THE MILKY WAY GALAXY MODEL

653-8020

**AN ILLUSTRATED GUIDE EXPLAINING
THE USE OF THE MILKY WAY GALAXY MODEL IN LEARNING THE STRUCTURE, CONTENT, AND DIMENSIONS OF OUR GALAXY**

Introduction:

The model of the Milky Way can be used to show the sun's position in the galaxy and to illustrate why the night sky appears as it does. It also shows the distribution of clusters, relationships of the new stars, old stars, gaseous spiral arms, and other related celestial objects within a coordinate system to illustrate the structure of the galaxy and its dimensions.

WARRANTY:
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LEGEND

Blue denotes the regions of the galaxy that contain the most dense clouds of gas and dust. Red indicates the position of the older stars of the stellar populations. Astronomers often call these Population II stars. Yellow shows the location of the relatively young stars which are sometimes called Population I stars. Red star symbols indicate positions of star clusters projected onto the model. Exact positions may be found by using *Tables I and II.*

USE OF THE GALAXY MODEL

The Galaxy Model is mounted on an adjustable base, and the position of the model maybe changed by loosening the wing nut. The galaxy may be rotated in a clockwise direction to show the motion of the sun within the galaxy. The actual positions of celestial objects such as globular clusters, listed in *Table II*, may be easily located if the galactic latitude, longitude and distance in light years are known.

SCALE

The scale of the model is 1 inch that equals 6,750 light years. The model is 15 inches in diameter representing approximately 100,000 light years, and it is 1 ¼ inch at the center representing approximately 10,000 light years. A comparative scale that can be used as a handy cross reference is located on the model.

DESCRIPTION OF THE MILKY WAY

Wherever we look, we can see galaxies; and our galaxy seems to be at the center of the entire galactic parade. However, we cannot conclude from first observation that our solar system is at the center of our galaxy or that our galaxy is at the center of a universe of galaxies.

We are well aware that we live on a planet, which along with eight others, moves about the sun. The sun is said to be moving through space on an orbit of its own that takes it around the center of our galaxy, the Milky Way. The grandest and most striking phenomenon of our local universe, The Galaxy, is our Milky Way. If observed with the unaided eye on the best of conditions, probably in summer at night, it sweeps out a beautiful, faint outlined milky path among the constellations.

The Milky Way goes through Aquila and Cygnus where it separates by splitting into two arms 15° or more apart, with the constellations Ophiuchus, Hercules, and Lyra being touched by the northern branch of the split, while Altair and Vulpecula are touched by the southern arm. The two arms join up again near Alpha Cygni.

As the Milky Way passes through Cassiopeia and Perseus, it becomes less bright.

The portion that is visible in winter passes through Auriga, Gemini, Taurus, Orion and Monoceros. By comparison, the southern hemisphere is much more abundant in stars than its northern hemisphere visible counterpart. The Milky Way goes through Puppius, Vela, Centauras, and the Southern Cross, returning by the way of Norma to Scorpius and Sagittarius.

The Milky Way is a very important part of our local star-studded system, which we all refer to as the capital Galaxy. It traces out what resembles a great circle on the celestial sphere, where the sun can be seen very nearly on its central plane. If the sun were north, then the milky Way could stand out in the southern sky, and if it were to the south, the Milky Way would stand out in the northern sky. Because of the difficulty of defining the mean plane of the Milky Way very precisely, astronomers have agreed to choose the mean plane as being the great circle passing through the point on the celestial Equator at right ascension, Alpha = 18 hours 40 minutes (1900) and inclined to the Equator at 62º. *(Figure 1)*

Harlow Shapley's investigation of the distribution of globular cluster (great symmetrical star cluster, containing tens of thousands to hundreds of thousands of stars) leads from the concept that the Galaxy was centered by the sun and extends only a few thousand light years from the sun. This observation led to what is believed to be the true size of our galaxy and our true position in our galaxy.

