Everything Galaxies!

Most images courtesy of NASA/*Hubble* Space Telescope, unless otherwise noted

We live in a vast Universe, full of fascinating objects. The most basic building blocks of the whole Universe are billions of galaxies, and the evolution of the Universe since the Big Bang (about 14 billion years ago) can be tracked by how galaxies formed and evolved over that time.

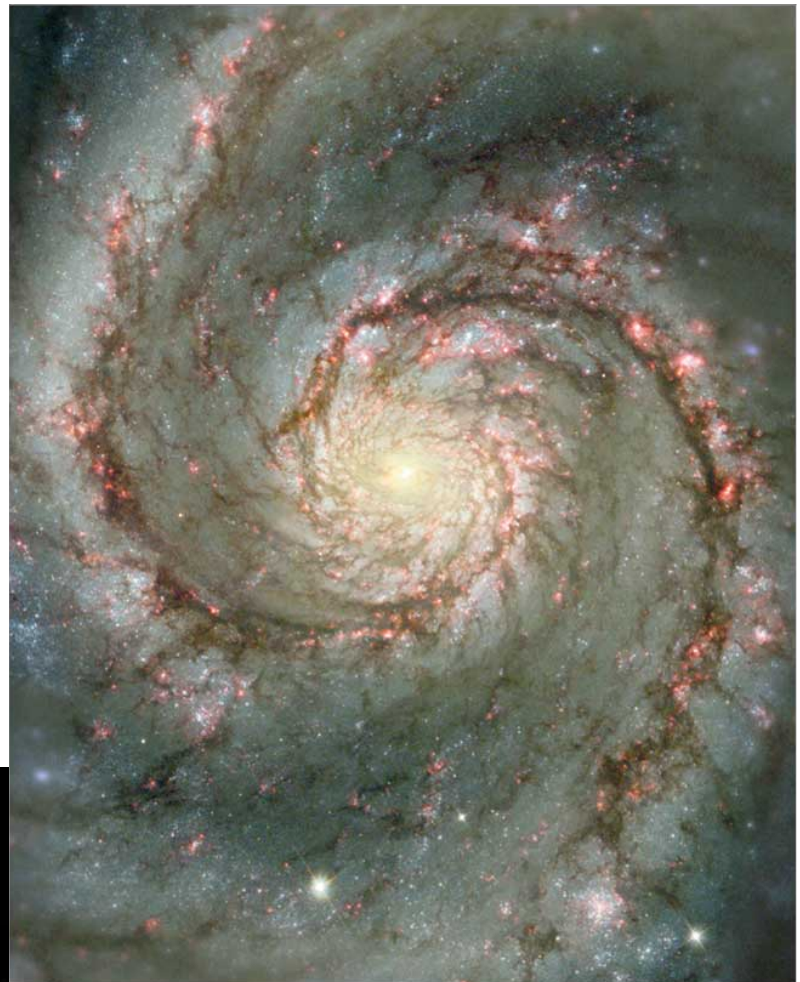
A slice of the Universe: galaxies come in all shapes and sizes.

But then, what are galaxies made of? When you look closely at a picture of a galaxy, you can see that they're mostly made up of stars — hundreds of billions of them for a large galaxy, down to only a few million for the smallest galaxies — plus clouds of gas and dust between the stars, called "nebulae." Also, many of these stars (like our Sun) may have a few planets going around them. Galaxies come in all shapes and sizes, and the details can tell us how they got to be the way we see them now. Basically, galaxies come in two varieties: "spirals" and "ellipticals."

Spiral Galaxies

You've probably seen pictures of spiral galaxies from *Hubble* and other telescopes — their name tells you what they look like. They're mostly broad, flat disks of stars with a bulge in the middle, like 2 dinner plates placed face-to-face. They're flat and circular because the stars go around the galaxy's center in a relatively orderly way, along almost circular orbits.

