

Galaxy Sorting

Activity H5

Grade Level: 7–12



Source: This activity was written especially for Project ASTRO by Sally Stephens, an astronomer and freelance writer. ©1999 by the Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112. <http://www.astrosociety.org> All rights reserved. We want to acknowledge the assistance of William Keel, University of Alabama, and David Malin, Anglo-Australian Observatory, in obtaining the images that go with the activity. Updated in 2010.

What’s This Activity About?

Seen through modern telescopes, galaxies of stars show a wide array of shapes and other visual characteristics. A key part of how astronomers came to understand galaxies was sorting them into categories based on their appearance. Students go through the same process in this activity, sorting galaxy images and deciding on useful classification criteria.

What Will Students Do?

Students are divided into groups and, after being introduced to galaxies in general, are given 20 galaxy images to sort into categories of their own devising. The groups then compare notes about their sorting criteria and learn more about what the different visual characteristics of galaxies imply.

Tips and Suggestions

- The 20 images for this activity are on *The Universe at Your Fingertips* disk. They’re also on the web at: <http://www.astrosociety.org/education/astro/act5/galaxysort.pdf>
- The activity also lists web sites where you can assemble different sets of galaxy images.
- At the end of the activity, students may ask you for the right answer. This is a good opportunity to explain that in science, there is no great authority that gives scientists “the right answer.” The only way to know if you are right is to keep doing more analysis and experiments.

What Will Students Learn?

Concepts

- Galaxies
- Classification of galaxies
- Evolution of galaxies

Inquiry Skills

- Observing
- Organizing
- Reasoning
- Inferring
- Explaining
- Ordering
- Describing

Big Ideas

- Scale and structure
- Diversity and unity
- Patterns of change
- Evolution

Galaxy Sorting

by Sally Stephens



When faced with unfamiliar birds or rocks or other things, the first thing scientists often do is to describe what they look like and determine how they resemble or are different from better-known birds or rocks or things. Then they ask what causes the similarities and differences.

That's what the astronomer Edwin Hubble did with galaxies in the 1920s. Astronomers photographing galaxies through telescopes could see that, although they were quite varied in appearance — some round, some flat, some irregular, — most seemed to belong to general categories of shapes. They also noticed that similar galaxies can look quite different depending on their orientation in space: Spiral galaxies, for instance, were like a Frisbee or a pancake: they look flat if we happen to see them edge on, but round if seen face on.

Hubble devised a system for classifying these great islands of stars by shape. His system has been modified as astronomers learned more about how galaxy shapes are influenced by their history and environment, but it is still in use and can help bring order to the bewildering

diversity of galaxies. In this activity, students sort galaxy images and decide on useful classification criteria, much as Edwin Hubble did generations ago.

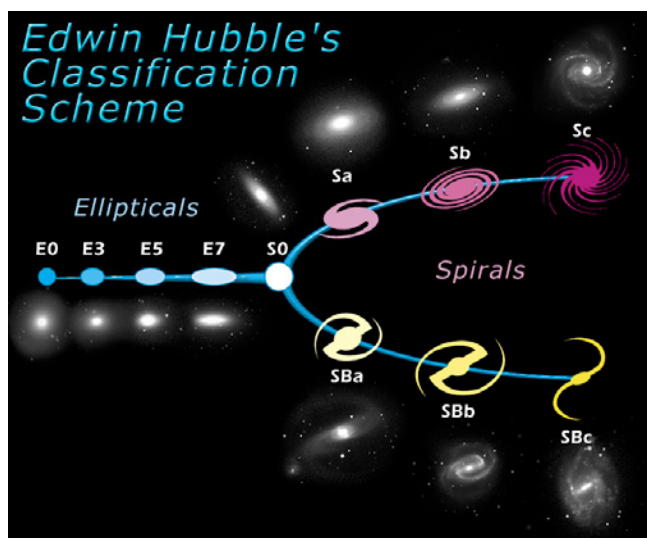
Objectives

Students will:

- compare specific similarities and differences among galaxies by examining features visible in photographs
- identify types of features found in galaxies by classifying the photographs into groups, using a classification scheme of their choice.
- discuss what the classification groups they devised might tell them about galaxies.

