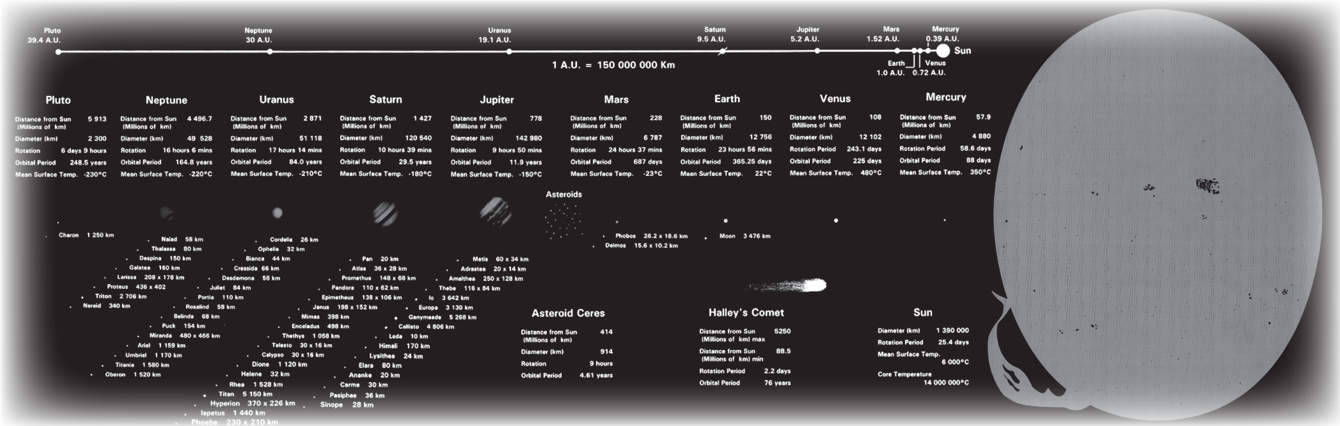


A Collection of Curricula for the STARLAB® Solar System & Galaxy Cylinder

Including:

The Solar System and Its Place in the Galaxy
by Murray R. Barber F.R.A.S.

Curriculum Guide Contents

The Solar System & Galaxy Cylinder

Curriculum Notes

1. Solar System & Galaxy Cylinder Review — The Solar System & Galaxy Cylinder shows a representation of our own galaxy, the Milky Way and the principle astronomical objects that make up the solar system. The Milky Way image is shown on top of the cylinder and the solar system around the walls of the cylinder. The Solar System & Galaxy Cylinder is supplied with magnetically attached covers that allow the lecturer to show either one or both projections.
2. Milky Way Representation — The top projection of the Solar System & Galaxy Cylinder shows an artist's impression of the Milky Way based upon recent astronomical studies in color. The central areas of the Galaxy are colored yellow, the spiral arms are mainly blue. Adjacent to the title text "The Milky Way," a scale in increments of 10,000 light years can be seen. The Milky Way, hence forth called the Galaxy, is seen in plan view (from above or below) from a position of 65,000 light years below its southern pole as seen from the center of the STARLAB. A bright, roughly bar-shaped core radiates spiralling arms and numerous spurs that fade out towards the edge. Stars, dust and gas can be seen within the Galaxy. Located in a position roughly opposite from that of the solar system can be seen an elliptical patch of light which is a second, much smaller galaxy that is passing the plane of the Galaxy.
3. Solar System Representation — The wall projection of the Solar System & Galaxy Cylinder shows the Sun and the nine known planets in correct scale allowing comparisons to be made in size from one object to the other. The distances between the planets and the moons are not shown to scale but as a uniform separation.
4. The Sun image is shown in a yellow color. Leaping away from Sun's atmosphere is a large prominence or flare. The Sun's surface is marked with sun spots.
5. The planets are shown in their correct order away from the Sun. Between Mars and Jupiter, a representation of the asteroid belt is shown. As an important representative of comets, Comet Halley is also shown. Above each planet is a table showing basic information including:

   Distance from Sun in millions of kilometers

   Diameter in Kilometers

   Rotation

   Orbital Period

   Mean Surface Temperature
6. Tables of important information can also be seen adjacent to the Sun and Comet Halley. As an important representative of asteroids, information regarding asteroid Ceres can be seen under the asteroid belt.
7. Sixty-one natural satellites or moons can be seen coming away in correct order from their parent planet. Each moon is identified and its dimensions are indicated. Dimensions for non-spherical moons are shown with the longest dimension first. Projected moon sizes below 1,550 km (963 miles) in diameter are not shown to scale but as a uniform size. Moons above the threshold of 1,550 km size are shown in approximate scale with one another and the planets.

8. The projection seen at the top of the wall of the Solar System & Galaxy Cylinder shows the distribution of the planets relative to the Sun at their correct scaled distances but not sizes. The unit of measurement used is the astronomical unit (AU). This unit assumes the mean distance of the Sun to the Earth (150,000,000 km or 93,205,500 miles) to be equal to one and is expressed as 1.0 AU. As the distance from the planets to the Sun increases, the AU gains a greater value. This projection allows for quick and easy comparisons to be made to demonstrate the size of the solar system and the separation of the planets relative to one another and the Sun.
9. The gas planets are shown in color. Cloudy atmospheric details can be seen within the projected images of Jupiter, Saturn, Uranus and Neptune.

The Milky Way Galaxy

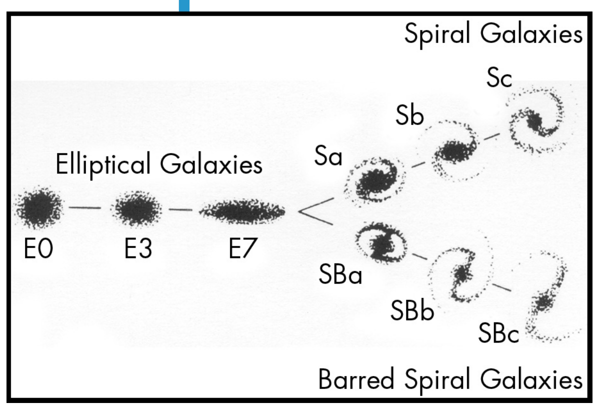
Background Information

The Milky Way Galaxy is a gigantic structure containing about two thousand million (two billion) separate stars, one of which is the Sun. During the evenings of summer from dark country locations, a faint band of light can be seen stretching across the sky from the northeast to the southwest. This band of light is composed of seemingly countless stars contained within our Galaxy, the Milky Way. The expression 'Milky Way' was coined by the ancient Greeks. To their imagination, the Galaxy looked like spilt milk upon a dark background. In Greek mythology it is associated with the infant Hercules over-enthusiastically suckling upon the unsuspecting Hera. The word "galaxy" is taken from the Greek word for milk.

Discovery of the Galaxy

The first person to realize that the Milky Way was made up of millions of stars was the Italian astronomer and physicist Galileo Galilei (1564-1642) in 1610. With a simple telescope he constructed, Galileo saw that the stars we see with our eyes are but a small fraction of the total number of stars within the Galaxy. Unbeknown to Galileo, the Milky Way is but one of many millions upon millions of galaxies that exist in the universe.

Since 1610 our understanding of the Milky Way Galaxy has been transformed with the advent of large telescopes and technologies of which Galileo could not even have dreamed.



Appearance and Size of the Galaxy

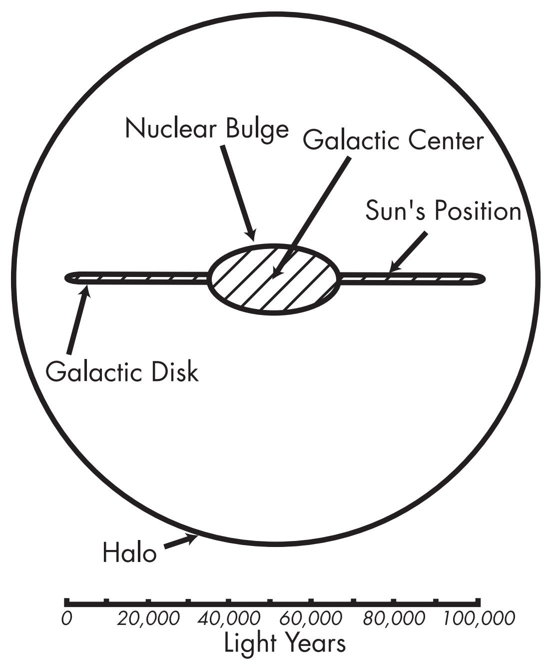
In the 1920s, the American astronomer Edwin Hubble (1889-1953) used the famous 100" Hooker Telescope on Mt. Wilson, California to devise a classification system of galaxies. This system is often represented in the schematic called the "Tuning Fork Diagram."

There are three basic types of galaxies — elliptical, spiral and barred spiral. There are also galaxies that have no recognizable, geometric shape called irregular galaxies. Our own Galaxy is classified as a "SBb" — a barred spiral galaxy.

The appearance of the Galaxy in section is like two fried eggs, sunny-side up, attached back to back. The central area or nuclear bulge contains gas, dust and is populated by elderly stars that are closely packed together. Moving away from the yoke along the thinning white of the egg, the number of stars continues to reduce towards the extreme feathered edges. This region from the nuclear bulge to the edge is called the ***galactic disk***. The entire Galaxy is contained within an enormous sphere or ***halo***. The outer region, like the nuclear bulge, contains elderly stars, dust and gas but very thinly spread.

