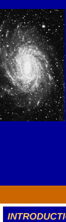
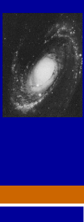



STARS, GALAXIES, SUPERUNIVERSES

and THE URANTIA BOOK

by Frederick L. Beckner

INTRODUCTION

In the past several years, since the advent of the Hubble Space Telescope (HST), there has been an explosion of astronomical information relating to our Milky Way galaxy, our Local Group of galaxies, and myriads of galaxies unknown at the time the Urantia Book was written. The HST has even allowed us a glimpse at galaxies believed to be near the edge of the universe itself. Figure 1 shows a portion of the Deep Field South image showing galaxies at distances out to 12 billion light years.

The Urantia Book contains a description of the universe which one might describe as "Urantian cosmology." This cosmological information, written prior to 1941 by celestial beings, was derived from revelation, not human astronomical science. It is therefore of interest to examine the Urantian cosmology, some 60 years later, to see how this revelation squares with current astronomical knowledge.

Much information of cosmological interest can be obtained by analysis of selected portions of the Urantia Book text. For example, the number of suns in the Master Universe, being all of material creation, is said to be equal to the number of glasses of water in the oceans of our planet. This paper describes a procedure for calculating this number given current readily-available information, arriving at a figure of 4.5 billion trillion suns. I will show that this number is in reasonable agreement with current knowledge.

Given this number and other astronomical information now available we are able to compute the average number of stars per galaxy. Given the identification of our Milky Way galaxy as the inhabitable portion of the superuniverse of Orvonton, we can estimate the number of inhabitable planets per star. It is even possible to determine, within limits, the size of the Grand Universe, our superuniverse, and our local universe of Nebadon.

After performing these calculations and comparing the results with current astronomical knowledge where possible, one finds that the Urantian cosmology is not generally inconsistent with our present knowledge of the universe. This is in spite of the fact that the Urantia Book states that it's cosmology is not divinely inspired and may require revision in the future.

> "The cosmology of these revelations is not inspired. It is limited by our permission for the co-ordination and sorting of present-day knowledge." (UB1109:3)

Figure 1. A portion of the Hubble Deep Field South image showing galaxies to near the edge of the universe. (NASA)

Urantian Cosmology

An overview of Urantian cosmology is given on the first page of the Urantia Book.

> "Your world, Urantia, is one of many similar inhabited planets which comprise the local universe of Nebadon. This universe, together with similar creations, makes up the superuniverse of Orvonton, from whose capital, Uversa, our commission hails. Orvonton is one of the seven evolutionary superuniverses of time and space which circle the never-beginning, never-ending creation of divine perfection—the central universe of Havona. At the heart of this eternal and central universe is the stationary Isle of Paradise, the geographic center of infinity and the dwelling place of the eternal God.
>
> The seven evolving superuniverses in association with the central and divine universe, we commonly refer to as the grand universe; these are the now organized and inhabited creations. They are all a part of the master universe, which also embraces the uninhabited but mobilizing universes of outer space." (UB1:5-6)

We thus live in the grand universe, which includes the presently-inhabited portion of the much larger master universe. The grand universe is subdivided into seven superuniverses, or collections of galaxies, one for each of the seven possible Master Spirits, or personality associations of the three triune manifestations of God. The seventh Master Spirit, being the association of the Universal Father, Eternal Son, and Infinite Spirit supervises our superuniverse of Orvonton. We will show that the Milky Way galaxy lies entirely within Orvonton, and is the greatest part of the inhabited portion of Orvonton. The capital of our superuniverse is called Uversa and will be shown to be located outside the Milky Way galaxy.

> "Satania has a headquarters world called Jerusem, and it is system number twenty-four in the constellation of Norlatiadek. Your constellation, Norlatiadek, consists of one hundred local systems and has a headquarters world called Edentia. Norlatiadek is number seventy in the universe of Nebadon. The local universe of Nebadon consists of one hundred constellations and has a capital known as Salvington. " (UB182:5)

We also live in a star system called Satania, presumably named after Satan, a lieutenant and associate of Lucifer, a former ruler of Satania, who led a rebellion against God, which resulted in the isolation of our planet, Urantia, from the rest of the universe. Jerusem is said to be an architectural sphere, or artificial world, and thus is nonluminous and is not visible by telescopic means from Urantia. It is of special interest because it is on a subsatellite of a satellite of Jerusem that we are resurrected after death. This is the location of the mansion worlds mentioned by Jesus.

Our star system of Satania is one of approximately 10,000 such systems in our local universe of Nebadon. This local universe was created by a Creator Son of God, Michael, who incarnated on Urantia to live the life of one of His mortal creatures and to reveal the nature of God the Father to the inhabitants of His local universe. Michael is better known on Urantia as His mortal incarnation, Jesus of Nazareth. The Urantia Book specifically says that our local universe of Nebadon is not a physical star system, but that its capital, Salvington, is within such a system. We will show that our local universe is approximately 4000 light years in diameter.

With this brief overview of Urantian cosmology, we are now prepared to examine specific teachings of the Urantia Book and to compare them with current astronomical knowledge.

The Master Universe

Size of the Master Universe

The Urantia Book does not explicitly give a size for the master universe. It does imply that the master universe is finite and is expanding.

> "Even if the master universe eventually expands to infinity…" (UB92:6)

Current scientific estimates of the size of the master universe are generally based on the theory of the "big bang" where the universe came into being at an instant of time about 14 billion years ago, and has expanded outwards from this point at the speed of light ever since. A good discussion of three techniques for determining this age is given at http://www.astro.ucla.edu/~wright/age.html. Under these assumptions, it is thus a sphere having a radius of about 14 billion light years.

The Urantia Book implicitly denies the big bang theory, for it implies that the master universe was already in existence 875 billion years ago. It was at this time the Andronover nebula was initiated which resulted in our local universe of Nebadon.

> "875,000,000,000 years ago the enormous Andronover nebula number 876,926 was duly initiated." (UB652:2)

Number of Stars in the Master Universe

The Urantia Book contains the following statement about the number of stars in the master universe.

> "But in the master universe there are as many suns as there are glasses of water in the oceans of your world." (UB173:0)

The volume of the oceans of Urantia can be found on the United States Geological Survey web site, www.usgs.gov/edu/waterdistribution.html, as 317 million cubic miles. Knowing this, and that one cubic mile is equivalent to 4.167 x 10^9 cubic meters, one finds that the volume of water on Urantia is 1.321 x 10^{18} m^3 or 1.321 x 10^{24} cm^3.

Another source states that the oceans cover 70 percent of the earth's surface and have an average depth of 2 miles. The area of the earth's surface is 4 pi times the square of the earth's radius of 6,350 km. Given this, one can calculate that the volume of this water is 1.14 x 10^{24} cm^3, which is in substantial agreement with the volume given by the USGS.

To compute the number of stars in the master universe we need a number for the volume of a glass of water. A small juice glass in my kitchen has a volume of 200 cm3. A typical drinking glass that I use daily has a volume of 300 cm3, and the volume of the largest glass I have is 500 cm^3. Thus, taking the volume to be 300 cm^3 will give results accurate to within about +/- 40%, a figure sufficient for our purposes. Given that the volume of a typical glass of water is about 300 cm^3, one can calculate that the number of glasses of water in the oceans of Urantia is about 4.4 x 10^{21}. Thus, according to the Urantia Book, the number of suns in the master universe must be on the order of 4.4 x 10^{21}. The web site, Atlas of the Universe (http://anzwers.org/free/universe/universe.html), states that there are 2.0 x 10^{21} stars in the visible universe.

To put this number in perspective consider that a cubic rock salt crystal 0.92 cm (0.36 inches) on an edge will contain the same number of molecules. This can be calculated given that rock salt is a cubic crystal with a lattice constant of 5.64 x 10^{-8} cm. We can conclude that the number of atoms in the human body is much greater than the number of stars in the universe.

The Mass of the Master Universe

Given the number of stars in the master universe it is possible to estimate its mass. Given that the sun is an average star, and the mass of the sun is 1.989 x 10^{33} g (grams), then the mass of all the stars in the master universe would be 4.4 x 10^{21} * 1.989 x 10^{33} = 9 x 10^{54} g. Currently astronomers believe that more than 90% of the mass of the universe is tied up in "dark matter." Thus the mass of the universe would be about ten times the mass of all the visible stars, or about 9 x 10^{55} g.

Eddington, in his book, *Fundamental Theory* (1946, p 105), computes the mass of the universe from general relativistic theory as 1.98 x 10^{55} g which is within a factor of 4.5 of the value inferred from UB statements. Thus these estimates agree within an order of magnitude, although we have no proof that either Eddington's value or the UB value is correct. Eddington also computes the number of protons in the universe to be 3/2 * 2^{256} * 136 = 2.36 x 10^{79} (p283).

Number of Galaxies in the Master Universe

> "In the not-distant future, new telescopes will reveal to the wondering gaze of Urantian astronomers no less than 375 million new galaxies in the remote stretches of outer space." (UB130:5)

The Urantia Book is probably referring here to the Hale (Mt Palomar) telescope, which went into operation in 1948. The figure 375 million thus refers to the additional new galaxies observable when the Hale telescope was put into operation, not the number of galaxies in the master universe. Recently the Hubble Space Telescope made two deep field images, in the region of the North Pole, and another in the region of the South Pole (see Figure 1), these regions being those which could be continuously observed for long periods of time without interruption by occultation by the Earth. Exposure times of 10 days were used. From the north deep field image astronomers estimate that there are 80 billion galaxies in the universe. From the southern image they estimate that there are 125 billion galaxies in the universe. For the purposes of this paper we will assume that there are at least 100 billion galaxies in the master universe.

Number of Stars Per Galaxy

Given this number of galaxies and the total number of stars in the master universe, one can calculate that the average number of stars per galaxy is 4.4 x 10^{21} stars divided by 1.0 x 10^{11} galaxies or 4.4 x 10^{10} stars per galaxy (44 billion). The number of stars in our Milky Way galaxy is estimated to be around 200 to 400 billion. This is pretty good agreement with our average number since our galaxy is the second largest in our local cluster of about 30 galaxies, and thus may be considered to be an exceptionally large galaxy. There are many more small galaxies of the elliptical or globular types than there are of the spiral type such as our Milky Way. The information on the number of stars in the Milky Way was obtained from the University of Arizona at http://seds.lpl.arizona.edu/messier/more/mw.html.

Density of Stars in the Master Universe

If there are 4.4 x 10^{21} stars in the master universe and if the radius of the master universe is 14 billion light years, then the average density of stars in the master universe is 3.8 x 10^{-10} stars per cubic light year. If the stars were uniformly distributed throughout the master universe the minimum distance between stars would be about 1,400 light years. Actually, the stars cluster into globular clusters, galaxies, clusters of galaxies, and galactic superclusters where the stellar density is significantly greater than the average density, and leaving great voids in which the stellar density is much less than average. Given knowledge of the density of stars in a given region, it is possible to estimate the volume of the sphere necessary to contain a given number of stars, and from this to determine the approximate radius of this sphere. This technique will be used later to compute radii for the grand universe, our superuniverse, and our local universe.

The Grand Universe and Orvonton

Size of the Grand Universe

The size of the grand universe can be estimated from the number of stars it contains and an estimate of the average star density on that scale. The Urantia Book says there are ten trillion stars in our superuniverse (UB172:7). If we assume that all seven superuniverses are of approximately the same size, then there would be 70 trillion stars in the grand universe.

If the grand universe contains seventy trillion stars, and if these stars are in galaxies which are approximately uniformly distributed throughout the master universe, then the volume of space occupied by the grand universe will be a fraction 70 x 10^{12}/4.4 x 10^{21} = 1.59 x 10^{-8} of the volume of the master universe. The current estimate of the radius of the master universe is about 14 billion light years. Since the volume is proportional to the radius cubed, the radius of the grand universe would be of the order of $(1.59 x 10^{-8})^{0.333}$ = 2.5 x 10^{-3} times the radius of the master universe, or about 35 million light years. This assumes that the star density in the Grand Universe is the same as in the Master Universe.

There is good reason to believe that the actual star density within our local part of the universe is considerably higher than the average density throughout the master universe. This is because the stars are grouped into galaxies, clusters of galaxies, and even larger superclusters of galaxies leaving other areas with voids containing relatively few galaxies. We may estimate the average density of stars in our local group of galaxies in the following manner.

One source, the Atlas of the Universe, http://anzwers.org/free/universe/localgr.html, states that there are about 700 x 10^9 stars within 5 million light years of Earth. The density of stars in this volume is thus about 1.3 x 10^{-9} per cubic light year, or about 3.3 times the average density of the master universe. The same source gives the density in a sphere of about 1 billion light years as 1.19 x 10^{-10} per cubic light year. Thus this source estimates that the star density in our local area is about 10 times greater than that in a volume much greater than the volume of any supercluster. Given this, we must reduce our estimate of the size of the grand universe by a factor of the cube root of ten ($10^{.333}$ = 2.15) to allow for the higher local density of stars. Our corrected estimate of the radius of the grand universe is then 35/2.15 = 16 million light years.

Since Havona is at the center of the grand universe, the distance from Earth to Havona would be about 16 million light years. If there are seven superuniverses distributed equally in angle about Havona, then the distance to the nearest superuniverse outside Orvonton would be about 14 million light years.

Another clue to the size of the grand universe is given in the following passage:

> "Long before the presence of life on Urantia the [Solitary] messenger now associated with me was assigned on a mission out of Uversa to the central universe—was absent from the roll calls of Orvonton for almost a million years but returned in due time with the desired information." (UB259:2)

The time given in this passage is most likely given in Uversa years, since the writers of the book seem to be quite explicit when they refer to Urantia years, calling such times either "Urantia years" or "years of Urantia time" 23 times throughout the book. Since the Solitary Messengers can travel at the rate of 4.52 million light years per Urantian year (UB267:1) and assuming the time given is in Uversa years (8.2 Urantia years, see UB174:2) the distance traveled by the Solitary Messenger would be less than 37 trillion light years. The distance to Havona would then be less than 18.5 trillion light years. This would be in good agreement with the value derived above from the number of stars in Orvonton if the Solitary Messenger had been absent only one Uversa year rather than one million years.

Number of Stars in Orvonton

The Urantia Book specifically gives the number of suns within Orvonton.

> "The superuniverse of Orvonton is illuminated and warmed by more than ten trillion blazing suns." (UB172:7)

This number of suns is indicative that Orvonton is composed of more than one galaxy, since the Milky Way, the second largest galaxy within the Local Group, is currently thought to contain about 200 to 400 billion stars. It would take at least 25 Milky Way or about 110 average galaxies to contain ten trillion stars. It is thus clear that our superuniverse of Orvonton is significantly bigger than our local group of about 30 galaxies and is much bigger than the Milky Way galaxy.

The Size of Orvonton

The Urantia Book gives at least seven different clues as to the size of our superuniverse, Orvonton.

> "Although the unaided human eye can see only two or three nebulae outside the borders of the superuniverse of Orvonton, your telescopes literally reveal millions upon millions of these physical universes in process of formation." (UB130:4)

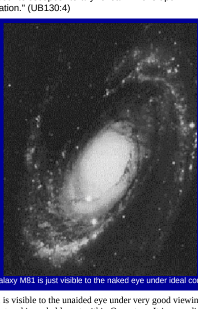


Figure 2. The galaxy M81 is just visible to the naked eye under ideal conditions. (SEDS)

The galaxy M81, shown in Figure 2, is visible to the unaided eye under very good viewing conditions. This 6.9 magnitude galaxy is 12 million light years distant and is probably not within Orvonton. It is a candidate for being another of the seven superuniverses.

This passage clearly delineates the spatial extension of Orvonton, since is says that the unaided human eye can see nebulae outside Orvonton. This means that the many galaxies visible by means of the telescope are not within Orvonton. This passage continues saying

> "Most of the starry realms visually exposed to the search of your present-day telescopes are in Orvonton, but with photographic technique the larger telescopes penetrate far beyond the borders of the grand universe into the domains of outer space, where untold universes are in process of organization." (UB130:4)

This sentence says that most the stars visible by eye through large telescopes are within Orvonton. This is one of the primary distinguishing characteristics of the galaxies within the Local Group; that they contain individual stars which are visible by aid of a telescope. An implication of this sentence is that some of these starry realms are outside of Orvonton. Thus some of the Local Group galaxies are outside of Orvonton. For more information on the Local Group refer to the web page of the University of Arizona Lunar and Planetary Laboratory, http://seds.lpl.arizona.edu/messier/more/local.html.

The upper limit on the radius of the grand universe of 16 million light years also implies an upper limit on the size of our superuniverse, Orvonton. If the seven superuniverses are spherical, equal in size, do not overlap, and are evenly distributed in a circle of radius equal to 16 million light years, then the radius of each superuniverse must be smaller than about 8 million light years. This must be considered to be an extreme upper limit to the size of Orvonton.

Another estimate of the size of Orvonton can be obtained in the same manner as our estimate of the size of the grand universe. If Orvonton contains 10 trillion stars, and if there are 4.4 x 10^{21} stars evenly distributed in the master universe, then a volume of space with a radius of 15.5 million light years would be required to hold this number of stars. Making the same correction for the difference between the local star density and that of the average density in the universe gives a radius of Orvonton of 15.6/2.15 = 7.2 million light years.

The statement that the Divine Counselor can reach any part of the superuniverse in less than one year implies that the radius of the superuniverse must be less than 4.5 million light years. Assuming that Urantia and Jerusem are in the relative close proximity of 2000 light years, then the radius of Orvonton must be less than 3.35 times 1.35 million light years, or 4.5 million light years.

Another limit to the size of Orvonton can be derived from a passage concerning the physical-energy circuits.

> "The power centers and physical controllers of the superuniverses assume direction and partial control of the thirty energy systems which comprise the gravita domain. The physical-energy circuits administered by the power centers of Uversa require a little over 968 million years to complete the encirclement of the superuniverse." (UB175:5)

This passage seems to indicate that the circumference of the superuniverse is 968 million light years. This would indicate that the radius of the superuniverse is 154 million light years. This value is inconsistent with our previously derived information about the size of the superuniverse. The value of 968 million years could be the sum of the travel times from the center of the superuniverse to the outer circumference, around the circumference, and back to the center, for all 30 energy systems. Assuming this, and if these circuits all travel at the velocity of light, then the radius of the superuniverse would be about 3.9 million light years. This value is consistent with our other information.