Materials

- Galaxy images (one set of 20 per four to six students, either printed out in color or viewed on a computer screen.) The images are included on *The Universe at Your Fingertips* disk and available on the web site of the Astronomical Society of the Pacific at: <http://www.astrosociety.org/education/astro/act5/galaxysort.pdf>
- Some paper and pens for writing down categories and ideas
- For the teacher, we have also included some background information on galaxies and captions for the 20 images. You can give them out later, but don't prejudice the activity by giving these out before the students have had a chance to devise their own classification scheme.



Hubble Classification System

Advance Preparation

Have enough photosets for the class to work in groups of four to six. Alternatively, reserve your school computer lab, so students can view or print the images from the web when they are needed.

Tips and Suggestions

- It is probably worth printing out the galaxy images on the highest quality color printer you can find. Once you have good copies, you may want to laminate them, or at least put them in plastic page protectors, so they can survive more than one class of students.
- To help students visualize how an elliptical or spiral galaxy might appear to us when seen from different vantage points, it helps to use models. A Frisbee or an old vinyl phonograph record approximates the shape of a spiral galaxy, while a football resembles some elliptical galaxies (and explains why they are called “elliptical”; a football seen from the side describes an ellipse but seen from the end looks round). Students can make a model galaxy out of clay or paper mache, and then turn it to see it might look like from the front, the side, or the top.
- While the 20 images picked for this activity show a good variety of galaxy characteristics, there is nothing sacred about this list. If you already have images of galaxies from another unrestricted source, such as the Space Telescope Science Institute, feel free to substitute some of them. Here are some web sites for finding good color galaxy images:
 - Hubble Images: <http://hubblesite.org/newscenter/archive/browse/images/>
 - NOAO Images: http://www.noao.edu/image_gallery/
 - ESO Images: <http://www.eso.org/public/images/archive/category/galaxies/>

Procedure:

1. Discuss with the students briefly what a galaxy is, mentioning that it contains billions of stars bound together by their mutual gravity. Our Sun is just one of an estimated two hundred billion stars that make up the Milky Way Galaxy. Note that other galaxies are very far away from us. Because of their size and distance, we cannot see any particular galaxy from more than one angle. You can't move around a galaxy and see what it looks like from behind or from the side, as you do when you pick up and examine an unknown object you find on the sidewalk. Discuss that most galaxies are not spheres (like the stars are). As a result, what a galaxy looks like may vary depending on the angle you see it at, for example,



Galaxy NGC 253, a spiral seen nearly edge-on
(European Southern Observatory)

looking down on it from above versus looking at it from the side. (Try not to give them any hints yet about what the different common shapes of galaxies are, so students can discover the different shapes for themselves.)

2. Distribute a set of the galaxy photographs to each group of four to six students (or have them bring up the images on their computers). Ask each group to come up with some categories into which it makes sense to classify the photographs. Point out that most of the sharp individual dots of light in each image are stars in our own Galaxy and should be ignored. Students should focus on the galaxies in the photographs, not how many foreground stars there are or how bright those stars appear.

Teacher's Note: If students ask how many categories they should have, tell them that it is up to them, based on traits they choose to use for the categories. Some students will also want to know more about what is shown in the photographs. Avoid giving answers at this point. Encourage them to discuss possible ideas with their group or to write any questions they have down for discussion later. (The idea is that we want to help the students act like scientist in this activity. When astronomers are first classifying a new category of celestial objects, they don't have any “higher authority” — such as a teacher — to ask for the right answer. They must rely on their own intuition and discussions with their peers

to come up with the best possible theories and models.)

3. Facilitate the student discussion by circulating through the classroom. As teams complete their groupings, discuss with them their reasoning behind how they grouped the photographs. Encourage them to try different classification schemes, or to include subcategories. If time allows, encourage students to continue this process for as long as they are examining and discussing the photographs.