The Galaxy as seen in plan (from above or below), consists of a central nuclear bulge of closely packed stars arranged in a bar-like form with ***spiral arms*** of young stars, dust and gas gradually unwinding towards the outer edge.

Sectional View of the Milky Way Galaxy

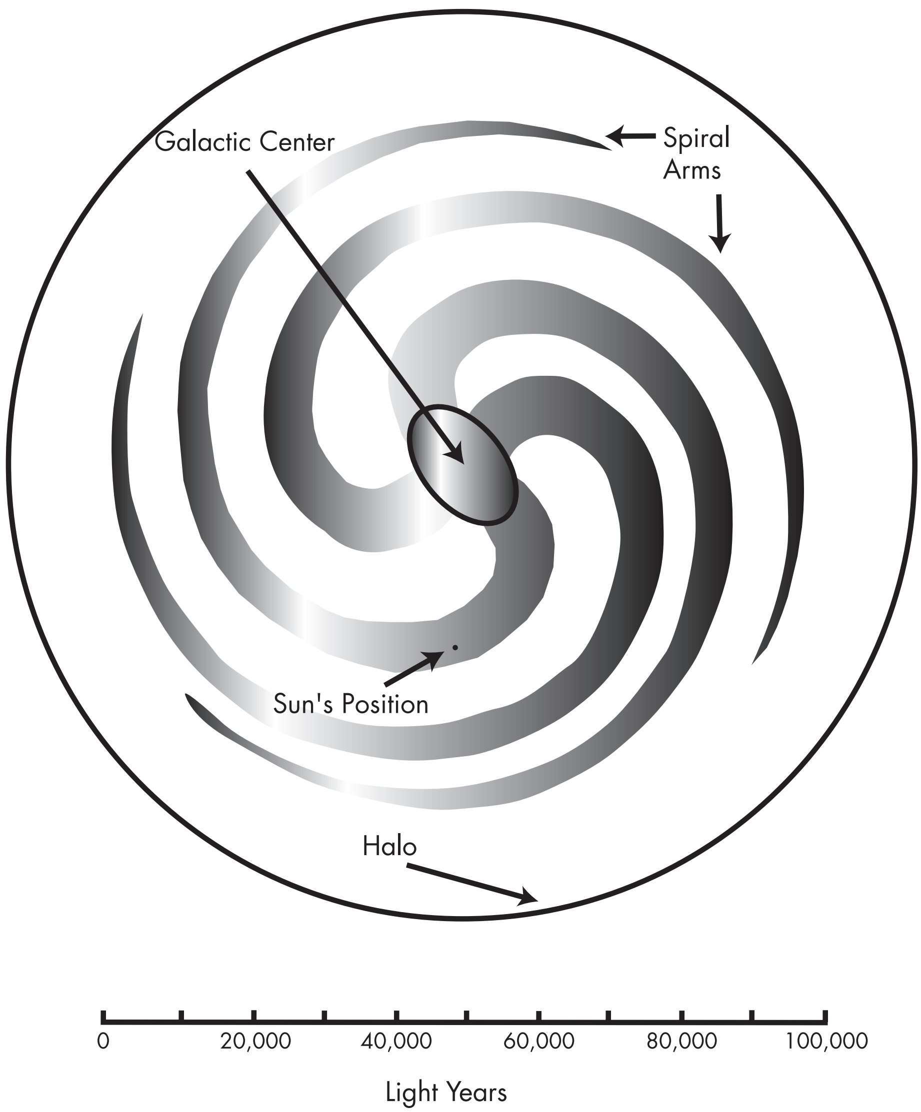


The dust, gas and stars within the Galaxy rotate about a central point within the nuclear bulge called the ***galactic center***. Distances measured within the Galaxy and its local neighborhood are measured in light years.

Light Year

Before detailing the five important features of the Galaxy, a sense of scale must be appreciated. The Galaxy is vast. Its diameter is so enormous that to use miles or kilometers to describe it would be very awkward and unwieldy. To measure the size of the Galaxy, the preferred unit is the ***light year***. The velocity of a beam of uninterrupted light travelling in a perfect vacuum is 299,792.5 km per second (186,291.1 miles per second) or approximately 300,000 km a second. To put this in some form of perspective, the Apollo astronauts took three days to travel to the Moon. If they could have travelled at the speed of light, their journey would only have taken them one and a quarter seconds! In one year a beam of light would travel 9,460,000,000,000 km (or 5,878,000,000,000 miles). This distance is referred to as the light year and is one of the standard units of measurement used by astronomers.

Plan View of the Milky Way Galaxy



The following table gives the important statistics of the Galaxy.

Diameter	*100,000 light years*
Nuclear Bulge Diameter	*32,000 light years*
Galactic Disk Thickness	*1,500 light years to 2,000 light years*
Halo Diameter	*130,000 light years*
Distance of Solar System from Galactic Center	*25,000 light years to 27,000 light years*
Rotational Speed	*220 km per second/136.7 miles per second*
Sun's Orbital Period Around the Galactic Center	*240 million years*
Number of stars	*100 to 200 billion*

Nuclear Bulge

At the Galaxy's center, the flattened spherical nuclear bulge glows with the light of crowded elderly yellowy-red stars. The center of our Galaxy is located in the constellation of Sagittarius. The stars have an estimated age of 10 billion years and are often referred to by astronomers as "Population II" stars. They travel around the galactic core in highly eccentric and often steeply-inclined orbits. Contained in the nuclear bulge is interstellar gas and dust clouds in which limited star formation is taking place.

Evidence from the Infrared Astronomical Satellite (IRAS) suggests that within the nuclear bulge there exists a bar-like structure of stars, gas and dust. From our vantage point, astronomers have detected that the bar is nearly edge on. This bar is approximately 17,000 light years long and about half as wide. IRAS has been able to peer through the obscuring material in our line of sight towards the center of the Galaxy and detect fast moving clouds at a distance of 5,000 light years from the Galactic core. This high speed is due to the gravitational influences of the bar. Examples of this type of bar feature are seen in other galaxies like M61 in the constellation of Virgo and M83 in the constellation of Hydra.

Galactic Center

The use of modern astronomical techniques using infrared, X-rays and gamma ray detection often in orbiting telescopes and radio telescopes here on the ground have given astronomers a well-resolved impression of the galactic center. Details smaller than the size of our solar system can be studied. It has been discovered that at the center of the Galaxy, and contained within the bar-like structure of the nuclear bulge there is a great concentration of mass, heat and turbulence. At a distance of 500 light years from the galactic center is a ring of comparatively cool clouds containing a rich and exotic chemistry of molecules. Motion in the ring may have been caused by a powerful explosion. This ring is called Sagittarius B2. Within this region, powerful magnetic fields have been detected in connection with a huge mass.

At the precise center of the Sagittarius B2 lies a mysterious object referred to as Sagittarius A. Although the evidence is confused due to a possible supernova explosion that has occurred in this region, many astronomers believe that part of the mass detected in Sagittarius A is in fact a black hole and it is this object that is responsible for much of the strange observations. This conclusion is controversial but, if true, the black hole is believed to have a mass three million times greater than the Sun. The second part of the mass is made up by five million solar masses of stars. It is often said that the galactic center is the "powerhouse" for the entire Galaxy.

Galactic Disk

Our Galaxy rotates because of gravitational influences and is flattened in shape. The thickness of the galactic disk relative to its diameter can be likened to the proportions of two CDs placed back to back. It contains mostly young blue stars that are referred to by astronomers as "Population I" stars. These stars are between one million and 10 billion years old.

The void between the stars in the Galaxy is called the interstellar medium. Once thought to be empty, the ***interstellar medium*** contains very thinly distributed dust and atoms of hydrogen gas. About 10% of the mass of the galactic disk consists of gas and dust from which new stars form. The gas within the feathered edge is slightly warped like the brim of a hat.

From a great distance in space looking back along the plane of the galaxy, the edge-on view of the galactic disk would not glow with an even light. The brightest part of the Galaxy would emanate from the galactic core but the galactic disk would glow with a mottled appearance. This is due not only to the distribution of stars but also due to the effect of regions of glowing gas and dust. Some of the dust and gas would behave like a foreground filter, obscuring brighter background material. Good examples of this effect can be seen in the galaxy M104 in Virgo. It is along the plane of our Galaxy that we see the Milky Way during the night. If it was possible to view our Galaxy from a great distance, it would be necessary for the observer to allow his or her eyes to become completely light-adapted and sensitive. The photographic appearance of galaxies as seen in text books suggests great brightness which is not actually the case.

Some of the brightest stars of the Galaxy are within the galactic disk and are relatively short-lived. Also within the galactic disk are found most of the objects that form the basis for any text book on astronomy. For example, double and variable stars, star clusters, nebulae, planetary nebulae, novae and supernovae.

The galactic disk and nuclear bulge are rotating but not in the manner of a solid body like a phonographic record, nor in the manner of the objects in the solar system. The rotation is due to gravitational effects inside and outside of the Galaxy. Because the mass of the Galaxy is widely separated, instead of increasing all of the way towards the edge, the rotation period, in fact, steadies down to a fixed speed. This reduced speed and steadying effect is believed to be caused by the presence of unseen dark matter beyond the plane of the galactic disk. The speed of the solar system and local neighborhood of stars around the galactic core is estimated to be 220 km per second (137 miles per second) or 804,640 km per hour (500,000 miles per hour). One rotation has a duration of about 240 million years and is often called the ***galactic year***. Since the solar system was formed, the Sun has orbited the galactic center 20 times, hence our existence is within the 20th galactic year!

