National Aeronautics and Space Administration

Student Reading

ABOUT GALAXIES

OUR HOME PLANET, Earth, resides in a glittering city of stars called the Milky Way galaxy. Our Milky Way is one of billions of galaxies in the cosmos, all of which blaze with the glow of millions of suns. What are galaxies? Are they all the same? Read on to find out.

The Milky Way Galaxy and Beyond

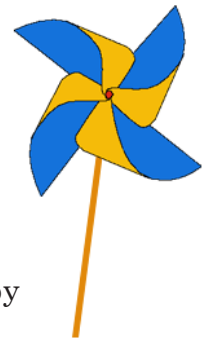
All the stars that can be seen in the night sky are part of our galaxy, the Milky Way. It contains more than 200 billion stars. Great distances separate these stars. The diameter of the Milky Way is about 100,000 light-years. A light-year is the distance light travels in one year. To appreciate how far this is, consider that light can travel from the Sun to Earth in about eight minutes, and from the Sun to distant Pluto in about five and a half hours. So the Sun and Earth are about eight "light-minutes" apart, and the Sun and Pluto are about five and a half "light-hours" apart. The closest star to the Sun is about four light-years away from it.

Stars produce light and make their galaxy bright. Galaxies are so far away that they look like fuzzy patches in the sky when viewed with the unaided eye or even with amateur telescopes. Only three galaxies can be seen with the unaided eye: the Small and Large Magellanic Clouds in the Southern Hemisphere, and the Andromeda Galaxy in the Northern Hemisphere.

Modern telescopes, including the Hubble Space Telescope, have made it possible to make detailed observations of other galaxies. When astronomers started studying galaxies, they discovered that these systems of stars also contain gas and dust and come in a variety of shapes, colors, sizes, and orientations. Some galaxies have a lot of gas and dust, while others have very little. Some have recognizable shapes, while others do not.

Astronomers classify galaxies by their shapes. Whatever their size or shape, all galaxies have the following traits: they are held together by the force of gravity; they are composed of stars, gas, and dust; and they have individual stars and star clusters circling the outer area, called the halo.

The Shapes of Galaxies



Galaxies have been divided into three basic shapes: elliptical, spiral, and irregular. Elliptical galaxies appear smooth and featureless. They can be baseball-shaped to football-shaped. Spiral galaxies are pinwheel-shaped disks with two or more "arms" winding out from a central bulge. These arms vary from tight spirals to very loose, bumpy spirals. Irregular galaxies don't have arms or a uniform appearance. Their stars and gas clouds are scattered in random patches.

Colors of the Stars Within Galaxies

The color of a star depends on its mass. Galaxies form stars with a range of masses, so we find stars with a range of colors inside galaxies.

Massive stars are hot and bright bluish-white in color. Smaller stars are cooler and have dimmer, yellow to red colors. Galaxies with blue stars are easy for us to see, because the blue stars are so bright.

Massive blue stars use up their fuel fast, so their lives are short. Yellow and red stars use their fuel more slowly. They have much longer lives than blue stars.

Colors of Galaxies

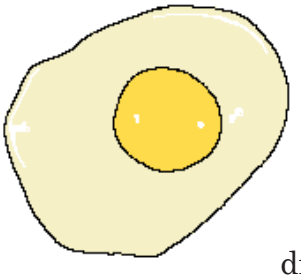
A galaxy's color is due to the combined color of its stars. A galaxy's color also tells us whether star formation occurred recently, within that galaxy. A galaxy with lots of recent star formation has many young, blue stars and will appear blue. After the short-lived blue stars end their lives, the cooler yellow to red stars continue to shine. The galaxy will then appear redder, indicating that it hasn't produced new stars for awhile.

Just as a galaxy with mostly young stars appears blue, and a galaxy with mostly old stars appears red, galaxies with stars of varying ages may appear to be a combination of colors. For example, a galaxy with some young and some old stars may be a combination of blue and red.

Ways of Measuring the Size of Galaxies

The number of stars contained in a galaxy can range from less than a million stars, in dwarf ellipticals, to several trillion stars, in giant ellipticals. Galaxies can be several thousand to hundreds of thousands of light-years across.