Teacher's Note: Some possible ways to classify the galaxies include whether they have spiral arms or not, whether the arms appear close together or loosely spaced, how prominent the central bulge of stars appears, whether the galaxy is viewed at an angle or not, how big or how bright the galaxies appear, how much dust it contains, whether the galaxy appears flattened or spherical, and whether it appears chaotic or fairly orderly. Encourage students to be creative in the schemes they come up with, just as scientists try to consider all possibilities when first studying a new class of objects.

4. Once students are done, ask several groups to explain their classification schemes to the rest of the class. Select a variety of schemes for presentation. Ask students to consider the various schemes within their groups after the presentations are finished. Does any group like another group's scheme better than its own? Give them a chance to re-discuss and reclassify their images, if they want. Students often think that there must be one "right"



Elliptical Galaxy NGC 1132 (Hubble image NASA/ESA)

classification scheme for this activity and that scientists somehow "know" that right scheme before they start. This is an excellent opportunity to discuss how a collection of objects can be classified in many different ways, depending on the traits chosen for making the categories.

5. After students make their presentations, you can discuss how astronomers have chosen to classify galaxies, pointing out features that the students may not have considered, for example, how bright the central bulge of stars in a galaxy appears relative to how bright its spiral arms appear. Students may find that the galaxies they had trouble classifying have also puzzled astronomers. In many cases, these troublesome galaxies are now thought to look odd because they are the result of mergers, collisions and other interactions between galaxies, something that earlier astronomers didn't consider an important factor in galactic appearance. Students should know that the criteria astronomers use to classify galaxies have changed over time, as we have learned more about galaxies and realized that some characteristics are more (or, sometimes, less) important than we had previously thought.

Teacher's Note: This is another good time to point out that there is no "right way" to classify galaxies. Some criteria may turn out to be more useful than others in explaining the differences and similarities between galaxies. But it's almost impossible to know in the beginning which criteria will end up being useful and which will not. Only time and further research into the characteristics and history of galaxies (research that goes beyond their mere appearance on a photograph) can answer that question.

6. Have students try to come up with ideas to explain the differences between galaxy types. You may want to point out, as they are looking at the differences, that the galaxies in our sample are at a range of distances away from us and that this may influence how they look to us. For example, we might not be able to see faint spiral arms in a galaxy that's very far away from us. Also, galaxies may be inclined at different angles to our line of sight and thus appear quite different. This is most obvious when comparing galaxies of the same type that we see face on with those that appear edge on to us.

7. After they have a chance to think about their own ideas for what causes the differences we see, you might

want to prompt them with questions like the following: Does the type of galaxy depend on conditions present when it was born (how much material was included, how fast the cloud of raw material that gave birth to the galaxy was spinning, etc.)? Or might things happen to it later in a galaxy's life that change its appearance (such as an interaction with a neighboring galaxy, or with hot fast moving gas)? Astronomers now think both "nature" and "nurture" play important parts in what galaxies look like. Discuss what astronomers now know about the relationships between the different types of galaxies and how galaxies themselves change their appearance over time. (See the handout.)

Follow-up Activities

1. Discuss Hubble's galaxy classification scheme with the class (see the background information sheet), describing spirals, barred spirals, ellipticals, and irregulars. Did any group come up with such a scheme? What do the students think of Hubble's scheme?
2. Have the students classify the galaxies they have been working on using Hubble's scheme? How easy is to decide?



Edwin Hubble

3. If there is time and access to other galaxy images, have students classify the new galaxies according to their own scheme and Hubble's scheme.

4. More advanced or motivated students can put their galaxy sorting skills to work in a "citizen-science" research project to help astronomers classify a huge number of galaxies at: <http://www.galaxyzoo.org>

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Background Information on Galaxy Classification

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In 1924, astronomer Edwin Hubble proved that galaxies are very distant “island universes” — each one a collection of millions or billions of stars bound together by gravity. Within a few years, he had set up a system to classify them that is still used today, albeit with some modifications and additions.

