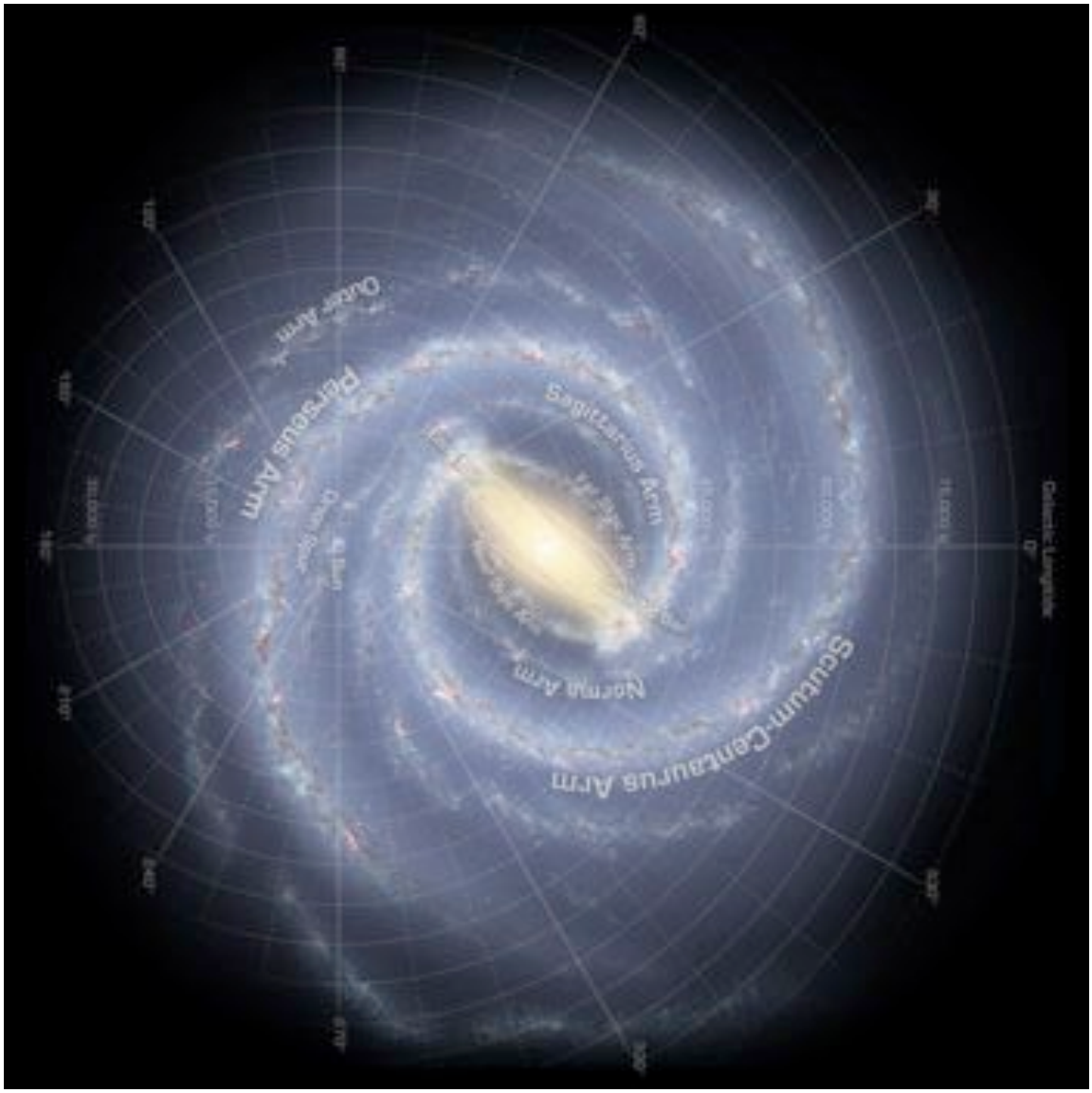
Chapter 8

The Milky Way



Introduction

The Milky Way: wraparound view showing our galaxy as seen from Earth. The center of the galaxy is in the direction of the constellation Sagittarius. Below the plane of the Galaxy and to the right of center are the Clouds of Magellan, nearby satellite galaxies. (Brunier).