The size of Orvonton can be estimated from the passage that implies that no less than 4% of the volume of Orvonton is inhabited (UB121:5). From this, and assuming that Orvonton is roughly spherical we may infer that the ratio of the radius of Orvonton to that of the inhabited portion of Orvonton is no less than 2.92. Given that the radius of the inhabited portion of Orvonton is 250,000 light years (UB359:8), then the radius of Orvonton is not less than 730,000 light years.

Another indication of the size of Orvonton comes from the information given in the UB on the Andromeda galaxy. If Andromeda is within Orvonton as indicated by the UB, and if the distance to Andromeda is 1 million light years, then the radius of Orvonton must be at least 500 thousand light years.

Given the above considerations, one may conclude that the radius of Orvonton is greater than 730,000 and less than 4 million light years, possibly about 3 million light years. This would include the large Andromeda and Triangulum galaxies as well as a great number of other smaller galaxies necessary to give the stated number of stars.

The Milky Way Galaxy is within Orvonton

The Urantia Book indicates that our Milky Way galaxy is within the superuniverse of Orvonton.

> "Practically all of the starry realms visible to the naked eye on Urantia belong to the seventh section of the grand universe, the superuniverse of Orvonton. The vast Milky Way starry system represents the central nucleus of Orvonton, being largely beyond the borders of your local universe. This great aggregation of suns, dark islands of space, double stars, globular clusters, star clouds, spiral and other nebulae, together with myriads of individual planets, forms a watchlike, elongated-circular grouping of about one seventh of the inhabited evolutionary universes." (UB167:3)

One-seventh of the inhabited evolutionary universes (I take this to mean local universes) may very well mean that the Milky Way contains nearly the entire inhabited portion of Orvonton, which is one-seventh of the superuniverses in the grand universe.

The idea that the Milky Way galaxy is within the superuniverse of Orvonton is made even more specific in the following passage.

> "They [the short space rays] emanate in the largest quantities from the densest plane of the superuniverse, the Milky Way, which is also the densest plane of the outer universes." (UB475:1)

This passage can also be read to imply that the other outer universes (the other six superuniverses) lie in the plane of the Milky Way galaxy. It can also be read as implying that the Milky Way galaxy is the superuniverse of Orvonton, but this interpretation is inconsistent with the statement that Orvonton contains ten trillion stars, which is much larger than the 200 to 400 billion stars in the Milky Way.

We may infer that other nebulae (galaxies) outside the Milky Way belong to Orvonton from the passage

> "some of the nebulae which Urantian astronomers regard as extragalactic are actually on the fringe of Orvonton and are traveling along with us." (UB131:0)

The Andromeda and Triangulum galaxies and the Large and Small Magellanic clouds are examples of such nebulae which are extragalactic (outside the Milky Way galaxy) but which are part of Orvonton.

The following passage indicates that there are at least seven galaxies in Orvonton.

> "Of the ten major divisions of Orvonton, eight have been roughly identified by Urantian astronomers. The other two are difficult of separate recognition because you are obliged to view these phenomena from the inside. If you could look upon the superuniverse of Orvonton from a position far-distant in space, you would immediately recognize the ten major sectors of the seventh galaxy." (UB167:8)

One can presume that they are talking about the Milky Way galaxy as the seventh galaxy in Orvonton. These ten major sectors also presumably refer to ten arms of our spiral galaxy. In one visualization of the spiral arms of the Milky Way (see http://casswww.ucsd.edu/public/tutorial/MW.html) I can count only eight arms. The Atlas of the Universe site gives the names of six arms of our galaxy: the Cygnas, Perseus, Orion, Sagittarius, Scutum-Crux, and Norma arms. At this time we cannot exclude the possibility of their being ten arms, since much of the structure of our galaxy is hidden from us by dust clouds, radio observations being the only practical way to observe behind these clouds.

The Small and Large Magellanic Clouds are within Orvonton

Two nearby extragalactic nebula which were known before the invention of the telescope are the Large and Small Magellanic Clouds, which were noted by Magellan in 1519 during his voyages in the southern oceans. The Small Magellanic Cloud, shown in Figure 3, is at a distance of about 210,000 light years, while the Large Magellanic Cloud is only 179,000 light years away. Being at a distance of less than 250,000 light years from the center of the Milky Way puts them within the inhabited portion of Orvonton.

Figure 3. The Small Magellanic Cloud located 210,000 light years from the center of the Milky Way lies within the inhabited portion of our superuniverse, Orvonton.

Uversa, the Capital of Orvonton, is not within the Milky Way

The Urantia Book gives the distance from our system capital of Jerusem to the center of the superuniverse of Orvonton. This distance corresponds to the distance to the Small Magellanic Cloud. Thus it is possible, although not likely as we will show later, that Uversa is within the SMC.

> "The Satania system of inhabited worlds is far removed from Uversa and that great sun cluster which functions as the physical or astronomic center of the seventh superuniverse. From Jerusem, the headquarters of Satania, it is over two hundred thousand light-years to the physical center of the superuniverse of Orvonton, far, far away in the dense diameter of the Milky Way. Satania is on the periphery of the local universe, and Nebadon is now well out towards the edge of Orvonton. From the outermost system of inhabited worlds to the center of the superuniverse is a trifle less than two hundred and fifty thousand light-years. " (UB359:8)

Being at a distance of 210,000 light years from the center of the Milky Way, the Small Magellanic Cloud is certainly "over two hundred thousand light-years" from Jerusem, and thus might be a candidate for the location of Uversa. The Small Magellanic Cloud does not, however, seem to be centrally located with respect to the three largest nearby galaxies, the Milky Way, Andromeda (M31), and Triangulum (M33). One must read "far, far away in the dense diameter of the Milky Way" as indicating a direction relative to Jerusem, rather than a position. This would be consistent with accepted astronomical usage of the word "in", as meaning in the same direction. Thus a planet is said to be "in" Aquarius, etc. To specifically locate the center of the superuniverse at the center of the Milky Way galaxy, one would use the words "at the center of" rather than "in."

Taking the center of the superuniverse at the center of the Milky Way galaxy would be inconsistent with current knowledge in that the disk of the Milky Way is about 120,000 light years in diameter, and that Urantia (and presumably Satania) is about 26,000 light years from the center of the galaxy. Thus the distance from Satania to the center of the superuniverse would likely be slightly less than 26,000 light years, and not over 200,000 light years as stated. We thus conclude that the center of the superuniverse of Orvonton is not within the Milky Way galaxy.

Uversa Is Not Near the Center of the Milky Way

A Divine Counselor of Uversa states that he required 109 days to travel from Uversa to Urantia. He also says that his velocity is less than that of a Solitary Messenger. This allows one to place a lower limit on the distance from Urantia to Uversa.

> "Trinity-origin beings possess prerogatives of transit which make them independent of transport personalities, such as seraphim. We all possess the power of moving about freely and quickly in the universe of universes. Excepting the Inspired Trinity Spirits, we cannot attain the almost unbelievable velocity of the Solitary Messengers, but we are able so to utilize the sum total of the transport facilities in space that we can reach any point in a superuniverse, from its headquarters [Uversa], in less than one year of Urantia time. It required 109 days of your time for me to journey from Uversa to Urantia." (UB222:6)

This passage also allows one to compute the ratio of the distance from Uversa to the outermost point of Orvonton, basically the radius of Orvonton to the distance from Uversa to Urantia. This ratio is that of one year to 109 days or 365.25/109 = 3.35. Since we know that the radius of the inhabited portion of Orvonton is greater than 250,000 light years, then the distance from Urantia to Uversa must be greater than 74,600 light years. Since the distance from Urantia to the center of the Milky Way galaxy is about 26,000 light years, one can conclude that Uversa is not near the center of the Milky Way.

Another passage of the Urantia Book supports the notion that Uversa is not located at the center of the Milky Way.

> "Uversa is favorably situated for the work of this [astronomy] colony, not only because of its central location, but also because there are no gigantic living or dead suns near at hand to disturb the energy currents." (UB338:4)

It is known that there is a black hole at the center of the Milky Way which should be even more effective at disturbing the energy currents than living or dead suns. Due to dust clouds, dark nebulae, and a very high density of stars, the center of the galaxy would be a most unfavorable location for an astronomy colony.

Uversa is at the Astronomic Center of Orvonton

The following passages indicate that the various components of Orvonton rotate about Uversa, and thus Uversa is the astronomic center of Orvonton.

> "The Sagittarius sector and all other sectors and divisions of Orvonton are in rotation around Uversa, … " (UB168:3)
>
> "6. The whirl of the ten major sectors, the so-called star drifts, about the Uversa headquarters of Orvonton." (UB168:3)

This rotation about Uversa is presumably not due to the gravitational attraction of Uversa since it is an architectural world and this would be of relatively insignificant mass.

> "10. Architectural Worlds. These are the worlds which are built according to plans and specifications for some special purpose, such as Salvington, the headquarters of your local universe, and Uversa, the seat of government of our superuniverse." (UB172:1)

The statement that

> "The Satania system of inhabited worlds is far removed from Uversa and that great sun cluster which functions as the physical or astronomic center of the seventh superuniverse." (UB359:8)

also supports the notion that Uversa is at the physical center of Orvonton, and that it is at a great distance from Urantia.

An Upper Limit on the Distance to Uversa

The velocity of a Solitary Messenger as given in the passage below can be shown to be equivalent to 4.52 million light years per year of Urantia time.

> "Their velocity in traversing space is variable, depending on a great variety of interfering influences, but the record shows that on the journey to fulfill this mission my associate messenger proceeded at the rate of 841,621,642,000 of your miles per second of your time." (UB261:1)

Since the speed of light is 1.862809 x 10^5 miles/sec, the speed of the Solitary Messenger is 8.41621642 x 10^{11} miles per second divided by 1.862809 x 10^5 = 4.518 x 10^6 light years/ year. This is warp 4.5 million!

Given this speed, the travel time of 109 days stated above, and the location of Jerusem within 4000 light years of Urantia implies that the distance from Urantia to Uversa must be less than 1.35 million light years

Fraction of Orvonton which is Inhabited.

The UB implies that only a small fraction, between one and four percent, of Orvonton is currently inhabited.

> "That portion of Paradise which has been designated for the use of the existing universes is occupied only from one to four per cent, while the area assigned to these activities is at least one million times that actually required for such purposes. Paradise is large enough to accommodate the activities of an almost infinite creation." (UB121:5)

This implies that the inhabited portion of each superuniverse occupies between one and four percent of the inhabitable planets of that superuniverse. Thus Orvonton contains 10 trillion stars, 40 trillion planets, 1 trillion inhabitable planets, and the inhabited portion of Orvonton contains between 10 and 40 billion inhabited planets, and must contain between 100 and 400 billion stars. The Milky Way galaxy has been estimated to contain between 200 and 500 billion stars. Thus it appears that the Milky Way galaxy contains most of the inhabited portion of Orvonton.

The ratio of the number of stars in the mostly uninhabited master universe to that of the grand universe is 4.4 x 10^{21}/7 x 10^{13} = 6.3 x 10^7 (63 million). Could this be the reason that this portion of Paradise is over one million times greater than that actually required at present?

The Size of the Inhabited Portion of Orvonton

The Urantia Book gives a fairly precise indication of the size of the inhabited portion of Orvonton.

> "From the outermost system of inhabited worlds to the center of the superuniverse is a trifle less than two hundred and fifty thousand light-years." (UB359:8)

The radius of the Milky Way galaxy is about 65,000 light years. If the Milky Way contains the "central nucleus", or inhabited portion, of Orvonton, then all of the Milky Way would likely be within the inhabited portion of Orvonton as we concluded above. This also establishes that the radius of Orvonton must be significantly greater than 250,000 light years.

Andromeda not within Inhabited Portion of Orvonton

The Urantia Book explicitly denies that the Andromeda galaxy, shown in Figure 4, is within the inhabited portion of Orvonton, our superuniverse.

Figure 4. The Andromeda Galaxy is probably within the uninhabited portion of our superuniverse.

> "There are not many sun-forming nebulae active in Orvonton at the present time, though Andromeda, which is outside the inhabited superuniverse, is very active." (UB170:1)

This passage implies that Andromeda is, however, within Orvonton. Notice that the UB is here making explicit the distinction between the inhabited and the uninhabited portions of the superuniverse.

The Distance to the Andromeda Galaxy

Speaking of the Andromeda galaxy (M31), the Urantia Book says

> "This far-distant nebula [Andromeda] is visible to the naked eye, and when you view it, pause to consider that the light you behold left those distant suns almost one million years ago." (UB170:1)

This contradicts current astronomical knowledge, which gives the distance to Andromeda as 2.39 +/- 0.09 million light years based on an average of 5 different types of determinations as discussed at http://www.earth.uni.edu/astro/cosmos/part6.html. This distance to Andromeda is not inferred from its red shift (Andromeda is actually blue shifted) but is obtained from a knowledge of the absolute brightness of certain Cephid variable stars which can be seen in Andromeda. The distance obtained by these methods could be in error by a factor of 2.667 (2.39/0.9) if the light we received from Andromeda were 86% absorbed by matter in the optical path, allowing only 14% to reach our telescopes. This might be due to the postulated "dark matter" surrounding our galaxy, but there is no evidence that this is the case. Such a severe light absorption would have to be exceedingly spatially uniform or its presence would be detectable as a patterning in the images obtained by our telescopes.

Upper Limit on the Distance to Andromeda

Given that Andromeda is within our superuniverse, there is an upper limit on the distance from Urantia to the Andromeda galaxy which would be consistent with other information given in the Urantia Book. This upper limit would be the distance from Urantia to Uversa plus the distance from Uversa to the edge of the superuniverse. In this limiting case Uversa would be directly between Urantia and Andromeda.

Knowing that the ratio of the distance from Uversa to the edge of the superuniverse to the distance from Uversa to Urantia is 3.35, then the maximum possible distance to the Andromeda galaxy is 4.35 (1 + 3.35) times the distance from Urantia to Uversa. Since Urantia is within the inhabited portion of Orvonton, then the distance from Urantia to Uversa is less than 250,000 light years, and so the maximum distance from Urantia to Andromeda is 4.35 x 250,000 = 1,087,500 light years.

This is consistent with the distance given in the Urantia Book as less than one million light years, but inconsistent with the current scientific value of this distance of about 2.4 million light years. In order to bring the Urantia Book cosmology into conformance with current science, the distance given in the UB from Uversa to the edge of the inhabited portion of the superuniverse would have to be scaled up by a factor of at least 2.4/1.0875 = 2.2.

Globular Clusters near the Edge of Orvonton

The Urantia Book states that

> "The globular type of star clusters predominates near the outer margins of Orvonton." (UB 170:2)

The existence and location of globular star clusters in a halo around the Milky Way was well known at the time the Urantia Book was written. A discussion of this subject can be found in *The Universe Around Us* by Sir James Jeans (1929, pp 60-62). This book also contains a description of the distribution of these globular clusters as

> "… lying on both sides of the Milky Way, its greatest diameter of about 250,000 light years lying in this plane, …"(p 62)

Given that the UB implies that the radius of the inhabited portion of Orvonton is 250,000 light years (UB359:8) and thus the radius of Orvonton itself must be significantly greater, it seems inconsistent to identify the star clusters mentioned in the UB with the globular clusters described by Jeans which have a maximum radius of 125,000 light years from the galactic center.

They may be speaking of the eleven dwarf spheroidal (or elliptical) galaxies that closely circle the Milky Way. More information on these can be found in an interesting paper by George Lake of the University of Washington. This paper can be found at the URL http://wwwhpcc.astro.washington.edu/papers/localgroup/lg.html. An image of the dwarf spheroidal galaxy Leo I, located about 830,000 light years away, can be seen at http://antwrp.gsfc.nasa.gov/apod/ap960519.html. I suspect that these dwarf galaxies are within Orvonton.

Orvonton Rotates about the Isle of Paradise and Havona

The Urantia Book states that our superuniverse of Orvonton circles the Isle of Paradise and the central universe of Havona.

> "Orvonton is one of the seven evolutionary superuniverses of time and space which circle the never-beginning, never-ending creation of divine perfection—the central universe of Havona. At the heart of this eternal and central universe is the stationary Isle of Paradise, the geographic center of infinity and the dwelling place of the eternal God." (UB1:5)

Location of Havona

The Urantia Book states that the location of Havona is in the direction of the center of the Milky Way galaxy. Of course it is not in the Milky Way at all, but is about 16 million light years distant.

> "When the angle of observation is propitious, gazing through the main body of this realm of maximum density, you are looking toward the residential universe [Havona] and the center of all things." (UB167:5)

The Period of Rotation of Orvonton about Havona

The Urantia Book gives a clue to the period of rotation of Orvonton about Havona.

> "Today, the solar system to which Urantia belongs is a few billion years past the swing around the southern curvature so that you are just now advancing beyond the southeastern bend and are moving swiftly through the long and comparatively straightaway northern path." (UB165:4)

If it took a few billion years to move from the southern curvature to just past the southeastern bend, a distance of one eighth of a complete revolution, then the period of rotation of Orvonton about Havona must be 8 times a few billion years. Assuming the word "few" indicates the number 3 gives a value of 24 billion years for the period of rotation of Orvonton about Havona. This is twice the current estimated age of the Universe and implies that Orvonton has not yet made one revolution about Havona.

The Orbital Velocity of Orvonton around Havona

The velocity of Orvonton in its orbit is the circumference of the orbit, 2 pi times the radius of the orbit, divided by the period of the orbit (24 billion years). Given that the period is 7.57 x 10^{17} s, and assuming a radius of 16 million light years, one finds that the velocity of Orvonton in its orbit around Havona is 1.25 x 10^6 m/s or 5.6 million miles per hour.

This velocity is of the order of magnitude of the currently estimated velocity of the Local Group of 400 km/s in the direction of the Virgo galactic cluster.

The Mass of Havona and the Isle of Paradise

Knowing the period of rotation of Orvonton about Havona to be about 24 billion years, and knowing the distance from Orvonton to Havona to be about 16 million light years, we can calculate an estimate of the mass of Havona. By equating the gravitational pull of Havona necessary to balance the centrifugal force of Orvonton in its orbit about Havona, one finds the mass of Havona to be given by

$$M = R V^2/G$$

Where R is the radius of Orvonton's orbit, V is the velocity of Orvonton in its orbit, and G is the universal gravitational constant (6.673 x 10^{-11} m^3 kg^{-1} s^{-2}). Knowing that 1 light year is 9.46 x 10^{15} m, the radius of Orvonton's orbit is 1.51 x 10^{23} m. The velocity is 1.25 x 10^6 m/s as found above.

Substituting the appropriate values into the equation above gives the mass of Havona to be 3.5 x 10^{45} kg. Given that the mass of the sun is 1.989 x 10^{30} kg, this is equivalent to 1.9 x 10^{15} solar masses. This is also equivalent to about 900 Milky Way galaxies.

