National Aeronautics and Space Administration

Teacher's Science Background

GALAXY Q&As

1. What is a galaxy?

A galaxy is an enormous collection of a few million to several trillion stars, gas, and dust held together by gravity. Galaxies can be several thousand to hundreds of thousands of light-years across.

2. What is the name of our galaxy?

The name of our galaxy is the Milky Way. Our Sun and all of the stars that you see at night belong to the Milky Way. When you go outside in the country on a dark night and look up, you will see a milky, misty-looking band stretching across the sky. When you look at this band, you are looking into the densest parts of the Milky Way — the "disk" and the "bulge." The Milky Way is a spiral galaxy. (See Q7 for more on spiral galaxies.)

3. Where is Earth in the Milky Way galaxy?

Our solar system is in one of the spiral arms of the Milky Way, called the Orion Arm, and is about two-thirds of the way from the center of the galaxy to the edge of the galaxy's starlight. Earth is the third planet from the Sun in our solar system of eight planets.

4. What is the closest galaxy that is similar to our own galaxy, and how far away is it?

The closest spiral galaxy is Andromeda, a galaxy much like our own Milky Way. It is 2.2 million light-years away from us. Andromeda is approaching our galaxy at a rate of 300,000 miles per hour. Five billion years from now it may even collide with our Milky Way galaxy.

5. Why do we study galaxies?

By studying other galaxies, astronomers learn more about the Milky Way, the galaxy that contains our solar system. Answers to such questions as "Do all

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galaxies have the same shape?," "Are all galaxies the same size?," "Do they all have the same number of stars?," and "How and when did galaxies form?" help astronomers learn about the history of the universe. Galaxies are visible at vast distances, and reveal the history of the visible universe with their collections of billions of stars, gas, and dust.

6. What are the parts of a galaxy?

A galaxy contains stars, gas, and dust. In a spiral galaxy like the Milky Way, the stars, gas, and dust are organized into a bulge, a halo, and a disk containing spiral arms. Elliptical galaxies have a bulge shape and a halo, but do not have a disk.

- Bulge—A round structure made up primarily of old stars, gas, and dust. The bulge of the Milky Way is roughly 10,000 light-years across. The outer parts of the bulge are difficult to distinguish from the halo.
- Disk—A flattened region that surrounds the bulge in a spiral galaxy. The disk is shaped like a pancake. The disk of the Milky Way is 100,000 light-years across and 2,000 light-years thick. It contains mostly young stars, gas, and dust, which are concentrated in the spiral arms. Some old stars are also present.
- Spiral arms—Curved material of gas, dust, and young blue stars that begins at the bulge of a spiral galaxy and curves outward, giving a galaxy a "pinwheel" appearance. Spiral arms are found only in spiral galaxies.
- Halo—A roughly spherical collection of old stars, clusters of old stars (called globular clusters), and a little bit of gas and dust that extends farther than all other components of a galaxy. Halos contain dark matter, which is material that we cannot see but whose gravitational force can be measured. Halos may be more than 130,000 light-years across.
- Stars, gas, and dust—Stars come in a variety of types. Blue stars are very hot and have shorter lifetimes than cooler, red stars. Regions of galaxies where stars are currently forming are therefore bluer than regions where there has

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been no recent star formation. Spiral galaxies have lots of gas and dust, while elliptical galaxies have very little gas and dust.

7. How are galaxies classified? What do they look like?

Galaxies can be classified according to their shapes: spiral, elliptical, or irregular. Edwin Hubble, for whom the Hubble Space Telescope is named, devised another famous classification scheme for galaxies. Hubble's system included elliptical and spiral galaxies but excluded irregulars. Today, astronomers use three main galaxy classes: spirals, ellipticals, and irregulars:

- A spiral galaxy consists of a flattened disk containing spiral (pinwheel-shaped) arms, a halo, and a bulge at its center. Spiral galaxies have a variety of shapes. They are classified according to the size of the bulge and the tightness and appearance of the arms. The spiral arms, which wrap around the bulge, contain many young blue stars and lots of gas and dust. Most of the stars in the bulge are older and redder. Yellow stars like our Sun are found throughout the disk of a spiral galaxy. These galaxies rotate somewhat like a hurricane or a whirlpool.