The spiral arms that you can see are where higher concentrations of stars and gas collect together, *The Whirlpool Galaxy M51 (right), a normal spiral seen face-on. The spiral arms are where concentrations of stars help collect the gas & dust clouds between the stars, until the clouds' internal gravity can make new stars form in cold, dark dust lanes. These new stars then heat the gas into pink nebulae.*

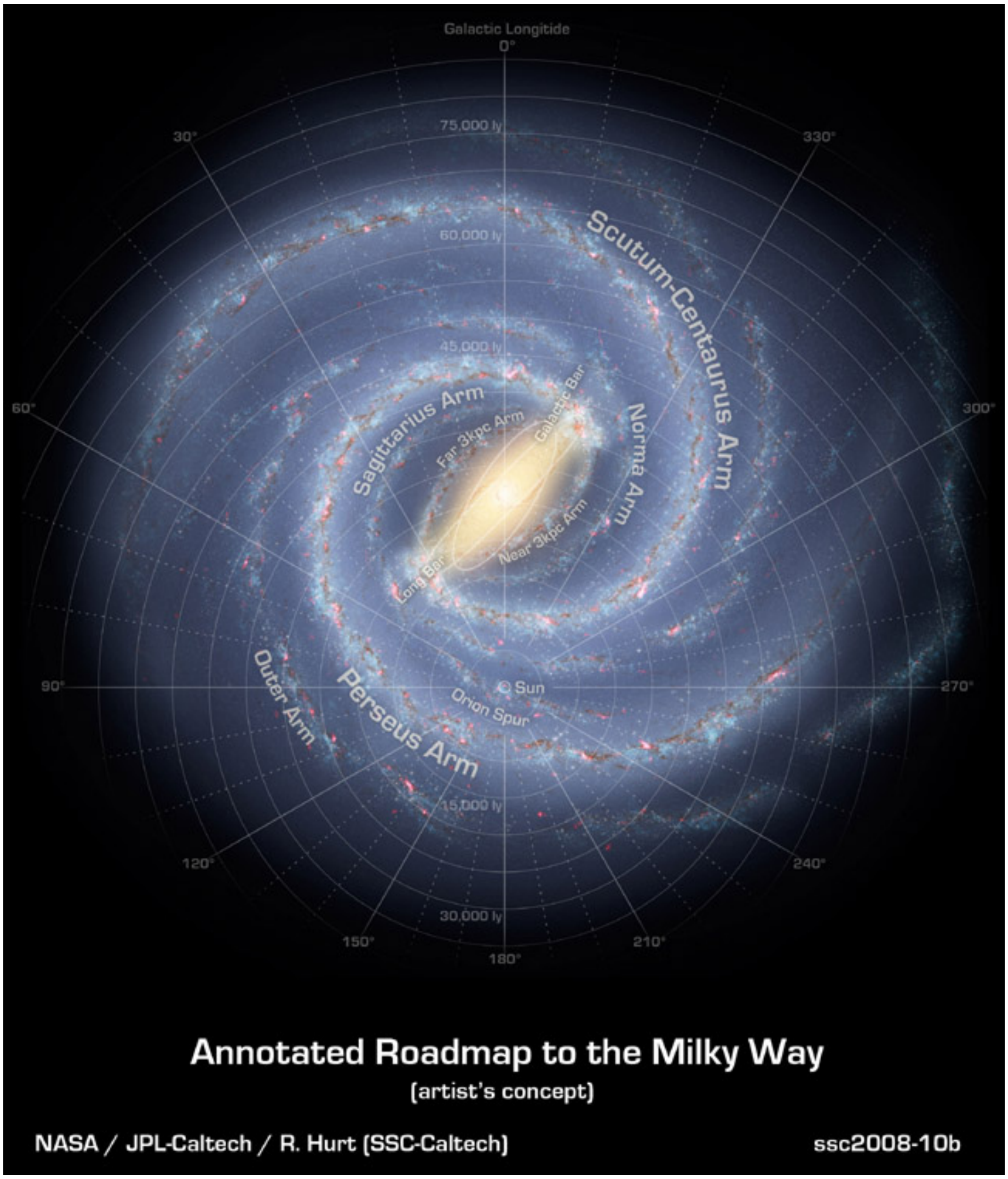


The galaxy NGC 891 (below), a normal spiral seen edge-on. The stellar disk is pretty flat. The dark dust lanes where all the star-forming gas lies is even flatter.

as the gravity of stars & gas jostle each other in their orbits. Sometimes the spirals are bold, where you can see lots of extra massive blue stars and pink nebulae where they form, tightly grouped along (usually) two clear arms in a "grand design." At the other extreme, some of these galaxies have more muted spiral patterns, where the number of arms is less clear because they're not as continuous as in the bold spirals. These more wishy-washy spirals are called "flocculent," meaning fluffy. One of our nearest neighbors, the Andromeda Galaxy, is a large spiral about halfway between grand design and flocculent.