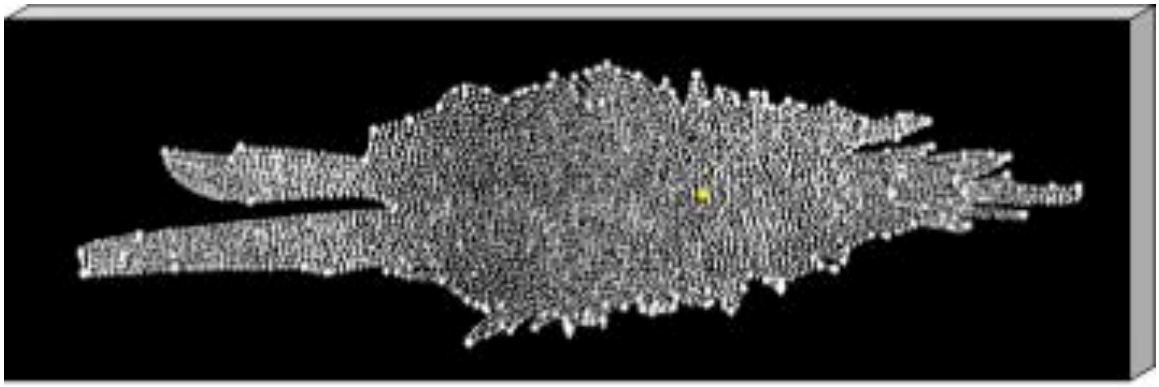
Our Galaxy is the Milky Way. We live in a spiral galaxy, a flat galaxy. Since it surrounds us, the disk of the Galaxy looks like a band of light circling all the way around the sky. You need a dark sky to see it, so people living in cities often are not aware that it is there until there is a power black-out. But in the desert it is a magnificent sight. It is best seen in the winter and in the summer, when it arcs high overhead in the early evening.

Changing Ideas About the Shape of the Milky Way

Prior the the invention of the telescope, nobody really knew what the Milky Way was made of. To the naked eye, all one sees is a creamy band of light, which the ancients imagined as a big milk spill in the sky. Galileo's telescope solved this ancient riddle when it revealed that the creamy band of light was nothing more than the combined light of millions of stars.

Because we see a band of light, it was apparent that the Galaxy was shaped like a disk, but where the Sun was in the disk was not clear: the center or the edge. The Milky Way is brighter and thicker in the direction of the constellations Sagittarius and Scorpius, which might have suggested that the Sun is not in the center. The first serious attempt to determine the Sun's position was made by William Herschel, the discoverer of the planet Uranus. Herschel had a simple idea:

looking throught a telescope, he simply counted the stars he saw in various directions around the Milky Way. He found roughly equal numbers of stars in all directions, so he concluded that the Sun is near the center of the disk. This is the famous "Big Wheel" model of the Galaxy.