Hubble’s system divides galaxies into three basic categories: 1) elliptical galaxies, relatively featureless spherical or ellipsoidal (football-shaped) collections of stars; 2) spiral galaxies, with their distinctive arms of stars that spiral out from their centers; and 3) irregular galaxies, a catchall category for galaxies that don’t look like either traditional ellipticals or spirals.

Elliptical galaxies, marked by the letter E, are further subdivided depending on how well-rounded they appear. A number is added that ranges from 0 to 7, with completely round ellipticals denoted by 0, and flattened systems (which look like a squashed football) denoted by 7. An E5 galaxy, for example, is not very spherical, appearing twice as long as it is wide.

Spiral galaxies are divided into two main types: regular spirals, denoted by the letter S, in which the arms spiral outward from the galaxy center, and barred spirals, marked SB, in which the arms wind outward from the ends of a straight “bar” of stars that passes through the center.

About two thirds of all spiral galaxies have some kind of bar. Indeed, astronomers have seen evidence of a bar in our own Galaxy’s center, making the Milky Way a barred spiral. Both regular and barred spiral galaxies are defined by a spherical bulge of stars at their center, which is surrounded by a thin, rotating disk of stars that contains the spiral arms. You can tell the direction in which the disk rotates by looking at the spiral arms; they trail behind the direction of rotation, much like the coattails of a runner or water thrown out by a twirling lawn sprinkler.

In addition, both regular and barred spirals are subdivided according to how tightly wound the spiral arms are and how prominent the central bulge of stars appears. In Sa galaxies, the spiral arms are tightly wound and the central bulge appears bright, whereas in Sc gal-

axies, the arms are more loosely wound and the central bulge is much less prominent. Sb galaxies fall in between the two. Similar criteria apply to barred spirals, which are denoted by SBa, SBb and SBc. Irregular galaxies have no subdivisions.

There is also a class Hubble called S0 galaxies, which have characteristics of both ellipticals and spirals, showing a large central bulge and a disk, but no obvious dust lanes or spiral structure.

Regardless of the type, galaxies come in all different sizes. It’s impossible to say how large a galaxy is based solely on its photograph. A very large galaxy that is also very distant might look like it is the same size as a much smaller one that’s nearby. You have to know its distance to know a galaxy’s true size. Our own Milky Way Galaxy is roughly 100,000 light years across; its disk is only 1000 light years thick, however. (A light year is the distance light travels in one year, that is, 9.5×10^{12} kilometers.)

The Milky Way is a large spiral galaxy, but there are galaxies that are ten times its size, and many that are thousands of times smaller. In fact, astronomers now think that tiny, faint galaxies, called dwarf galaxies, may be the most plentiful galaxies in the universe. There are probably so many dwarf galaxies that their combined mass exceeds that of all the larger galaxies taken together. But their small size and dimness make them hard to detect and we have only been able to discover them when they are relatively nearby.

Hubble based his classification scheme solely on what galaxies look like. His scheme is still used today because it turns out there are significant physical differences between the different types of galaxies, differences that were not known when Hubble first classified them. Elliptical galaxies contain mostly old stars, with very little gas and dust found between stars. Since new stars form from clouds of interstellar gas and dust, elliptical galaxies lack the raw ingredients to make new stars. Spiral galaxies, on the other hand, have a mix of young and old stars. Interstellar gas and dust fill the disks of spiral galaxies, and new star formation continues to take place in their disks. Irregular galaxies appear chaotic, and often have many bright, young stars, the result of

recent bursts of intense star formation.

For many years, astronomers thought the dissimilarities between galaxy types reflected different conditions present in each when they originally formed. Put another way, this view held that galaxies look like they do because they were “born that way.” In this view, the stars in elliptical galaxies formed very quickly, using up all the interstellar gas and dust before the material had time to settle into a disk. Star formation in spiral galaxies, on the other hand, took place slowly over the galaxy’s lifetime, continuing after the interstellar gas and dust had settled into a disk. One problem with this view has been trying to figure out why star formation would occur rapidly in ellipticals, but much slower in spirals.