Barred Spirals

Although most spirals can be described this way, about 10% of spirals are distinctly dif-



ferent. Instead of graceful spiral arcs all the way into the galaxy's center, around halfway in from the edges in these unusual galaxies, the arms stop spiralling and are joined together by a much straighter, bright "bar" of stars and gas. Not surprisingly, these are called "barred spirals," and our own Milky Way happens to be a large version (about 400 billion stars, more than 100,000 light years across) of one of them — see the diagram above.

The bars are where the normally circular orbits have been disturbed by a gravitational encounter with (say) another nearby galaxy, into "plunging" orbits. These are where the stars and gas drop from each end of the bar, deep down into the galaxy's center. This sudden change of orbit usually produces a mass pileup at the ends of the bar, compressing the gas and causing more star formation at these locations. You can often see the same blue & pink signposts of vigorous star formation in bars as you can see in normal spiral arms.

For all types of spirals, there is a mix of older stars (many billions of years old), intermediate-age stars, and quite young stars (from ongoing star formation, so only a few million years old).

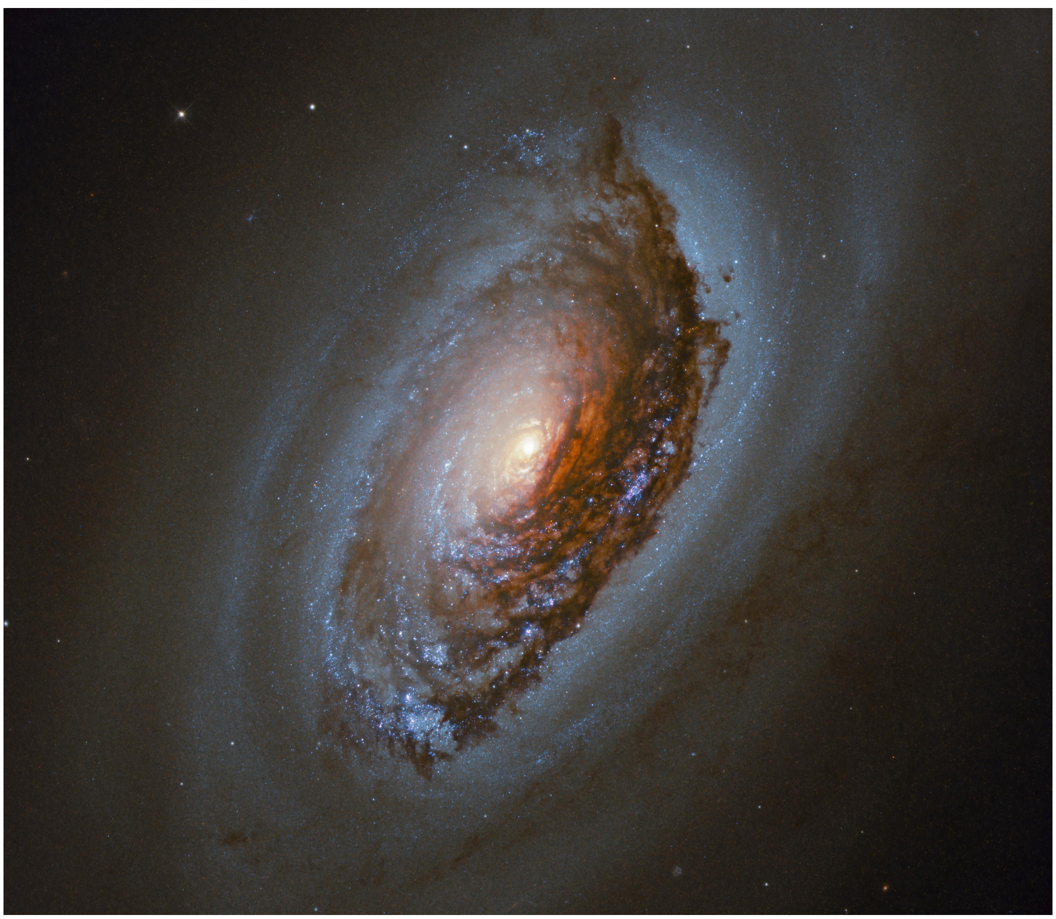
Ellipticals

Instead of being flat and circular, the other common type of galaxy is rounder in 3 dimensions, somewhere between a soccer ball and a football. They have this shape because their stars are not all organised into nice circular orbits, but instead, orbit the galaxies' centers in a more random way — sort of like a cloud of bees around a beehive. Such galaxies are called "ellipticals."

