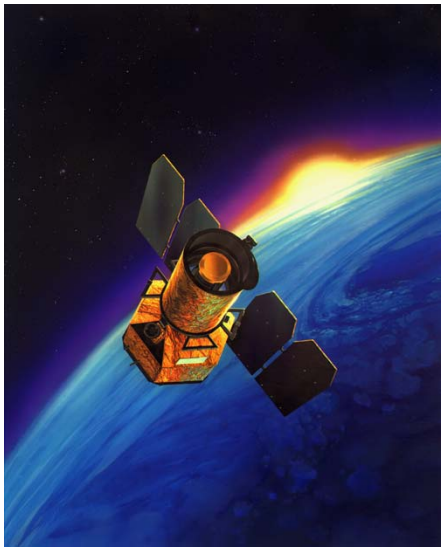
TELESCOPE AS TIME MACHINE

Read this article about NASA's latest high-tech space telescope.
Then, have fun doing one or both of the word puzzles that use the important words in the article.

A TELESCOPE FOR (ALMOST) ALL TIME

GALEX is a new NASA space telescope that can see back in time 80% of the way to the Big Bang. The Big Bang is the colossal explosion that gave the universe its start around 14 billion years ago (give or take a few billion years). The Galaxy Evolution Explorer, or GALEX for short, is an Earth-orbiting telescope that is looking back 11 billion years to help scientists understand how galaxies like our Milky Way came to be and how they have changed over cosmic time. GALEX was launched April 28, 2003. During its 29-month mission, GALEX will survey nearly the entire sky and gather galactic light that has been journeying toward us for nearly the entire history of the universe.

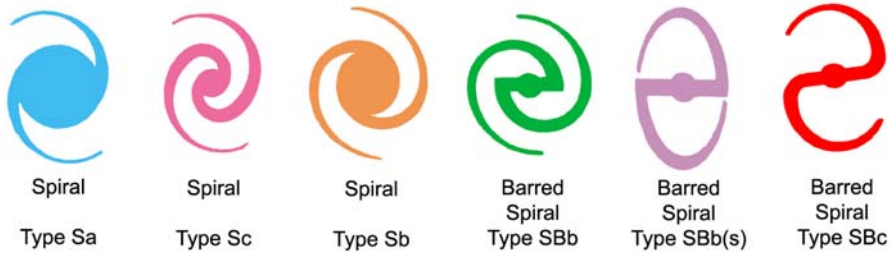


The Galaxy Evolution Explorer (GALEX) orbiting space telescope will look back in time 11 billion years.

GALAXIES 101

Galaxies are clusters of gas, dust, many different types of stars in all different phases of their life cycles, and various strange objects such as black holes. Our own Milky Way galaxy contains over 200 billion stars, and the entire universe probably contains over 100 billion galaxies. Galaxies come in a huge variety of shapes and sizes. Dwarf galaxies may contain as few as 10 million stars, while massive galaxies may have a trillion (that's a thousand billion) stars. Shapes of galaxies may be spiral, elliptical, or irregular.

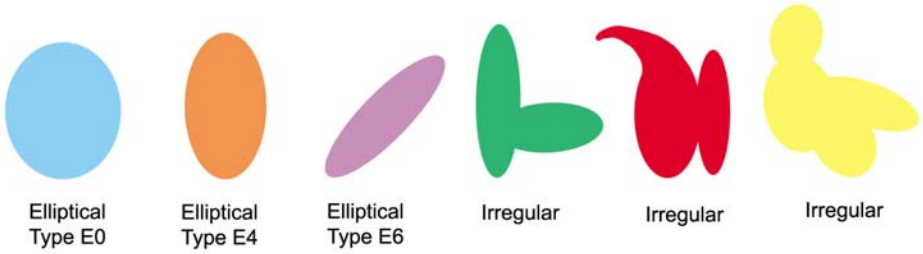
Spiral galaxies have a large concentration of stars at the center, called the "bulge," and "arms" that extend outward. Viewed face on, they often look like giant pinwheels. The spiral arms are rich in gas and dust needed to form new stars. Spiral galaxies that are sending out large amounts of blue and ultraviolet light (more about this kind of light later) tell scientists that a lot of new stars are forming. Our galaxy, the Milky Way, is an average-sized, spiral-shaped galaxy and is forming new stars at a rate of one star like our Sun every year.



