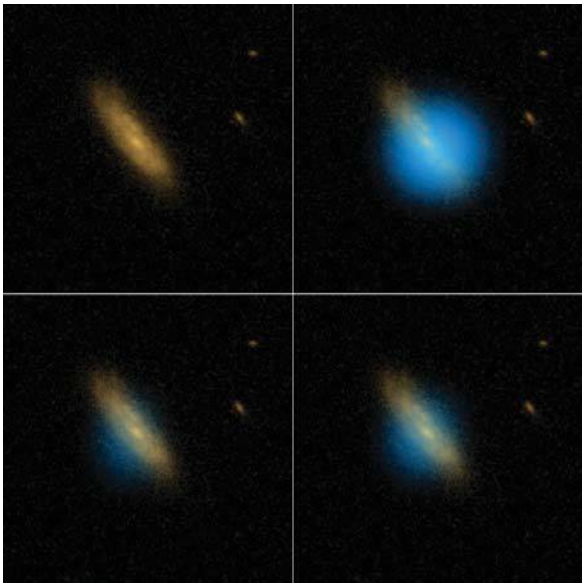
In this artist's concept, a giant black hole is caught devouring a star that ventured too close.

Every day in the Universe, millions of stars fall into millions of black holes. Yet astronomers rarely catch a black hole in the act. A great place to look is deep in the cores of galaxies. Most galaxies have massive black holes sitting in their pinwheel centers, with dense swarms of stars all around.

Using GALEX, a group of astronomers caught one. In a distant, unnamed elliptical galaxy, a star fell into a central black hole and "burped" a blast of ultraviolet radiation.

Although other telescopes have seen black holes devouring stars before, this was the first time scientists have been able to watch the process from beginning to end. Studying the process in its entirety helps them understand how black holes feed and grow in their host galaxies.

Death of a Supergiant

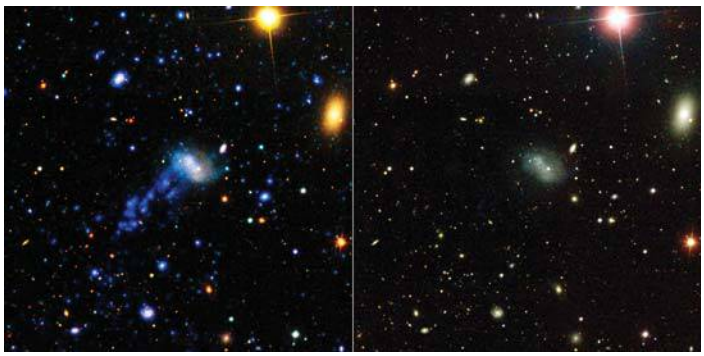


This sequence of images shows a supernova start to finish. The top left image shows the galaxy before the supernova. At top right, the bright UV flash called the shock breakout indicates a red supergiant has collapsed. At bottom left, moments later, the flash is mostly gone. As the debris expands, it heats up again and becomes brighter (bottom right). The supernova became 10 times the size of the original over the following few days, thus becoming visible to supernova hunters.

As visible in this series of images, long before the supernova explosion's visible light was detected by telescopes on Earth, GALEX captured the earlier pulse of UV light — scientists' first glimpse of a star entering its death throes. This UV light has traveled through the star at the moment of its death but before it was blown apart. So this light encodes some information about the state of the star the moment it died. The information encoded in supernova UV "pre-flashes" could offer scientists an unprecedented window into the innards of stars on the verge of exploding. In this case, scientists calculated that just before its death, the star was 500 to 1000 times larger in diameter than our sun, confirming that the star was in fact a red supergiant.