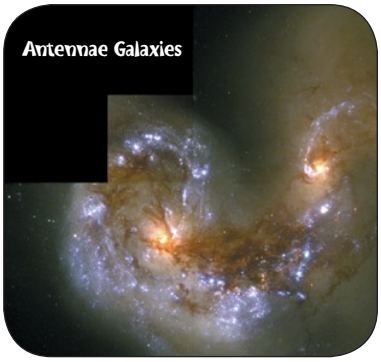
A Galaxy's Orientation in Space



The orientation of a galaxy refers to the angle from which we view it. For ellipticals, the orientation isn't very important, because an elliptical shape looks rounded from any viewing angle. The viewing angle may determine just how rounded it will appear. Spiral galaxies, on the other hand, look very different depending on how you view them. When viewed "face-

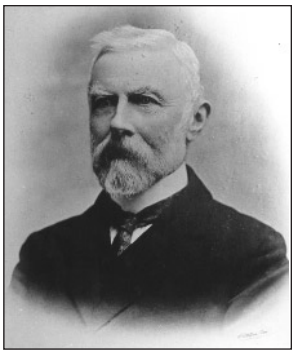
on," spiral galaxies show their nice pinwheel shape, but when viewed "edge-on," spiral galaxies look like fried eggs viewed from the side. When viewed edge-on, other features of the spiral galaxy come into view: the central bulge (the yolk of the egg), the halo, and the disk where the spiral arms are located (the white of the fried egg). Often a dark lane of dust can be seen in the disk. The orientation of irregular galaxies isn't important because they have no set pattern or structure.

Identifying and Cataloging Galaxies



Some galaxies have common names, such as the Cartwheel Galaxy or the Antennae Galaxies. They also have scientific names, usually a combination of letters and numbers. Galaxy names begin with a letter or combination of letters to designate the astronomy catalog in which scientists listed them, such as "M" for *Messier's Catalogue of Nebulous* [cloudy] *Objects* or "NGC" for *The New General Catalogue of Nebulae and Clusters of Stars*.

Some of these catalogs were compiled by astronomers while they were searching for other objects. For example, Charles Messier, who compiled his catalog in the eighteenth century, was studying the sky with his small telescope, searching for comets. Distant comets and what he called "cloudy objects" looked similar through his telescope. So, he began to compile a list of the objects that he knew were not comets, in order to make his comet-hunting easier.



John L. E. Dreyer

The New General Catalogue of Nebulae and Clusters of Stars (NGC) was compiled by John L.E. Dreyer in the nineteenth century. This comprehensive list of nebulae and star clusters

remains the standard reference guide used by astronomers all over the world. The numbers following the letter(s) are the entry numbers.

Some objects appear in more than one catalog. They are identified by either of their catalog numbers. One example of such an object is NGC 4321, also known as M100, a spiral galaxy in the Virgo cluster of galaxies in the Northern Hemisphere.

Classification of Galaxies

Galaxies can be classified according to their shapes: elliptical, spiral, 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: ellipticals, spirals, and irregulars.

Elliptical Galaxies ("E")

An elliptical galaxy 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 (E0) to oval (E7) (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.

Spiral Galaxies ("S" and "SB")

A spiral galaxy consists of a flattened disk containing spiral (pinwheel-shaped) arms, a central bulge, and a halo. Spiral galaxies have a variety of forms, and 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. Stars in the bulge tend to be 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. A barred spiral galaxy is a spiral that has a bar-shaped collection of stars running across its center. The arms of a barred spiral are attached to the bar.

Irregular Galaxies ("Irr")

An irregular galaxy is neither a spiral nor an elliptical. Irregular galaxies tend to be smaller objects without definite shape, and they typically have very hot newer 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 between galaxies. Observations such as the Hubble Deep Fields show that irregular galaxies are more common in the distant (early) universe.