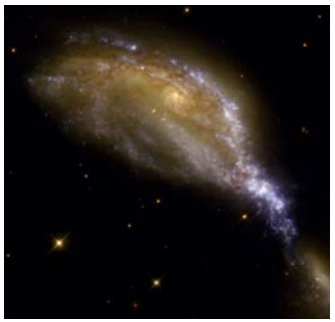
Some different types of spiral galaxies.

Elliptical galaxies range from spherical to cigar-shaped. These galaxies don't contain much gas, so are rarely seen to be forming new stars. Their red color tells scientists that they contain mostly old stars. Irregular galaxies don't have much structure and are generally smaller than spiral or elliptical galaxies.

This spiral galaxy, photographed in ultraviolet light by GALEX, is called M81. It is about the same size and brightness as our own Milky Way galaxy. It is about 10 million light-years away.



Some different types of elliptical and irregular galaxies. Irregular galaxies are often formed when two galaxies merge.



The shape of this formerly spiral galaxy, called NGC 6745, has been distorted as it collides with another galaxy.

Stretching Imagination's Limits

So how is looking at far away galaxies like looking back in time? At 300,000 kilometers per second (186,000 miles per second), nothing travels faster than light. Even at this speed, though, it still takes time for light to get from one place to another. If you are looking at your girlfriend just across the classroom, you are seeing her as she was a tiny fraction of a second ago, rather than as she looks right now. It takes about 8 minutes for light from the Sun to reach Earth. The Voyager 1 spacecraft, which NASA launched back in 1977, is now the farthest human-made object from Earth. Even though this spacecraft is still inside our solar system, its signal, traveling at light speed, takes 12 hours to reach Earth!

So, if Voyager's signal takes that long to reach us, you can begin to imagine how long it takes light to reach us from far distant galaxies. What we are seeing of those galaxies is not how they look today, but how they looked when that now-very-old light left them, thousands or millions or billions of years ago.

Does the Light Show Its Age?

How will scientists know how old the light is that GALEX is receiving?

Scientists know that the universe is expanding. Like a chocolate chip cake in the oven, space is the "cake batter" that keeps getting bigger and bigger, while the stars and galaxies are the "chocolate chips" that keep getting farther and farther apart.

Like energy pulsing through the ocean, light energy travels in waves. Scientists are very familiar with the "fingerprints" of light waves from nearby stars (such as the Sun). They also know that light behaves the same way everywhere in the universe. As light travels toward us through this expanding space from distant stars, the light waves get stretched out, and the "fingerprints" shift. The more time light waves spend traveling through space, the more stretched out they get, and the more shifted the fingerprints become. Because red light waves are longer than the light waves of other visible colors, scientists say that light coming from distant stars and galaxies is "red-shifted." The more red-shifted the light waves, the farther (and longer) they have traveled. GALEX is able to detect light that is extremely old, extremely red-shifted.

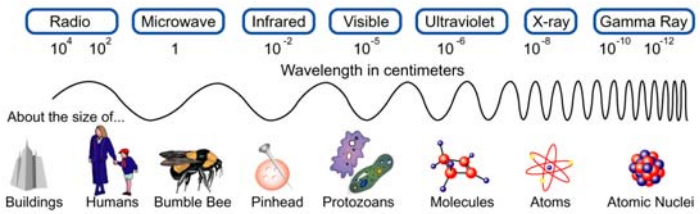
Like the Hubble Space Telescope that has given us so many awesome pictures of the universe, GALEX operates above Earth's atmosphere, so gathers light that cannot penetrate to telescopes on Earth's surface. While the Hubble is used by many astronomers around the world to study very particular, tiny regions of the sky, GALEX has its very specific mission to look at nearly the whole sky, a substantial piece at a time.

With GALEX's "all-sky survey,"scientists will be able to see how galaxies in the early universe (far, far away) are different from galaxies of more recent times (relatively nearby). Because distant galaxies appear to us as they were millions or even billions of years ago, we can study how galaxies evolve. We see what they looked like when the universe was much younger, as galaxies were first forming. As we look at closer and closer galaxies we see how they change as they age, just as looking at babies, children, teenagers, and then adults can show how we humans change as we age.

More Violet Than Violet?

GALEX makes its measurement of the universe in ultraviolet (UV) light. UV light waves are not visible to humans. The shortest light waves that humans can see are blue or violet. Ultraviolet waves, as their name implies, are shorter than violet waves. These shorter waves carry more energy than do visible light waves (or the light waves that are longer than those we can see, such as

infrared and radio waves). Most of the UV light from the Sun is absorbed or scattered by Earth's atmosphere, but what does get through to Earth's surface is what causes fair-skinned people to get sunburned.