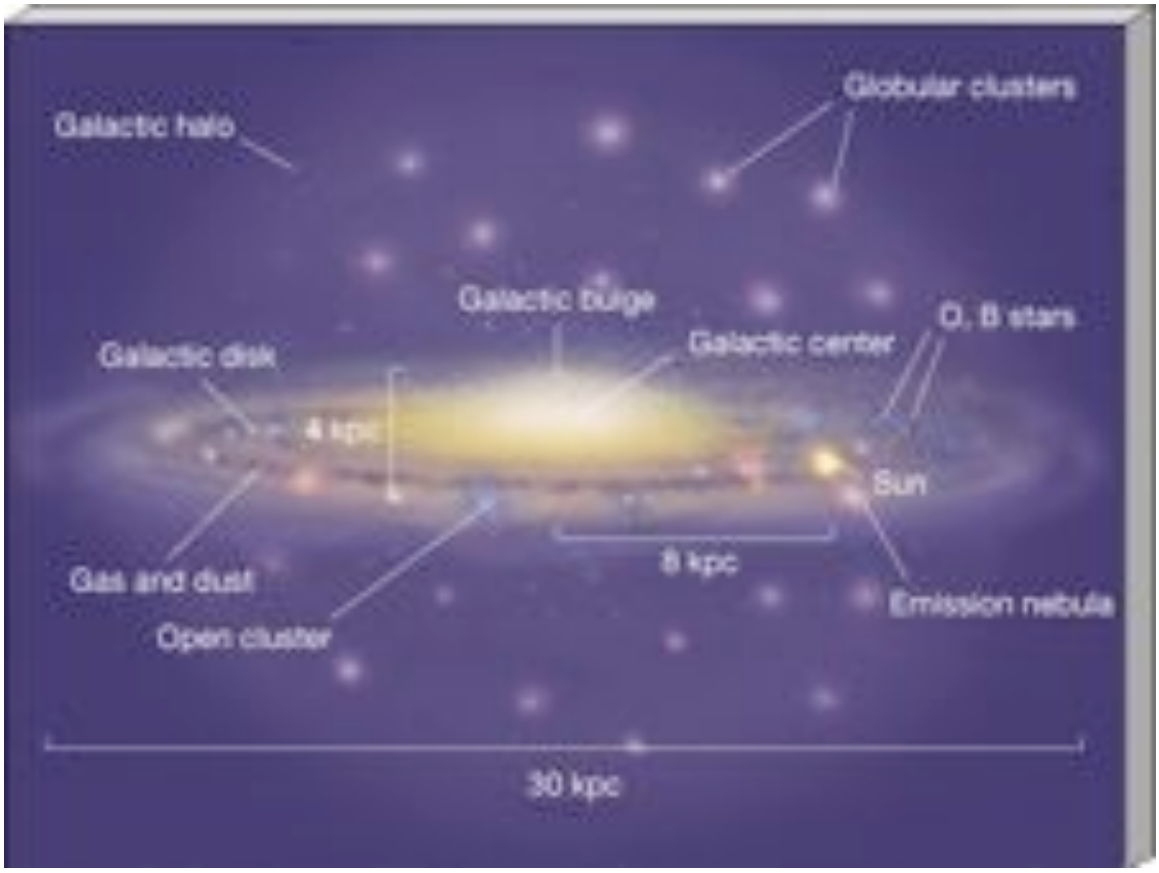


What Herschel didn't realize –and what was not discovered until the twentieth century – is that the disk of the Galaxy is filled with "dust" – microscopic particles that absorb starlight. The dust forms a thin layer about 100 light-years thick in the middle of the disk. This dust layer is quite obvious in other spiral galaxies that are seen edge-on. The dust lane in the Milky Way is visible to the unaided eye; it appears as the "Great Rift" divining the Milky way into two streams extending from Cygnus toward Sagittarius.

The Milky Way from Cygnus (left) to Sagittarius (right), showing the dust lane known as the "Great Rift." (J.P. Gleason).

The dust prevents us from seeing more than a few thousand light-years through the disk, although we can easily look *out* of the disk. Since the center of the Milky Way is 25,000 light-years away, Herschel was seeing only a tiny part of the Galaxy in his telescope.

It wasn't until Shapley mapped out the size of the Milky Way using the globular clusters (as discussed in Chapter 3), that it was realized that the Sun is located far from the center of the Galaxy, about halfway out to the edge. Soon after, the American astronomer Trumpler demonstrated the existence of the dust that prevents us from seeing far through the disk of the Galaxy.