In a position opposite to the solar system and on the extreme edge of the galactic disk, a small galaxy has recently been discovered. This object is called the Sagittarius Dwarf Galaxy after the constellation in which its presence was detected. It is approximately 80,000 light years away from the solar system and about 50,000 light years away from the galactic core. The Sagittarius Dwarf Galaxy is about 10,000 light years long. Its apparent size in the sky is roughly 10 by 5° which equals an area 20 times the size of the full Moon. Impressive as these dimensions are, the Sagittarius Dwarf Galaxy is impossible for us to see directly as it is obscured by dust and gas in our line of sight. It is passing through the plane of the galactic disk travelling north to south as it orbits our Galaxy. It is unlikely that stars in the two galaxies will collide because of the large distances that naturally separate them. It is, however, possible that inter-reactions between gas and dust of the interstellar medium might lead to star formation.

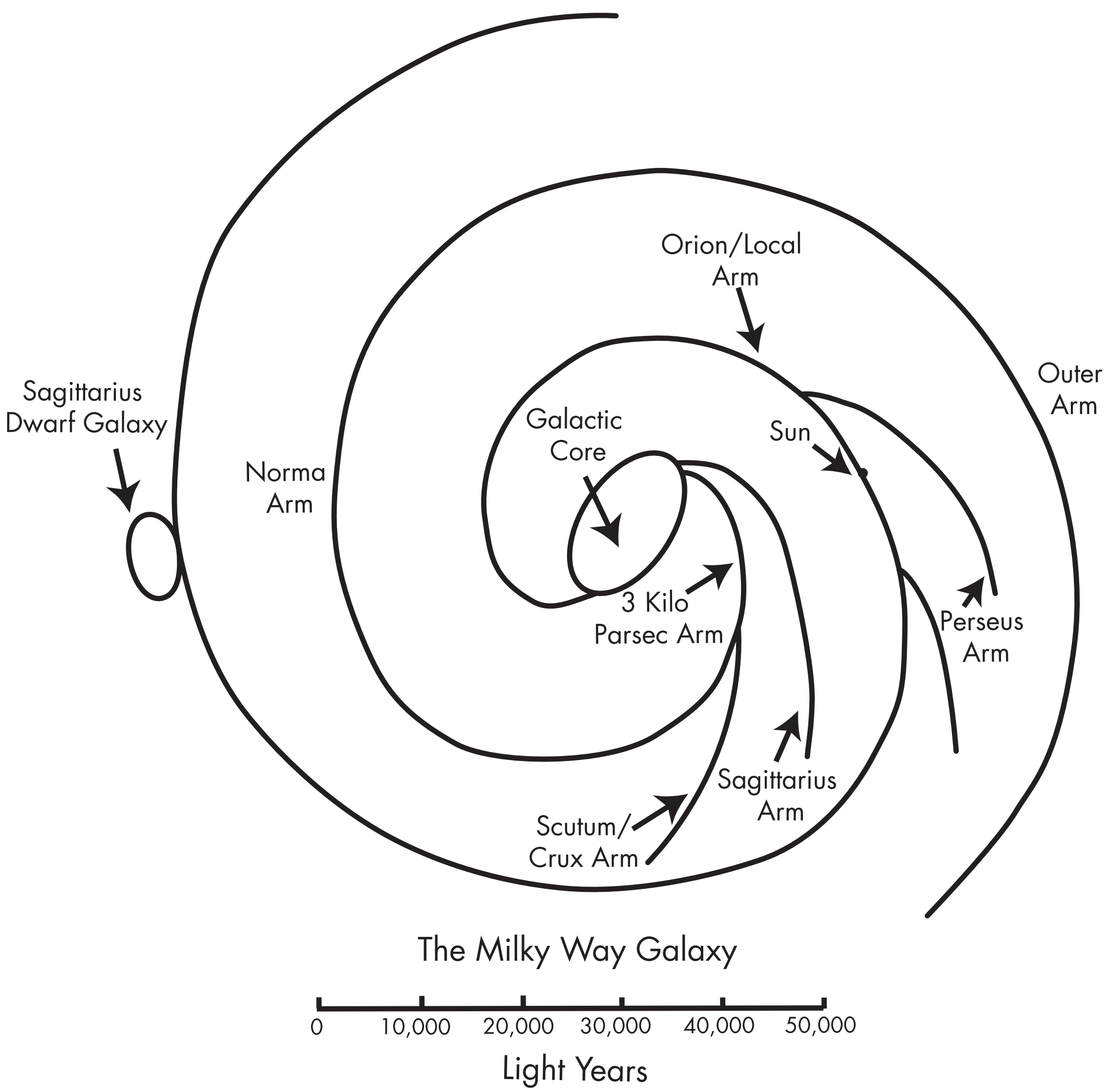
Spiral Arms

Our Galaxy, as seen from above or below, would be a truly awesome sight. Sweeping away from the central bulge, spiral arms would radiate out towards the edge of the galactic disk. The arms would not be perfect mathematical spirals but instead would be distorted due to local and external gravitational effects. Modern astronomical techniques help to give an impression of our galaxy's spiral arms but at this time, no single complete and commonly held description exists. The difficulties arise from the obscuring material present in the Galaxy. Direct visual observations are impossible. The very first maps to show the spiral arms in our Galaxy were produced in the mid 1970s using radio astronomy. These maps show spiral arms not as continuous sweeping structures but disjointed arcs trailing away from the galactic core. The breaks in information are due to instrumental and observation difficulties.

The description that follows is therefore an attempt to combine current theories into a coherent picture. Coming away from the galactic bulge, two (or possibly four) spiral arms unwind — perhaps one and a half times towards the edge of the galactic disk. Smaller arms or spurs also spiral out away from the main arms. It is within one of these arms that the Sun is located. All of the stars that we see at night are located within these arms. The solar system is in the ***local arm***, which astronomers often refer to as the Orion arm. When we look towards the galactic core of our Galaxy, we are in fact looking towards another spiral arm. This is called the ***Sagittarius arm***.

A Schematic of the Galactic Cylinder Milky Way Projection

(as seen looking towards its Southern Pole)



Unseen to us and beyond this arm in the direction of the core, lie two further arms, the ***Scutum–Crux*** and the ***3 Kiloparsec***.

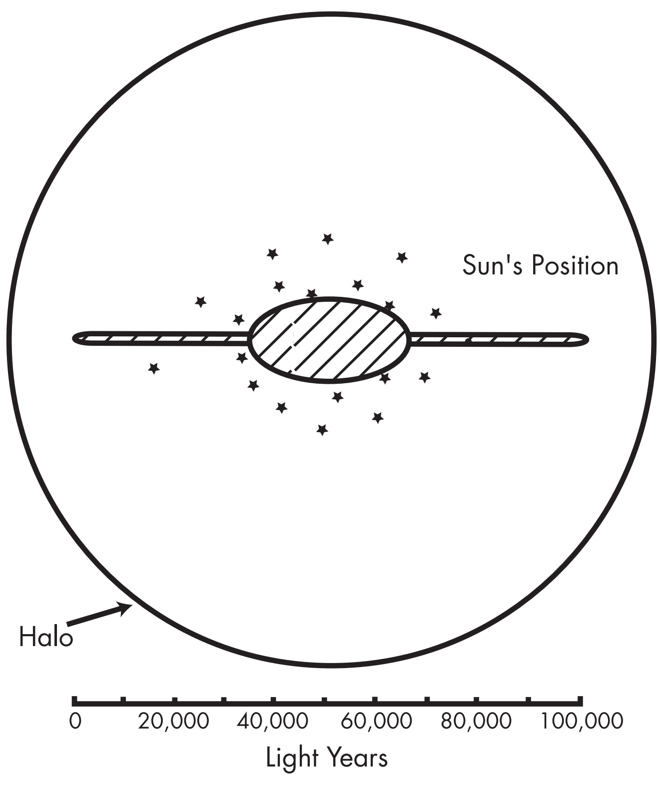
When we look out towards Sagittarius during the summer nights, we are peering towards the galactic core and when we look behind us in the opposite direction we are gazing towards the thinnest part of the galactic disc towards Orion in the winter sky. The winter Milky Way is a great deal less bright than the summer Milky Way.

Peering at right angles away from the plane of the Galaxy our eyes fall upon the constellation of Coma Berenices. It is within Coma Berenices that the North Galactic Pole is plotted on star atlases. In a direction opposite to this lies the Southern Galactic Pole in the constellation of Sculptor. It is in these two opposing directions that the least amount of obscuration of dust and gas occurs. Not surprisingly, astronomers are able to study very remote far flung galaxies in these regions.

The Sun in the local arm is moving at a higher speed than the local stars. It is also moving in towards the galactic core in a roughly elliptical orbit. Additionally, the Sun is moving upwards and is about 50 light years from the Galaxy's plane. This motion will continue until the Sun is about 250 light years above the plane, thereafter gravitational attraction will pull it back to the plane of the Galaxy. As the Sun falls, it will gather momentum and then continue its motion through the galaxy's plane until once more gravity brings it back. This constant bobbing up and down motion through the plane of the Galaxy occurs once every 33 million years and might be associated with mass extinction here on the Earth. The evidence for this, however, is not strong.