This changed the "heliocentric" concept to "galactconcentric" view of our system. From being close to globular diameters, he then obtained the true diameters of the cluster. Indirectly, he was able to determine basic information concerning distant globular clusters.

After mapping out three-dimensional distribution in space of 93 globular clusters then known (1917), Shapley found that clusters formed a spheroidal system having at its own center the highest concentration of clusters. He also found that the center of the galaxy was not the sun, but a point in the middle of the Milky Way in the direction of Sagittarius, 25,000 to 30,000 light years away. Shapely's "Bony Frame" assumption suggested that this

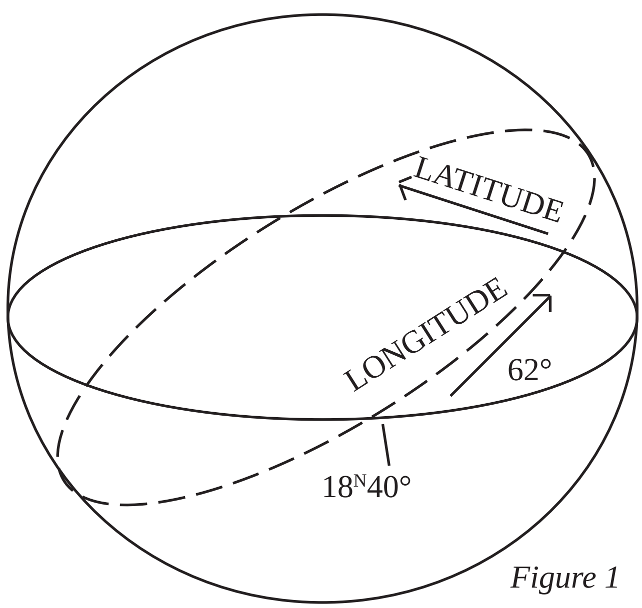


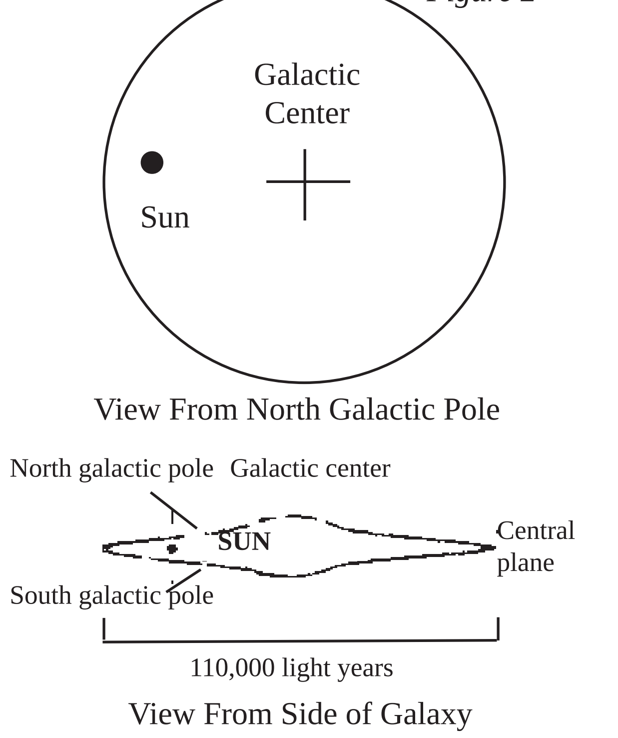
Figure 1

was the shape of the structure of the entire Galaxy. Not only the distribution of clusters centered upon the center of the Galaxy, but the extent of the galactic system is indicated by the cluster distribution. His assumption has been verified by modern experimental effects. The Sun lies far from the galactic center while the main disk of the Galaxy comprises a gigantic system of 34,000 pc (parsecs) or 110,000 light years. *(Figure 2)*

Star counts have allowed us to conclude that there are more stars in the galactic plane than at the galactic poles.