- An elliptical galaxy does not have a disk or spiral arms. It is characterized by a smooth, ball-shaped appearance. Ellipticals contain old stars and possess little gas or dust. They are classified by the shape of the ball, which can range from round to oval (baseball-shaped to football-shaped). The smallest elliptical galaxies (called dwarf ellipticals) are probably the most common type of galaxy in the nearby universe. In contrast to spirals, the stars in ellipticals do not revolve around the center in an organized way. The stars move in randomly oriented orbits within the galaxy, like a swarm of bees.

- An irregular galaxy is neither a spiral nor an elliptical. Irregular galaxies tend to be smaller objects without a definite shape, and they typically have very hot newborn stars mixed in with lots of gas and dust. These galaxies often have active regions of star formation. Sometimes their irregular shape is the result of interactions or collisions with other galaxies. Observations such as the

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Hubble Deep Fields show that irregular galaxies were more common in the distant (early) universe.

8. How do astronomers classify galaxies today?

Hubble's system included elliptical and spiral galaxies but excluded irregulars. Today, astronomers use three main galaxy classes: ellipticals, spirals, and irregulars. Elliptical galaxies range from round shapes (E0) to oval shapes (E7). Spiral galaxies have a pinwheel shape and are classified according to their bulge, as well as how tightly their arms are wrapped around the bulge. They range from Sa, which has a large bulge and tight, smooth arms, to Sc, which has a small bulge and loose, lumpy arms. Barred spiral galaxies classified as SB are pinwheel-shaped and have a distinct "bar" of stars, dust, and gas across their bulge. They range from an SBa, which has a bar across its large bulge and tight, smooth arms, to an SBc, which has a bar across its small bulge and loose, lumpy arms. Irregular galaxies have no definite shape but still contain new stars, gas, and dust. The chart below summarizes the properties of the main classes of galaxies.

Main Classes of Galaxies		
Spiral galaxies	**Elliptical galaxies**	**Irregular galaxies**
• Huge; contain stars, gas, and dust	• Huge; contain stars, gas, and dust	• Huge; contain stars, gas, and dust
• Held together by gravity	• Held together by gravity	• Held together by gravity
• Pinwheel shape	• Round-to-oval shape	• No regular shape
• Bulge and thin disk; halo is present	• Bulge but no disk; halo is present	• May show signs of a disk and/or a bulge; halo is present
• Rich in gas and dust	• Small amount of cool gas and dust	• Usually rich in gas and dust
• Young and old stars are present	• Mainly old stars are present	• Young and old stars are present

9. What is the most common type of galaxy in the nearby universe?
When one counts both large and small galaxies, dwarf ellipticals (small ellipticals) are probably the most common type of galaxy in the nearby universe. Since these galaxies are small and faint, their exact number is not well known. The majority of large, bright galaxies in the nearby universe are spirals.

10. Galaxies are often identified by a group of letters and numbers. What do they stand for?
Scientists classify galaxies in different catalogs. The most common catalog is NGC, which stands for *The New General Catalogue of Nebulae and Clusters of Stars*. Other catalogs include M (Messier), ESO (European Southern Observatory), IR (Infrared Astronomical Satellite), Mrk (Markarian), and UGC (Uppsala General Catalog). Sometimes a galaxy appears in more than one catalog and can have more than one name.

The numbers following the letters, such as Mrk 917 (Sc) or NGC 1433 (SB), indicate the galaxy's entry in the catalog and are often related to the galaxy's relative position in the sky.

11. What are colliding galaxies?
When two or more galaxies are close enough to each other, gravitational forces will pull the galaxies toward each other. This gravitational attraction increases as the galaxies travel toward each other. The galaxies then may pass by each other or collide. Two galaxies that are interacting or colliding may be referred to as a pair, or one galaxy may be referred to as a companion of the other.