Strewn along the spiral arms are vast clouds of dust and gas. These clouds are called nebulae and it is from these that clusters of stars have evolved. Red colored clouds shine with the light of excited gas and are called ***emission nebulae***. Blue colored clouds shine with reflected light from nearby stars and are called ***reflection nebulae***. The nebulae are eventually consumed during stellar evolution or simply thin out into the interstellar medium. The stars in the clusters also in time gradually disperse into the throng of the Galaxy.

Sectional View of the Milky Way Galaxy
Showing Distribution of Globular Clusters



The presence of spiral arms is currently explained by ***Density Wave Theory***. This theory assumes that a galaxy's contents are evenly distributed like an even layer of cream floating and rotating on a cup of coffee. The even distribution is disturbed by either internal effects like supernova explosions or the gravitational influences of a passing galaxy. In much the same way that a stirring spoon affects the cream, the accidental influences of exploding stars and temporary gravitational imbalance encourages the development of the spiral arms. Once produced, the spiral arms are very long-lived as they sweep around the Galaxy. The density wave can be thought of as slow-moving traffic caused by trucks on a freeway. As cars from behind join the jam and gradually make their way through the congestion, other cars having passed the trucks gather speed and continue on their way.

As the density wave sweeps through the galactic plane, it causes compressional effects in the interstellar medium. As the interstellar medium condenses into nebulae, star formation is initiated. The solar system has passed through the density wave of the spiral arm many times.

Density Wave Theory explains some of the phenomena seen in our Galaxy and others but not all. Although 75% of all galaxies are spirals, some of these have complicated shapes and distorted arms that are not easily explained.

Halo

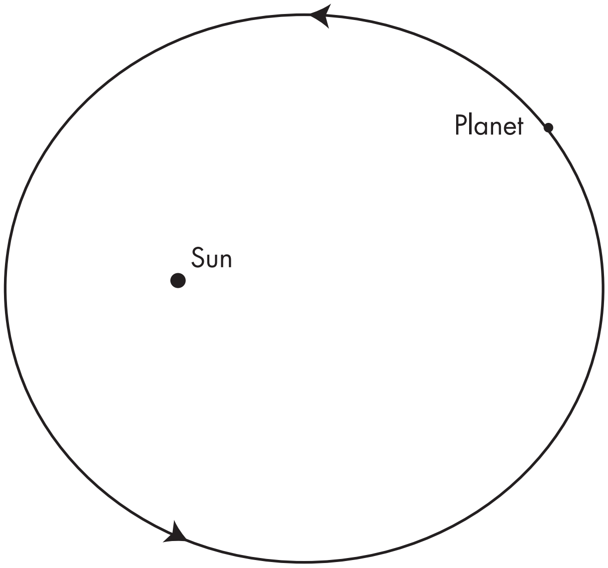
Surrounding and encompassing the Galaxy is a gigantic halo. The halo has a diameter of 130,000 light years and it contains a comparatively small number of old stars, globular clusters, very thinly spread gas, dust and ***dark matter***.

Visually the most impressive features of the halo are the ***globular clusters***. These are huge numbers of stars gravitationally bonded into spherical-shaped structures, 100 to 300 light years in diameter. The globular clusters are not only within the halo but are also distributed around the galactic bulge. Because of the line of sight effect, the greatest concentration of globular clusters is in Sagittarius. Globular clusters appear to be a product of the Galaxy's early formation and are extremely old containing cool red giant stars like the stars found in the galactic bulge. Globular clusters orbit the galactic core and sometimes pass through the galactic plane. There are about 140 known globular clusters in the Galaxy.

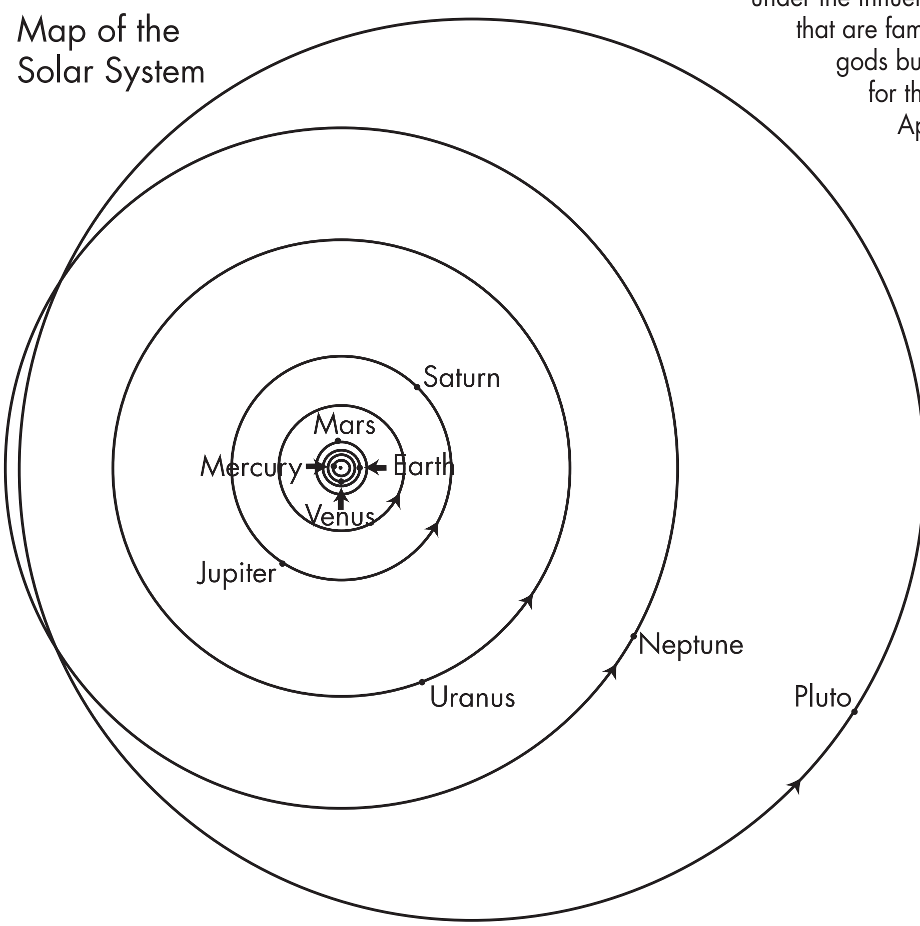
For astronomers, the most important feature of the halo is the dark matter. The dark matter, which is often detected in other galaxies, could be made of exotic subatomic particles, pebbled-sized objects or brown dwarf stars. The great interest in dark matter is that its presence explains the rotation of the outer parts of the Galaxy. This phenomena was mentioned earlier in the "Galactic Plane" section. By its very nature, dark matter is very difficult to study but astronomers are hoping that eventually the apparent discrepancy between the observable universe and the theoretical universe will be resolved. Simply put, there is not enough material in the universe to explain its existence. Perhaps the missing mass is the dark matter. The resolution of this discrepancy may ultimately determine not only the fate of the Galaxy but the universe as well.

The Solar System

A Solar System Planet
in an Elliptical Circle



Map of the
Solar System



The solar system consists of the Sun and nine major bodies — the planets. The planets travel around the Sun in elliptical orbits in regular periods of time. The solar system is also made up of smaller objects, planetary moons, meteors, asteroids, comets and thinly spread gas and dust. These objects also orbit the Sun. The distances separating the Sun from the planets is enormous. If the solar system were shrunk to the size of an average classroom, the planets would be microscopically small with the Sun slightly less than 1/2 mm in diameter!

The solar system can be divided into three main zones:

Zone One — The Sun and Terrestrial Planets

Zone Two — The Giant Gas Planets

Zone Three — The Oort Cloud

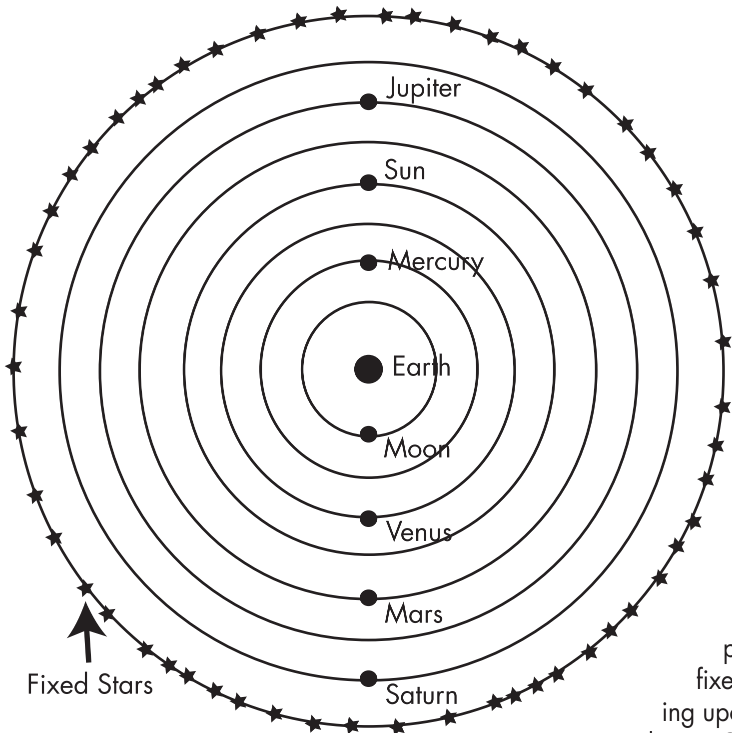
The planets Mercury, Venus, Mars, Jupiter and Saturn have been known since ancient times. These objects can be easily seen and are often called the "naked eye planets." The other planets, Uranus, Neptune and Pluto are not visible to the naked eye. Originally the planets were thought of as "wondering stars" under the influence of gods or goddesses. The names that are familiar to us are the names of Roman gods but the ancient Greeks had other names for the naked eye planets — Hermes, Aphrodite, Ares, Zeus and Cronus. Each of these deities, like the planets themselves, have different characteristics. Often in ancient religions, the Sun held a very special place. Ancient civilizations realized the supreme importance of the Sun and seasonal change, brought about by the Sun's motion through the twelve constellations of the zodiac, would be marked by religious festivals.