Schematic figures showing the regions of the Milky Way; one for stars 1800, 600, and 300 parsecs, numbers of stars observable are proportional to the volumes of the cones shown in black. (*Figure 3)*

Figure 2



Stars of the 4th magnitude are twice as numerous in the galactic plane as at the poles, and this ratio goes up to 17 for stars of the 17th magnitude. As has been pointed out before, our Galaxy is a highly flattened system.

By the study of the concentration of stars of high intrinsic luminosity, the flattened system was confirmed and the following groups of stars by spectral class have been found much more numerous near the Milky Way than at great distances from it. Stars of O and B Planetary Nebulae, Novae, Cepheids, Emission, Nebulae, and open star clusters show greater intrinsic luminosities than other stars, which is easily understood in terms of a flattened system. The existence of interstellar nebular matter, which hides the innermost parts our stellar system, presents some difficulties in determining the thickness of our Galaxy.

However, it has been shown that open clusters are nearly all found with a layer 400 parsecs thick (3.26 x 400 = distance in light years).

The sun is found within this layer about 20 parsecs to the north of the plane of symmetry.

The whole collection of stars forms a flattened disk, the center of which is in the constellation of Sagittarius. The Sun is about 9000 parsecs from the center. The thickness of the system is about 400 parsecs near the Sun, which is slightly above the plane of symmetry, 20 parsecs to the North. From the apparent width of the Milky Way, the thickness near the center can be deduced to be about 5000 parsecs or 16,000 light years. (*Figure 4)*

Figure 3

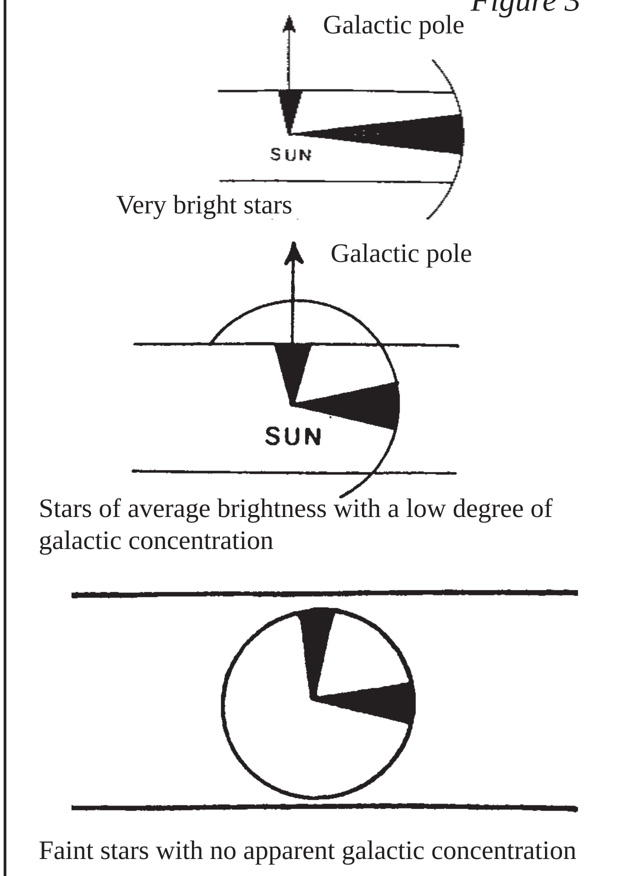
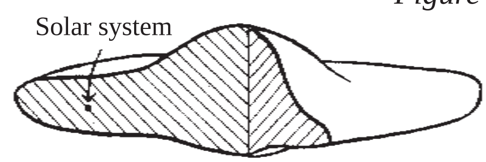