The UB says this about the mass of Havona and the Isle of Paradise:

> "Owing to the enormous encircling masses of the dark gravity bodies about the fringe of the central universe, the mass content of this central creation is far in excess of the total known mass of all seven sectors of the grand universe." (UB:129:2)

The Urantia Book states that Orvonton contains about 10^{13} solar masses. The seven sectors of the grand universe thus must contain about 7 x 10^{13} solar masses. Our calculated value of the mass of Havona and the Isle of Paradise is thus about 27 times that of the seven sectors of the grand universe, in agreement with the UB statement.

Possible Other Galaxies within the Grand Universe

Given that the radius of the grand universe is about 16 million light years, one can compile a list of the galaxies, or groups of galaxies, which could be possible locations of the other six superuniverses. If these superuniverses are in a circular orbit around Havona with radius of 16 million light years, we would expect to find two at a distance of 31 Mly, at +/- 0.86H (0.86 hours = 12.9 deg) galactic azimuth, two at 25 Mly distance at +/- 2.6H azimuth, and two at 14 Mly at +/- 4.3 H azimuth. This is because Havona is said to be in the direction of the center of the Milky Way galaxy (0 H galactic azimuth). Such candidates would also be found near the plane of our galaxy, that is, having small values of galactic elevation, Such a list will include:

Figure 5. NGC 5128, Centaurus A, is possibly one of the other inhabited superuniverses. (NOAO/AURA/NSF)

1. **NGC5128** (Centaurus A), shown in Figure 5, is located about 21 deg above the galactic plane at -3.4 H azimuth, and is 12 Mly distant. This makes it a candidate for one of the two closest superuniverses.

2. **NGC6744** shown in Figure 6 is located about 26 deg below the galactic plane at -1.8 H azimuth, and is 25 Mly distant. This is thought to be one of the most similar galaxies to the Milky Way.

Figure 6. NGC 6744 is similar to the Milky Way, and is a possible inhabited superuniverse. (NOAO/AURA/NSF)

After looking through lists of the many galaxies in the vicinity of Urantia, one finds that there are at least 192 galaxies within 32 Mly, and over 1000 galaxies within 100 Mly. It becomes clear that the local universe structure is more complex than the concept of seven superuniverses revolving about Havona presented in the Urantia Book. The concept of the seven superuniverses must be considered as referring to seven inhabited regions of space, and that it must be considered that there are many other uninhabited galaxies within the grand universe, besides Andromeda, not mentioned in the Urantia Book.

The lack of candidate galaxies having the characteristics stated above may be due to the fact that it is difficult to observe galaxies which lie in the plane of the Milky Way, and which are on the opposite side of the Milky Way from Urantia. Recently, some radio observations have revealed galaxies which are otherwise hidden by the obscuring matter of the Milky Way. Undoubtedly there are many unknown galaxies in this region that might be suitable candidates for the location of the other superuniverses.

Our Local Universe

Size of Our Local Universe, Nebadon

Nebadon is said to have about 10 million inhabitable planets. This implies that Nebadon contains about 100 million stars, assuming that on average one star in ten has an inhabitable planet. If the local stellar density is about one star per 240 cubic light years (there are 30 stars within a radius of 12 light years from Urantia), then the volume of space required to hold 100 million stars would be 2.4 x 10^{10} cubic light years. If this volume were approximately spherical, then the radius of this sphere would be about 1,800 light years. One might conclude that our local universe is about this size, or about 3000 to 4,000 light years in diameter. Thus is is clear that our local universe of Nebadon is not the same as our Local Group of galaxies, which is much bigger, on the order of several million light years in diameter.

The Location of Salvington

The UB makes the following statement concerning the location of Salvington, the capital of our local universe.

> "Salvington, the headquarters of Nebadon, is situated at the exact energy-mass center of the local universe. But your local universe is not a single astronomic system, though a large system does exist at its physical center." (UB359:1)

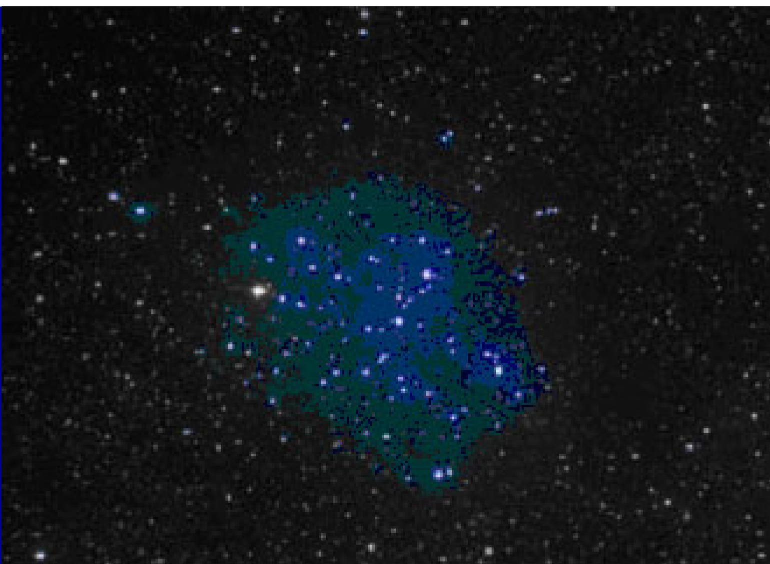


Figure 7. M6, the Butterfly Cluster is located 2000 light years from Urantia in the direction of the galactic center and is likely near Salvington.

We can also guess that Salvington, the capital of our local universe is perhaps about 2000 light years from Urantia in the direction of the center of the Milky Way, since the book says that we are on the outer fringe of Nebadon. This would be near the location of M6, the Butterfly star cluster shown in Figure 7.

It is also likely that the majority of Nebadon is within the Orion arm of the Milky Way galaxy.

Planets, Inhabited and Inhabitable

Fraction of Planets in Orvonton which are Inhabitable

The Urantia Book gives information on the fraction of planets that are inhabitable. One reads:

> "In your superuniverse not one cool planet in forty is habitable by beings of your order. And, of course, the superheated suns and the frigid outlying worlds are unfit to harbor higher life. In your solar system only three planets are at present suited to harbor life." (UB173:5)

Thus the upper limit on the fraction of planets which are inhabitable by human beings is 1 in 40 (0.025). This statement concerns our superuniverse of Orvonton, but since I assume the laws of nature are the same in all superuniverses I will assume this number is applicable to the other superuniverses as well.

The Number of Inhabitable Planets in Orvonton

The number of inhabitable planets in Orvonton is specifically given in the UB.

> "Seven superuniverses make up the present organized grand universe, consisting of approximately seven trillion inhabitable worlds plus the architectural spheres and the one billion inhabited spheres of Havona." (UB166:8)

Given this, one can conclude that our superuniverse of Orvonton contains about one trillion inhabitable worlds. Notice that the UB is careful to distinguish between inhabitable planets and inhabited planets. We will show later that most of these one trillion inhabitable worlds are currently uninhabited.

Fraction of Stars in Orvonton Containing an Inhabitable Planet

Given that there are one trillion inhabitable worlds in Orvonton, and 10 trillion stars in Orvonton, one must conclude that if stars had no multiple inhabitable planets, then one star in ten has an inhabitable planet. If, as is indicated in the section on the distribution of inhabited planets in Satania below, stellar systems tend to have only one inhabitable planet, then generally only one star in about ten would have any inhabitable planets.

A recent survey of 800 nearby stars using the Doppler method, has shown that about one star in twenty has at least a Jupiter-sized planet. That one star in ten has an inhabitable planet therefore seems not improbable.

Average Number of Planets per Star in Orvonton

If there are 0.1 inhabitable planets per star, and 0.025 inhabitable planets per planet then on the average there must be 0.1/0.025 = 4 planets per star in Orvonton. This would indicate that planets are a common occurrence. This is verified by current astronomical science which, although it can detect only large planets approximately the size of Jupiter, has shown such planets to be relatively common.

Number of Inhabitable Planets in our Solar System

> "In your solar system only three planets are at present suited to harbor life." (UB173:5)

Because of the wide diversity of life forms in the Universe, many planets which we would consider uninhabitable for man, may be perfectly habitable for some of the radically-different other life forms. Our solar system having three inhabitable planets is a rare occurrence since as we show below, only 0.7% of solar systems with inhabitable planets have three.

Distribution of Inhabited Planets in Satania

The UB gives the distribution of inhabited planets in Satania among the physical systems (solar systems) containing such planets.

> "Satania is not a uniform physical system, a single astronomic unit or organization. Its 619 inhabited worlds are located in over five hundred different physical systems. Only five have more than two inhabited worlds, and of these only one has four peopled planets, while there are forty-six having two inhabited worlds." (UB359: 7)

Thus there are 511 solar systems with one, 46 with two, 4 with 3, and only 1 with 4 inhabited planets. There are thus 511 + 46 + 4 + 1 = 562 solar systems with inhabited planets in the Satania system.

Average Number of Inhabited Planets per Star in Satania

The Urantia Book gives the number of stars in our system, Satania, which allows computing the average number of inhabited planets per star.

> "There are upward of two thousand brilliant suns pouring forth light and energy in Satania, and your own sun is an average blazing orb." (UB458:1)

Since there are 619 inhabited planets and 2000 stars in Satania, then there are on the average 0.31 inhabited planets per star, or equivalently, approximately one inhabited planet for every 3 stars. Given that there are 562 solar systems with an inhabited planet, then one star out of every 3.6 in Satania has an inhabited planet.

Given that one star in ten in Orvonton has an inhabitable planet, the fact that in Satania one star in 3.6 has an inhabited planet indicates that the Satania star system is an especially favorable environment for life. Current science accepts that only certain zones within a galaxy are favorable for supporting human life.

Fraction of Satania Presently Inhabited

According to a Table given in the Urantia Book (UB167:1), a system contains about 1000 inhabitable planets, therefore the Satania system containing 619 inhabited planets makes it about 62% inhabited. This is much higher than the fraction of Orvonton that is presently inhabited (around 1 to 4%).

The Size of Satania

Given the number of stars in Satania, one can estimate its size under the assumptions that the star density in Satania is uniform and the same as our local star density (one star per 240 cubic light years). Assuming this, one finds that a sphere of radius 48.5 light years is required to contain the 2000 stars said to comprise Satania.

Urantian Cosmology which may Require Future Revision

The Urantia Book states that its cosmology is not necessarily inspired, and that it may require revision in the future. In this article to this point we have been focusing on positive correspondences between Urantian cosmology and current knowledge. In truth, there are some aspects of this cosmology which are not validated by current science and which are likely to require revision.

For instance, the Urantia Book says

> "The Uversa star students observe that the grand universe is surrounded by the ancestors of a series of starry and planetary clusters which completely encircle the present inhabited creation as concentric rings of outer universes upon universes." (UB131:1)

In the past decade there has become available on the Internet a number of 3-dimensional visualizations of the universe. Studying these visualizations, one is struck by the fact that there is no evidence of a structure that can be described as "concentric rings of outer universes." In fact, the universe appears to consist of large superclusters of galaxies, which are distributed in a more or less random manner.

In another instance the Urantia Book describes the "space zones" beyond the grand universe as

> "Between the energy circuits of the seven superuniverses and this gigantic outer belt of force activity, there is a space zone of comparative quiet, which varies in width but averages about four hundred thousand light-years. These space zones are free from star dust—cosmic fog. Our students of these phenomena are in doubt as to the exact status of the space-forces existing in this zone of relative quiet which encircles the seven superuniverses. But about one-half million light-years beyond the periphery of the present grand universe we observe the beginnings of a zone of an unbelievable energy action which increases in volume and intensity for over twenty-five million light-years." (UB130:0)

Again, there is no evidence of spherical zones of empty space surrounding any structure which might be the grand universe. Given the relatively small size of these space zones compared to the size of the grand universe and the distances between galaxies, this statement cannot be reconciled with known universe structure.

The idealized picture of seven superuniverses circling Havona in approximately the plane of our galaxy ignores the fact that assuming this cosmology is true, the space containing these universes also contains numerous other galaxy clusters outside the plane of our galaxy. There is no evidence of any organization of nearby galaxies resulting in a preferential localization near the plane of the Milky Way galaxy.

In another apparent disagreement with current scientific thought, the Urantia Book specifically denies the reality of the expansion of the universe, that the apparent recession of galaxies is linked to their distance by means of the Hubble constant. The UB says:

> "Many influences interpose to make it appear that the recessional velocity of the external universes increases at the rate of more than one hundred miles a second for every million light-years increase in distance. By this method of reckoning, subsequent to the perfection of more powerful telescopes, it will appear that these far-distant systems are in flight from this part of the universe at the unbelievable rate of more than thirty thousand miles a second. But this apparent speed of recession is not real; it results from numerous factors of error embracing angles of observation and other time-space distortions." (UB134:3)

Current science regards this Hubble effect as real. In fact, all the current 3-dimensional representations of the universe largely rely on this effect to establish the distance to the galaxies, Andromeda being an exception. If the Hubble effect is not real, then all such current representations are invalid. At this time there is no scientific evidence that the Hubble effect is not real, and in fact, there is significant evidence that it is real.

The Urantia Book states that only a very small portion of the observable universe contains life.

> "As far as we know, no material beings on the order of humans, no angels or other spirit creatures, exist in this outer ring of nebulae, suns, and planets. This distant domain is beyond the jurisdiction and administration of the superuniverse governments." (UB131:2)

Current scientific opinion is that life formed by a chance combination of chemicals and evolved into the complex life forms known today. It would be deemed as most unlikely that life was concentrated on only a few clusters of galaxies as implied by this UB statement. Of course, we have at present no way to know if this is true or not.

One of the most serious disagreements between current astronomical science and the Urantia Book cosmology concerns the size of Orvonton, The radius of Orvonton can be inferred to be about 3.35 times between 200,000 and 250,000 light years or about 770,000 light years as indicated by UB222:6 and UB359:8. This assumes that Jerusem, the capital of our star system, Satania, is relatively near (within 50 light years) to Urantia and is thus within the Milky Way. Such a small radius would exclude both the Andromeda and Triangulum galaxies from the uninhabited portion of Orvonton and it seems impossible that there are 10 trillion stars (UB172:7) within such a small volume.

One possible explanation for this inconsistency and also for that involving the distance to the Andromeda galaxy is to postulate that the authors of the Urantia Book presented a cosmology that was scaled to fit the astronomic knowledge of the time when the book was written. The value of one million light years for the distance to Andromeda was the current astronomical knowledge during the period of 1923 to 1953. The Urantia papers were written within this time period. If the authors scaled the true distance to the Andromeda galaxy down by a factor of about 3 to prevent the disclosure of unearned knowledge, to be maximally self-consistent they may have also scaled down the other two distances which they directly give. These distances are the 200,000 light years from Uversa to Jerusem, and the 250,000 light years corresponding to the radius of the inhabited portion of Orvonton.

If this hypothesis is true, then the true distances can be found by multiplying the values given in the UB by a factor of about 3. This makes the distance to the Andromeda galaxy agree with current knowledge. It makes the distance from Jerusem to Uversa to be greater than 600,000 light years, and the radius of the inhabited portion of Orvonton to be less than 750,000 light years. The overall radius of Orvonton would then be greater than 3.35 times 600,000 or 2.0 million light years. It would be less than 750,000/0.34 or 2.2 million light years. This places both the Andromeda and Triangulum galaxies within the uninhabited portion of Orvonton. It also makes the UB statement that Orvonton contains ten trillion stars much more plausible.

Such a scaling would not be inconsistent with the statement that the Divine Counselor can reach any part in Orvonton in one Urantia year. If the distance from Uversa to the edge of Orvonton is about 2.1 million light years, then the velocity of the Divine Counselor would be 2.1/4.51 = 0.47 times that of the Solitary Messengers, or consistent with his statement that he could not attain the speed of a Solitary Messenger. Apparently a Solitary Messenger travels at about twice the speed of a Divine Counselor. Any scaling factor greater than about 6 would be inconsistent with the stated speed of the Divine Counselor.

Could it be that the revision of the Urantian cosmology which the UB authors state may be required in the future is this scaling upwards of the stated distances by a factor of 3? This is probably one of the simplest possible revisions, which could be imagined.

Another discrepancy in UB cosmology concerns the time required for a Solitary Messenger to travel to the central universe (Havona) and back. The Urantia Book states that a Solitary Messenger can travel at a speed of

> "841,621,642,000 of your miles per second of your time." (UB261:1)

Since the speed of light is 186,281 miles per second, the speed of the Solitary Messenger is 4,512,000 times the speed of light.

The Urantia Book also says the following about a Solitary Messenger:

> "Long before the presence of life on Urantia the [Solitary] messenger now associated with me was assigned on a mission out of Uversa to the central universe—was absent from the roll calls of Orvonton for almost a million years but returned in due time with the desired information." (UB259:2)

In a million Urantia years a Solitary Messenger can travel a distance of 2,256 billion light years and back. The age of the universe is thought to be only 14 billion years, so the radius of the universe is no greater than 14 billion light years. It would take a Solitary Messenger only 6,200 years to travel to the edge of the known universe and back.

There is good reason, based on the number of stars in the grand universe, to believe that the distance from Uversa to the central universe is only about 16 million light years. A Solitary Messenger can travel this distance and back in only seven Urantia years. If this distance is correct the Solitary Messenger had 999,993 years to spend in the central Universe before he had to return.

There is also good reason to believe that the speed given for the Solitary Messenger is correct. This is based on the ability of a Divine Counselor, travelling at a lesser speed, to reach any part of Orvonton in one Urantia year, and the apparent size of Orvonton based on the number of stars in Orvonton. If this is so, it appears that he could have made the trip to the central universe and back in less than one Uversa year, or 8.2 Urantia years and still have had 1.2 Urantia years to conduct his business.

Thus it appears that the statement given in UB259:2 is grossly inconsistent with the other cosmology given in the UB. Perhaps it should have read that the Solitary Messenger was gone only one (Uversa) year?

Conclusions

These results show that the major aspects of Urantia Book cosmology are, in most part, in reasonable agreement with our present cosmological understanding. The major conflicts with current astronomical knowledge can be resolved if the three absolute distances given in the book are scaled up by a factor of about 3 to make the distance to the Andromeda galaxy conform approximately to current estimates.