Discovery of the Solar System

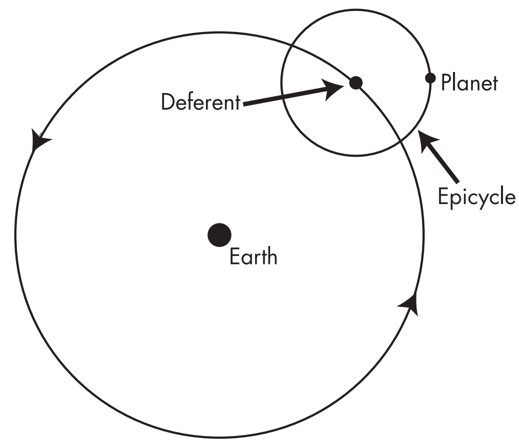
The ancients did not realize that the naked eye planets and the Earth revolved around the Sun. For thousands of years, it had been assumed that the center of the solar system and the entire universe was the Earth.

The famous Greek philosopher Ptolomy (120-180 A.D.), placed the Earth at the center of every-

The Ptolemaic System



Detail of the Ptolemaic System



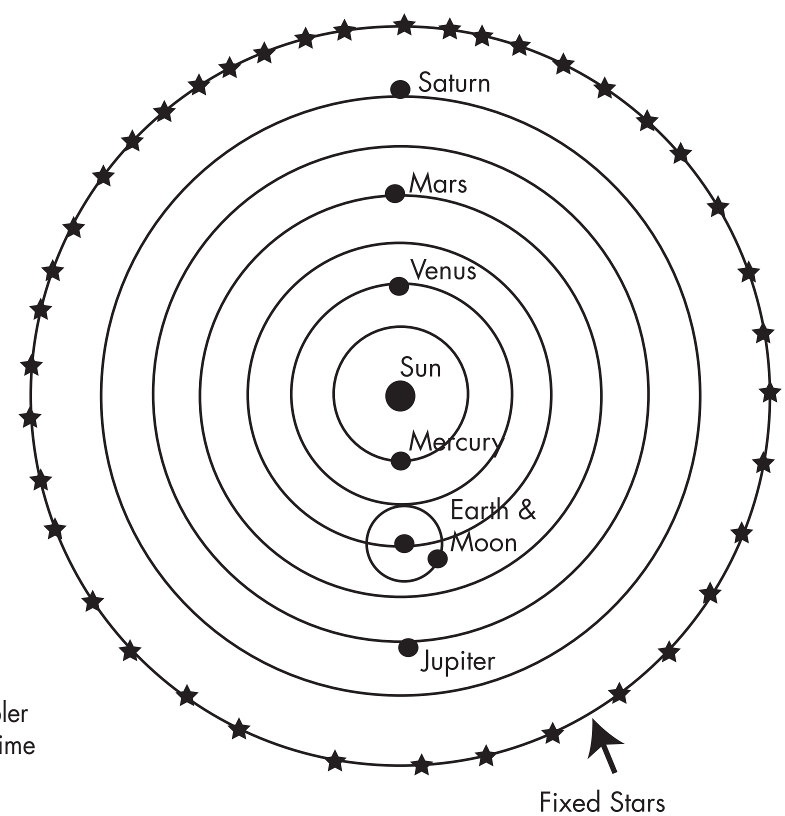
thing with the Moon, planets, Sun and fixed stars revolving upon transparent spheres. Occasionally, as the planets orbit the Sun, they appear as seen from the Earth to move backwards across the sky. This phenomena is called ***retrograde motion***. To explain this, Ptolomy also stated that the planets moved in an epicycle around a fixed point or deferent as it travelled the orbit. This archaic theory to explain the solar system is called the Ptolemaic.

The Polish astronomer Nicolas Copernicus (1473-1543), however, was convinced that the Sun was at the center of the universe and that the subservient planets revolved around it in perfect circles. This contrary and heretical view to the Ptolemaic was called the Copernican.

Later the German mathematician Johannes Kepler (1571-1630), using the statistical observational work of the Danish astronomer Tycho Brahe (1546-1601), proved with his famous "Three Laws of Planetary Motion" that not only did the planets travel around the Sun but that their orbits were elliptical.

As Kepler strived to produce the Planetary Laws, Galileo using his telescope made startling observations. He recorded the movement of the four bright moons in orbit around Jupiter in 1609 and in 1610 he observed the changing phases of Venus. His observations proved that the Earth was not the center of the universe. The conclusions of Kepler and Galileo were considered to be heretical, but in time they were accepted as fact.

The Copernican System



Although the observable workings of the solar system were now understood, the actual force responsible for maintaining the planets in their orbits remained a mystery. The English scientist and mathematician Sir Isaac Newton (1642-1727), determined the nature of this force — ***gravity***. It was named after the Latin word for heavy, "gravis." Newton's "Universal Law of Gravitation" states that:

> *". . . any two particles of matter attract each other with a force proportional to the product of their masses and inversely proportional to the distance between them."*

The same forces at work for an apple falling from a tree are observed throughout the solar system and the universe. The planets in motion are falling towards the center of the solar system but because they are moving at particular speeds within their orbits, they never 'fall' and reach the Sun.

The Universal Law of Gravitation in everyday life stood the pace of time very well for 300 years. However, as astronomical equipment and observational techniques became increasingly sophisticated, the law was seen to break down. The error was most acutely observed in the movement of Mercury as it orbited the Sun. In 1916 the German born American physicist Albert Einstein, (1879-1955), published the "General Theory of Relativity." This work superseded that of Newton's and completely explained the behavior of Mercury's orbit and the workings of the solar system.

Thanks to interplanetary robotic spacecraft, we now have a greater understanding of the physical characteristics of nearly all the planets and their moons.

Zone One, The Sun and Terrestrial Planets

The Sun

The Sun is a star like the many stars that are seen at night. It is a fairly ordinary star that astronomers refer to as a yellow/white variable dwarf star. It is believed that the Sun coalesced from a gigantic rotating nebula nearly 5,000 million years ago. As the Sun is the nearest star to the Earth, it is very closely studied to give astronomers an insight into the rest of the stars in the Galaxy. The most distinguishing feature is the retinue of objects that orbit and pursue the Sun as it travels through space.

The Sun is the single most massive object in the solar system and around it, bound by gravity, the planets orbit. The Sun is a sphere of mainly hydrogen and helium gas with a diameter of 1.4 million km which is 107 times larger than the Earth. It maintains a spherical form due to gravity and outward pressure and rotates on its axis once every 25.4 days.

Its energy is created by nuclear fusion deep at its core where pressure and temperatures are at great extremes. The surface temperature is 6,000° C, while at its central core the temperature is estimated to be 15,000,000° C. The nuclear process converting hydrogen into helium and hence producing energy is making the Sun lighter by as much as 5 million metric tons per second.

The central core of the Sun is surrounded by two main layers. The layers in order from the core are the radiative and convective zones. The movement of energy from the core of the Sun to its outer surface is believed to take ten million years. Energy is transported from the central core through the radiative zone by radiation. The energy then passes the convective zone through turbulent mixing of gases before eventually passing through the photosphere which is the upper atmosphere of the Sun. It is within the photosphere that telescopic features like the dark sunspots, towering prominences and arches of gas are detected.

Sunspots, prominences and arches are driven by magnetic forces and other disturbances under the photosphere. Sunspots are regions of cooler surface temperature and reduced luminosity and appear dark against the radiant surface of the Sun. They vary greatly in size from tiny spots to huge structures so immense that giant gas planets of the solar system could be dropped into them. Prominences and arches can only rarely be observed in natural light. Specialized equipment however can show huge amounts of gaseous material and energy being ejected into the perpetual solar wind of the Sun. Prominences can leap great distances out into space. The consequences of the Earth being 'struck' by the outburst of prominences can result in power outages, magnetic disturbances and the beautiful Aurora Borealis. Much of the solar phenomena like sunspots are not continuous but follow a regular 11 year cycle.

Above the photosphere is the chromosphere and above this lies the corona. The corona is seen spectacularly during a total eclipse as a pale pearly light surrounding the Sun. The corona consists of very rarefied gas at extremely high temperatures of approximately 2,000,000° C. The influence of the Sun stretches far out into space perhaps as great as 125 AU. It is often said by astronomers that the planets orbit within the outer atmosphere of the Sun!