STRUCTURE OF THE MILKY WAY

The Milky Way is a barred spiral galaxy. Like any spiral galaxy, it has three basic components:

1) the Galactic Bulge

2) the Disk

3) the Halo

The whole thing is roughly 100,000 light-years or 30 kiloparsecs across. The number of stars in the Galaxy is quite uncertain, but it is of the order of hundreds of billions, perhaps as many as a trillion. That's a lot of stars!

The Halo

The **halo** is a sparse population of stars that envelops the disk. The precise dimensions of the halo are unknown, but probably extends 100,000 light-years or more from the center of the Galaxy. The most visible part of the halo are the **globular clusters,** large round groups of hundreds of thousands of stars. The globular cluster stars, as well as the free stars in the halo, are mostly quite old: over 10 billion years. Given their age, and the fact that they have low amounts of heavy elements, tell us that these stars were the first stars to be formed in the galaxy.

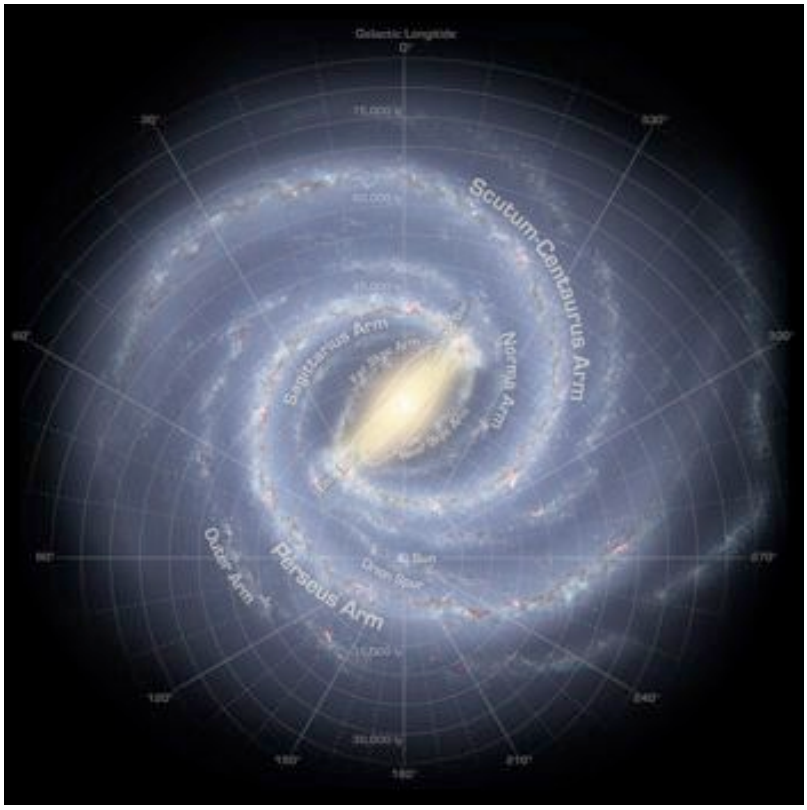
There are about 300 globular clusters in the Milky Way Galaxy. The largest by far is **omega Centauri,** which has over a million stars. It is thought to be the core of a dwarf galaxy that was absorbed by the Milky Way. Omega Centauri is really a star name; the cluster is bright enough to be seen with the unaided eye, looking like a rather dim star. In the telescope, it is one of the most beautiful things in the sky. Second in size is **47 Tucanae,** which is in the southern sky. It can be seen with the naked eye near the Small Magellanic Cloud.

The Disk

The Disk of the Galaxy contains the spiral arms. It is difficult to map the structure of the spiral arms from the inside of the galaxy, but their approximate location can be worked out by studying

clouds of hydrogen that give off radio waves at a wavelength of **21 cm.** Radio waves pass freely through the dust, so can be see clear on the other side of the Galaxy.

In the 90s it was realized that our Galaxy has a bar in the center, like many spiral galaxies. It was noticed before because we see the bar nearly end-on. It is now thought that the two main spiral arms emerge from the ends of the bar. This is typical of barred spiral galaxies.