The reader may question why the revelators chose to present a false value for the scale of the cosmology given in the UB. I believe that this choice actually demonstrates the wisdom of the revelators. Given that the currently-accepted value of the distance to the Andromeda galaxy was 900,000 light years at the time the book was written (Jeans, op.cit. p66), the revelators were faced with several conflicting choices. At the time, the distance to the Andromeda galaxy was the only extra-galactic distance known with any belief of certainty. I believe they chose to give this distance to provide an absolute scale to the size of our superuniverse because it was the largest distance determined by Urantian science of that time. Given this, they were faced with two choices: revealing the true distance or presenting a distance in agreement with accepted knowledge. Given the fact that the Urantian science was inaccurate at the time, any statement made would inevitably be at odds with current opinion, either before or after the truth was known. Revealing the true distance would immediately create disbelief in the revelation among the science-minded audience at which the revelation is directed, and would impart unearned scientific knowledge, prohibited by the mandate of revelation, which would shortly be acquired unaided by Urantian scientists in any event. In giving the then-accepted value, they avoided any controversy during the early stages of the acceptance of the revelation. The impact of the later inconsistency with Urantian astronomy they defused by explicitly admitting that the cosmology presented was not divinely inspired and would require revision in the future. Scaling all distances down by the same factor would create the minimum possible distortion to the presented cosmology, and would allow recovery of the true distances in the future when the true distance to the Andromeda galaxy was known.

The Urantia Book expressly condones not revealing facts when it might inhibit spiritual advancement. Speaking of the seraphic recorders it says,

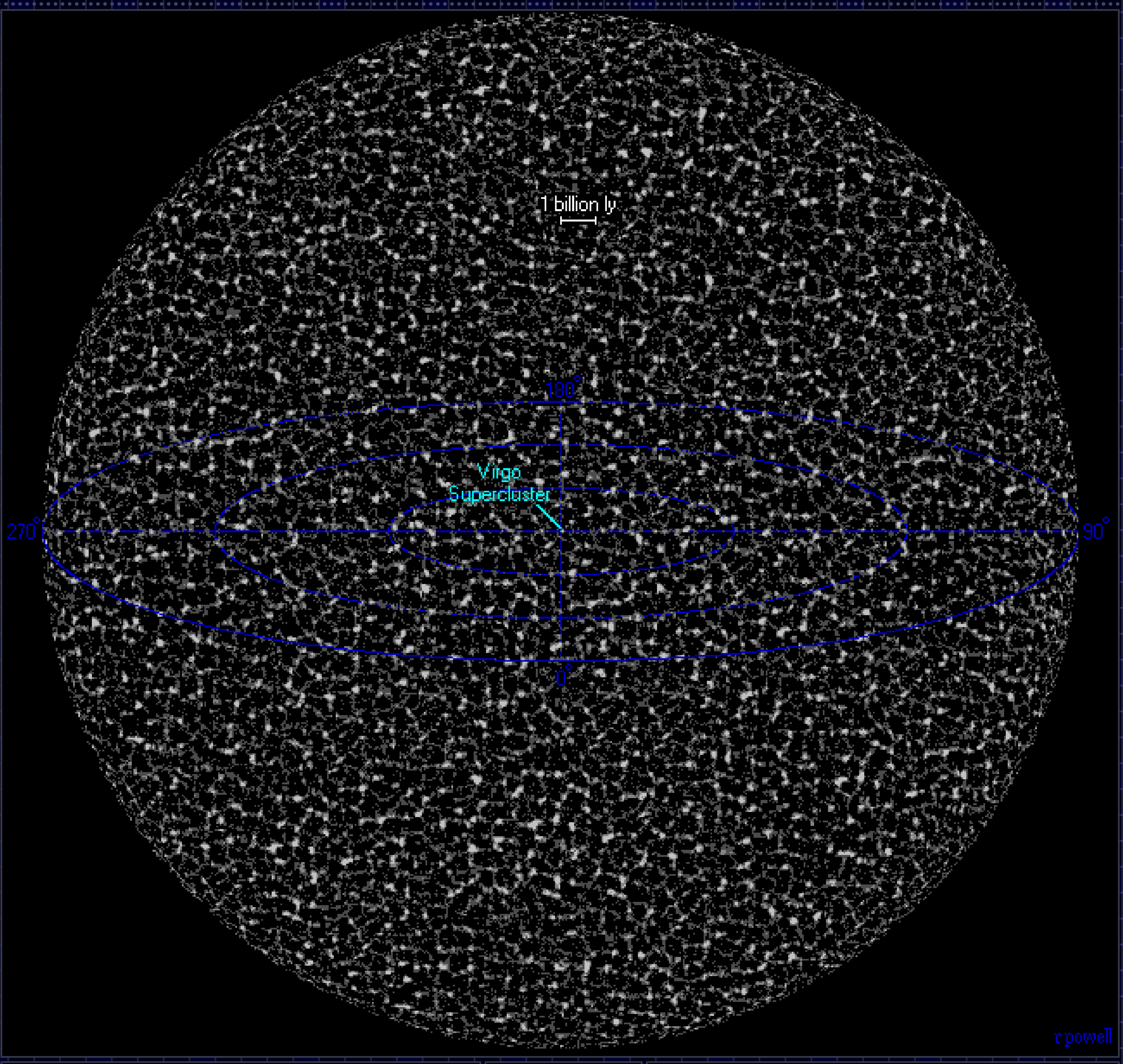
> "Some day they will teach you to seek truth as well as fact, to expand your soul as well as your mind. … But sometimes error is so great that its rectification by revelation would be fatal to those slowly emerging truths which are essential to its experiential overthrow. When children have their ideals, do not dislodge them; let them grow." (UB554:6)

Did the revelators decide that correcting the factual error concerning the distance to Andromeda might inhibit the spread of the spiritual truths they were trying to implant?

The apparent inconsistency in the time taken by the Solitary Messenger in his trip to the central universe and back is not convincing evidence of the inaccuracy of UB cosmology. It may be that the Solitary Messenger spent the vast majority of the time during his trip in collecting the desired information, or it may be that the value "one million" was inserted by a human editor who could not believe that such a trip would take only one year.

It appears unlikely that the other disagreement with Urantian science, that of the purposeful implantation of life in the seven superuniverses, or galaxy clusters, versus the random spontaneous self-assembly of life from inert matter, will be resolved anytime within the foreseeable future. It does seem possible to verify the presence of life in the near vicinity of our solar system, which the UB states is a relatively common occurrence. This should be encouraging to those engaged in the present SETI efforts.

The Universe within 14 billion Light Years
The Visible Universe



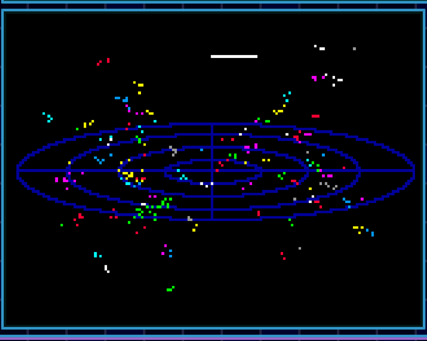
Zoom In x14 | Home

- Number of superclusters in the visible universe = 10 million
- Number of galaxy groups in the visible universe = 25 billion
- Number of large galaxies in the visible universe = 350 billion
- Number of dwarf galaxies in the visible universe = 3.5 trillion
- Number of stars in the visible universe = 30 billion trillion

About the Map

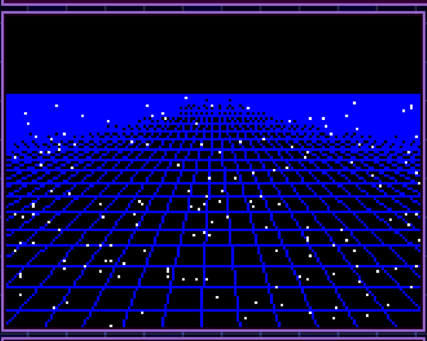
This map attempts to show the entire visible Universe. The galaxies in the universe tend to collect into vast sheets and superclusters of galaxies surrounding large voids giving the universe a cellular appearance. Because light in the universe only travels at a fixed speed, we see objects at the edge of the universe when it was very young up to 14 billion years ago.

Additional Maps

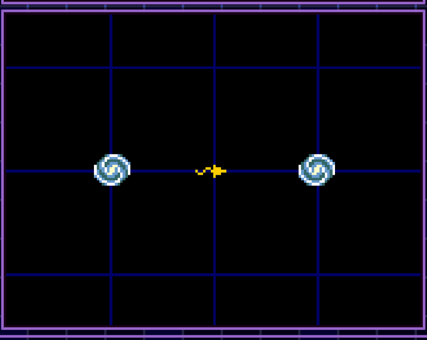


A Map of the Universe within 2 billion Light Years
The universe has been partially mapped out to about 2 billion light years. Here is a map showing many of the major superclusters within 2 billion light years.

Data and Catalogs



The Big Bang and the Expansion of the Universe
This page is a brief explanation of the Big Bang and it explains how the universe is expanding and why there is no centre or edge of the expanding universe.

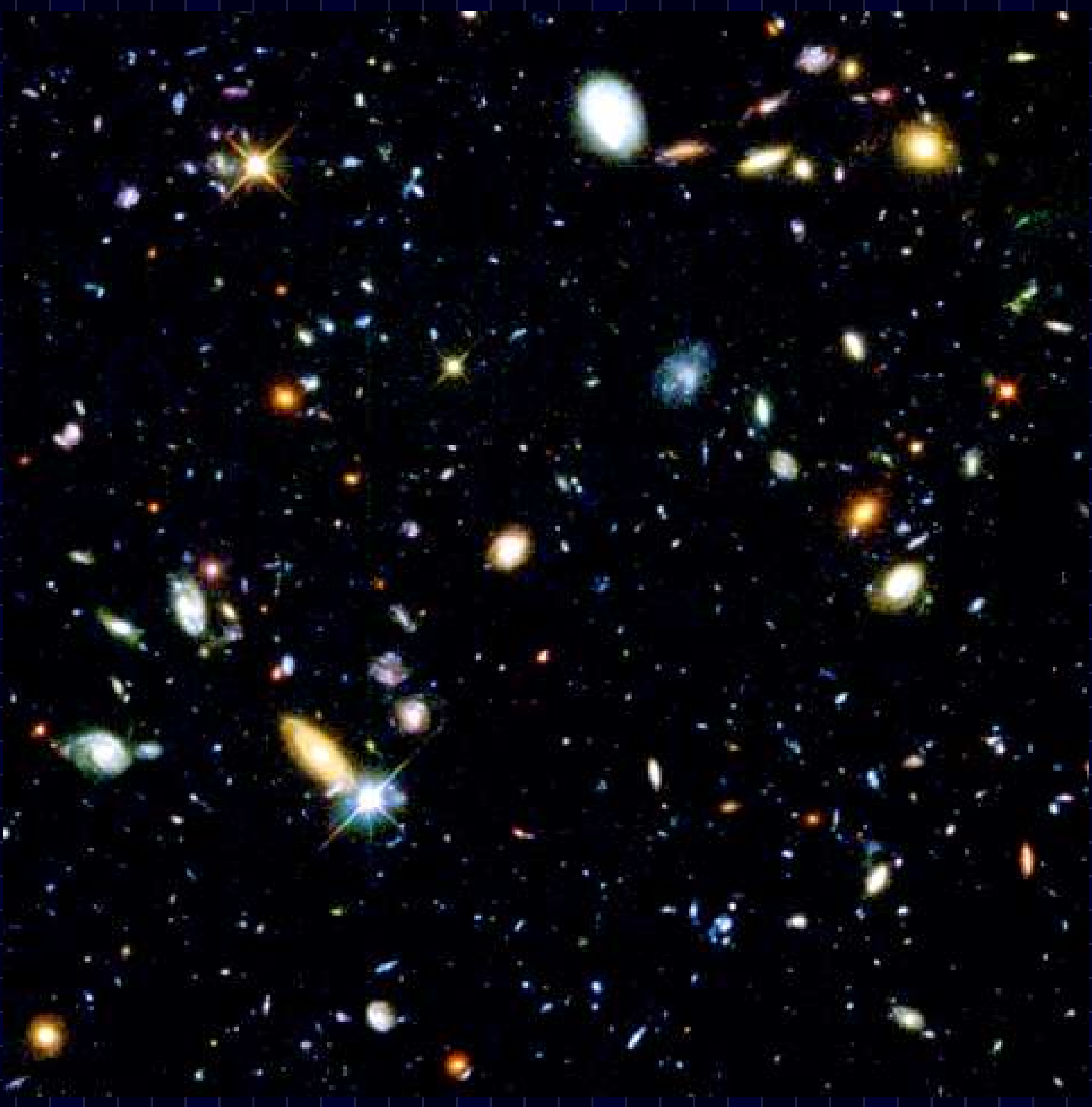


The Distance Scale of the Universe
What exactly is the distance to the edge of the visible universe? How do you define distance in an expanding universe? This page tries to answer this difficult question.

The Size of the Universe

The visible universe appears to have a radius of 14 billion light years because the universe is about 14 billion years old. The light from more distant objects simply has not had time to reach us. For this reason everybody in the universe will find themselves at the middle of their own visible universe. The precise scale of the universe is complicated by the fact that the universe is expanding. Galaxies we see near the edge of the visible universe emitted their light when they were much closer to us, and they will now be much further away.

The true size of the universe is probably much larger than the visible universe. The geometry of the universe suggests that it may have an infinite size and that it will expand forever. Even if the universe is not infinite, our visible universe must be a minute speck in a much larger totality.

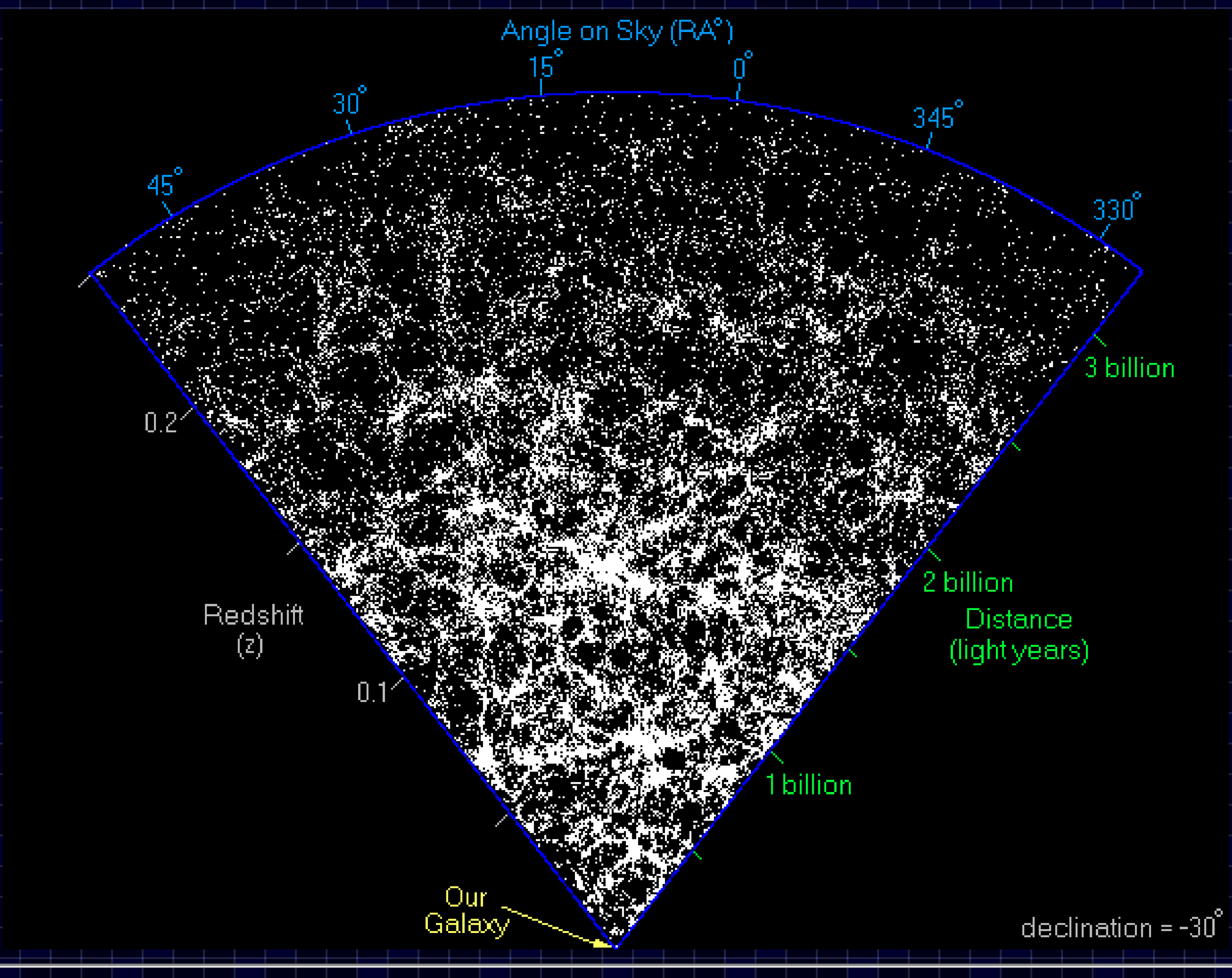


The Hubble Deep Field

In December 1995, the Hubble Space Telescope was pointed at a blank area of the sky in Ursa Major for ten days. It produced one of the most famous astronomy pictures of modern times - the Hubble Deep Field Image. A part of it is shown here. Almost every object in this image is a galaxy typically lying 5 to 10 billion light years away. The galaxies revealed here are all shapes and colours, some are young and blue, whereas others are old, red and dusty.

A Slice of the Universe

By collecting distances to thousands of galaxies in a narrow strip of the sky, it is possible to produce a 'slice' of the universe, like this one shown below from the 2dF Galaxy Redshift Survey which looks out into the universe to 3.5 billion light years, although not much data was collected for galaxies beyond 3 billion light years. These types of plots show how clustered the galaxies in the universe really are, even on the largest scales. About 52 000 galaxies are plotted.



Home

The Milky Way Galaxy

A *spiral galaxy*, type Sbc, centered in Sagittarius

The Milky Way is the galaxy which is the home of our Solar System together with at least 200 billion other stars (more recent estimates have given numbers around 400 billion) and their planets, and thousands of clusters and nebulae, including at least almost all objects of Messier's catalog which are not galaxies on their own (one might consider two globular clusters as possible exceptions, as probably they are just being, or have recently been, incorporated or imported into our Galaxy from dwarf galaxies which are currently in close encounters with the Milky Way: M54 from SagDEG, and possibly M79 from the Canis Major Dwarf). See our Messier Objects in the Milky Way page, where details are given for each object to which part of our Galaxy it is related. All the objects in the Milky Way Galaxy orbit their common center of mass, called the **Galactic Center** (see below).