Special Warning

Without the Sun's energy, life on the Earth would cease to exist. However, too much energy can be extremely hazardous. Students of astronomy should always be warned never to look at the Sun with the naked eye or directly with a telescope of any kind. Additionally students should also be warned of overexposure of the Sun to the skin. The energy of the Sun is passed through the solar system by a process called radiation and some of this energy is in the form of ultraviolet light and radiation that can do great damage to the skin in the form of premature aging of the epidermis and in extreme circumstances, skin cancer. The safest way to view the Sun is indirectly by projecting its image from a telescope onto a piece of white paper held at a distance from the eyepiece. Under no circumstances, however, should such a telescope in this guise be left unattended.

Terrestrial Planets

The planets in order away from the Sun are Mercury, Venus, Earth and Mars. The largest of the terrestrial planets is the Earth with a diameter of 12,756 km, the smallest is Mercury with a diameter of 4,880 km. The terrestrial planets are "crowded" within the central region of the solar system — a radius of only 228 million km (1.52 AU). The most striking features of these planets are the iron-nickel rich metal and silicate cores and the small number of natural satellites in orbit around them.

The terrestrial planets all have cores surrounded by a mantle and an upper crust. Mercury has the largest and densest core in proportion to the other planets. The Earth and possibly Venus are distinct because they have liquid inner cores. The inner cores typically have a temperature of 5,000 to 6,000° C and are responsible for the active geology of the Earth and possibly that of Venus. This high temperature is a consequence of radioactive isotope decay and residual heat from the collapse of dust and gas that formed the planets some 4,500 million years ago. Mercury and Mars now appear to be geologically inactive due to the cooled inner cores. Mars in the past was volcanically active and boasts the largest known volcano, Olympus Mons, 600 km in diameter and 27 km in height. Olympus Mons stands three times higher than Mt. Everest!

All the terrestrial planets show signs of impact from astronomical bodies during the early part of the solar system's evolution. Mercury, like the Moon, has no atmosphere and both show a very ancient surface. The surface of Mercury appears to have shrunk about its metal core. The freshest planetary geology is seen upon the Earth as weathering and plate tectonics are constantly eroding and remodelling the surface.

Venus has the most tortured surface of the terrestrial planets as it suffers greatly from the extremes of "Green House Effect."

Venus's thick and visually impenetrable atmosphere is rich in carbon dioxide with fast moving clouds of sulfuric acid. The effect of trapped heat, a highly acidic atmosphere plus the high atmospheric pressure has produced geology on Venus not seen elsewhere in the solar system. Lowland plains and huge rolling uplands are interrupted by shallow craters, valleys and possibly active volcanoes.

The Earth is of supreme importance as the depository of all known life. It occupies a very special place in the inner part of the solar system where temperatures are perfect to sustain life. This region is often referred to as the biosphere. If the Earth were any closer to the Sun, life would not be able to exist as is seen on broiling Venus. Any further away, life would not be able to exist because of perpetual freezing conditions as is seen on Mars. Earth is also significant because of its oxygen and nitrogen rich atmosphere and its ability to sustain water in all three forms; solid, liquid and gas. However, the presence of water in the form of ice has been detected in deep shadowy craters near the north and south poles of Mercury and the Moon.

Mars continues to fascinate and intrigue following NASA's announcement in August 1996 that life may have existed upon it millions of years ago. Photographic evidence suggests that in the past, Mars had a great deal of water and probably a denser atmosphere. Today, unfortunately, we know that Mars is a cold dry desert planet with a thin unbreathable carbon dioxide atmosphere. Like the Earth, seasonal changes due to the tilt of the axis affect the shrinking and expanding polar caps and Martian meteorology. Polar caps on Mars are made mainly of dry ice (solid carbon dioxide).

The geology of Mars is extraordinary. As previously mentioned, Olympus Mons is just one of four mighty extinct volcanoes. Due to the lack of plate tectonics, huge shield volcanoes have developed on the flat plains. Cratered highlands, canyons and channels are also important features. One vast canyon, Valles Marineris is over 4,000 km in length and in places over 7 km deep! These canyons appear to have occurred from geological faulting.

Planetary Moons of the Terrestrial Planets

Of the four terrestrial planets, only two have satellites or moons. The Earth's Moon is approximately 1/4 the diameter and 1/81 of the mass of the Earth. Although its origin is not precisely known, the "Big Splash" theory suggests that the Earth was struck by an object the size of Mars 4,500 million years ago. The ejected material then coalesced to form the Moon. Alternatively, perhaps the Moon was formed elsewhere in the solar system and was somehow captured to orbit around the Earth. As the Moon orbits the Earth once every 27.3 days, it displays changes in illumination called phases.

Mars has two small potato-shaped moons, Phobos and Deimos. They appear to be captured asteroids and orbit Mars in 8 hours and 30 hours respectively. The Moon, Phobos and Deimos are airless ancient objects and carry the scars of meteor impacts.

Asteroids

Distributed mostly along the plane of the solar system, between the orbits of Mars and Jupiter is the asteroid zone. Asteroids are believed to be the remnants from an earlier time when the solar system was formed. They vary in size from the largest, Ceres, at 914 km in diameter to the size of dust grains. It has been suggested that asteroids may have been the 'building blocks' for a planet that was prevented from forming due to the gravitational influences of Jupiter. The greatest concentration of asteroids lies between 2.0 and 3.3 AU from the Sun. The distribution of asteroids is not even and it is now known that different groups exist. The first of over 7,200 known asteroids was discovered by the Italian astronomer and monk, Giuseppe Piazzi (1746-1826) in 1801.

Zone Two, The Gas Planets

Ranging from 5.2 to 30.0 AU from the Sun is the realm of the giant gas planets, Jupiter, Saturn, Uranus and Neptune. Although Jupiter and Saturn were known from ancient times, Uranus and Neptune were discovered through telescopic observation and with respect to Neptune, mathematical predictions. Uranus was discovered by the German born English astronomer William Herschel (1738-1822) in 1781 using a telescope from his backyard in Bath, England. Oddities in the motion of Uranus's orbit suggested the gravitational influences of a further, more remote planet. Neptune, as it was later to be named, was discovered by the German astronomer J. G. Galle (1812-1910) in 1846 after its position was independently calculated by J. C. Adams (1819-92) and U. J. J. Le Verrier (1811-77).

The most striking features of gas planets are their great size and distance from the Sun. The largest, Jupiter, is approximately ten times larger in diameter than the Earth. The smallest, Neptune, is nearly four times larger than the Earth. Light from the Sun takes 41 minutes to reach Jupiter and four hours to reach Neptune.

The giant planets all possess solid metal and silicate cores surrounded by gas. Although proportions and quantities vary, the most abundant of these gases is hydrogen and helium. The gasses of Uranus and Neptune contain greater amounts of methane, ammonia and water than Jupiter and Saturn. The cores of the gas planets are subject to high pressures and in the case of Jupiter in particular, high temperatures. Due to extreme conditions, the gas closest to the core is metallized. This inner core is surrounded by a spherical shell of liquid gasses. As pressure and gravity reduces further away from the core, the gas atmospheres take on a more familiar appearance of clouds.

The most dynamic atmosphere of the gas planets is Jupiter. Its outermost atmosphere is banded in zones, belts of pastel-shaded clouds, festoons and white ovals. The most distinctive feature on Jupiter is the famous Great Red Spot. The GRS as it is called by astronomers is an elliptical hurricane-like vortex approximately 26,000 km by 14,000 km that has been observed with certainty since 1831. In more recent times its color has paled from brick red to a subtle shade of salmon pink! Neptune also has shown evidence of a similar but smaller vortex that has been given the uninspiring title of the Great Dark Spot (GDS).

The flattened appearances of the gas planets is due to high speeds of rotation bulging out their equatorial regions. The bizarre 91° tilted axis of Uranus, relative to its orbital pathway, suggests an ancient catastrophic collision with a large object.

Gas Planet Rings

The gas planets exhibit ring systems and a large number of orbiting natural satellites or moons. Saturn's ring system is well known due to its brightness and ease of observation from ground-based telescopes. The rings of Jupiter, Uranus and Neptune are thinner and darker and in the case of Neptune, broken into arcs. The rings are not solid but made up of dust and fragmented pieces of rock and ice. The ring systems are very thin, perhaps a few hundred meters and are aligned with the equatorial plane of the parent planet. The rings of Saturn are not uniform in brightness and have been divided up into seven-lettered ring groups. The outermost, telescopically-obvious A-ring has a diameter of 273,600 km. This huge size represents well over half the distance of the Earth to the Moon! When seen at a closer range, the rings appear to be made of ringlets and narrow divisions.

Planetary Moons of the Gas Planets

The moons of the gas planets can be likened to miniature planetary systems in their own right. The moons often show ancient surfaces, pock-marked with craters. Others exhibit smooth frozen surfaces perhaps covering vast spherical oceans. Jupiter's innermost of the Galilian moons, Io, is the most volcanic place known in the solar system. Probably the most enigmatic of all is Saturn's moon, Titan, for its surface is permanently shrouded in an atmosphere of nitrogen. Uranus's moon, Miranda, shows possible evidence of massive impact damage and wholesale reconstruction. Neptune's moon, Triton, features active geysers of liquid nitrogen!