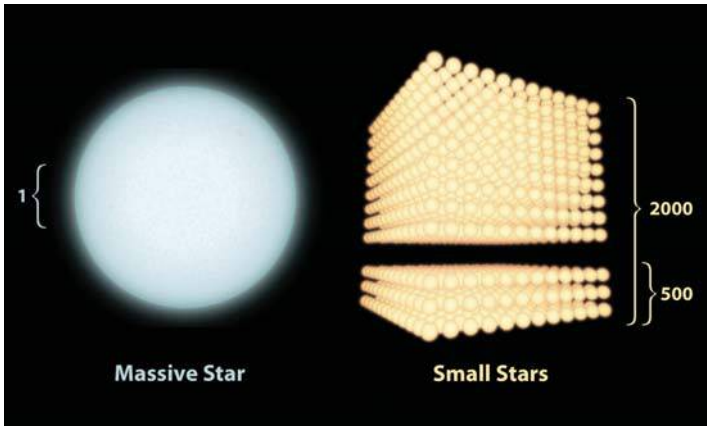
The Turbulent Tale of a Tiny Galaxy

Astronomers have found star formation occurring in the turbulent wake of a tiny galaxy that is plunging into a cluster of 1,500 galaxies in the constellation Virgo. It's a fascinating case of turbulence, rather than gravity, trapping the gas, allowing it to become dense enough to form stars. Ultraviolet images from GALEX revealed a long tail filled with clusters of massive, young stars. The lack of older stars was one tip-off that IC 3418's tail isn't tidal. IC 3418 experiences "a stiff wind" that sweeps interstellar gas right out of the little galaxy.



In the ultraviolet image on the left, from GALEX, galaxy IC 3418 leaves a turbulent star forming region in its wake. In the visible light image on the right (from the Sloan Digital Sky Survey), the wake with its new stars is not apparent.

A Stellar Recount



Astronomers have recently found that some galaxies have as many as 2000 small stars for every 1 massive star. They used to think all galaxies had only about 500 small stars for every 1 massive star.

From their years of research, astronomers assumed that for every big star, there should be 500 small stars. They thought this relationship was true in all the galaxies throughout the universe. GALEX has turned this idea upside-down. Data from GALEX and from the Cerro Tololo Inter-American Observatory in Chile have shown that in some galaxies there could be as many as 2,000 smaller stars for every big star! So how many stars are there really? Scientists think the universe contains about one billion trillion, or 1,000,000,000,000,000,000,000 stars! But that was before this new discovery. How many more zeroes will they need to add now?

I Am Light!

Although there's much to me you never will see
I surround you and pound you. You never can flee.
Without me you'd starve, be blinded and cold.
The oceans would freeze and darkness take hold.

I am light!

And very little of me
Is all that your poor eyes ever will see.
You will never make out the radio waves
From broadcasting towers and cell phones . . . and space.

The infrared rays from the warmth of your knuckles
Look as dim to you as those from your buckles.
You see *no* ultraviolet, from stars or from Sun.
And x-rays, to you, there might well be none!

I am light!

I am waves. Some are short. Some are long.
The long ones are weak and the short ones are strong.
The long ones, the radio waves, are quite tired.
The short ones, the gamma and x-rays, are wired.

No matter my mood, when I'm traveling through space,
I always proceed at the same speedy pace.
For I set the limit, the maximum speed,
That everything moving in space has to heed.

I am light!

I am waves. But I'm particles too!
I am packets of energy called photons. And you
Can probably guess that they hold different sums
Of pep and pizzazz. Like waves, some are glum,

Like photons of radio energy—they're weary.
But infrared photons are often quite cheery.
Ultraviolet bundles will scorch even you,
While photons of x-rays will zip right on through!

I am light.

But what's that? Should I make up my mind?
Am I wave? Am I particle? Am I both all combined?
What works is what matters. You've figured that out.
You know what I do. How I act, you've no doubt.

I am light!