Figure 4



General shape of the Milky Way galaxy, showing position of our solar system

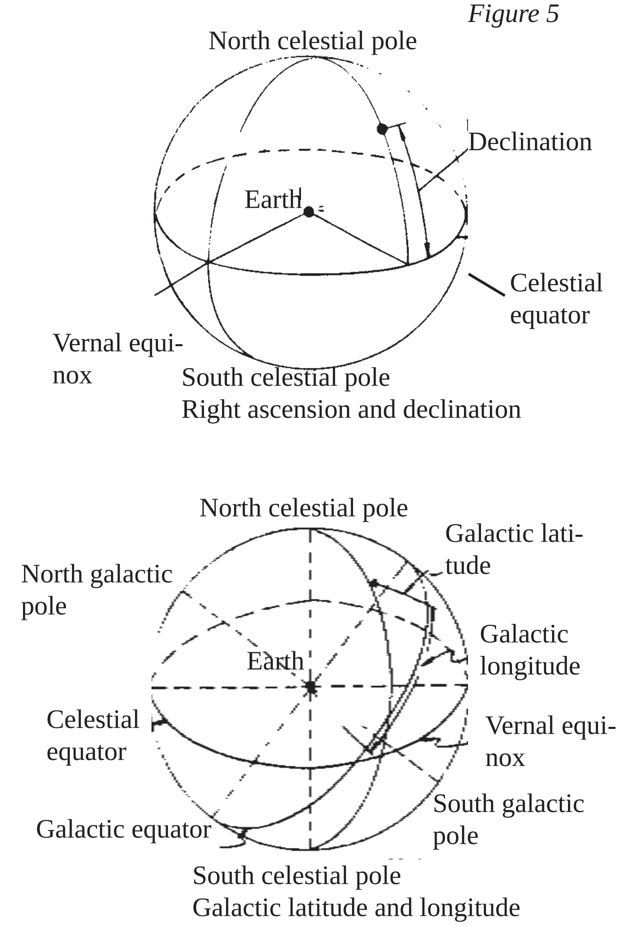
GALACTIC LATITUDE AND LONGITUDE

A system of coordinates based on the great circle of the Milky Way helps describe the special relationship between objects in the galaxy. The central plane of the Milky Way defines the galactic equator which intersects the celestial equator (the projection of the earth' equator onto the celestial sphere) in Aquila and Monoceros.

The galactic poles are 90º away from any point on the galactic equator. The north galactic pole is in the constellation Coma Berenices (Right Ascension – 12h49m, Declination- 20º in the year 1950), and the south galactic pole is in Fornax. Circles of galactic longitude pass from galactic pole to pole similar to the way circles of terrestrial longitude extend from each of the earth's poles of rotation. An object's galactic latitude is its angular distance north or south of the equator, toward either pole, measured along the circle of galactic longitude passing through the body. The direction of the center of the new system was adopted by the International Astronomical Union in 1958. Longitude increases from 0º to 360º in an eastward direction from Sagittarius, through Cygnus, Perseus, Canis Major, Carina to Sagittarius. Galactic latitude and longitude for celestial objects must be calculated from their ascensions and declinations measured on the celestial sphere.

(*Figure 5*)

Figure 5



STAR CLUSTERS

Galactic Open Cluster

Some stars are associated in compact groups called clusters. The Pleiades, well known and beautiful, is an excellent example. Due to the fact that they are open and can basically be resolved into separate stars, we call them open clusters; and because they are found within our Galaxy, they are often referred to as Galactic Clusters.

This cluster is evidentially a real group in space; such an accumulation of stars cannot be explained as an accident of perspective. The grouping of stars into clusters is not uncommon; about 350 clusters are known. Not far from the Pleiades, in the center of the constellation of Taurus is another famous cluster. These clusters are rather close to us, and their stars appear to be rather far apart; however, in a remote cluster, the stars appear to be more closely grouped together. The distinction between open cluster and globular cluster is an essential one. It is now known that the stars in the open cluster are similar to those that surround us, and they are always fairly close to the plane of the Milky Way.