Thanks to interplanetary probes and modern techniques, astronomers have discovered that even in the frozen outer regions of the solar system, dynamic and extraordinary worlds exist and await further investigation. Perhaps the greatest challenge of solar system exploration will be to search for life deep under the frozen surfaces of the watery moons of Europa and Ganymede.

Pluto

The ninth planet away from the Sun, Pluto, was discovered by the American astronomer Clyde Tombaugh (1906-97) in 1930 after an exhaustive search of photographs of the night sky. In more recent times, the status of Pluto has been challenged because some astronomers believe it to be a comet while others consider it to be simply the largest member of the Kuiper Belt of asteroid objects. Clyde Tombaugh was committed to the planetary status which many, including the writer, support.

At a distance of 40 AU from the Sun, it takes light 5 hours and 20 minutes to reach Pluto. In addition to being on average the most remote planet from the Sun, it is also the smallest, coldest and slowest moving known planet in the solar system. Pluto has one moon, Charon, which is approximately half the size of the parent body. Pluto appears to have a thin atmosphere of mainly methane. Regrettably, Pluto and Charon remain the only planetary bodies yet to be examined by robotic spacecraft.

Zone Three, The Oort Cloud

Although Pluto signposts the very edge of the known planetary system, it is not at the frontier of the solar system and interplanetary space. The Dutch astronomer Jan Oort (1900-92) suggested that most comets originated from a distant spherical depository now known as the Oort Cloud. The greatest concentration of the Oort Cloud is estimated to be between 10,000 to 20,000 AU away from the Sun with the outermost comets being 100,000 AU (1.5 light years) distant. The comets slowly orbit the Sun. When disturbed by gravitational influences, the comets break away from the Oort Cloud and begin an inward journey towards the Sun and then journey out again, perhaps to travel interplanetary space forever.

Comets

Of the many beautiful objects visible in the night sky, one of the most wonderful is a bright comet with its delicate and fragile tail stretched out upon the starry background. Ancient peoples considered comets to be portends of disaster and the fall of kings and princes. The word comet is taken from the Greek "kometes," meaning hairy star!

Comets are small objects of little mass, consisting of frozen water ices, dust, methane, carbon monoxide and carbon dioxide. Some comets contain exotic chemicals that are detectable in distant star-forming nebulae. Evidence indicates that comets are very ancient objects and may have been part of the "building blocks" material from which the solar system was formed.

Some comets orbit the Sun in highly elliptical orbits in relatively short periods of time. The English scientist Edmund Halley (1656-1742) published in 1705 the theory that comets orbited around the Sun like the planets and were therefore, predictable. He stated that the comet of 1531, 1607 and 1682 was the same object and its orbital period was approximately 76 years. He successfully predicted this comet's return in 1758. In common with other comet discoverers, this famous object now bears his name. Although a disappointing faint sight for northern observers, Comet Halley returned in 1986 and will return once more in 2062.

The European Space Agency probe, Giotto, was able to image the nucleus of Halley's Comet in March 1986. Images revealed an icy and dusty potato-shaped object, 16 x 8 km in size. Erupting from the dark-crated surface, bright dust jets could be seen.

Comets develop tails millions of kilometers in length as they approach the Sun in the innermost part of the solar system. Solar wind and the increasing temperatures, melt and erode the comet's surface. The short-lived tail of a comet always points away from the Sun and contains dust and gas.

Meteors

The dust from the regular so-called "periodic comets" are responsible for the annual meteor showers. The famous annual showers of the Leonids (November 17th) are linked with the parent comet Tempel-Tuttle, while the Perseids (August 12th) are associated with the comet Swift-Tuttle. Meteors or "shooting stars" are seen as streaking lines of light moving quickly across the night sky. They burn incandescently due to friction as they enter the Earth's atmosphere.

Activity 1: Investigation of the Milky Way Galaxy

Materials

- STARLAB Portable Planetarium
- Starfield Cylinder
- Solar System & Galaxy Cylinder
- arrow pointer
- pencils and paper
- clipboards
- slide projector complete with suitable supporting images
- audio tape of music (optional)

Objectives and Aims

To understand and appreciate the scale and appearance of the Galaxy.

Suggested Levels for Presentation

All ages with suitable modifications.

Integrated Subjects

- Science
- History
- Cultural religous beliefs

Process Skills

• Co-operative learning • Observing • Pattern finding • Interpreting • Listening • Inferring • Discovering • Concluding

Preparation

Read support material supplied with the Solar System & Galaxy Cylinder, in particular, the Galaxy content and any other suitable resource information. Hand out to the students clipboards, pencils and drawing paper for note taking. Set up the STARLAB projector with the Starfield Cylinder positioned at 0° latitude and with the stars of the constellation Orion the Hunter directly above and in the middle of STARLAB Planetarium ceiling. Prepare the Solar System & Galaxy Cylinder for use with side wall covers in place and the top projection uncovered. Play suitable atmospheric music if available as students enter STARLAB. At the end of this section, worksheets are included and may be photocopied. Worksheet One is intended for seven- to eleven-year olds and Worksheet Two for students ages twelve and older.

Procedure

- With the Starfield Cylinder on the projector, make sure the students are seated and gradually introduce the darkness by lowering the side lights.
- Explain to the students that today's visit to the STARLAB is going to introduce them to the Milky Way Galaxy. Extinguish side lights and increase projection brightness. Without using the arrow pointer, ask the students to look across the sky and ask if the distribution of stars is even or not. If necessary, use a red pointer to point out the broad band of bright and faint stars that are stretching across the sky. Point out the stars in the constellation, Orion. Tell them that this is the Milky Way which is the name that we have for our own Galaxy. Explain that the Milky way is best seen from dark country locations during the summer time and is made up of millions of stars like the Sun. Every single star that we see at night belongs to the Galaxy. Mention Galileo's first telescope observations of the Galaxy. Explain that ancient peoples have interpreted the Milky Way in many different ways but today our understanding is so great that we now have a good idea of what the Galaxy would look like if we could see it from far away in space.
- At this point, decrease the STARLAB projector brightness and increase the side lights sufficiently to give enough light to allow the change from the Starfield Cylinder to the Solar System & Galaxy Cylinder. Set the Solar System & Galaxy

Cylinder for 90° North. Explain that they are going to see a view of the Galaxy that would be seen if the entire class had been transported far out into space. Completely dim the side lights and increase projector brightness to about only 1/4 power so the Galaxy image is only just beginning to appear upon the ceiling. Ask the students if they can see the Galaxy. Point out the bright core and explain that this is where most of the stars are located. Explain that in photographs the students may have seen of galaxies in books or on TV, the images are exaggerated because the actual brightness of galaxies is not great. Further explain that you, the presenter, will now increase the brightness so the lesson can continue. Increase projector brightness to normal operating levels.

- Explain that if the Galaxy was chopped in half, right down the middle so it could be seen in section, it would look like two fried eggs attached back to back, but that this is a view seen from under the southern pole of the Galaxy. Explain the use of light years and point out the distance line and then explain that the view of the Galaxy is from around 65,000 light years from its center. Discuss the diameter, thickness and other important specifications. Further discuss the basic features of the Galaxy e.g. nuclear bulge, galactic disk, halo, spiral arms and the galactic center.
- Show the approximate position of the Sun and mention that from this great distance of 65,000 light years, the Sun would be completely invisible. Make the important point that in times past, people thought that the Earth was at the very center of the universe. Discuss the Sun's distance from the edge of the galactic disk and from the galactic core. Mention that the stars of Orion are located in an arm between the Sun and the outer edge of the galactic disk. Further point out the Sagittarius Dwarf Galaxy directly opposite from the Sun's location.
- Explain that nothing in space is standing still. Remind the students that the Earth rotates once every 24 hours and orbits the Sun every year. At which point, turn on the motor drive for the projector so the cylinder now rotates. Explain that the Galaxy itself is rotating and then discuss the galactic year. Further explain that the Galaxy itself is moving through space.
- If necessary increase the side lights gently so that background ambient light is just bright enough to allow students to see their worksheets.

Further Investigations

In the classroom, the students could be encouraged to find out as much as possible about the different types of galaxies and at what distances these galaxies are away from our own Galaxy using various resources. What are the distances of the closest galaxies? Are galaxies separate entities or do they cluster into groups? How do astronomers determine such great distances? Additionally they could investigate the motion of the galaxies and discover what this tells us about the evolution of the universe.