GALEX detects ultraviolet objects in the sky that are more than a million times fainter than objects we can see in visible light from even the darkest locations on the ground.

What is so special about UV in studying stars and galaxies? The youngest stars are the brightest and hottest stars, and they produce a lot of UV light. By precisely measuring the brightness of the UV light coming from a galaxy, scientists can tell how fast that galaxy is churning out new stars. GALEX's UV surveys will help scientists measure not only star formation rates, but many other characteristics of galaxies, such as luminosity (brightness), shape, gas content, how galaxies cluster together, and how such properties change over cosmic time.

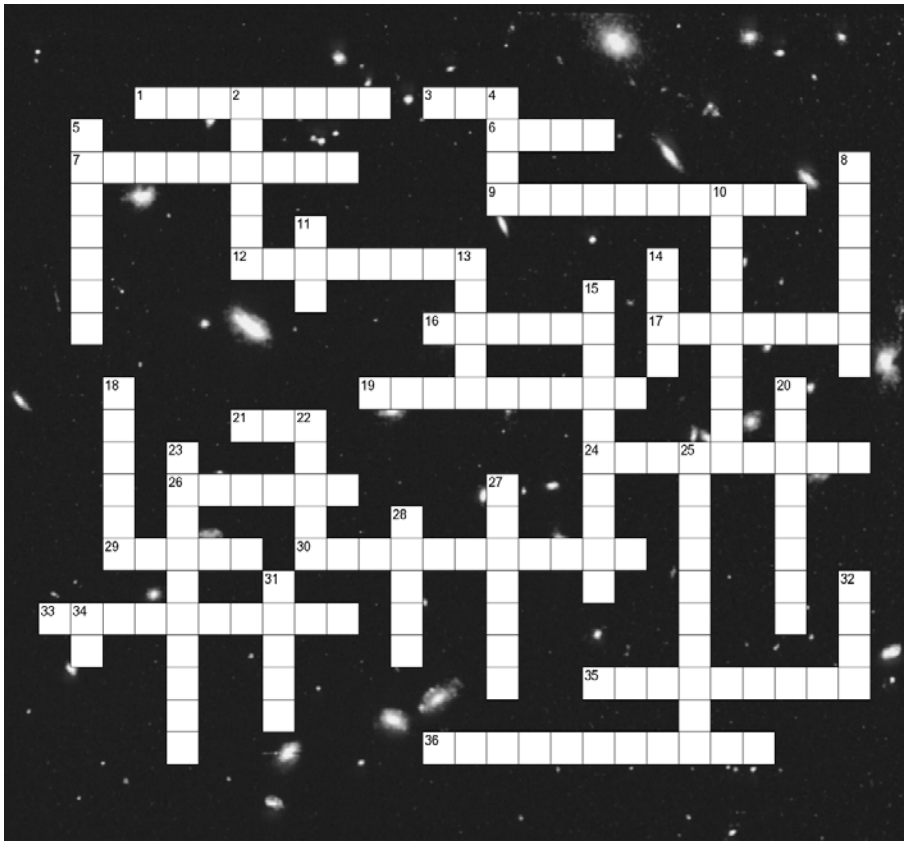
We may not actually be able to place ourselves into the past, but remember: Space is time and time is space. So to look far back in time, all you need is a good telescope!

Visit www.galex.caltech.edu to learn more about GALEX and see some images it has captured.

Galactic Puzzles

Now, test your galactic IQ by solving one or both of these word puzzles. But don't cheat! If you do both puzzles, do the crossword first.