A map of the Milky Way as it might be seen from above. Don't take this map too seriously; it involves a lot of guesswork, and so my look very different ten or twenty years from now. Note the Sun's location on the Orion "Spur".

The Sun is located in the **Orion Spur,** a minor arm located between the main Perseus and Scutum-Centaurus arms. We are on the inside of the Orion Spur, so when we are looking toward the galactic center (in the direction of Sagittarius and Scorpius), we are looking across a gap about 2000 light-years wide toward another small arm or spur, the **Sagittarius Arm.**

The Sun's immediate vicinity is a small region a few hundred light-years across where the interstellar medium is hotter and thinner than average. This region is the **Local Bubble.**

Contained within the spiral arms are the **open clusters** and the **nebulae.** Nebulae are tenuous clouds of hydrogen gas mixed with a sprinkling of dust. If a hot star is nearby, the ultraviolet light of the star will energize the hydrogen gas, causing it to glow. The process is called **fluorescence** because it is similar to the way a flourescent light works. A fluorescing nebula is called an **emission nebula,** because the clouds is emitting light. In other situations, the light from the star will be reflected by the gas and dust, creating a **reflection nebula.** Reflection nebulae are bluish in color. Very dense nebula are black because the dust blocks all light from passing though the clouds; this is a **dark nebula.** Emission nebulae, reflection nebulae, and dark nebulae are all the same thing; they are just illuminated differently. A general term for all three is **diffuse nebula.** ("Nebulae" is the plural of "nebula.")

Diffuse nebulae are where new stars are born. They form in groups of a few hundred to a few thousand, creating an open cluster of stars all about the same age. In other words, nebulae turn into open star clusters. The nearest star cluster to the Sun is the **Ursa Major Moving Cluster,** which comprises most of the stars of the Big Dipper. It is about 100 light-years away. About twice as far away are the **Hyades,** which make up the head of Taurus the bull. About 400 light-years away are the **Pleiades** or 7 Sisters. Most people can only see six stars, so why it's called the 7 Sisters has long been a mystery! Another famous nearby cluster is the **Beehive Cluster,** also know by its Latin name, **Praesepe,** which means "manger." Two stars on either side of the Beehive are called the **Asselli** – the Little Asses!

The Hyades (left) and Pleiades (right) in Taurus. (Fuji).

In contrast to diffuse nebulae, which are large and irregular in appearance, **planetary nebulae** are small and round. This is a completely different phenomenon. Instead of being places where new stars are born, planetary nebulae are stars that are dying, in the process throwing off their outer layers to form a cloud of gas. This cloud is energized the the UV light of the exposed stellar core, causing the nebula to fluoresce.

The Helix Nebula, planetary nebula in Aquarius. (Hubble Space Telescope)

A **supernova remnant** is the expanding cloud of debris from a massive star that explodes at the end of its life. The most famous supernova remnant is the **Crab Nebula** in Taurus. This cloud is the site of a star whose explosion was seen in the summer of 1054.

The Crab Nebula (M1) in Taurus. (VLT)

The spiral arm are explained by **spiral density wave theory.** In essence, the spiral arms are giant traffic jams. Stars continually move into the spiral arms, slow down and bunch up, then speed up and spread out as they leave the arm. At the same time, the gas and dust also bunches up. This triggers the formation of nebulae and star clusters. If you look down on a spiral galaxy, you will see a dense lane of dust lining the inside of the spiral arm. Associated with the dust lane are diffuse nebulae and star clusters. The biggest and brightests stars, the **O and B stars,** form in the spiral arms but die before they have the time to move out of the arms. Consequently, these bright stars light up the spiral arms and give them their bluish color.