Name____ **Date**____________________

Galaxy Questions, Worksheet One

Fill in the missing ten blanks:

1. The Milky Way is a gigantic _ _ _ _ _ _ and is full of billions of _ _ _ _ _ .

2. Astronomers who study stars use _ _ _ _ _ _ _ _ _ _ _ to find things out about the Galaxy.

3. The very first person to see that the Milky Way has so many stars in it was _ _ _ _ _ _ _.

4. Astronomers don't use miles when they are measuring the Galaxy, they use _ _ _ _ _ _ _ _ _ _ instead.

5. The Galaxy is _ _ _ _ _ _ light years across.

6. The Sun is not in the middle of the Galaxy, it's about _ _ _ _ _ light years from the middle.

7. The Galaxy has lots of spiral _ _ _ _ and they come away from its middle.

8. The Galaxy turns around once every 240,000,000 years and this is called the _ _ _ _ _ _ _ _ Year.

9. Our Galaxy is not the only one, out in space there are _ _ _ _ _ _ _ _ _ of other galaxies.

Name____ **Date**________________________

Galaxy Questions, Worksheet Two

1. Why do astronomer's use light years when measuring the Galaxy?

2. What is the approximate distance from the Sun to the Sagittarius Dwarf Galaxy?

3. How many main arms can be seen in the Galaxy?

4. If the Galaxy has so many stars in it, why is the night sky not brighter?

5. Why is the summer Milky Way brighter than in the winter?

6. How long does it take light to travel from the galaxy core to the solar system?

7. Why can we not 'see' the middle of the Galaxy?

8. Why do the arms in the Galaxy look lumpy?

9. What is a galactic year?

10. What keeps the stars from wandering out into deep space?

Materials

- STARLAB Portable Planetarium
- Starfield Cylinder
- Solar System & Galaxy Cylinder
- arrow pointer
- pencils and paper
- clipboards
- slide projector complete with suitable supporting images
- popular astronomical magazine such as (*Astronomy* or *Sky & Telescope*)
- audio tape of music

Activity 2: Investigation of the Solar System

Objectives and Aims

To investigate the size and position of the principal objects of the solar system

Suggested Levels for Presentation

All ages but with modification.

Integrated Subjects

- Cultural religious beliefs
- History

Process Skills

Observing • Listening • Inferring • Discovering • Pattern finding • Concluding • Interpreting

Preparation

Read support material supplied with the Solar System & Galaxy Cylinder, in particular, the solar system content and any other suitable resource information. Hand out to the students clipboards, pencils and drawing paper for note taking. At the end of this section, worksheets are included and may be photocopied. Worksheet One is intended for five- to seven-year olds, Worksheet Two is intended for seven- to eleven-year olds and Worksheet Three for twelve and older students.

With reference to a popular astronomical magazine such as Sky & Telescope, set up STARLAB projector with Starfield Cylinder positioned to your correct latitude with the Sun and all the five naked eye planets correctly located throughout the zodiac. Alternatively, use artistic license and set the planet projectors so that all five planets appear in one single view. Ensure, however, that Mercury and Venus are not too far away from the Sun! Prepare the Solar System & Galaxy Cylinder for use with top projection cover in place and the side wall uncovered. Play suitable atmospheric music if available as students enter STARLAB.

Procedure

- With the Starfield Cylinder on the projector, make sure the students are seated and gradually introduce the darkness by lowering the side lights.
- Explain to the students that throughout history, civilizations have seen the sky and interpreted what they saw very differently. Further explain that the differences stem from their religious beliefs and scientific understanding. Explain that today's visit to the STARLAB is going to introduce them to some very special objects that can be seen in the sky. These objects are not in the far away distant stars but are in our own back yard (astronomically speaking!) — the planets.

Special Preparation Note

If the lesson plan is designed for younger children, it might be necessary to use Post-it™ Notes or black electrician's tape to mask out excessive information to prevent confusion. Sticky surfaces can be later cleaned using a nondestructive solvent. Test solvent on the base of Solar System & Galaxy Cylinder to check its suitability.

- Extinguish the side lights and increase projection brightness. Using the red pointer, pick out the Sun, perhaps a few prominent constellations but most importantly, the planets. Explain what ancient civilizations thought of the planets, typically the Greeks, and then explain how the position of the Earth has lost its importance in the universe as our understanding has grown. Mention the Ptolemaic, Copernican beliefs and modern day understanding of the solar system.
- At this part of the proceedings decrease the STARLAB projector brightness and increase the side lights sufficiently to give enough light to allow the change from the Starfield Cylinder to the Solar System & Galaxy Cylinder. Set the Solar System & Galaxy Cylinder for 70° North and position the Sun so it is centered upon the ceiling. This is the optimum start position to show the important aspects of the solar system content of the Solar System & Galaxy Cylinder. Completely dim the side lights and increase projector brightness to normal operating levels. If using the Giant STARLAB or if excessive light pollution is entering the entrance tunnel, it may be necessary to operate the projector brightness at higher levels.
- Continue by explaining that this special representation shows the planets to the correct scale and that the solar system distance line shows the separation of the planets. Explain the use of the Astronomical Unit (AU). With reference to the text displayed upon the ceiling, call out the size of the Sun and compare its size to that of the planets. Rotate the Solar System & Galaxy Cylinder and as each planet appears, continue the dialogue of comparative sizes and distances. If time allows, discuss other features that are visible, e.g. solar flares, planetary moons, gas planet details, comets and asteroids. Increase the side lights gently so that background ambient light is just bright enough to allow students to see for note taking on the second rotation of the Solar System & Galaxy Cylinder. If necessary, pause the rotation so that the students have an opportunity to record information important to their studies.

Further Investigations

In the classroom, the students could be encouraged to find out as much as possible about the planets and their moons using various resources. What robotic spacecraft have helped our understanding? What is the closest planet to the Earth and does this situation change? What are the peculiar aspects of Pluto that have brought into question its status as a planet? How could new planets be discovered in our solar system? Why is the Earth so suitable for life? Could any other objects in the solar system have life? Do other stars have planets? If so, what is the likelihood of these planets supporting life? How have astronomers determined the astronomical unit? How did the solar system come into existence? What will eventually happen to the Earth and solar system in the future?

Name____ Date________________________

Solar System Questions, Worksheet One

1. How many planets are in the solar system?

2. What is the name of the closest planet to the Sun?

3. What is the name of the furthest planet from the Sun?

4. If the Sun is not a planet, what is the Sun?

5. How many giant planets go around the Sun?

6. What planet is famous for a Great Red Spot?

7. What planet has bright rings that go around it?

8. How many moons does Neptune have?

9. How many moons does Mars have?

10. What does a comet have coming out of it?

11. What is the smallest planet that goes around the Sun?

Name____ **Date**_______________________

Solar System Questions, Worksheet Two

1. What is an Astronomical Unit?

2. How many AU's is the Sun away from Pluto?

3. What is the region between Mars and Jupiter called?

4. How many planets are solid?

5. Why are some planets hot and some cold?

6. What is the name of a famous comet?

7. What is the hottest planet?

8. What planet has the greatest number of moons?

9. What are the names of Jupiter's largest moons?

10. If you only have a birthday once every 84 Earth years, where were you born?

Name____ Date________________________

Solar System Questions, Worksheet Three

1. Which planet has a rotational period greater than its orbital period?

2. What is the largest moon in the solar system?

3. What planet has moons named after Shakespearean characters?

4. How many kilometers are in an AU.

5. Why is the surface temperature of Venus greater than that on Mercury?

6. Why do the giant gas planets "bulge" around their middle?

7. How many times could the diameter of Jupiter go across that of the Sun?

8. What is the possible place of origin of the Martian moons?

9. Why do the planets change brightness as seen from Earth?

10. Why is it difficult trying to find planets beyond Pluto?

Solar System & Galaxy Answer Key

Galaxy Questions, Sheet One

1. galaxy . . . stars.
2. telescopes.
3. Galileo.
4. light years.
5. 100,000.
6. 27,000.
7. arms.
8. galactic.
9. billions.

Galaxy Questions, Sheet Two

1. Light years are used because miles or kilometers would be too small a unit for such great distances.
2. 80,000 light years.
3. Two main arms with numerous smaller spurs.
4. Because stars have different magnitudes and are at different distances from the Sun.
5. The summer Milky Way is brighter because we are looking towards the Galaxy's center. In the winter time we are looking in the opposite direction away from the Galaxy's center.
6. Somewhere between 25,000 to 27,000 years.
7. Because the Galaxy's middle is obscured by spiral arms full of stars and dust masking out the center.
8. The Galaxy's arms appear lumpy because of the unequal distribution of both stars, star forming regions and the dust in the interstellar medium.
9. A galactic year is the period of time required for the Sun to orbit the Galaxy's center once.
10. Stars are gravitationally bonded to the Galaxy and each other.

Solar System Questions, Sheet One

1. Nine.
2. Mercury.
3. Pluto.
4. A star.
5. Four.
6. Jupiter.

7. Saturn.
8. Eight moons.
9. Two moons.
10. A tail.
11. Pluto.

Solar System Questions, Sheet Two

1. An astronomical unit is the mean distance from the Sun to the Earth, 150,000,000 km.
2. 39.4 AU's.
3. Asteroid zone.
4. Five.
5. The outer surface temperatures of the planets are related to their distances from the Sun.
6. Halley's Comet.
7. Venus has the hottest surface temperature, 480 C.
8. Saturn (as of the beginning of 1999).
9. Io, Europa, Ganymede and Callisto.
10. Uranus.

Solar System Questions, Sheet Three

1. Venus. Rotational period = 243.1 days, orbital period = 225 days.
2. Ganymede, 5,268 km in diameter.
3. Uranus.
4. 150,000,000 km.
5. Although Mercury is close to the Sun, Venus suffers from the extremes of the 'Green House' effect which traps heat down to its surface making it hotter.
6. The gas planets bulge because of high rotational speeds that push out their equatorial regions.
7. 9.72 times.
8. The asteroid zone.
9. Planets change brightness depending upon their ever changing distance from the Earth and the Sun. Additionally, Mercury and Venus show phases similar to the Moon.
10. Because they are likely to be small and their distances so great that reflected light from them will be very faint.