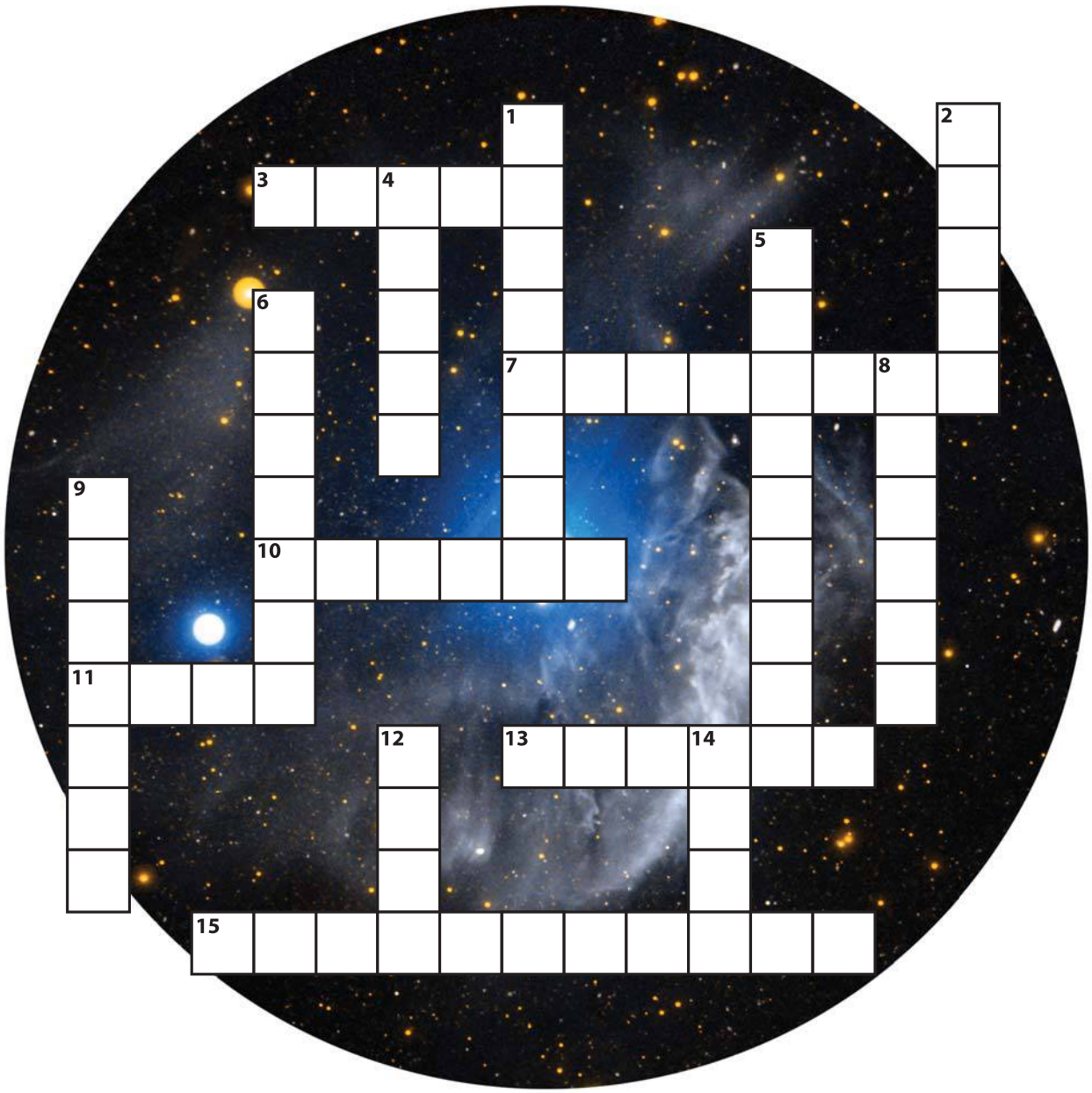
No, you do not see me well.
It's within just a *visible light* world you dwell.
But through some new windows you now see some clues
That would otherwise ever be hidden from view—

Of all that is beauty and mystery sublime
From far, far away and far back in time.
For now you have sensors to see all my forms
From cool cosmic clouds to bright solar storms.

You've learned how to see me, in every disguise.
All my beauty, my mystery, you see with new eyes.
Your old eyes were small, they had boundaries and limits.
Now curiosity reigns, and nothing can dim it!

by Diane K. Fisher

I Am Light Crossword



Across

3 The shortest waves of light are x-rays and _____ rays.
7 Your knuckles and the rest of your body emit _____ light.
10 The Galaxy Evolution Explorer has discovered that many spiral galaxies are much _____ than they appear in visible light.
11 The Galaxy Evolution Explorer sees back in _____.
13 Nothing in space can travel _____ than light.
15 The Galaxy Evolution Explorer sees _____ light.