As a galaxy, the Milky Way is actually a giant, as its mass is probably between 750 billion and one trillion solar masses, and its diameter is about 100,000 light years. Radio astronomial investigations of the distribution of hydrogen clouds have revealed that the Milky Way is a spiral galaxy of Hubble type Sb or Sc. Therefore, out galaxy has both a pronounced disk component exhibiting a spiral structure, and a prominent nuclear region which is part of a notable bulge/halo component. It is still not clear if it has a bar structure (so that it would be type SB) or not, but an increasing number of investigations has given some evidence for this, so that the Milky Way may look like M61 or M83, and is perhaps best classified as SABbc.

- More on the structure of the Milky Way

The Milky Way Galaxy belongs to the Local Group, a smaller group of 3 large and over 30 small galaxies, and is the second largest (after the Andromeda Galaxy M31) but perhaps the most massive member of this group. M31, at about 2.9 million light years, is the nearest large galaxy, but a number of faint galaxies are much closer: Many of the dwarf Local Group members are satellites or companions of the Milky Way. The two closest neighbors, both already mentioned, have only recently been discovered: The nearest of all, discovered in 2003, is an already almost disrupted dwarf galaxy, the Canis Major Dwarf, the nucleus of which is about 25,000 light-years away from us and about 45,000 light-years from the Galactic Center. Second comes SagDEG at about 88,000 light years from us and some 50,000 light years from the Galactic Center. These two dwarfs are currently in close encounters with our Galaxy and in sections of their orbits situated well within the volume ocupied by our Milky Way. They are followed in distance by the more conspicuous Large and Small Magellanic Cloud, at 179,000 and 210,000 light years, respectively.

The spiral arms of our Milky Way contain interstellar matter, diffuse nebulae, and young stars and open star clusters emerging from this matter. On the other hand, the bulge component consists of old stars and contains the globular star clusters; our galaxy has probably about 200 globulars, of which we know about 150. These globular clusters are strongly concentrated toward the Galactic Center: From their apparent distribution in the sky, Harlow Shapley has concluded that this center of the Milky Way lies at a considerable distance (which he overestimated by factors) in the direction of Sagittarius and not rather close to us, as had been thought previously.

Our solar system is thus situated within the outer regions of this galaxy, well within the disk and only about 20 light years above the equatorial symmetry plane but about 28,000 light years from the Galactic Center. Therefore, the Milky Way shows up as luminous band spanning all around the sky along this symmetry plane, which is also called the "Galactic Equator". Its center lies in the direction of the constellation Sagittarius, but very close to the border of both neighbor constellations Scorpius and Ophiuchus. The distance of 28,000 light years has recently (1997) been confirmed by the data of ESA's astrometric satellite Hipparcos. Other investigations published consequently have disputed this value and propose a smaller value of some 25,000 light years, based on stellar dynamics; a recent investigation (McNamara *et.al* 2000, based on RR Lyrae variables) yields roughly 26,000 light years. These data, if of significance, wouldn't immediately effect values for distances of particular objects in the Milky Way or beyond.

The solar system is situated within a smaller spiral arm, called the *Local* or *Orion Arm*, which is merely connection between the inner and outer next more massive arms, the *Sagittarius Arm* and the *Perseus Arm*; see our Milky Way Spiral Structure page.

Similar to other galaxies, there occur supernovae in the Milky Way at irregular intervals of time. If they are not too heavily obscured by interstellar matter, they can be, and have been seen as spectacular events from Earth. Unfortunately, none has yet appeared since the invention of the telescope (the last well observed supernova was studied by Johannes Kepler in 1604).

Milky Way pictures are wide-field exposures. Besides being attractive and often colorful, they are often suited to view the Milky Way objects (including nebulae and star clusters) in their celestial surroundings of field stars. Some fields include lots of Messier objects and thus included here:

- Milky Way central region including constellations Sagittarius, Scorpius, Ophiuchus and Scutum, and map of the Milky Way Central Region, by Bill Keel of the University of Alabama
- Milky Way in Sagittarius, including portions of Scorpius and Ophiuchus
- Milky Way around M17, M18, and M24

Our image was obtained by David Malin of the Anglo-Australian Observatory, and shows the many Messier objects around the direction of the Galactic Center. It is copyrighted and may be used for private purpose only. For any other kind of use, including internet mirroring and storing on CD-ROM, please contact the Photo Permissions Department (photo at aaoepp.aao.gov.au) of the Anglo Australian Observatory.

- More information on this image by David Malin
- Old style AAT image

In order to obtain a picture of the whole Milky Way as it appears from Earth, one must either compose a mosaic of many photographs (optionally computer-processed), or create a drawing; fine examples may be accessed below:

- A good Milky Way photo mosaic
- Knut Lundmark's drawing of the Milky Way

In the infrared light, the structure of the Milky Way can be better investigated, as the obscurring dust clouds are of better transparency for long wavelength IR than for the visible light. The Cobe satellite has provided an infrared image of the Milky Way's central region.

The central region of the Milky Way, as those of many other galaxies, is more densely crouded with stars than the outer region, and contains a massive central object, Sagittarius A*.

Below we give some data for the **Galactic Center** (this and all following positions for epoch 2000.0):

Right ascension	17 : 45.6 (h : m)
Declination	-28 : 56 (deg : m)
Distance	28 (kly)

The **Galactic North Pole** is at

Right ascension	12 : 51.4 (h : m)
Declination	+27 : 07 (deg : m)

The coordinate data given here were extracted from the online coordinate calculator at Nasa/IPAC's Extragalactical Database (NED) (also available by telnet).

Our Sun, together with the whole Solar System, is orbiting the Galactic Center at the distance given, on a nearly circular orbit. We are moving at about 250 km/sec, and need about 220 million years to complete one orbit (so the Solar System has orbited the Galactic Center about 20 to 21 times since its formation about 4.6 billion years ago).

In addition to the overall Galactic Rotation, the solar system is moving between the neighboring stars (peculiar motion) at a velocity of about 20 km/s, to a direction called "Solar Apex," at the approximate position RA=18:01, Dec=+26 (2000.0); this motion has been discovered by William Herschel in 1783.

Considering the sense of rotation, the Galaxy, at the Sun's position, is rotating toward the direction of Right Ascension 21:12.0, Declination +48:19. This shows that it rotates "backward" in the Galactic coordinate system, i.e. the Galactic North Pole is actually a physical South Pole with respect to galactic rotation (defined by the direction of the angular momentum vector).

- More info on the Milky Way Spiral Structure
- Messier Objects in the Milky Way page

More links to Milky Way materials:

- Milky Way Galaxy images from the Astronomical Picture of the Day archives
- Milky Way Wide-Angle Photos
- Multi Wavelength Images of the Milky Way (Nasa ADC)
- Milky Way page of the MAP space observatory project
- The Summer Milky Way from S.E. Arizona
- Milky Way panorama by Axel Mellinger
- The Milky Way Galaxy within 50,000 light years, A Map of the Milky Way, and The Milky Way's Satellite Galaxies, from An Atlas of the Universe
- The Structure of the Milky Way Tutorial, Gene Smith
- Yahoo's index of Milky Way webpages

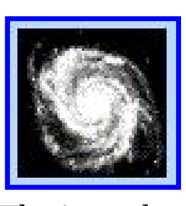
References:

- D.H. McNamara, J.B. Madsen, J. Barnes, and F.B. Ericksen, 2000. The Distance to the Galactic Center. *PASP* **112** p. 202 (Feb. 2000)

General References and Further Reading:

- *The Milky Way*, by Bart J. and Priscilla F. Bok. 5th edition. Harvard University Press, 1981.
- *The Guide to the Galaxy*, by Nigel Henbest and Heather Cooper. Cambridge University Press, 1994.
- *The Alchemy of the Heavens*, by Ken Croswell. Anchor Books, New York, 1995.

Galaxies



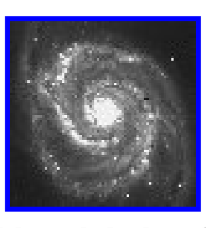
Click the icon to view galaxies of the Messier catalog

>>Links; >>References; >>Galaxy Clusters

The icon shows M51, the Whirlpool Galaxy.

Galaxies are large systems of stars and interstellar matter, typically containing several million to some trillion stars, of masses between several million and several trillion times that of our Sun, of an extension of a few thousands to several 100,000s light years, typically separated by millions of light years distance. They come in a variety of flavors: Spiral, lenticular, elliptical and irregular. Besides simple stars, they typically contain various types of star clusters and nebulae.

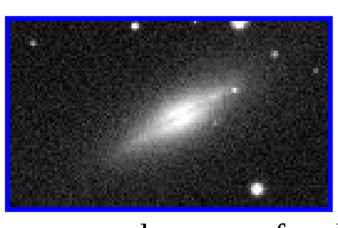
We live in a giant spiral galaxy, the Milky Way Galaxy, of 100,000 light years diameter and a mass of roughly a trillion solar masses. The nearest dwarf galaxies, stellites of the Milky Way, are only a few 100,000 light years distant, while the nearest giant neighbor, the Andromeda Galaxy, also a spiral, is about 2-3 million light years distant.



Spiral

Spiral galaxies usually consist of two major components: A flat, large disk which often contains a lot of interstellar matter (visible sometimes as reddish diffuse emission nebulae, or as dark dust clouds) and young (open) star clusters and associations, which have emerged from them (recognizable from the blueish light of their hottest, short-living, most massive stars), often arranged in conspicuous and striking spiral patterns and/or bar structures, and an ellipsoidally formed bulge component, consisting of an old stellar population without interstellar matter, and often associated with globular clusters. The young stars in the disk are classified as stellar population I, the old bulge stars as population II. The luminosity and mass relation of these components seem to vary in a wide range, giving rise to a classification scheme. The pattern structures in the disk are most probably transient phenomena only, caused by gravitational interaction with neighboring galaxies.

Our sun is one of several 100 billion stars in a spiral galaxy, the Milky Way.



Lenticular (S0)

These are, in short, "spiral galaxies without spiral structure", i.e. smooth disk galaxies, where stellar formation has stopped long ago, because the interstellar matter was used up. Therefore, they consist of old population II stars only, or at least chiefly. From their appearance and stellar contents, they can often hardly be distinguished from ellipticals observationally.

Elliptical

Elliptical galaxies are actually of ellipsoidal shape, and it is now quite safe from observation that they are usually triaxial (*cosmic footballs*, as Paul Murdin, David Allen, and David Malin put it). They have little or no global angular momentum, i.e. do not rotate as a whole (of course, the stars still orbit the centers of these galaxies, but the orbits are statistically oriented so that only little net orbital angular momentum sums up). Normally, elliptical galaxies contain very little or no interstellar matter, and consist of old population II stars only: They appear like luminous bulges of spirals, without a disk component.

However, for some ellipticals, small disk components have been discovered, so that they may be representatives of one end of a common scheme of galaxy forms which includes the disk galaxies.

Irregular

Often due to distortion by the gravitation of their intergalactic neighbors, these galaxies do not fit well into the scheme of disks and ellipsoids, but exhibit peculiar shapes. A subclass of distorted disks is however frequently occuring.

From their appearance, galaxies are classified in types as given above, as spiral, lenticular, elliptical, and irregular galaxies, where spirals may be further classified for the presence of a bar (S: spirals, SAB: Intermediate, SB: Barred spirals). More precisely, ellipticals are sub-classified for ellipticity from E7 (strongly elongated) to E0 (circular), and spirals for prominence of bulge versus spiral arms from Sa (or SABa, SBa) to Sc or Sd. This so-called Hubble Classification Scheme can well be illustrated by Messier's galaxies:

- Hubble Scheme with Messier galaxies for HTML browser supporting tables (e.g., Netscape, IBM Webexplorer)
- Hubble Scheme for HTML browsers not supporting tables (Lynx, Mosaic)

Galaxies of all types, though of a wide variety of shapes and appearances, have many basic common features. They are huge agglomerations of stars like our Sun, counting several millions to several trillions. Most of the stars are not lonely in space like our Sun, but occur in pairs (binaries) or multiple systems.

The most massive galaxies are giants which are a million times more massive than the lightest: Their mass range is from at most some million times that of our Sun in case of the smallest dwarfs, to several trillion solar masses in case of giants like M87 or M77. Accordingly, the number of stars in them varies in the same range.

The linear size of galaxies also scatters, ranging from small dwarfs of few thousands of light years diameter (like M32) to respectable several 100,000 light years. Among the biggest Messier galaxies are the Andromeda galaxy M31 and the bright active Seyfert II galaxy M77.

Our *Milky Way Galaxy*, a spiral galaxy, is among the massive and big galaxies with at least 250 billion solar masses (there are hints that the total mass may even be as large as 750 billion to 1 trillion times that of the Sun) and a disk diameter of 100,000 light years.

Besides very many individual stars, most galaxies contain the following typical objects:

- **Globular star clusters**, large but quite compact agglomerations of some 100,000 to several million stars. These large clusters have about the same mass as the smallest galaxies, and are among the oldest objects in galaxies. Often, they form conspicuous systems, and occur at galaxies of every type and size. The globular cluster systems vary in a wide range in richness between the individual galaxies.
- As the stars develop, many of them leave nebulous remnants (**planetary nebulae** or **supernova remnants**) which then populate the galaxies.
- While the older stars, including the globular clusters, tend to form an ellipsoidal **bulge**, the interstellar gas and dust tends to accumulate in clouds near an equatorial **disk**, which is often conspicuous (i.e., in spiral and lenticular galaxies).
- The interstellar clouds are the places of **star formation**. More acurately, huge **diffuse nebulae** are places where crowded (open) **clusters** and **associations** of stars are formed.
- A rather dense galactic **nucleus**, which is somewhat similar to a "superlarge" globular cluster. In many cases, galactic nuclei contain **supermassive dark objects**, which are often considered as Black Hole candidates.

Galaxies normally emit light of every wavelength, from the long radio and microwave end over the IR, visual and UV light to the short, high-enregy X- and gamma rays. Interstellar matter is coolest and therefore best visible in radio and IR, while supernova remnants are most conspicuous in the high-energy part of the electromagnetic spectrum.

Some galactic nuclei are remarkably distinguished from the average: These so-called **Active Galactic Nuclei (AGNs)** are intensive sources of light of all wavelengths from radio to X-rays. The activities seen in the AGNs are caused by gaseous matter falling into, and interacting with, the supermassive central objects mentioned above, according to the current consensus of most researchers. Sometimes, the spectra of these nuclei indicate enormous gaseous masses in rapid motion; galaxies with such a nucleus are called **Seyfert galaxies** (for their discoverer, Karl Seyfert). M77 is the brightest Seyfert galaxy in the sky. Few galaxies have even more exotic nuclei, which are extremely compact and extremely bright, outshining their whole parent galaxy; these are called **quasars** (an acronym for QUAsi-StellAR objects). From their properties, quasars resemble extremely active Seyfert galaxy nuclei. However, quasars are so rare and the nearest is so remote that the brightest of them, 3C273, about 2 billion lightyears away in the constellation Virgo, is only of magnitude 13.7, and none of them is in Messier's or even in the NGC or IC catalog.

Occasionally, at irregular intervals given by chance, in any type of galaxies, a supernova occurs: This is a star suddenly brightning to a high luminosity which may well outshine the whole galaxy; the maximal absolute magnitude of a supernova may well reach -19 to -20 magnitudes. This remarkable phenomenon has attracted the attention of many astronomers (equally both professionals and amateurs), who observe galaxies regularly as they "hunt" supernovae. Supernovae have been observed in several Messier catalog galaxies.

According to our current scientific understanding, at least most galaxies (including our Milky Way and those in Messier's catalog) have formed during a comparatively short period, at about the same time, within the first billion years after the universe started to expand, from an initial hot state. Thus they are all almost as old as the universe itself, currently thought to be about 10-15 billion years. It is thought that galaxy formation started when primordial clouds of gaseous matter (hydrogene and helium), the proto-galaxies, were singled out and started to collapse by their own gravity. According to computer simulations, the variety of galaxy forms results from different initial parameters of the proto-galaxies such as the amount of (initial) angular momentum, as well as their later evolution in their environments, such as interaction with other neighboring galaxies.

Links

- Radial velocities of the Messier galaxies
- Nasa's Extragalactical Database (NED) (also available by telnet)
  - NED data of the Messier galaxies
- Galaxy Informations from the University of Alabama
- Galaxies and the Universe - WWW Course Notes by Bill Keel
- Galaxies text (by Nick Strobel; Scholar series at the MAA)
- Galaxy Catalogs List
- Arp's Catalog of Peculiar Galaxies; this catalog includes some of Messier's galaxies (see also the Arp Galaxies in Other Catalogs page of the Online Arp Catalog)
- Zsolt Frei's Catalog of 113 Nearby Galaxies with images taken at different wavelengths; [also by ftp]
- ARVAL Catalog of Bright Galaxies
- Globular cluster systems in other galaxies: Catalog by W. E. Harris (we hold a possibly older copy); Globular Clusters in Other Galaxies (M. Kissler-Patig)
- From An Atlas of the Universe:
  - The 200 Brightest Galaxies
  - Galaxies and Groups of Galaxies within 20 million light
  - The Virgo Supercluster within 100 million Light Years
  - The Universe within 200 million Light Years
- Look at Galaxies in Messier's Catalog
- Also look at our collection of some significant non-Messier galaxies

References

Imagery and atlasses:

- **Allan Sandage**. *The Hubble Atlas of Galaxies*. Carnegie Institution of Washington, 1961. 185 superb black & white photographs of galaxies of all types, obtained by the Mt. Palomar and Mt. Wilson Observatory telescopes, with captions and data, and a technical and scientific introduction.
- **James D. Wray**. *The Color Atlas of Galaxies*. Cambridge University Press, 1988. 3-color (UBV) images of 616 galaxies (including all Messier galaxies but M89), taken with telescopes at the McDonald Observatory, Texas, and the Cerro Tololo Interamerican Observatory, Chile, with data and captions.
- **Timothy Ferris**. *Galaxies*. Sierra Club Books, San Francisco, 1980. Superb book (look to get the more expensive full-size edition) with color and b/w photographs of galaxies and some other objects, from various observatories.

Of course, fine galaxy photos can be found in many more general astronomy books also.

Special observing Guides:

- **Kenneth Glyn Jones** (editor). *Webb Society Deep-Sky Observer's Handbook*, Volume 4, *Galaxies*, 1981; Volume 6, *Anonymous Galaxies*, 1987. Enslow Publishers, Hillside, NJ.