Exploring the Galaxies



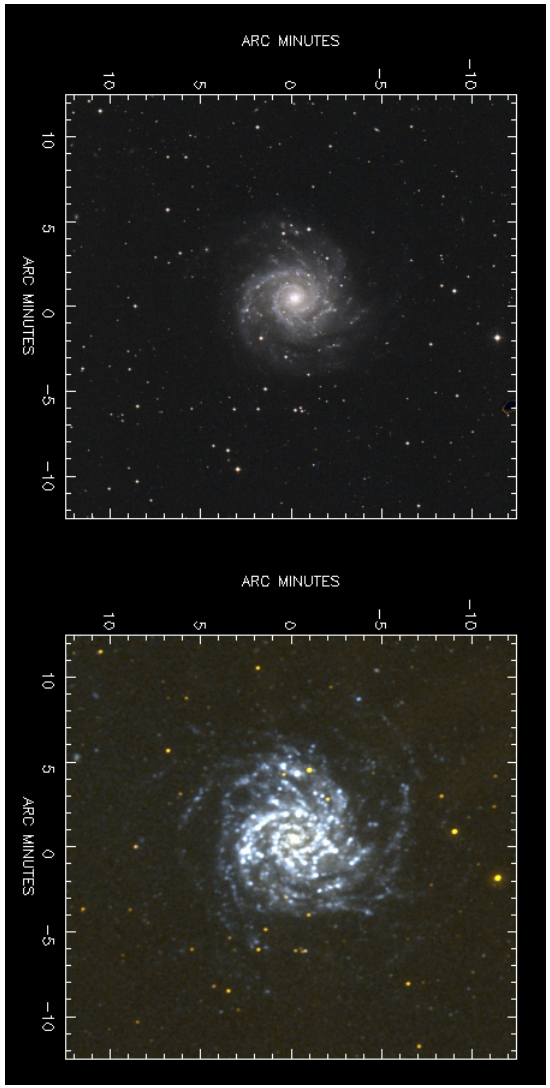
Across

1 All there is
3 Nearby star
6 Common to human, octopus, and some galaxies
7 Viewer into the past
9 The blanket above us
12 Our galactic home
16 Another eye in the sky
17 Light gets under your skin
19 The youngest and the _____
21 Like air out in space
24 Amoeba-like galaxy
26 Pinwheel galaxy
29 From where we stand
30 Our closest celestial family
33 How much it shines
35 Much stranger than that of Alice's rabbit
36 More than blue

Down

2 True nothingness
4 Space agency of the U.S.
5 Make longer
8 What started the whole thing
10 Opposite of contracting
11 A red star is this
13 A blue star is this
14 Raw material for new stars
15 Light made longer
18 Change over time
20 Age of the universe, times about 12 years
22 Great balls of fire
23 Star student
25 Egg-shaped galaxy
27 The farthest artifact
28 Surveying the galaxies
31 Speediest traveler
32 Pulse of energy
34 Lots made where stars are born, abbreviation

Puzzle solution on Page 6.



These are both images of galaxy NGC628, which is about 17 million light years away. The top image was made with visible light (from the Digitized Sky Survey). The bottom image was made with ultraviolet light from GALEX data. It shows that the spiral arms of the galaxy extend much farther than we can see in visible light.

The words in the list on the left are hidden in the jumble of letters. Words may be spelled out forwards, backwards, up, down, or diagonal. When you find a word, draw a box around it and cross it off the list.

Puzzle solution on Page 6.

GALEX Words

ASTRONOMER
ATMOSPHERE
BIGBANG
BILLIONS
BLACKHOLE
BRIGHTEST
DUST
EARTH
ELLIPTICAL
EVOLVE
EXPANDING
GALAXIES
GALEX
GAS
HUBBLE
IRREGULAR
LIGHT
LUMINOSITY
MILKYWAY
NASA
REDSHIFTED
SOLARSYSTEM
SPIRAL
STARS
STRETCH
SUN
TELESCOPE
ULTRAVIOLET
UNIVERSE
VACUUM
VOYAGER
WAVE
YOUNG

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

Why is the Night Sky Black?

If the universe goes on forever and has an infinite number of stars, no matter where you look in the sky, you should see a star. So the night sky should be as bright as day!

Why is the sky black at night, even though we can see thousands of other suns? Does this sound like a dumb question? It's not! It took the smartest humans thousands of years of observation, thought, discussion, conjecture, and analysis to finally come up with an answer that makes scientific sense.

You might be thinking, well, of course the sky is dark at night because that is when our side of Earth faces away from the Sun as our planet rotates on its axis every 24 hours. But what about all those other far away suns that appear as stars in the night sky? Our own Milky Way galaxy contains over 200 billion stars, and the entire universe probably contains over 100 billion galaxies. You might suppose that that many stars would light up the night like daytime.

Until the 20th century, astronomers didn't think it was even possible to count all the stars in the universe. They thought the universe went on forever. In other words, they thought the universe was infinite.

Uh-oh. No Paradoxes Allowed

Besides being very hard to imagine, the trouble with an infinite universe is that no matter where you look in the night sky, you should see a star. Stars should overlap each other in the sky like tree trunks in the middle of a very thick forest. But, if this were the case, the sky would be blazing with light. This problem greatly troubled astronomers and became known as "Olbers' Paradox" after Heinrich Wilhelm Matthuas Olbers (1758 - 1840), the German physician and amateur astronomer who wrote about it in 1823. A paradox is a statement that seems to disagree with itself.