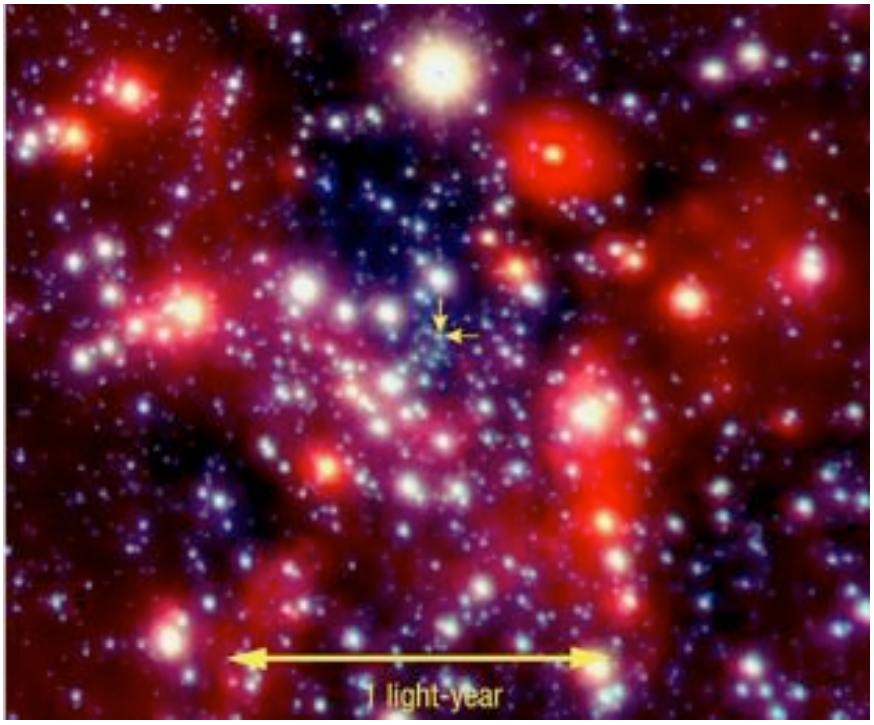
The spiral galaxy NGC 6946 in Cygnus. Note the pink emission nebulae and the dark dust lanes marking the spiral arms. (Gemini Telescope)

The Galactic Center

Extending out about 10,000 light-years from the center is the **galactic bulge,** the thick center of the Galaxy. The bulge is like a small elliptical galaxy in the center of the disk. There is in general less gas and dust and less star formation in the bulge, so the stars found there are old and yellowish. Aimed nearly at the Sun is the **bar,** to which the two main spiral arms are attached.

The **galactic center** is the active region within 200 light-years of the exact center. This region is rich in gas. There is a lot of star formation which leads to frequent supernovas. The supernovas inject a lot of energy into the gas, causing it to give off radio waves. The galactic center is the brightest source of radio waves in the sky after the Sun. In the jargon of radio astronomy, the galactic center is called **Sagittarius A (Sgr A).**

For many years, the galactic center was hidden from view by the vast clouds of gas and dust in the spiral arms between the Sun and the center. It is impossible to see more than a few thousand light-years in the direction of the center, which is 25,000 light-years away. Infrared light, however, is not absorbed by the dust as much as visible light. With the development of infrared telescopes in the 1980s, astronomers could at last peer all the way to the very center of the Galaxy.



The galactic center in infrared light.

Here we see a dense cluster of stars clustered into the central light-year. Recall that the nearest star to the Sun is 4 light-years away. If you were living in the galactic center, the sky would be ablaze with bright stars – even in a big city!

A small pinprick at the very center is the source **Sgr A*** (read "Sagittairus A-star"). Astronomers have seen stars orbiting about this point at high speeds. Using Kepler's Third Law, they can calculate that Sgr A* must have a mass of three million times the mass of the Sun. Since we do not see three million stars there, we can only conclude that Sgr A* harbors a supermassive black hole. At present the black hole is quiet, but if a star were to come close, it would be ripped apart by the gravity of the black hole and vast amounts of energy would be released.