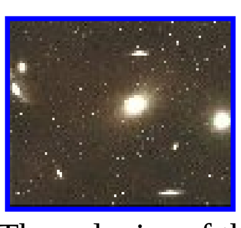
Most general Deep Sky Observing Guides are good as well.

Textbooks:

- **Dimitri Mihalas** and **James Binney**. *Galactic Astronomy*. W.H. Freeman, 1981 (probably out of print).
  Now replaced by: **James Binney** and **Michael Merrifield**. *Galactic Astronomy*. Princeton University Press, 1998.
  This is a good introduction and review especially for the observational properties of galaxies (as they were known at the time of publication).
- **James Binney** and **Scott Tremaine**. *Galactic Dynamics*. Princeton Series in Astrophysics, Princeton University Press, 1987.
  In-depth treatment of the physics of galaxies. Some mathematical and physical background is required for this book.
- **Paul W. Hodge**. *Galaxies*. Harvard University Press, 1986.

Historical Review:

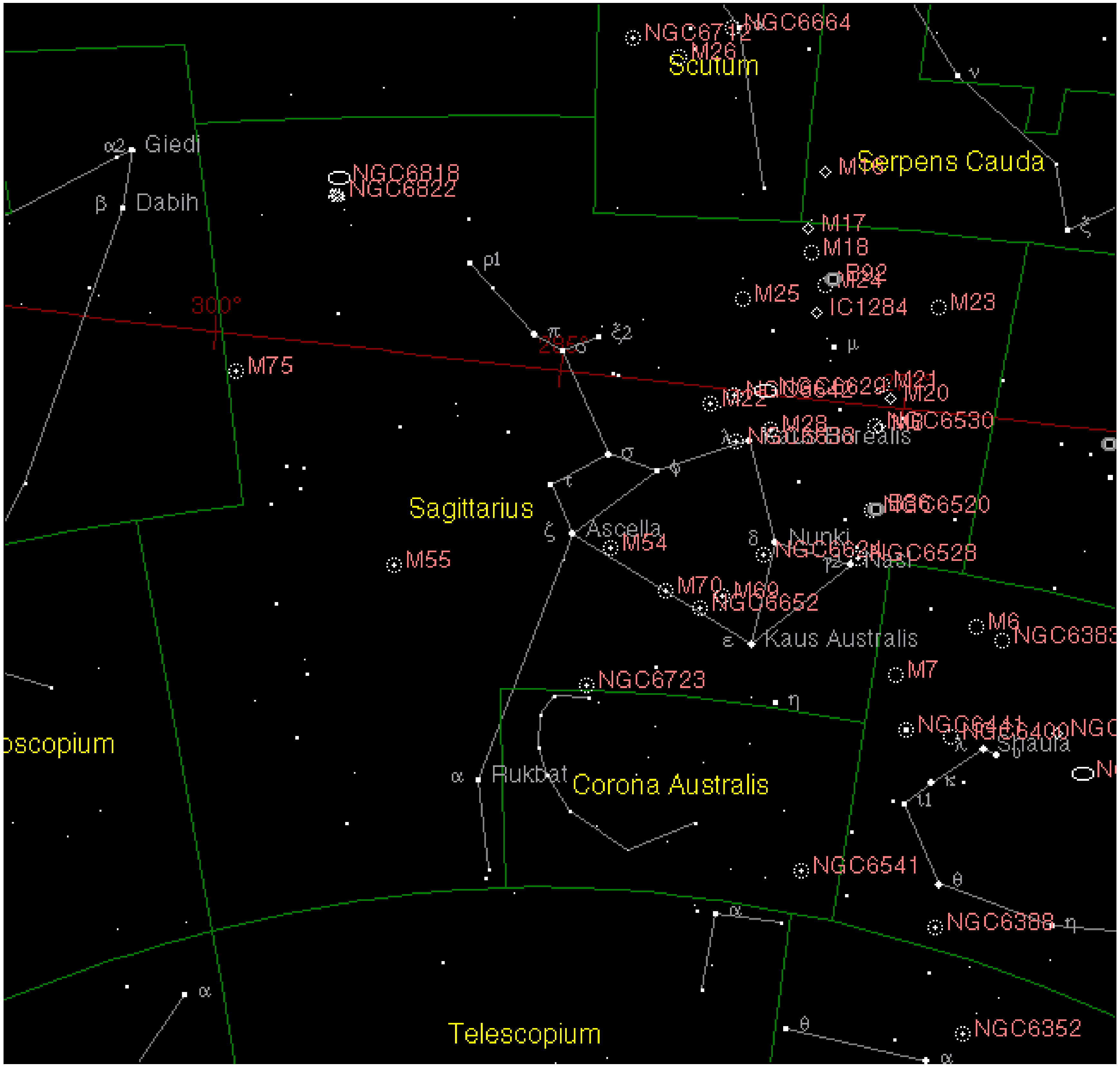
- **Richard Berendzen**, **Richard Hart**, and **Daniel Seeley**. *Man Discovers the Galaxies*. Science History Publications, Neale Watson Academic Publications, New York 1976.



Galaxy Clusters

Some galaxies are isolated "island universes" which float lonely through an otherwise empty region of the universe. But usually, space is too densely crowded with them, so that they form groups of some galaxies (or some dozens of galaxies), or even large clusters of up to several thousands of galaxies. The galaxies of these groups are in mutual gravitational interaction which may have significant influence on their appearance.

Sagittarius



- Download map

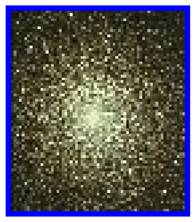
Messier Objects in Sagittarius: M8, M17, M18, M20, M21, M22, M23, M24, M25, M28, M54, M55, M69, M70, M75

- Constellation index
- More on constellation Sagittarius [MAA Original]
- More on Sagittarius (Chris Dolan)
- Digital images - Constellation Sagittarius page (T. Credner/S. Kohle) [unframed version] - M75 in Capricornus page

Star Clusters


Click the icon to view Star Clusters of the Messier Catalog

>> Links >>

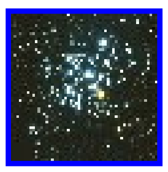


Globular

Globular clusters are gravitationally bound concentrations of approximately ten thousand to one million stars. They populate the halo or bulge of the Milky Way and other galaxies with a significant concentration toward the Galactic Center. Spectroscopic study of globular clusters shows that they are much lower in heavy element abundance than stars such as the Sun that form in the disks of galaxies. Thus, globular clusters are believed to be very old and formed from an earlier generation of stars (*Population II*). More recent estimates yield an age of 12 to 20 billion years; the best value for observation is perhaps 14 to 16 billion (see e.g. the discussion at M92). As their age is crucial as a lower limit for the age of our universe, it was subject to vivid and continuous discussion since decades. The age of globular clusters is determined by investigating their H-R diagrams, as discussed in our globular cluster page.

The disk stars, by contrast, have evolved through many cycles of starbirth and supernovae, which enrich the heavy element concentration in star-forming clouds and may also trigger their collapse.

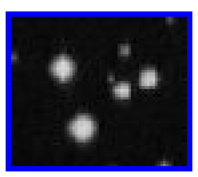
Our galaxy has about 200 globular clusters, most in highly eccentric orbits that take them far outside the Milky Way. Most other galaxies have globular cluster systems as well, in some cases (e.g., for M87) containing several thousands of globulars!



Open

Open (or **galactic**) clusters are physically related groups of stars held together by mutual gravitational attraction. They are believed to originate from large cosmic gas/dust clouds in the Milky Way, and to continue to orbit the galaxy through the disk. In many clouds visible as diffuse nebulae star formation takes still place at this moment, so that we can observe the formation of new young open star clusters (composed of young *Population I* stars). Open clusters populate about the same regions of the Milky Way and other galaxies as diffuse nebulae, notably spiral arms in disk galaxies, and irregular galaxies, and are thus found along the band of the Milky Way in the sky.

Most open clusters have only a short life as stellar swarms. As they drift along their orbits, some of their members escape the cluster, due to velocity changes in mutual closer encounters, tidal forces in the galactic gravitational field, and encounters with field stars and interstellar clouds crossing their way. An average open cluster has spread most of its member stars along its path after several 100 million years; only few of them have an age counted by billions of years. The escaped individual stars continue to orbit the Galaxy on their own as field stars: All field stars in our and the external galaxies are thought to have their origin in clusters.



Binary and Multiple Star Systems

Star formation leads to the formation of multiple star systems at least as often as it does single star systems, such as our own Solar System. In fact, if the mass of the planet Jupiter were a few times larger, it would become a star.

One should keep in mind that almost all Messier clusters are members of our Milky Way Galaxy (the only probable exception is globular cluster M54 which apparently belongs to the Sagittarius Dwarf Elliptical Galaxy, a closely neighbored dwarf spheroidal galaxy which was discovered in 1994). Other galaxies contain clusters of any type, too, which can be detected with sufficiently sensitive instruments.

Links

- Look at Clusters in Messier's Catalog
- Also look at our collection of some significant non-Messier clusters

---

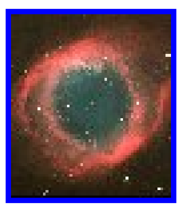
Nebulae

Click the icon to view Nebulae of the Messier Catalog

The icon shows the Horsehead Nebula (Barnard 33), a dark nebula superimposed on an emission nebula (IC 434).

Diffuse Nebulae

Diffuse nebulae are clouds of interstellar matter, namely thin but widespread agglomerations of gas and dust. If they are large and massive enough they are frequently places of star formation, thus generating big associations or clusters of stars. Some of the young stars are often very massive and so hot that their high energy radiation can excite the gas of the nebula (mostly hydrogene) to shine; such nebula is called *emission nebula.* If the stars are not hot enough, their light is reflected by the dust and can be seen as white or bluish *reflection nebula.* As most diffuse emission nebulae also contain dust, they typically have a reflectin nebula component also.



Planetary Nebulae

When a star like our sun has used up all its central nuclear fuel, it finally ejects a significant portion of its mass in a gaseous shell which is then visible in the light emitted due to high-energy excitation by its extremely hot central star, which previously was the core of the stellar progenitor (thus, planetary nebulae are a special kind of emission nebulae). These nebulae quickly expand and fade while their matter is spread in the interstellar surroundings.

Supernova Remnants

Stars which are considerably more massive than our Sun, and have at least about 3 solar masses left after their giant state, can most probably not evolve quitely into an end state as a white dwarf, but when coming to age, explode in a most violent detonation which flashes up at a luminosity of up to 10 billion times that of the sun, called supernova (of type II) and ejecting the very greatest part of the stellar matter in a violently expanding shell. Alternatively, infalling matter on a white dwarf star can cause it to explode as a supernova of type I. The nebulous ejecta of supernovae of either type are called supernova remnants.

The only supernova remnant in Messier's catalog is the first object, the Crab Nebula M1, the remnant of a type II supernova.

Dark Nebulae

Although none of them is in Messier's catalog, some of these objects are conspicuous. Unlike the others, the bright nebulae, these dust clouds are only visible by the absorption of light from objects behind them. They are distinguished from diffuse nebula mainly because they happen to be not illuminated by embedded or nearby stars.

The term "Nebula" has varied in the history of astronomy. In pre-telescopic times it was used to distinguish objects which look non-stellar from the pointlike stars. Most "nebulae" known at that time have been shown to be open star clusters. The term "Nebula" was thus used for what we now call "Deepsky Object".

In early telescopic times, the nature of these objects was still widely unknown. With open clusters resolved, still all other deepsky objects were summarized as "Nebulae". Only the use of large telescopes, the discovery of spectroscopy and the invention of photography in the second half of the 19th century made it possible to distinguish "real" nebulae - i.e., gas and dust clouds - with certainty from objects made up of stars (globular clusters and galaxies).

Now that the nature of nebulae as interstellar masses of gas and dust is known, there are still several classification schemes. The first is based on spectroscopy and the light which is seen from the nebulae:

- **Emission Nebulae**: Emit light because the atoms in their gases are excited by high energy radiation of stars involved.
- **Reflection Nebulae**: Reflect light of nearby stars by their dust particles.
- **Absorption Nebulae** or **Dark Nebulae**: Absorb light: Their gas component can be seen as absorption spectra in the light of background stars, their dust component by absorbing and reddening background light.

This scheme tells nothing on the nature of the nebulae.

A more modern scheme distinguishes *star-forming* or *pre-stellar nebulae* (basically diffuse and dark nebulae) from *post-stellar nebulae* (basically planetary nebulae and supernova remnants). The first of these classes typically includes clouds of interstellar matter of a mass of several 100 or several 1,000 stars, while the latter is related to one specific star in advanced state of evolution, at or just beyond the end of its nuclear life.

There are a number of variations and special classes of nebulae such as the *Herbig-Haro Nebulae* (related to stars in the process of formation, and emit jets of gaseous material, thus often found near large diffuse nebulae with star formation) and *Wolf-Rayet Nebulae* (related to hot Wolf-Rayet stars, stars of some age that have ejected matter they now cause to shine).

On cosmic timescales, all these types of nebulae, in particular the bright nebulae, undergo rapid changes and have only comparatively short lifetimes, so that those we observe are all rather young objects. Planetary nebulae and supernova remnants usually have only a few thousands of years before they fade and spread their matter into the this interstellar matter of their environment, while star forming H II regions while shine bright for the few 100,000 or million years they are brightened by the very hot massive O stars that formed within them. The giant molecular clouds have a somewhat longer life of some 10s of millions of years, while they form new stars and star clusters.

One should keep in mind that all Messier nebulae are members of our Milky Way Galaxy (together with many others). Other galaxies contain nebulae, too, which can be detected with considerably sensitive instruments within the images of these galaxies.

Links

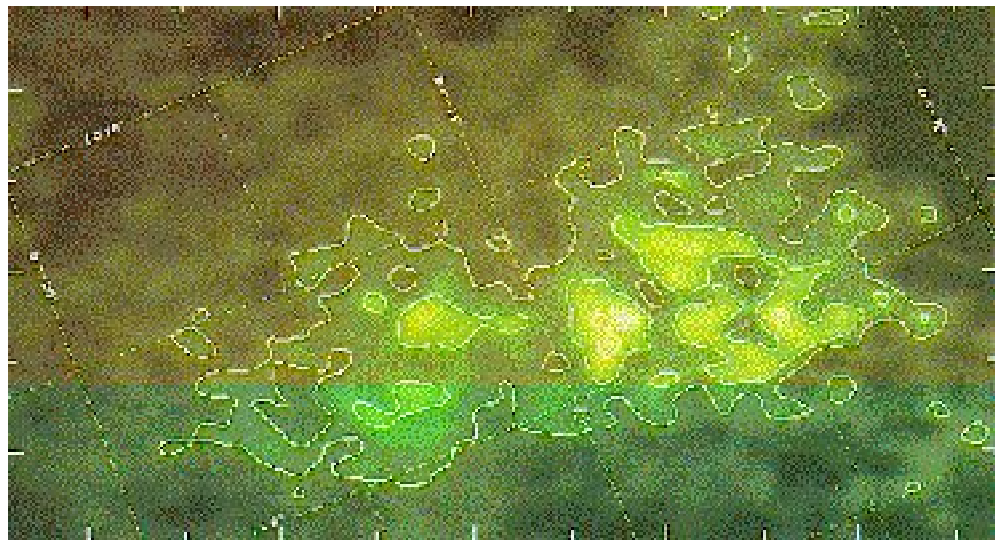
- Nebulae and Star Clusters within 10000 light years map from An Atlas of The Universe - also note their Map of the Orion Arm within 2000 light years for nearby nebulae
- Look at Nebulae in Messier's Catalog
- View some significant non-Messier nebulae
- Bill Arnett's *Web Nebula* collection

References

- Webb Society Deep-Sky Observer's Handbook Vol. 2: Planetary and Gaseous Nebulae, by Kenneth Glyn Jones (ed.). Enslow Publishers 1978/1979.
- James B. Kaler, *Cosmic Clouds*, Scientific American Library, W.H. Freeman, 1997 (German edition: Kosmische Wolken, 1998)

The Sagittarius Dwarf Elliptical Galaxy, SagDEG

Dwarf Elliptical Galaxy *SagDEG* (also *Sagittarius dSph*) in Sagittarius



Right Ascension	18 : 55.1 (h : m)
Declination	-30:29 (deg : m)
Distance	88.0 (kly)
Apparent Dimension	190x490 (arc min)

In 1994, R. Ibata, M. Irwin, and G. Gilmore found this small Local Group galaxy by stellar brightness density investigations (see also e.g. the August 1994 issues of *Astronomy* or *Sky & Telescope* or the German *Sterne und Weltraum*). This galaxy was immediately recognized as being the nearest known neighbor to our Milky Way, significantly closer than the Large Magellanic Cloud which was considered to be our closest companion until than. It held the title of our nearest intergalactic neighbor for nine years, but lost it in November 2003 to the then newly discovered Canis Major Dwarf.

This dwarf galaxy is called SagDEG (for Sagittarius Dwarf Elliptical Galaxy), or sometimes Sagittarius Dwarf Spheroidal Galaxy; don't confuse it with another member, SagD**I**G (Sagittarius Dwarf Irregular Galaxy). It is strongly recommended to avoid misleading designations such as "Sagittarius Dwarf" (which is an older designation for SagDIG), "Sagittarius I Dwarf", or similar ambiguous names for this galaxy, although they occasionally occur in websites, databases, articles and papers.

These are two minor galaxies in the same constellation Sagittarius, which are of different type: The difference between these types is that dwarf irregulars still have interstellar matter and/or young stars while the dwarf elliptical have only an old yellowish stellar population. From its stellar contents, it is resembling other low surface brightness members of the local group such as the Sculptor dwarf galaxy, but it is so highly obscured that it was hidden up to the 1994 investigation.

SagDEG is one of the most recently discovered members of the Local Group, and is currently in a very close encounter to our Milky Way galaxy. It is apparently in process of being disrupted by tidal gravitational forces of its big massive neighbor in this encounter. Nevertheless it is apparently big: 5x10 degrees in the sky.

Globular cluster M54 coincides with one of the galaxy's two bright knots, and is also receding at about the same velocity. It may also be at the same distance (about 88,000 light years), so probably M54 is the first "extragalactic" globular ever discovered (by Charles Messier in 1778), or a recent immigrant to the globular cluster system of our Milky Way galaxy. When SagDEG will be disrupted after the current encounter, M54 and the other at least three globulars of this dwarf (Arp 2, Terzan 7 and Terzan 8, which are all much fainter than M54) will be the "remnants", while the other stars will be spread over the galactic halo, or escape as intergalactic travelers. The globulars will perhaps be captured and find their place in the halo of the Milky Way galaxy. There is already one Milky Way globular cluster which is suspected to have been captured from SagDEG: Palomar 12.