The Hubble images on the next page show that colliding galaxies can look very different from each other. The appearance of an interacting system of galaxies depends on many factors, including the number of galaxies involved in the interaction, their masses and types, how close they are, and how they approach each other. The Antennae Galaxies (upper right, next page) are an example of two spirals that are in the process of colliding. We will not see the end result during

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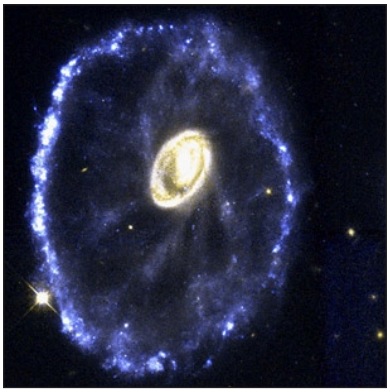
our lifetimes because this process takes hundreds of millions of years. Sometimes smaller galaxies plunge into larger galaxies. This type of collision produces a ripple effect, like a rock thrown into a pond. The Cartwheel Galaxy (top row, center) is an example of this type of collision. The outer ring of blue stars in this galaxy indicates a ripple of star formation resulting from the collision.

Andromeda and our Milky Way are two spiral galaxies that may eventually collide, about 5 billion years in the future.

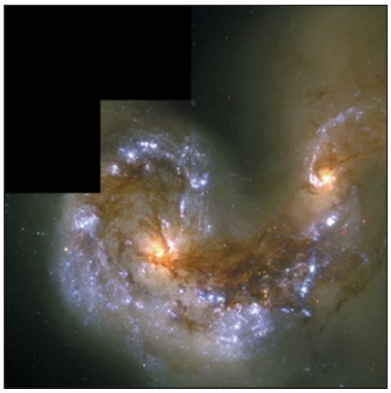
Examples of Colliding Galaxies

NGC 1409 & 1410

ESO 350 & 6040 (Cartwheel Galaxy)



4038 & 4039 (The Antennae Galaxies)



NGC 4676

NGC 4650A

Stephan's Quintet

12. What is the Hubble Space Telescope?

The Hubble Space Telescope (HST) is a space-based telescope that was deployed in 1990 from the space shuttle. From its position 380 miles above the Earth's surface, the HST has expanded our understanding of star birth, star death, and galaxy evolution, and has moved black holes from theory to fact. It has taken hundreds of thousands of images.

The telescope's instruments are the astronomer's eyes to the universe. Its instruments include the Wide Field Planetary Camera 2 (WFPC2), the Space Telescope Imaging Spectrograph (STIS), the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), and the Advanced Camera for Surveys (ACS).

When first launched, the edges of the HST's lens were misshapen by an amount equal to 1/50 the thickness of a human hair. This very small defect made it difficult for Hubble to focus on faint objects.

Because the HST is in low-Earth orbit, it could be serviced by a shuttle. The defect was corrected in the first servicing mission, with the installation of COSTAR, the Corrective Optics Space Telescope Axial Replacement.

If the telescope is serviced in 2008, it will be able to observe the universe until approximately 2013. After that, it will be "de-orbited" by NASA, becoming a man-made "shooting star," as it burns up upon re-entering Earth's atmosphere.

13. What is the Hubble Deep Field?

The Hubble Space Telescope reached back 10 billion years to capture the Hubble Deep Field image, which shows some of the dimmest, most distant objects in the universe. The image, the longest exposure that Hubble had taken at the time, was made by pointing the telescope at one point in the sky for 10 straight days in December 1995.

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The Hubble Deep Field shows hundreds of thousands of galaxies in an area of the sky that is as small as the size of President Franklin Roosevelt's eye on a dime held at arm's length. The field lies in a dark patch of sky just above the Big Dipper. This field is so small that just a few foreground stars in our Milky Way galaxy are visible.

14. What is the Hubble Ultra Deep Field?

In 2004, the Hubble Ultra Deep Field image surpassed the record-setting Hubble Deep Field images.

The HUDF reached back even farther — 12.9 billion years — to reveal over 10,000 galaxies, some of which were the first galaxies to emerge shortly after the Big Bang. (The Big Bang occurred 13.7 billion years ago.) The HUDF now holds the record as the deepest portrait of the visible universe yet achieved by humankind.

The image was made by aiming the telescope at one point in the sky below the constellation Orion for 11.3 separate days (falling between Sept. 2003 and Jan. 2004), resulting in a million-second-long exposure. This patch of sky looks largely empty in ground-based images.

Some of the galaxies uncovered in the image existed between 400 and 800 million years after the Big Bang, long before Earth and our solar system existed. Many of these still-forming galaxies exhibit strange shapes.

As with all astronomical images, since the light from these distant galaxies must travel for billions of years before arriving at Earth, we are seeing the galaxies as they appeared when the light left them, billions of years ago.