To try to explain the paradox, some 19th century scientists thought that dust clouds between the stars must be absorbing a lot of the starlight so it wouldn't shine through to us. But later scientists realized that the dust itself would absorb so much energy from the starlight that it would glow as hot and bright as the stars themselves!

Ah. Bad Assumptions

Astronomers now realize that the universe is neither infinitely large nor infinitely old.

A finite universe—that is, a universe of limited size—even one with trillions of stars, just wouldn't have enough stars to light up all of space.

Although the idea of a finite universe explains why Earth's sky is dark at night, other causes work to make it even darker.

Not only is the universe finite in size, it is also finite in age. That is, it had a beginning, just as you and I did. The universe was born about 14 billion years ago in a fantastic explosion called the Big Bang. It began at a single point and has been expanding ever since.

W-a-a-a-a-a-ve Bye-bye

Because the universe is still expanding, the distant stars and galaxies are getting farther away all the time. Although nothing travels faster than light, it still

takes time for light to cross any distance. So, when astronomers look at a galaxy a million light years away, they are seeing the galaxy as it looked a million years ago. The light that leaves that galaxy today will have much farther to travel to our eyes than the light that left it a million years ago or even one year ago, because the distance between that galaxy and us constantly increases. That means the amount of light energy reaching us from distant stars dwindles all the time. And the farther away the star, the less bright it will look to us.

In addition, because the stars are constantly moving away from us, the wavelengths of their light get stretched out. Longer wavelengths of light have less energy than shorter wavelengths. Astronomers say the light is "red shifted" because red is the longest wavelength of visible light.

Red-shifting is similar to the Doppler effect you've probably noticed with sound. As you are riding down a road in a car, a truck approaches from the other direction, blowing its horn. As the truck zooms past, the horn suddenly sounds lower pitched. When the truck was moving toward you, the sound waves were piling up as the distance between "transmitter" (the horn) and "receiver" (your ears) decreased, so the wavelength was shorter and the sound seemed higher pitched. As the truck moves away, the distance is constantly increasing, so the sound waves gets stretched out and the sound seems lower pitched.

In the case of starlight, as the stars move away, the wavelength increases and therefore the energy reaching Earth is reduced. These two effects reduce the contributions of distant stars to the brightness of the sky below what would be observed if Olbers' assumption that the universe is unchanging were true. Although the expansion of the universe by itself turns out to be insufficient to produce a dark sky, it does contribute to the explanation of how dark the sky is. The rest can be explained by a finite (limited) universe.

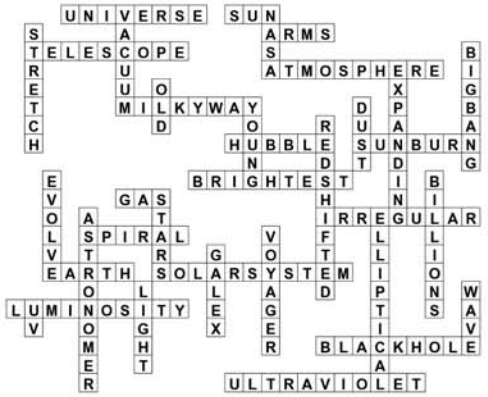
The universe, both finite in size and finite in age, is full of wonderful sights.

The Blackest Night: An activity for you

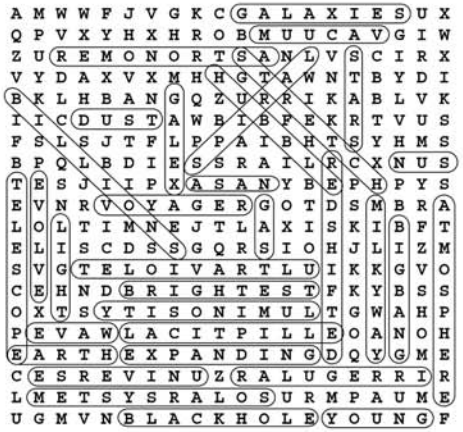
Write a poem or essay (or song!) about the blackest, clearest (not cloudy) night you ever experienced. How did the sky look? Where were you? What time of year was it? What were you doing? Who were you with? How did it smell? What did you hear? Was it cold or hot or something in between? What did you feel?

Does looking at a black sky seem any different now that you know why it appears as it does?

Answers to GALEX Crossword



Solution to GALEX Wordfind



Please take a moment to evaluate this product at **http://ehb2.gsfc.nasa.gov/edcats/educational_wallsheet**
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.