Down

1 Light acts as both wave and _____.
2 Light travels at the _____ of light.
4 Cell phones communicate using _____ waves.
5 The Galaxy Evolution Explorer watched a star being consumed by a _____ _____.
6 Your eyes see only the _____ part of light.
8 Long light waves have less _____ than short light waves.
9 Packets of light are called _____.
12 The Galaxy Evolution Explorer finds regions of _____ formation.
14 The Galaxy Evolution Explorer showed that the star Mira has a _____.

Draw a line from the question on the left to the answer on the right.

Remember, "light" includes all its wavelengths, not just the ones you can see.

1. What wavelength of light is used by cell phones?
2. What is the kind of light our eyes can see?
3. What kind of light is given off by our bodies?
4. What kind of light does the Galaxy Evolution Explorer see?
5. What kind of light do doctors use to check for broken bones?
6. What wavelength of light is often used to make popcorn quickly?
7. What are the shortest wavelengths of light?
8. What are the most energetic wavelengths of light?
9. What are the laziest wavelengths of light?
10. What wavelengths travel at the speed of light?

Radio

Microwave

Infrared

Visible

Ultraviolet

X-ray

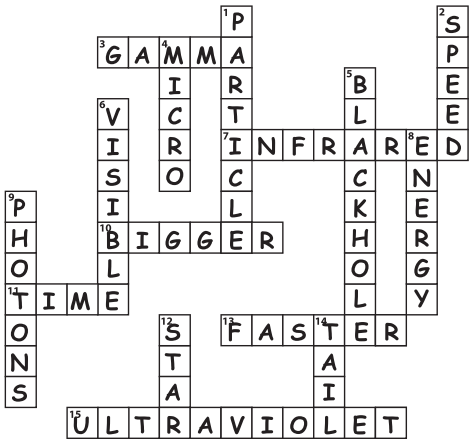
Gamma Ray

Galaxy Evolution Explorer Word Find

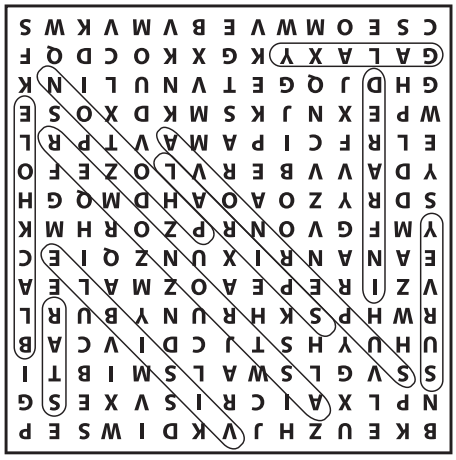
STAR
SURVEY
SPIRAL
GALAXY
PHOTON
VISIBLE
INFRARED
BLACKHOLE
SUPERNOVA
ASTRONOMER

B	K	E	U	Z	H	J	V	K	D	I	W	S	E	P
N	P	L	X	A	I	C	R	I	S	V	X	E	S	G
S	S	V	G	L	S	W	A	L	S	M	I	B	T	I
U	H	U	Y	H	S	T	J	C	D	I	V	C	A	B
R	W	H	P	S	K	H	R	U	N	Y	B	U	R	L
V	Z	I	R	E	P	E	A	O	Z	M	A	L	E	A
E	A	N	A	N	R	I	X	U	N	Z	Q	I	E	C
Y	M	F	G	V	O	N	R	P	Z	O	R	H	M	K
S	D	R	Y	Z	O	A	O	A	H	D	M	Q	G	H
Y	D	A	V	V	B	E	R	V	L	O	Z	E	F	O
E	L	R	F	C	I	P	A	M	A	V	T	P	R	L
W	P	E	X	N	J	K	S	M	K	D	X	O	S	E
G	H	D	J	Q	G	E	T	V	N	U	L	I	N	K
G	A	L	A	X	Y	K	G	X	K	O	C	D	Q	F
C	S	E	O	M	W	V	E	B	V	M	V	K	W	S

Crossword Solution:



Wordfind Solution:



Matching Game Answers:

1. Microwave
2. Visible
3. Infrared
4. Ultraviolet
5. X-ray
6. Microwave
7. Gamma Ray
8. Gamma Ray
9. Radio waves
10. All wavelengths

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