The Pleiades, the most famous star cluster has always struck the human imagination. The Chinese, the Indians, the Chaldeans, the Greeks, the Romans and the Bible talk about the Pleiades. Homer and Hesiod also mentioned them. The ancients believed that the cluster consisted of seven stars, the seven daughters of Atlas and Pleinoe. Their names were given: Alcyone, Electra, Maia, Merope, Taygete, Celaeno, and Asterope. In 1579, eleven stars appeared in a map published by Maelstling; and on a moon less night, a well-trained eye could see eleven stars (refers to Table I and II).

Galileo counted 36 of the Pleiades with the aid of a telescope and in 1665 Hoale counted 76 stars in the Pleiades cluster. Afterward, several hundred were found within a radius 1° around the brightest of them, Alcyone.

Globular Cluster

A globular cluster consists of tens to hundreds of thousands of stars in a closely packed globule. A globular cluster is an unusual sight as its myriads of stars conglomerate around a nucleus that is difficult to resolve. The clusters in Hercules and Canes Venatici are two of the most striking globular clusters that can be found in the Northern Hemisphere. There is the Hercules (M13) cluster which is a white central portion in which the stars are so closely packed that they remain unresolved on a photographic plate, but the characteristic light leaves no doubt that they are stars.

In this conglomeration of stars, the velocities are not too great; however, one must suspect collision between stars, providing a magnificent source for novae. The usual examination of a globular cluster through a large reflector shows many red stars; all of the brightest stars are definitely red and they stand out against the white background lit up by the fainter stars. It was thought for a very long

The Galaxy

1. Diameter in the plane .....34,000 parsecs or 110,00 light years
2. Thickness of central condensation .....5,000 parsecs or 16,000 light years
3. Degree of flattening 1/6
4. Diameter of system of globular clusters .....50,000 parsecs or 160,000 light years
5. Thickness of galaxy near the Sun .....400 parsecs or 1,300 light years
6. Distance of the sun from the median plane..... 15 parsecs or 50 light years
7. Direction of the center of the galaxy; galactic longitude.....325º (Sagittarius)
8. Distance of the Sun from the center of the galaxy.....9,000 parsecs or 30,000 light years
9. Orbital speed of stars near the Sun.....280km/seconds or 174 miles/seconds
10. Direction of motion; galactic longitude.....55º
11. Period of revolution.....220 million years (2.2×10^8year)
12. Total mass.....200 billion Solar Masses (2.0×10^{11} S.M.)
13. Mass concentrated in the central Nucleus.....160 billion Solar Masses (1.6×10^{11} S.M.)
14. Mean density.....0.1 Solar Mass per cubic parsec
15. Mean mass per cube of side 1000 Km (kilometers).....7 gm
16. Absolute magnitude.....-18(a billion times the sun's luminosity)

time that these stars were giants or supergiants identical to the ones we know in the vicinity of the sun. However, we know now that there is a basic difference between the stars in the galaxy and stars in globular clusters. Stars in the globular clusters are old stars.

The distribution of globular clusters in space which is easy to define as a result of our knowledge of their distance is a simple one. Practically all the clusters are all contained within a sphere 30,000 parsecs or 100,000 light years in diameter.

This is a very big sphere and it surrounds the whole of our galaxy. We are all certain of the fact that the globular clusters belong to our galaxy because the centers of the two systems coincide. Moreover, they form the most extended part spreading out far beyond the spiral arms.

ROTATION OF THE MILKY WAY

Relative to the nearby stars, the sun has a speed of 42.5 miles/second directed toward a point in the constellation Hercules. However, this only refers to the motion of the sun relative to its immediate neighbors. Different results are obtained when one takes as one's frame of reference systems somewhat larger, i.e. globular cluster or extragalactic nebula.