History of Galaxy Observations

Charles Messier

In the late 1700s, Charles Messier was using a telescope to look for comets and found many blurry objects, which he did not recognize as stars. These blurry objects did not change position over time as a comet would. He called these objects "nebulae." In his search, Messier listed over 100 nebulae, many of which today are classified as galaxies or star clusters (for example, M51 was the 51st object that Messier listed). Cataloging these stationary objects in the night sky helped Messier focus his attention on those objects that did change their positions over time. Thus, he located comets, which travel through the sky. Messier became famous in his lifetime for the discovery of 20 comets. Messier never thought, however, about what these strange nebulae might be. He simply marked them down and continued looking for his comets.

In 1845, Lord Rosse used a powerful telescope to make a careful and accurate drawing of the object called M51. The drawing resembles a question mark. (Today,

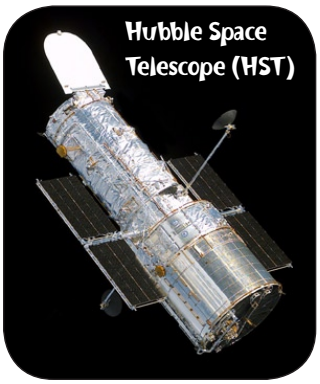
we know that M51 is a spiral galaxy with a smaller companion galaxy nearby.) Rosse's drawing of M51 allowed astronomers to discover the pinwheel shape of a spiral galaxy.

Edwin Hubble

Initially, astronomers debated whether objects like M51 were simply odd structures in our own galaxy or separate objects outside of our own galaxy. In fact, an important discussion in astronomy at the time questioned whether our galaxy was unique in the universe. Some scientists believed that our galaxy took up the entire universe, and everything in the sky was part of our galaxy. Other scientists insisted that the Milky Way was only one of many galaxies in the universe and that spiral nebulae like M51 were actually galaxies similar to our own galaxy, but outside of it. It was not until the twentieth century that Edwin Hubble determined the distance to another "spiral nebula" known as M31 or the Great Andromeda Nebula. Based on this distance, Hubble determined M31 and others like it had to be outside of the Milky Way.

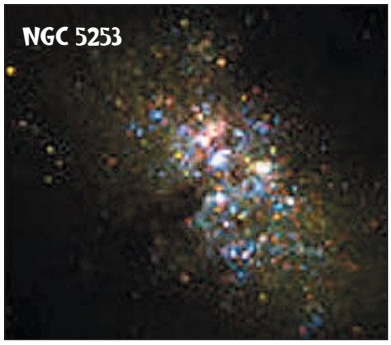
About the Hubble Space Telescope

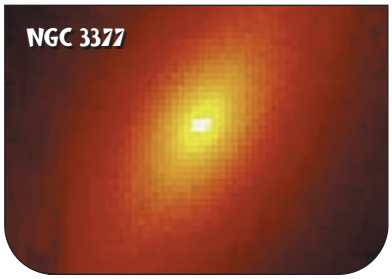
The Hubble Space Telescope (HST) is as large as a school bus and looks like a five-story tower of stacked silver canisters. Each canister houses important telescope equipment: the focusing mirrors, computers, imaging instruments, and pointing and control mechanisms. Extending from the telescope are solar panels for generating electricity and antennae for communicating with operators on the ground.



Astronomers cannot look through Hubble's lens to see the universe, as they can with some ground-based telescopes. Instead, Hubble's scientific instruments are the astronomers' electronic eyes. The telescope's instruments include cameras and spectrographs. The cameras don't use photographic film, but rather electronic detectors similar to those used in home video cameras. The spectrographs analyze data by separating starlight into its rainbow of colors, just as a prism does to sunlight. By closely studying the colors of light from a star, astronomers can decode the star's temperature, motion, composition, and age.

Hubble's powerful capabilities have allowed astronomers to peer into the outer limits of the universe and uncover a variety of never-before-seen galaxies. The observations clearly show that different types of galaxies evolved at different rates. Giant elliptical galaxies formed shortly after the Big Bang and changed little; spiral galaxies like our Milky Way took longer to form and have undergone dramatic changes.