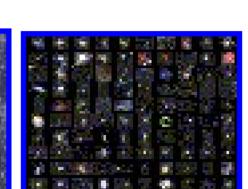
In February 1998, a team of astronomers headed by Rosemary Wyse of John Hopkins University found that SagDEG orbits the Milky Way Galaxy in less than one billion years. Because it must have passed the dense central region of our Galaxy at least about ten times, it is surprising that the dwarf has not been disrupted for so far. Astronomers suspect that this fact is an indication for significant amounts of dark matter within this small galaxy, which ties the stars stronger to the galaxy by its gravity. We have their press release here, or you can read their original report online.

References:

- R. A. Ibata, G. Gilmore, and M. J. Irwin, 1994. A Dwarf Satellite Galaxy in Sagittarius. *Nature*, Vol. 370, No. 6486 (July 21, 1994)

- SIMBAD data for SagDEG
- NED data for SagDEG

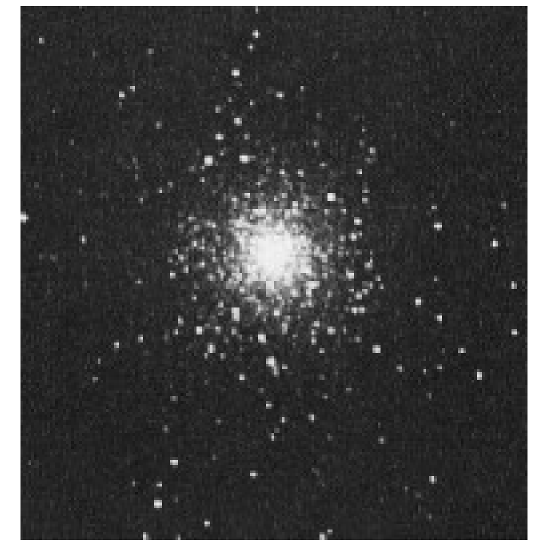
Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 23 Nov 2003

M 79

Globular Cluster *M79 (NGC 1904)*, class V, in Lepus



Right Ascension	05 : 24.5 (h:m)
Declination	-24 : 33 (deg:m)
Distance	42.1 (kly)
Visual Brightness	7.7 (mag)
Apparent Dimension	9.6 (arc min)

Discovered 1780 by Pierre Méchain.

Globular cluster M79 was found by Pierre Méchain on October 26, 1780, and reported his discovery to his friend and colleague, Charles Messier, who determined its position and included it in his catalog on December 17, 1780. It was first resolved into stars and recognized as a globular cluster by William Herschel in about 1784.

M79 is a beautiful globular cluster at a quite unusual location in the sky: Most globulars are grouped around the Galactic center, but this is one of the few which are situated in the other hemisphere, i.e. it is beyond us for hypothetical observers in the central stellar bulge of our Milky Way galaxy. It is little over 40,000 light years from us, but about 60,000 light years from the galactic center.

At this distance, M79's apparent diameter of 9.6 minutes of arc corresponds to a linear extension of about 118 light years. This cluster is slightly elliptical, extended at position angle 45 deg, and has only 7 known variables. It is receding from us at about 200 km/sec.

In 2003, it was found that M79 is perhaps a rather new immigrant into the globular cluster system ot our Milky Way: It may come from, or still be a member, of the remnant globular cluster system of the Canis Major Dwarf galaxy, which is currently undergoing a very close encounter with our Galaxy, and in progressive state of dissolution. Together with M79, three more globular clusters are suspected to have immigrated from the Canis Major Dwarf: NGC 1851, NGC 2298, and NGC 2808.

About 0.5 degrees to the SW of M79 lies the 5.5 mag star ADS 3954 with its 7th mag companion, separated by 3".

- Historical Observations and Descriptions of M79
- UIT images of M79 (visible and UV) from the Astro-1 Space Shuttle mission (STS-35)
- More images of M79
- Amateur images of M79

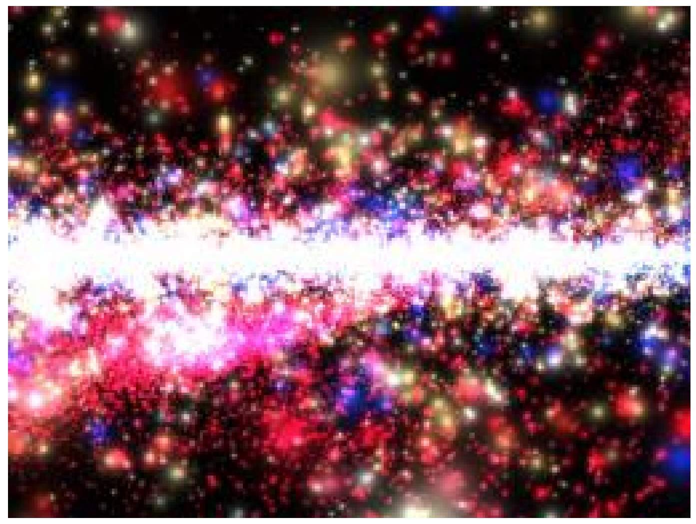
- Multispectral Image Collection of M79, SIRTF Multiwavelength Messier Museum
- Marco Castellani's data for M 79
- SIMBAD Data of M79
- NED Data of M79
- Publications on M79 (NASA ADS)
- Observing Reports for M79 (IAAC Netastrocatalog)

Hartmut Frommert
Christine Kronberg
[contact]

Canis Major Dwarf

Irregular Galaxy *Canis Major Dwarf*, centered in Canis Major

Right Ascension	07 : 15 (h : m)
Declination	-28: (deg : m)
Distance	25.0 (kly)
Apparent Dimension	720 (arc min)



Discovered in November 2003 by Martin, Ibata, Bellazzini, Irwin, Lewis, and Dehnen.

This small galaxy, or galaxy remnant, was discovered only in 2003 by a team of astronomers from France, Italy, the UK, and Australia. It was found from the analysis of data on asymmetries in the population of Galactic red giant stars (of spectral type M) in the 2MASS All Sky catalog. These stars show several large-scale asymmetries, the most significant of which is a strong elliptical-shaped over-density close to the Galactic plane, around the position l=240deg, b=-8deg in Galactic coordinates, or about RA=07:20, Dec=-30, with an extension in Galactic longitude of about 12 deg (720 arc min). The distance of this concentration was estimated at 25,000 light-years from us and 42,000 light-years from the center of our Milky Way Galaxy.

The authors find that this concentration is the nucleus of a dwarf galaxy which is in a progressive state of disruption, as it orbits our Milky Way Galaxy. This galaxy is thus our nearest known intergalactic neighbor, and a new dwarf member of the Local Group. The major part of its matter has been distributed along its orbit, and forms arc structures around the Milky Way. It may have been a considerable though small galaxy at one time, having of the order of one billion stars, and may have contributed up to about one percent of the matter of our Milky Way.

The image on the right shows the Canis Major Dwarf's nucleus just below the stellar band indicating the equatorial plane of our Milky Way. This is an infrared view, composed from the Two-Micron All Sky Survey (2MASS).

In many respects such as size, orbit and the process of dissolution, the Canis Major Dwarf is similar to SagDEG, which had been discovered in 1994 and taken the place as the nearest known neighbor for nine years.

Some Milky Way globular clusters are loosely grouped around the nucleus of the Canis Major dwarf, and at least some of them may have their origin in the halo of this small galaxy, and may represent the remnant of its former globular cluster system: M79, NGC 1851, NGC 2298, and NGC 2808. Open clusters AM-2 and Tombaugh 2 are strong candidates for being physically associated with the Canis Major Dwarf.

Links:

- University of Strasbough Press Release (November 4, 2003) - [Local Copy]
- Canis Major Dwarf: A New Closest Galaxy. Astronomy Picture of the Day (APOD) November 23, 2003.

References:

- Nicolas F. Martin, Rodrigo A. Ibata, Michele Bellazzini, Michael J. Irwin, Geraint F. Lewis and Walter Dehnen, 2003. A dwarf galaxy remnant in Canis Major: the fossil of an in-plane accretion onto the Milky Way. To appear in: Monthly Notes of the Royal Astronomical Society. Preprint: astro-ph/0311010
- Michele Bellazzini, Rodrigo A. Ibata, L. Monaco, Nicolas F. Martin, Michael J. Irwin, and Geraint F. Lewis, 2003. The Moon befind the finger. Detection of the Canis Major galaxy in the background of galactic open clusters. To appear in: Monthly Notes of the Royal Astronomical Society. Preprint: astro-ph/0311119

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 22 Nov 2003

Messier Objects in the Milky Way Galaxy

Most of the 70 Messier objects which are not galaxies are part or member of the Milky Way galaxy of some kind; the only probable exception being globular cluster M54 which belongs to the nearest neighbor galaxy, SagDEG. Basically, all the diffuse nebulae and open star clusters as well as supernova remnants trace the spiral arms of our galaxy, while the globular clusters populate the galactic bulge with a strong concentration toward the Galactic center, and the planetary nebulae are somewhat an intermediate object class and occur in both; the four Messier planetaries happen to be situated not far from the disk and situated either within or close to the spiral arms (more acurately, our Local or Orion Arm).

Spiral Arms traced by Messier Objects:

- "+I", **Perseus Arm**
- "0", **Local Arm**, **Orion Arm**
- "-I", **Sagittarius Arm**, **Sagittarius-Carina Arm**

Perseus Arm

Object		Con	Type	RA	(2000) Dec	dist
M 52	NGC 7654	Cas	OC	23:24.2	+61:35	5.0
M103	NGC 581	Cas	OC	01:33.2	+60:42	8.0
M 38 *	NGC 1912	Aur	OC	05:28.4	+35:50	4.2
M 1	NGC 1952	Tau	SNR	05:34.5	+22:01	6.3
M 36 *	NGC 1960	Aur	OC	05:36.1	+34:08	4.1
M 37 *	NGC 2099	Aur	OC	05:52.4	+32:33	4.4

Orion Arm

Object		Con	Type	RA	(2000) Dec	dist
M 6	NGC 6405	Sco	OC	17:40.1	-32:13	2
M 7	NGC 6475	Sco	OC	17:53.9	-34:49	0.8
M 23	NGC 6494	Sgr	OC	17:56.8	-19:01	2.15
M 25	IC 4725	Sgr	OC	18:31.6	-19:15	2
M 57	NGC 6720	Lyr	PN	18:53.6	+33:02	2.3
M 27	NGC 6853	Vul	PN	19:59.6	+22:43	1.25
M 29	NGC 6913	Cyg	OC	20:23.9	+38:32	4.0
M 73	NGC 6994	Aqr	OC?	20:58.9	-12:38	2.0
M 39	NGC 7092	Cyg	OC	21:32.2	+48:26	0.825
M 76	NGC 650	Per	PN	01:42.4	+51:34	3.4
M 34	NGC 1039	Per	OC	02:42.0	+42:47	1.4
M 45		Tau	C+N	03:47.0	+24:07	0.38
M 42	NGC 1976	Ori	DN	05:35.4	-05:27	1.6
M 43	NGC 1982	Ori	DN	05:35.6	-05:16	1.6
M 78	NGC 2068	Ori	DN	05:46.7	+00:03	1.6
M 35	NGC 2168	Gem	OC	06:08.9	+24:20	2.8
M 41	NGC 2287	CMa	OC	06:46.0	-20:44	2.3
M 50	NGC 2323	Mon	OC	07:03.2	-08:20	3
M 47	NGC 2422	Pup	OC	07:36.6	-14:30	1.6
M 46	NGC 2437	Pup	OC	07:41.8	-14:49	5.4
M 93	NGC 2447	Pup	OC	07:44.6	-23:52	3.6
M 48	NGC 2548	Hya	OC	08:13.8	-05:48	1.5
M 44	NGC 2632	Cnc	OC	08:40.1	+19:59	0.577
M 67	NGC 2682	Cnc	OC	08:50.4	+11:49	2.7
M 97	NGC 3587	UMa	PN	11:14.8	+55:01	2.6
M 40		UMa	DS	12:22.4	+58:05	0.51

Sagittarius Arm

Object		Con	Type	RA	(2000) Dec	dist
M 20	NGC 6514	Sgr	DN	18:02.6	-23:02	5.2
M 8	NGC 6523	Sgr	DN	18:03.8	-24:23	5.2
M 21	NGC 6531	Sgr	OC	18:04.6	-22:30	4.25
M 24	IC 4715?	Sgr	MWP	18:16.9	-18:29	10-15
	NGC 6603	Sgr	OC	18:18.4	-18:25	10
M 16	NGC 6611	Ser	C/N	18:18.8	-13:47	7
M 18	NGC 6613	Sgr	OC	18:19.9	-17:08	4.9
M 17	NGC 6618	Sgr	DN	18:20.8	-16:11	5
M 26	NGC 6694	Sct	OC	18:45.2	-09:24	5
M 11 *	NGC 6705	Sct	OC	18:51.1	-06:16	6

Halo Globular Clusters

Object		Con	Type	RA	(2000) Dec	dist
M 79(*)	NGC 1904	Lep	GC	05:24.5	-24:33	42.1
M 68	NGC 4590	Hya	GC	12:39.5	-26:45	33.3
M 53	NGC 5024	Com	GC	13:12.9	+18:10	59.7
M 3	NGC 5272	CVn	GC	13:42.2	+28:23	33.9
M 5	NGC 5904	Ser	GC	15:18.6	+02:05	24.5
M 80	NGC 6093	Sco	GC	16:17.0	-22:59	32.6
M 4	NGC 6121	Sco	GC	16:23.6	-26:32	7.2
M107	NGC 6171	Oph	GC	16:32.5	-13:03	20.9
M 13	NGC 6205	Her	GC	16:41.7	+36:28	25.1
M 12	NGC 6218	Oph	GC	16:47.2	-01:57	16.0
M 10	NGC 6254	Oph	GC	16:57.1	-04:06	14.4
M 62	NGC 6266	Oph	GC	17:01.2	-30:07	22.5
M 19	NGC 6273	Oph	GC	17:02.6	-26:16	28.4
M 92	NGC 6341	Her	GC	17:17.1	+43:08	26.7
M 9	NGC 6333	Oph	GC	17:19.2	-18:31	26.7
M 14	NGC 6402	Oph	GC	17:37.6	-03:15	29.0
M 28	NGC 6626	Sgr	GC	18:24.5	-24:52	18.6
M 69	NGC 6637	Sgr	GC	18:31.4	-32:21	28.0
M 22	NGC 6656	Sgr	GC	18:36.4	-23:54	10.4
M 70	NGC 6681	Sgr	GC	18:43.2	-32:18	29.4
M 54(*)	NGC 6715	Sgr	GC	18:55.1	-30:29	88.7
M 56	NGC 6779	Lyr	GC	19:16.6	+30:11	32.9
M 55	NGC 6809	Sgr	GC	19:40.0	-30:58	17.6
M 71	NGC 6838	Sge	GC	19:53.8	+18:47	12.7
M 75	NGC 6864	Sgr	GC	20:06.1	-21:55	61.3
M 72	NGC 6981	Aqr	GC	20:53.5	-12:32	55.4
M 15	NGC 7078	Peg	GC	21:30.0	+12:10	33.6
M 2	NGC 7089	Aqr	GC	21:33.5	-00:49	37.5
M 30	NGC 7099	Cap	GC	21:40.4	-23:11	26.1

Notes:

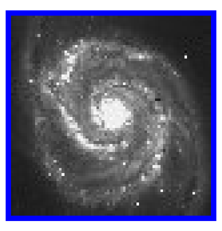
- "*****": M36, M37 and M38 as well as M11 are sometimes listed as in the Orion Arm
- "**(*)**": M79 and M54 are probably recent immigrants to the Milky Way galaxy's globular cluster system, coming from nearby dwarf galaxies that are currently in close encounters with our Galaxy, and in the process of disintegration: M79 from the Canis Major Dwarf, and M54 from SagDEG.

Links:

- Map of Star Clusters and Nebulae within 10,000 light years, by Richard Powell. From his "An Atlas of the Universe" project.

Hartmut Frommert
Christine Kronberg
[contact]

Spiral Galaxies (and other disks)


Click icon to see a spiral galaxy of Messier's catalog

>> Messier's spiral galaxies; Links

The icon shows M51, the Whirlpool Galaxy.

Among the galaxies, there are apparently three main categories, according to their appearance: the disk galaxies (`*cosmic frisbies*' according to P. Murdin, D. Allen, and D. Malin), consisting of a huge disk of stars and interstellar matter, which may form interesting patterns, the elliptical galaxies (`*cosmic footballs*') which are uniformly looking, ellipsoidal agglomerations of stars, and the irregular galaxies (`*cosmic misfits*') which cannot be integrated in this scheme.

Physically, it is not necessary so clear (at least in the opinion of the present author) if this classification is real, because there exist intermediate types even between ellipticals and spirals, i.e. spiral galaxies often have an ellipsoidally formed "bulge" which may be very luminous (as in case of the Sombrero galaxy M104) or rather inconspicuous; some spirals seem to lack this component at all. A heavy bulge is often connected with the presence of a big ellipsoidal core. On the other hand, at least some ellipticals seem to house a disk component also; ths most conspicuous example of such a galaxy is probably Centaurus A (NGC 5128), a prominent galaxy in the Southern hemisphere which is not a Messier object because of its southern declination, but forms a group with the beautiful spiral M83. Centaurus A is regarded as peculiar. One may speculate that e.g. the disk around the center of M87, which is often regarded as the accretion disk around the supermassive object in that galaxy's nucleus, may be a smaller manifestation of the same disk phenomenon.

Focussing on the disk (or disk dominated) galaxies, these often show beautiful and conspicuous patterns in the form of spiral arms and/or luminous bars. These structures have been a mystery for a long time, it was thought that there may be physically different classes of disks (e.g., "normal" and "barred" disks), but now it seems as if they are all the consequences of gravitational interactions with neighboring galaxies. Encounters with neighbors cause inhomogenities and un-symmetries in the gravitational field within the disk, which tends to compress the gas in some regions. If the density of the gas in these regions exceeds a certain critical value (which depends on parameters as the temperature), star formation can take place, resulting in the formation of red diffuse emission nebulae and blue clusters of hot young stars, which slowly change their color to the yellow when they come to age, and their hottest stars have disappeared (i.e., exploded as supernovae).