Relative to the globular cluster and/or extragalactic nebula, the sun has a velocity of the order of 174 miles/second (280 kilometers/second) directed toward a point in Cygnus (cygni). This point is in the plane of the Milky Way and exactly 90º from the direction of Sagittarius. The whole local group of stars to which the sun belongs revolve around the center of the galaxy. The speed of revolution is 280 kilometers (174 miles/second). The velocity of the sun toward Hercules can be regarded as the sun in a peculiar motion relative to the local group. By making certain assumptions about the orbital path, center of rotation, and distance a star is away from the center, the distribution of mass in our galaxy, we can deduce certain basic information.

The period of the sun's revolution about the nucleus, (the galactic year) can be found by dividing the circumference of the sun in orbit by its speed; it comes out to roughly 200 million (2×10^8) of our terrestrial years.

Knowing that the sun moves in a strictly circular orbit of radius 10,000 pcs and that it completes an orbital revolution in about 200,000,000 years, we can calculate the mass of the galaxy. We will ignore the contribution of matter farther from the galactic nucleus and assume that all of the galaxy mass is internal to our sun's orbit. These two assumptions allow us to regard to the galaxy and the sun as two mutually revolving bodies as a whole. There are 200,000 astronomical units per parsec; the radius of the sun in orbit is 2,000,000,000 astronomical units.
From Kepler's Third Law, and ignoring the mass of the sun in comparison to that of the galaxy, we find:

$$M_{galaxy} = \frac{(2,000,000,000)^3}{(200,000,000)^2} = \frac{8 \times 10^{27}}{4 \times 10^{16}}$$

Therefore: $M_{galaxy} = 2 \times 10^{11}$ or

(200 billion) times that of the sun.

Table I

Galactic Cluster	Right Ascension	Declination	Galactic Longitude	Galactic Latitude	Distance in LightYears From the Sun
Hyades	04^h 18^m 0	15° 34’	178° 2’	24° 0’	120
Pleiades	03^h 44^m 1	24° 2’	165° 8’	23° 6’	260
Coma Berenices	12^h 22^m 6	26° 23’	220° 4’	88° 9’	410
M67	08^h 50^m 0	11° 54’	215° 1’	31° 4’	2600
M36	05^h 32^m 8	34° 08’	186° 5’	0° 4’	3780
NGC 6530	18^h 01^m 7	24° 20’	5° 8’	1° 3’	5155
M11	18^h 49^m 42	-6° 18’	27° 0	2° 7’	4200
h-Persei	02^h 15^m 5	56° 55’	135° 8’	3° 8’	4300
x-Persei	02^h 17^m 12	57° 1’	135° 1’	3° 6’	4300
47 Tucanae	0^h 24^m 2	72° 04’	322° 5’	27° 6’	21,530

Table II

Globular Cluster	Right Ascension	Declination	Galactic Longitude	Galactic Latitude	Distance in LightYears From the Sun
W Centuri	13 39 9	28° 38’	222° 0’	78° 7’	15,005
NGC 2419	07 34 8	39° 12’	179° 8’	25° 3’	187,565
M53	13 12	18° 20’	333° 8’	80° 3’	65,000
M3	13 41	28° 32’	42° 0’	87° 8’	45,000
M5	15 17	02° 12’	0° 8’	47° 6’	27,000
M4	16 22	-26° 27’	350° 6’	16° 0’	7,500
M13	16 41	36° 30’	58° 5’	41° 4’	22,200
M92	17 17	43° 11’	69° 5’	34° 9’	35,800
M22	18 34	-23° 57’	9° 5’	7° 5’	9,800
M15	21 28	12° 02’	64 ° 5’	27° 1’	49,000

USING RADIO ASTRONOMY TO MAP THE MILKY WAY

Karl Jansky, when employed by the Bell Telephone Company in 1931, discovered the interference in overseas telephone calls was due to radio emission coming from our galaxy. More specifically, it was proven by Jansky that the radio interference varied with the sidereal period of rotation of the Earth, that in 23 hours and 56 minutes rather than 24 hours. This radiation was proven to have come from the constellation Sagittarius, or more specifically, from the direction of the center of the Milky Way. With this observation well in mind, knowing that galactic emission is greater than that of the sun, it is possible to make detections in daylight without receiving disturbances from the sun. (*Figure 6)*

Jansky’s observations were actually followed up from 1940 until the present , and a map of radio emission from the Milky Way was drawn (*Figure 7*). The radiation comes from a band 15º North and South of the Milky Way and there is a sharp maximum near longitude 330 near the center of the Milky Way.