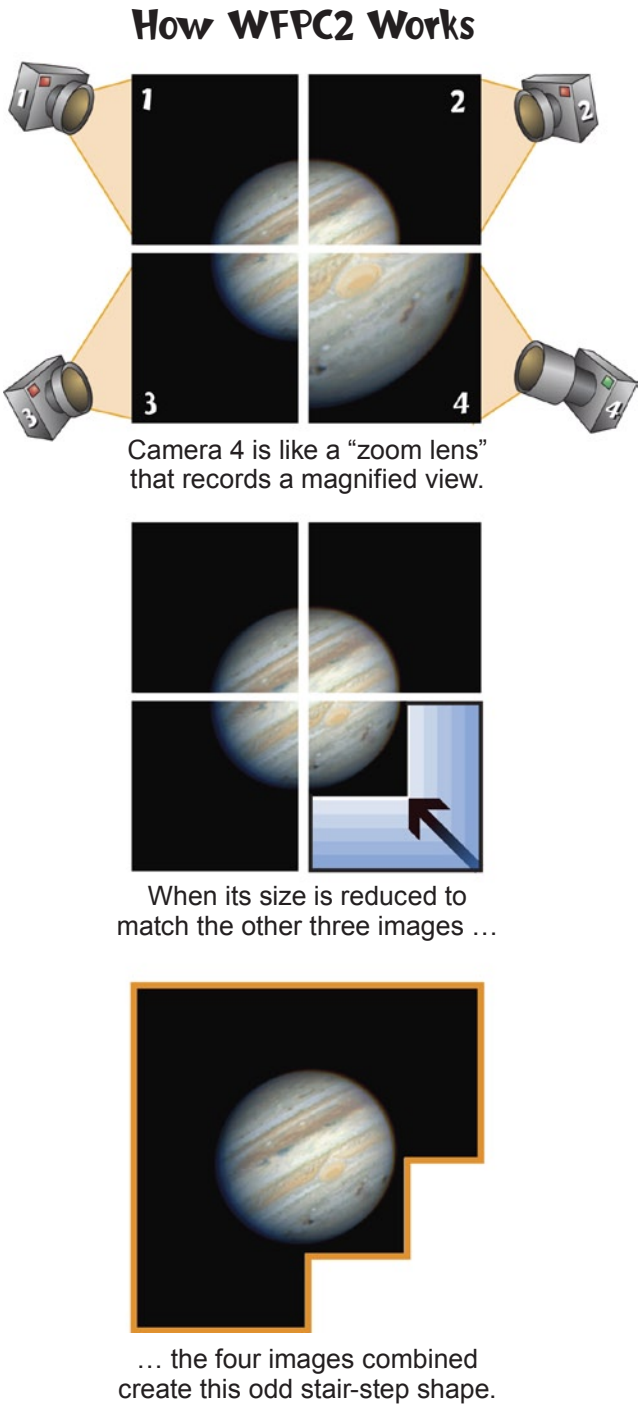
About the Images on the Galaxy Trading Cards

All of the pictures on the cards are Hubble Space Telescope (HST) images. Many of the galaxies on the cards have been featured in news stories over the years. For example, the image NGC 4321, also known as M100, was one of the first images released after the Hubble Space Telescope's first servicing mission. Other images were taken from HST's archives of scientific observations. The observations may have been made by scientists looking for special features of galaxies, such as a

supermassive black hole at the center of a galaxy or an "active galactic nucleus," where the core of the galaxy produces more energy than the rest of the galaxy combined.

Many Hubble images have a curious stair-step shape (called a chevron). These images come from a scientific instrument called the Wide Field and Planetary Camera 2, or WFPC2 — one of the second set of instruments flown aboard the telescope. WFPC2's unique design causes the oddly-shaped images.

WFPC2 is actually made up of four cameras. Each camera records a separate image that represents one part of the overall view. It's rather like seeing a view through a four-paned household window. But WFPC2 has a unique feature. One of its cameras records a magnified view of the section it is observing, which allows us to see finer detail in that section.



During image processing the magnified view has been reduced to the proportion of the other three, resulting in one small image and three larger images. The stair-step shape emerges when the four images are stitched together to make the final image.