Over the past few decades, however, astronomers have learned that galaxies can change their appearance over time, usually as a result of interactions, collisions, or mergers between galaxies. Interactions between galaxies are common because, relatively speaking, galaxies (especially those found in rich groups) are closer to each other than typical stars are. The distance between the Milky Way and its closest large neighbor (the Andromeda Galaxy) is only about 25 times the diameter of the Milky Way. (And our Galaxy has several smaller neighbor galaxies that are significantly closer than that.) By contrast, the distance between the Sun and its nearest neighboring star is about 30 million times greater than the Sun’s diameter.

Galaxy interactions can turn one type of galaxy into another. Two or more spiral galaxies, for example, can collide and merge, turning into a larger elliptical galaxy. Mergers and collisions often stimulate intense bursts of star formation in the affected galaxies. As a result, many irregular galaxies are now also thought to be the result of galactic interactions or collisions.

Although collisions alter the overall appearance of galaxies, they rarely bother the stars themselves, other than changing their galactic orbits. There is so much empty space between the stars that the stars of two colliding galaxies can pass among each other, like ships on the dark ocean at night. The galaxies as a whole can’t miss hitting each other, but the individual stars within them rarely collide. On the other hand, great clouds of gas and dust (spread out over much larger distances than individual stars) can more easily collide during galaxy mergers. It is the collision of such clouds of raw

material that leads to the bursts of star formation that follow galaxy interactions.

Astronomers now know that interactions and collisions can play a role in what galaxies look like. But they still don’t know exactly how important that role is. It is now thought that both the initial conditions and interactions later in a galaxy’s life combine to influence how galaxies appear.

Over the years, astronomers have added a few refinements to Hubble’s classification scheme. For example, one modification considers whether arms spiral outward from a ring of stars or not. Another considers a spiral galaxy’s total brightness, and assigns a “luminosity class” to each spiral. These changes have come about as astronomers learned more about galaxies and which properties are more (or less) important. No doubt future astronomers will make additional changes to Hubble’s classification scheme as they try to understand why galaxies look the way they do.

A Note on Galaxy Names

Astronomers generally refer to galaxies by their catalog names, that is, by the number by which they are listed in a specific catalog. Eighteenth-century comet hunter Charles Messier compiled a list of “fuzzy looking” objects in the night sky, so he wouldn’t mistake them for new comets (which were his real interest). Many of the brightest galaxies are included in the Messier catalog, and are denoted by the letter “M” followed by their number on the list, e.g., M32.

Another major source of galaxies is the New General Catalog, a list of nonstellar objects compiled initially by J.L.E. Dreyer in 1888. The list has since been expanded to include (in the catalog and its supplements) nearly 15,000 objects. Objects in the catalog are identified by the catalog’s initials, “NGC”, followed by their number in the catalog, e.g., NGC 4565. The later additions are called Index Catalogs, and so some galaxies have an IC number instead of an NGC number. The same galaxy may be referenced in more than one catalog. Thus, for example, the names M101 and NGC 5457 refer to the same galaxy.

Galaxies within the “Local Group” of several dozen galaxies (that includes the Milky Way) are often just denoted by the constellation in which they are found, such

as Leo I or Andromeda II.

For more information on galaxies and their classification, see:

Sloan Digital Sky Survey Page: <http://cas.sdss.org/dr4/en/astro/galaxies/galaxies.asp>

Spitzer Telescope Poster of Hubble Classification of 75 Galaxies in the Infra-red: <http://www.spitzer.caltech.edu/images/2095-sig07-025-Lifestyles-of-the-Galaxies-Next-Door>

William Keel's Page of Galaxy Classification Schemes (a bit technical): <http://www.astr.ua.edu/keel/galaxies/classify.html>

Captions for the Galaxy Images

NOTE: These captions are for the information of the activity leader. It is best to hold off giving out any of this information until AFTER the students have had a chance to develop and critique their own classification schemes.