In 1945, Dutch astrophysicist van de Hulst showed that under certain conditions atoms of neutral hydrogen emit a line at 21 cm long, in the ultrashort wave radio band.

With progressive improvements in quantum mechanics, energy states or levels of atoms have proven to have a fine structure less simple than thought. The atom showed a splitting effect and that the electron has a spin and is not a simple electric charge at best. A hyperfine structure has been shown in addition to the fine structure. In the ground state (unexcited), the hydrogen atom shows, not fine, but only hyperfine structure. (*Figure 8)*

The ground level is split into two levels about 1/200,000th of the separation between two ordinary levels. Changing from the upper to the lover level occurs with the emission of the 21 centimeter wavelength. When the inverse transition occurs, this line is absorbed. (See *Figure 10, a Schematic Representation).*

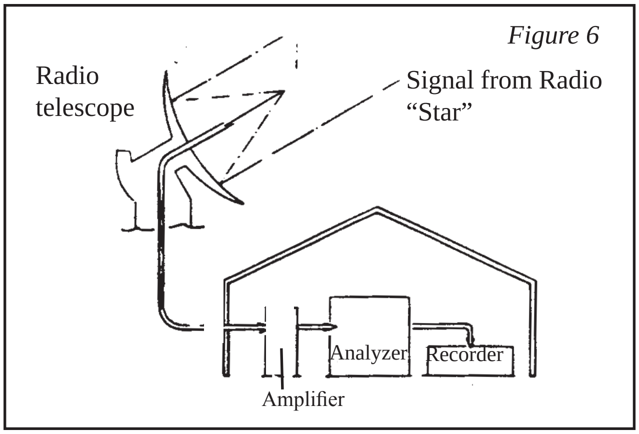


Figure 6

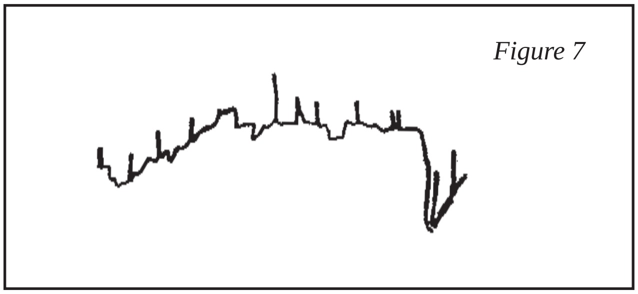


Figure 7

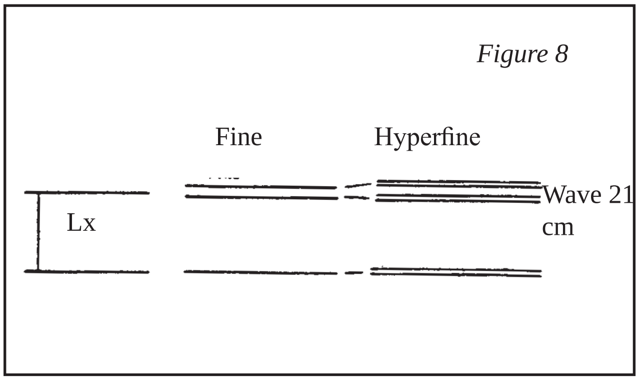


Figure 8

Hydrogen is that gas which serves as "food" for stars during their birth, youth, adolescence, maturity, old age and until death. This gas has always been thought of as the material necessary for existence and maintenance of galactic systems.

DISCRETE SOURCE

In 1948, Cygnus was noticed to give off emission of radio waves that underwent fluctuation varying in length from seconds to a minute.