Ellipticals have much less gas than spirals, and as a result, much less new star formation. This also means that most of the stars in ellipticals are old, usually more than a billion years old, and there are very few young stars: their star formation is said to be "quenched."

Large and Small

The largest galaxies, whether spiral or elliptical, can contain several 100s of billions of stars, but each variety of galaxy can range down to having less than a billions stars, sometimes even only a few million. These smaller or "dwarf" galaxies sometimes have less well-defined structure, and are not always spirals or ellipticals, in which case they're called "Irregular." Whatever their structure, though, they are most often found as satellites of larger galaxies, orbiting around them like moons orbiting planets.



The Black Eye Galaxy (right). The dark dust clouds across this galaxy are probably the remnants of gas from a smaller galaxy that is being absorbed into the near side of the larger spiral. On the far side of the spiral, and in between the dust clouds, we can see the blue glow from newly-formed massive young stars.

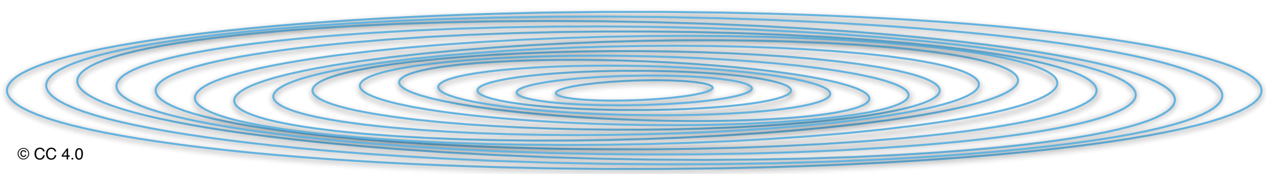
Interacting galaxy group Arp 248 (above). Perhaps a few billion years ago, the two large galaxies were normal spirals. But they have now gotten close enough that their mutual gravity is heavily distorting their shapes — they are now barred spirals with vigorous star formation and long tidal tails. (The smaller spirals are far behind the brighter two.)

Collisions

Occasionally, these satellites even "collide" with their larger neighbors, although this is not like a car crash. For the stars in each galaxy, there is a huge amount of mostly empty space between them, so in a collision, two galaxies' stars can easily pass right by each other, with very little effect on the stars. However, the stars' orbits in their original galaxies can be strongly affected by the other galaxy's gravity, resulting in a kind of "disassembly" of (especially) the smaller galaxy by the larger one, and eventually the migration of the smaller galaxy's stars into orbits around the larger galaxy. This is called "galactic cannibalism."

In contrast, any gas of the galaxies involved in a "gravitational encounter" is strongly affected. Usually the smaller galaxy's gas is quickly stripped away and falls into the larger galaxy's gas reservoir. The larger galaxy's gas is not stripped, but is strongly rearranged and "shocked." This usually results in lots of vigorous star formation in either galaxy's gas clouds, along with its blue & pink signposts. The results can be physically chaotic and visually peculiar.

We can see some effects like this in the Milky Way too, from an ongoing encounter with one of the Milky Way's satellites, the Sagittarius dwarf. This small galaxy of about a billion stars has recently (perhaps a few 100 million years ago) passed by the Milky Way for the third time, and is now being thoroughly disassembled. Meanwhile, ripples from this disturbance (as illustrated below) have just been discovered in the not-quite-flat layer of gas and dust where our Galaxy forms new stars.



More Information

This sampler is just a start: you can search the web for all sorts of images and information about galaxies in general, or the Milky Way in particular, e.g., using a combination of search terms like NASA, Hubble images of galaxies, maps of the Milky Way, or whatever you can think of. What about these ideas and images can inspire your art? Can you use your art to highlight some of the science behind the images? Have fun!