1) **M32** – This is an E2 elliptical galaxy. Note that it is a little more flattened or squashed than an E0 galaxy would be (compare with image 11). M32 is a companion galaxy to the Milky Way Galaxy’s nearest large-galaxy neighbor, the Andromeda Galaxy (also known as M31). M32 is known as a dwarf elliptical galaxy because it is so small, only 2400 light years across (compared to the Milky Way’s 100,000 light year diameter). It is located about 2.5 million light years away in the direction of the constellation Andromeda. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa, and the Kitt Peak National Observatory.*

2) **M101** – This is a Sc spiral galaxy. Notice how loosely wound the spiral arms appear, and how weak the central bulge looks relative to the brightness of the spiral arms. Both characteristics are typical of Sc galaxies. Compare the spiral arm winding and the central bulge strength with images 3, 6, 10, and 18. M101 is among the largest disk galaxies, with a diameter of 170,000 light years. It is located about 22 million light years away in the constellation Ursa Major. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa, and the Kitt Peak National Observatory.*

3) **M65** – This Sa spiral galaxy is seen at a highly tilted angle. Because of the tilt, the dust in one of its spiral arms (the one closest to us) appears to block the light behind it. This can help give us a sense of how thick the dust-filled disk is relative to its width (compare to spiral galaxies seen edge-on in images 9 and 12). Although M65 is viewed at an angle, its spiral arms appear to be fairly tightly wound, with little space between them. In addition, its central bulge is very bright, especially when compared to how bright the spiral arms appear (compare the arm winding and central bulge brightness to those in other spiral galaxies in images 2, 6, 10 and 18). M65 is roughly half the size of the Milky Way, and is located about 35 million light years away in the direction of the constellation Leo. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa, and the Kitt Peak National Observatory.*

4) **M109** – This SBc barred spiral galaxy has a prominent bar passing through its center. In addition, a ring

of stars surrounds the center, and the outer arms seem to spiral outward from the end of the bar and the ring. The central bulge is bright but fairly small. Compare this to the other barred spirals in images 14 and 20. It is located about 55 million light years away in the direction of the constellation Ursa Major. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa, and the Lowell Observatory.*

5) **M82** – This chaotic-looking Irregular galaxy is known as a “starburst” galaxy because it shows evidence of a recent intense burst of star formation. The burst was caused by its interaction with another galaxy (M81, image 10). M82 is actually a rather small galaxy, about $\frac{1}{4}$ the size of the Milky Way. It contains about $\frac{1}{5}$ the mass of its interacting companion M81. It is located about 12 million light years away in the direction of the constellation Ursa Major. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa.*

6) **M51** – Also known as the “Whirlpool Galaxy,” this Sc spiral galaxy is clearly interacting with a much smaller Irregular companion galaxy. Notice how its spiral arms (especially the outer ones) appear distorted by the gravitational effects of the companion. In three dimensions, the companion is actually located well behind the arm that appears to connect the two galaxies. Indeed, some lanes of dust in the spiral arm block light from the companion. The central bulge of M51 is relatively small and not much brighter than the spiral arms (compare to other spiral galaxies in images 2, 3, 10, and 18). M51 is very similar in size to the Milky Way, and is located about 22 million light years away in the direction of the constellation Canes Venatici (the Hunting Dogs). *Image courtesy William C. Keel, University of Alabama, Tuscaloosa, and the Lowell Observatory.*

7) **The Large Magellanic Cloud** – This Irregular galaxy is one of the Milky Way Galaxy’s closest companions, located only 160,000 light years away. It has a diameter of about 20,000 light years. It is part of the Local Group, a small grouping of several dozen galaxies, including the Milky Way, that are gravitationally bound together. The Large Magellanic Cloud (also known as the LMC) is so close, it is interacting with the