This type of emission was analyzed as being a kind of atmospheric scintillation, analogous to the twinkling of normal stars.

Another source was noticed in Taurus and another in Virgo. Probably the strongest source detected was in Cassiopeia which was twice as strong as the Cygnus source. Probably most radio sources are related to remnants of supernovae and galaxies undergoing some violent explosion. For example, the Taurus radio source has been identified with the Crab Nebula, remnant of a supernova explosion in A. D. 1054, as recorded in the Chinese Annals.

By the interferometric measurements these sources have been proven to have small diameters and are not point sources. Observational results do not seem to confirm the view that radio sources are numerous enough to explain the general emission from the Milky Way.

TYPES OF GALAXIES

Extragalactic nebulae are very numerous. The largest ones are usually designated by the names of the constellation in which they are found. The others are generally referred to by their ordinal number in a catalogue. In 1784, Messier published in the Connaissance des Temps a catalogue of 103 nebulae, the majority of which are extragalactic objects.

The designations of M31 and M51 refer to the Nebulae in Andromeda and Canes Venatici according to their numbers in Messier's catalogue. In 1888, Dreyers's New General Catalogue (N.G.C.) contained 13,226 nebulae and clusters. This was completed in 1895 and 1908 by two supplements know as Index Catalogues (I.C.). The Andromeda nebula is NGC224 while that Cane Venatici is NGC5194. In 1932, the Annals was published by Shapley and Ames which contains 1249 nebulae, including 1025 brighter than Magnitude 13 and 21 brighter than Magnitude 10.

THE ANDROMEDA GALAXY M31 OR NGC 224

A visible fuzzy looking cloud near Nu Andromedae, almost on the straight of the line going through the three stars Beta, Mu, and Nu. It reveals a very bright central region, from which two spiral arms emerge symmetrically. Its elliptical shape suggests a flat, circular object seen in perspective.

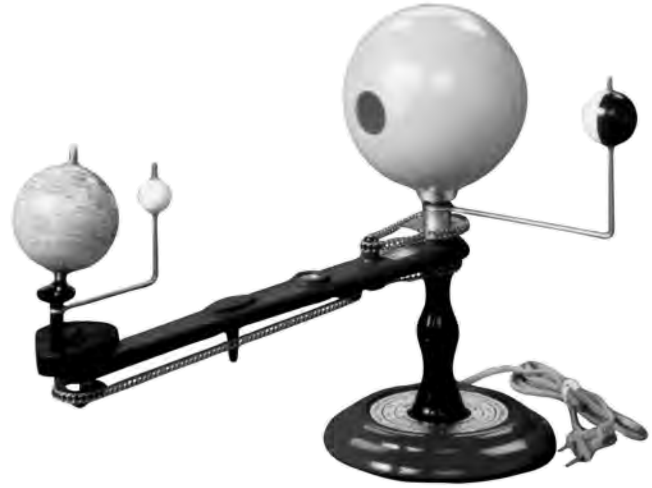
THE TRIANGULUM GALAXY M33 OR NGC 598

This nebula is found in the constellation of Triangulum. It consists of a very small nucleus and two ill-defined arms. The diameter of this object is 9,000 parsecs, or one-third that of our Galaxy or M31. Its brightness is smaller, corresponding to that of the Magellanic Clouds.

GALAXY IN CANES VENATICI M51 OR NGC5194

Found in the constellation Canes Venatici, 3° from the end of the Plough at eta Ursae majoris. It is smaller than Andromeda galaxy. It has two spiral arms, one end being in a bright condensation while the other end has none.

Normal spirals are distinguished by Sa, Sb, or Sc according to whether the nucleus is large, medium or small. Barred spirals Sb subdivide like normal spirals into subclasses a, b and c and finally, elliptical galaxies divide into subclasses from 0 to 7 according to their ellipticity, an E0 being circular whereas an E7 is highly elongated.



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