Milky Way Galaxy. In fact, astronomers now think interaction with the LMC may have helped form the bar in the Milky Way's center. In about a few billion years, the Milky Way will "swallow" the LMC. While the LMC as a distinct physical entity will cease to exist, its stars will live on as part of the larger Milky Way Galaxy. The LMC is visible to the naked eye in the Southern Hemisphere in the constellations of Dorado. *Image courtesy AURA/NOAO/NSF.*

8) **Arp 252** – The interaction between these two spiral galaxies has distorted their spiral arms, stretching them out into long tails. These long tails are characteristic of galaxy collisions and interactions. Arp 252 gets its name from a catalog of peculiar and interacting galaxies, put together by astronomer Halton C. Arp, that helped draw attention to these unusually shaped galaxies. It is located about 450 million light years away in the direction of the constellation Hydra. *Image courtesy William C. Keel, of the University of Alabama, Tuscaloosa, and the European Southern Observatory.*

9) **NGC 4565** – This is an edge-on Sb spiral galaxy. Dust in the thin disk blocks light from the central bulge of stars. All spiral galaxies would look like this if we could see them from the side. Compare this to another edge-on spiral galaxy (image 12) to see how the prominence of the central bulge can vary from galaxy to galaxy. NGC 4565 is about the same size as the Milky Way and is located roughly 31 million light years away in the direction of the constellation Coma Berenices. *Image courtesy William C. Keel, University of Alabama, Tuscaloosa.*

10) **M81** – This Sb spiral galaxy had a close encounter with the small irregular galaxy M82 (image 5) a few tens of million years ago. Although only about half the size of the Milky Way, it is more than twice M82's size. M81's gravity caused the chaotic distortions seen in M82, and the close encounter initiated M82's burst of star formation. The encounter may have also had an effect on M81's spiral pattern, making it more pronounced. M81 and M82 are now roughly 150,000 light years apart, about as far as the LMC is from the Milky Way. M81 is located about 12 million light years away in the direction of the constellation Ursa Major. *Image courtesy AURA/NOAO/NSF.*

11) **M87** – This giant elliptical galaxy (E0 or E1) appears almost completely circular. Astronomers don't know for sure if elliptical galaxies look the same from

all angles, so it's not known for certain if M87 is perfectly spherical, or if it might look more flattened if viewed from another angle. Over 100,000 light years across, M87 may contain enough matter to make several thousand billion Suns. Although M87 looks very much like M32 (image 1), M87 is more than 40 times larger. It is a prominent member of the Virgo Cluster of galaxies, one of the nearest rich groups of galaxies (about 50 million light years away). Astronomers think M87 may have formed from the merger of several spiral galaxies billions of years ago. It is located in the constellation Virgo. *Image courtesy AURA/NOAO/NSF.*

12) **M104** – Also known as the "Sombrero Galaxy," this Sa or Sb spiral galaxy is seen edge-on, i.e., from the side. Because it is seen from the side, it's difficult to tell how tightly wound its spiral arms are – a factor in why its galaxy type is not certain. Dust in its thin disk blocks out light from the central bulge of stars, clearly showing the dimensions of the disk. The central bulge in M104 is much more prominent than that in another edge-on spiral, NGC 4565 (image 9). M104 is generally thought to be a member of the Virgo Cluster of galaxies, which would put it at roughly 50 million light years distant. It is about 80,000 light years across, and is located in the constellation Virgo. *Image courtesy AURA/NOAO/NSF.*

13) **NGC 2146** – This is a peculiar Sab spiral galaxy. Dust in one of its spiral arms blocks out light from the central bulge of stars. NGC 2146 is located about 42 million light years away in the constellation Camelopardus (the Giraffe). *Image courtesy AURA/NOAO/NSF.*

14) **NGC 1365** – This is one of the most prominent barred spiral galaxies in the sky, with spiral arms that extend from the ends of the central bar. The bar and spiral pattern in this SBb galaxy rotate clockwise, taking about 350 million years to complete one rotation. With a diameter of about 200,000 light years, NGC 1365 is a supergiant galaxy located about 60 million light years away in the constellation Fornax (the Furnace). *Image courtesy of the European Southern Observatory.*

15) **NGC 4650A** – This Irregular galaxy is an example of a class known as "polar ring galaxies." Only about 100 polar ring galaxies are known. Located about 130 million light years away, NGC 4650A is thought to be the result of a collision between two galaxies at least a billion years ago. The remnants of one galaxy form

what looks like a flattened elliptical galaxy in the center. Gas from a smaller galaxy that came too close was then stripped from its original host galaxy and pulled into a ring of gas, dust and stars that orbits at right angles the remnants of the first galaxy. The ring in NGC 4650A is seen nearly edge-on. The galaxy is located in the constellation Centaurus. *Image courtesy Hubble Heritage Team (AURA/STScI/NASA).*

16) **NGC 6946** – This face-on spiral galaxy has the rather unusual classification of SAB(rs)cd, which refers to the fact that it has a poorly-developed bar across the middle (the AB in the classification), a small core with a number of well-developed spiral arms (the cd), and an inner confused ring (the rs). NGC 6946 is over 70,000 light years across and is located nearly 20 million light years away in the constellation of Cygnus. *Image courtesy AURA/NOAO/NSF.*

17) **Leo I** – This loose grouping of stars is a dwarf elliptical galaxy (E3). It is a member of the Local Group of galaxies that includes the Milky Way. Located about 600,000 light years away, it is a mere 1000 light years across. Small, faint galaxies like this one may be the most common galaxies in the universe, but, because they are small and dim, they can be very hard to detect. *Image courtesy David Malin, Anglo-Australian Observatory.*

18) **NGC 253** – This Sc spiral galaxy is seen nearly edge-on. It is located about 8 million light years away in the constellation Sculptor. Notice that the central bulge of stars is not very prominent in this galaxy. *Image courtesy European Southern Observatory.*

19) **M59** – This E5 elliptical galaxy is significantly flattened. Compare its shape to that of the E0 galaxy M87 (image 11) and the E2 galaxy M32 (image 1), and look for the increasingly flattened shapes as you go from E0 to E5. M59 is a member of the Virgo Cluster of galaxies. At a rough distance of 50 million light years, it has a diameter of about 75,000 light years, smaller than M87. M59 is located in the constellation Virgo. *Image courtesy AURA/NOAO/NSF.*

20) **NGC 1073** – This SBc barred spiral has a fairly prominent bar that passes through its center. Its arms spiral outward from points that are offset slightly from the ends of the bar. The galaxy's central bulge is rather small and of comparable brightness to its spiral arms,

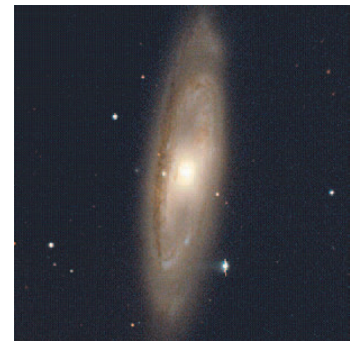
leading to its designation as a type “c” barred spiral. NGC 1073 is located about 56 million light years away in the constellation Cetus. *Image courtesy SEDS.*



M32



M101



M65



M109



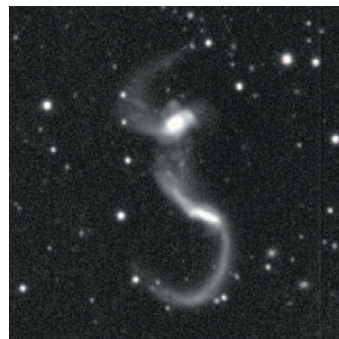
M82



M51



Large Magellanic Cloud



Arp 252



NGC 4565



M81



M87



M104



NGC 2146



NGC 1365



NGC 4650a



NGC 6946



Leo 1



NGC 253



M59



NGC 1073