The star forming regions tend to be aligned along spiral arms, as the denser regions in the interstellar matter apparently prefer to form such patterns. When getting older, they sometimes stay conspicuous as yellowish "fossil arms", which can be traced in several galaxies.

Galaxies are classified, according to their appearance, in the so-called **Hubble scheme** (after its inventor, Edwin Powell Hubble; see e.g. our illustration of the Hubble Scheme with Messier galaxies). This scheme defines the classes listed above, i.e. spiral, elliptical and irregular galaxies, and is especially interesting for spirals: Those with pronounced bar structures are called "barred spirals" and classified "SB", while normal spirals are simply called "S" or sometimes "SA"; some authors take "SAB" or "S(B)" for mixed types. Spiral galaxies, "normal" and barred, with conspicuous bulges (especially near their center) are classified "Sa" or "SBa", those which have prominent bulges and pronounced arms are clssified "Sb" or "SBb", and those which are dominated by the arms are "Sc" or "SBc". If the core and bulge seems to be lacking, a galaxy is classified "Sd" or "SBd", and those which have no pronounced core and show irregularities are classified as "Sm"; these represent a type between disk and irregular galaxies.

Some of the galaxies, mostly those who had no closer encounters for a longer period of time, and those who have lost most of their interstellar matter for some reason, do not show any conspicuous pattern within their disks; these are often called "S0" or "lenticular" galaxies. Although they are disks, they can often hardly be distinguished from ellipticals from their appearance, and have often been misclassified in the past. This misclassification happened to all the four Messier lenticulars in the past, and to many other galaxies of this type.

When undergoing a heavy interaction, or collision, with a massive neighbor, disk galaxies may be distorted very peculiarly, and then are often classified as irregular; this is the case for the only Messier irregular, M82.

All disk galaxies have a very different appearance, depending from what direction they are seen, or under which angle toward the line of sight (to us) their disk is inclined. According to this situation, they are either seen from their edge (or "edge-on"), or from near their equatorial plane, as thin, flat, linear and elongated patches, often with dusty structures along their equators, or almost from their poles so that we can see their disks "face-on". Tom Polakis has featured some edge-on galaxies.

Our Milky Way is one of the big and more massive spiral galaxies, and is of Hubble type Sbc, or perhaps SBbc if it should have a bar.

Spiral galaxies in Messier's catalog: M31, M33, M51, M58, M61, M63, M64, M65, M66, M74, M77, M81, M83, M88, M90, M91, M94, M95, M96, M98, M99, M100, M101, M104, M106, M108, M109.
Other early known spiral galaxy: Milky Way.

(Probable) S0 galaxies in Messier's catalog: M84, M85, M86, NGC 5866 (M102 ?).

The irregular galaxy M82 is also a distorted disk galaxy.

Links:

- Look at Spiral Galaxies in Messier's Catalog
- Also look at our collection of some significant non-Messier spiral galaxies

---


Lenticular

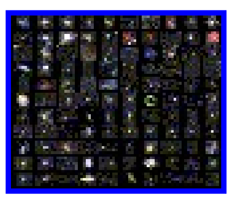

Elliptical


Irregular

This webpage was selected as Houston Astronomical Society Site Of The Week for August 17, 2003

Hartmut Frommert
Christine Kronberg
[contact]



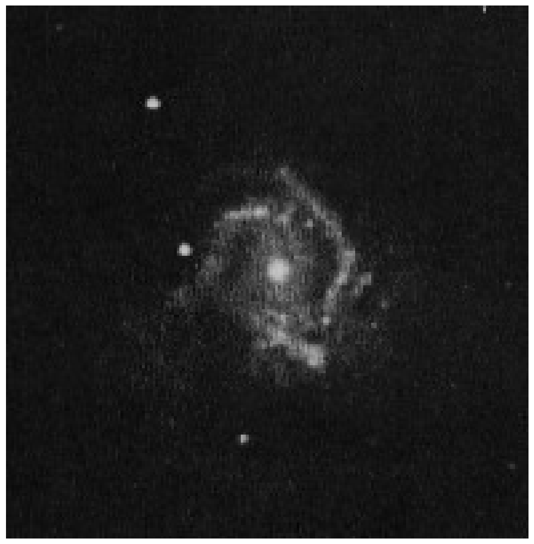


Last Modification: 25 Jan 1998, 16:26 MET

M 61

Spiral Galaxy M61 (NGC 4303), type SABbc, in Virgo

Right Ascension	12 : 21.9 (h:m)
Declination	+04 : 28 (deg:m)
Distance	60000 (kly)
Visual Brightness	9.7 (mag)
Apparent Dimension	6x5.5 (arc min)



Discovered 1779 by Barnabus Oriani.

M61 was discovered by Barnabus Oriani on May 5, 1779 when following the comet of that year, 6 days before Charles Messier's discovery, who had seen it on the same day as Oriani but mistaken it for the comet. Messier mistook it for two nights more, until he realized that it did not move. As for a small number of others, this object was assigned an own number, H I.139, by William Herschel, who normally avoided to give own numbers to Messier's objects, when he observed and cataloged it on April 17, 1786.

M61 is one of the larger galaxies in the Virgo cluster; its 6 arc minutes of diameter correspond to about 100,000 light years, similar to the diameter of the Milky Way galaxy. Its 10th magnitude corresponds to an absolute magnitude of -21.2.

Four supernovae have been observed in M61: 1926A (12.8 mag) was discovered by Wolf and Reinmuth, 1961I (mag 13, Humason), 1964F (mag 12, Rosino), and 1999gn (13.4 mag, Dimai). NED gives the following types and (alternative values for) maxima: SN 1926A, type IIL, 14pv; SN 1961I, type II, 13.0; SN 1964F, type I, 14.0. The Supernova 1961I appeared in the spiral arms, about 82" from the center, and was photographed by the Lick observatory, see e.g. Burnham (you may also order this image from them as slide or print).

- Historical Observations and Descriptions of M61
- More images of M61
- Amateur images of M61

- SIMBAD Data of M61
- NED Data of M61
- Publications on M61 (NASA ADS)
- Observing Reports for M61 (IAAC Netastrocatalog)

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 28 Dec 1999

M 83

Spiral Galaxy *M83 (NGC 5236)*, type SABc, in Hydra

Southern Pinwheel

Right Ascension	13 : 37.0 (h:m)
Declination	-29 : 52 (deg:m)
Distance	15000 (kly)
Visual Brightness	7.6 (mag)
Apparent Dimension	11x10 (arc min)

Discovered 1751-52 by Abbe Nicholas Louis de la Caille.

M83 was classified as intermediate between normal and barred spiral galaxies by G. de Vaucouleurs, in his classification this is SAB(s)c. It is magnificient in our image, has very well defined spiral arms and displays a very dynamic appearance, appealing by the red and blue knots tracing the arms. The red knots are apparently diffuse gaseous nebulae in which star formation is just taking place, and which are excited to shine by its very hot young stars. The blue regions represent young stellar populations which have formed shortly (i.e., some million or some dozens of million years ago). Between the pronounced spiral arms are regions with fewer stars. Dark dust lanes follow the spiral structure throughout the disk, and may be traced well into the central region to the nucleus, which has only 20" diameter. This nucleus shows strong emission lines. It is composed of an older yellowish stellar population which dominates the whole central region, and extends along the barlike structure.

Our image was obtained by David Malin with the 3.9-meter Anglo-Australian Telescope of the Anglo-Australian Observatory. Interested parties can get more detailed information on this image. Also available are more images of M83 with the same telescope.

David Malin, in his older publications, always gave a distance of about 25 million light years, as he does in his book *A View of the Universe* in chapter 4, while in his Galaxies chapter 8, he joins the lot of those claiming a distance of about 10 million light years, and gives an argument, namely that the brightest stars can be viewed as individuals over this distance. M83 recedes at 337 km/sec, implying a bit larger distance from Hubble's law (H0=75 yields about 15 million light years, uncorrected for the disturbation by the Virgo cluster of galaxies, the Virgo centric flow, but in excellent agreement with the value of 15.3 million light years given in R. Brent Tully's *Nearby Galaxies Catalog*). Kepple/Sanner give another deviating distance value of 22 million ly.

This galaxy is sometimes called the "**Southern Pinwheel**". It forms a small physical group, the M83 group, with the peculiar radio galaxy Centaurus A (NGC 5128) and the unusual galaxy NGC 5253 in Centaurus. R. Brent Tully also lists the following smaller and fainter presumable (or possible) members of this group: NGC 4945, NGC 5102, NGC 5164, NGC 5408, ESO 381-20 (MCG-6-28-017; 1243-33), ESO 324-24 (MCG-6-30-003; 1324-41), ESO 444-84 (MCG-5-32-000; 1334-27), ESO 325-11 (1342-41), and ESO 383-87 (MCG-6-30-025; 1346-35).

Five or six supernovae were reported in M83 up to now, more than in any other Messier galaxy:

- 1923A was observed by C.O. Lampland at Lowell Observatory at mag 14.
- 1945B appeared on July 13, 1945 and reached mag 14.2). This supernova was only detected in 1990 by W. Liller on photographic plates taken at Harvard's station at Bloemfontein (South Africa), and could be traced from July 13 to August 7 (see IAU Circular 5091).
- 1950B was observed by G. Haro and reached mag 14.5 in its maximum,
- 1957D was discovered by H.S. Gates on December 13, 1957 and reached only mag 15.0, it was about 3' NNE of the nucleus.
- Supernova 1968L was discovered visually by amateur astronomer Jack C. Bennett of Pretoria, South Africa, when sweeping for comets; this was a type I, located 5" preceding the nucleus and reached mag 11 to 12.
- 1983N appeared on July 3, 1983 and became as bright as 12.5 mag.

For years, M83 had been the galaxy with most discovered supernovae, but recently NGC 6946 came up with the same number of 6, or even one more if 1945B should be an error.

M83 was discovered by Abbe Nicholas Louis de la Caille at the Cape of Good Hope in 1751-52, it was his object Lacaille I.6. Thus it became the first galaxy discovered beyond the Local Group. It was next cataloged by Charles Messier on February 17, 1781; from his mid-northern location in Paris (at 49 degrees Northern latitude), it is such a difficult object that he stated that: "One is only able with the greatest concentration to see it at all." The present author can confirm it is one of the most difficult Messier objects from South Germany. Due to this fact, older Northern-compiled catalogs tended to underestimate its brightness considerably; e.g., Becvar has it at a mere 10.1 mag only.

Early 19th century Australian observer James Dunlop has it as No. 628 in his catalog. Its spiral structure was noted and sketched by William Lassell who described it as a "three-branched spiral."

M83 is one of the showpieces in the southern deep sky, but difficult for mid-northern observers, as already stated. It is even rather difficult to find: First locate one of the stars Gamma or Pi Hydrae. It can be found either by star hopping from Gamma Hydrae (mag 3.00, spectral type G5 III) which is 6.5 deg N and 3deg 15' (19 min in RA) W, or from Pi Hydrae (3.27 mag, spectral type K2 III) from which M83 is about 3deg 15' S and 6deg 20' W. Following a trail of 5th to 7th mag stars, one arrives at a yellowish 5.83-mag star of spectral type F6 and a mag 7.0 white star (spectrum A5 V) which lie about 30' NE of M83. Star hopping from Gamma will bring you close to NGC 5061 (H 1.138), an elliptical galaxy of mag 10.2.

Southerners may find it easier by locating M83 from the constellation Centaurus, as it is just north of the border from Hydra to this constellation. From Iota and Theta Centauri, in the Head of the Centaurus figure, locate the stars *i*, *h* and *k* (mentioned by Messier) as well as *g* Centauri, all between mag 4 and 5; they are also known as 1 *i* Cen, 2 *g* Cen, 3 *k* Cen, and 4 *h* Cen. *g* and *i* just point to M83 (and further to Gamma Hydrae); the galaxy comes beyond *i*, at double distance from it than has *g*.

- Historical Observations and Descriptions of M83
- More Anglo-Australian Telescope images of M83
- ESO/VLT images of M83
- NRAO/VLA radio images of M83
- Chandra X-ray Observatory images of M83
- GALEX images of M83 in the ultraviolet light
- More images of M83
- Amateur images of M83

- SIMBAD Data of M83
- NED Data of M83
- Publications on M83 (NASA ADS)
- Observing Reports for M83 (IAAC Netastrocatalog)

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 20 Jul 2003

Under construction!

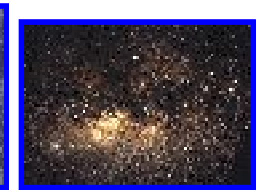
Classification of the Milky Way Galaxy

Our Galaxy is classified as Sb (Sky Catalogue 2000.0) or Sbc by most sources. Newer investigations have brought up more and more evidence that the Milky Way probably has a bar, or barlike structure, in its central region, which would modify its classification to become a barred spiral of type SB, or intermediate type between barred and "normal" spirals, SAB.

Already in the 1970s, Gerard de Vaucouleurs has classified the Milky Way Galaxy as "SAB(rs)bc II", where

- "SAB" means that the Milky Way has (probably) a less evolved central bar structure - "SA" would be a "normal", barless spiral, "SB" a barred spiral galaxy
- "(rs)" means that there is a weak central ring of stars and gas around the nucleus
- "bc"

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 7 Jan 2000

Under construction!

The Structure of the Milky Way Galaxy

As the Milky Way is seen from Earth as a diffuse band all around the sky, and as we live within it and have no opportunity to view it from outside, our Galaxy's global structure is not immediately obvious.

Our Galaxy is classified as Sb (Sky Catalogue 2000.0) or Sbc by most sources. Newer investigations have brought up more and more evidence that the Milky Way probably has a bar, or barlike structure, in its central region, which would modify its classification to become a barred spiral of type SB, or intermediate type between barred and "normal" spirals, SAB.

- More on the Classification of the Milky Way

Hartmut Frommert
Christine Kronberg
[contact]


Last Modification: 13 Aug 1999

The Local Group of Galaxies

This is "our" group of galaxies. It was first recognized by Hubble, in the time of the first distance determinations and redshift measurements (see, e.g., his *The Realm of the Nebulae*).

Messier objects: The Andromeda Galaxy M31 and its satellites M32 and M110, as well as the Triangulum Galaxy M33.

Other members (over 30 in all) include our Milky Way Galaxy, the Large and the Small Magellanic Cloud (LMC and SMC), which have been known before the invention of the telescope, as well as several smaller galaxies which were discovered more recently. These galaxies are spread in a volume of nearly 10 million light years diameter, centered somewhere between the Milky Way and M31. Membership is not certain for all these galaxies, and there are possible other candidate members.

Of the Local Group member galaxies, the Milky Way and M31 are by far the most massive, and therefore dominant members. Each of these two giant spirals has accumulated a system of satellite galaxies, where

- the system of the Milky Way contains many (nearby) dwarf galaxies, spread all over the sky, namely Sag DEG, LMC, SMC, the recently discovered and widely disrupted Canis Major Dwarf, and the dwarf galaxies in Ursa Minor, Draco, Carina, Sextans (dwarf), Sculptor, Fornax, Leo I, Leo II, and perhaps the Phoenix Dwarf, and Leo A (which may alternatively belong to the NGC 3109 subgroup),
- the system of the Andromeda galaxy is seen from outside, and thus grouped around its main galaxy M31 in Andromeda, containing bright nearby M32 and M110 as well as fainter and more far-out NGCs 147 and 185, the very faint systems And I, And II, And III and possibly And IV (but for this one see remark below), And V, And VI (Pegasus dwarf), And VII (Cassiopeia dwarf), and And VIII.

  The third-largest galaxy, the Triangulum spiral M33, may or may not be an outlying gravitationally bound companion of M31, but has itself probably the dwarf LGS 3 as a satellite. Also, IC 1613 may perhaps be a member of the M31 subgroup, as may be the doubtful members UGCA 86 and UGCA 92.
- There is a third potential subgroup around irregular galaxy NGC 3109, which contains Sextans A, Sextans B, the Antlia Dwarf and perhaps Leo A (but that one may belong to the Milky Way subgroup).
- The other members, mostly dwarf irregulars, cannot be assigned to one of these main subgroups, and float quite alone in the gravitational field of the giant group members. They tend to form a vast cloud, the Local Group Cloud.

Only one dwarf galaxy, GR 8, seems to be so isolated that it doesn't belong to any of these substructures.

The substructures of the group are probably not stable. Observations and calculations suggest that the group is highly dynamic and has changed significantly in the past: The galaxies around the large elliptical Maffei 1 have probably been once part of our galaxy group.

As this shows, the Local Group is not isolated, but in gravitional interaction, and member exchange, with the nearest surrounding groups, notably:

- the Maffei 1 group, which besides the giant elliptical galaxy Maffei 1 also contains smaller Maffei 2, and is associated with nearby IC 342 and a number of smaller galaxies. Highly obscurred by dark dust near the Milky Way's equatorial plane.
- the Sculptor Group or South Polar Group (with members situated around the South Galactic pole), dominated by NGC 253
- the M81 group
- the M83 group

The next more distant galaxy groups, the NGC 4244 group and the CVn I Cloud (with M94 and M64) are probably too remote to have interacted significantly with the Local Group in the past.

It is of interest that of the subgroups of the Local Group mentioned above, the NGC 3109 group tends to the general direction of the Maffei 1 group and the M81 group, while the Local Group Cloud tends to the general direction of the Sculptor Group.

In the future, interaction between the member galaxies and with the cosmic neighborhood will continue to change the Local Group. Some astronomers speculate that the two large spirals, our Milky Way and the Andromeda Galaxy, may perhaps collide and merge in some distant future, to form a giant elliptical (see a summary of a possible scenario). In addition, there is evidence that our nearest big cluster of galaxies, the Virgo Cluster, will probably stop our cosmological recession away from it, accelerate the Local Group toward itself so that it will finally fall and merge into this huge cluster of galaxies, see our Virgo Cluster & Local Group page.

A table of the currently known Local Group member galaxies follows. While the positions are known very acurately, the distances are only very vaguely known for some members, and the sources even disagree for the most prominent members such as M31 and M33. If interested, look at our compilation of distances from various sources. Please note that this table is currently under review, as new data (Hipparcos distances, discovery of new members) keep our knowledge in flow.

Local Group Member Galaxies

Galaxy	RA	Dec	Type	m_v	dim	RV	Dist
WLM	00:02.0	-15:28	IB(s) IV-V	10.9	12 x 4	- 42	3400
IC 10	00:20.4	+59:18	KBm?	10.3	7.3 x 6.4	- 83	4200:
Cet dw	00:26.1	-11:02	dSph/E4	14.4			2800
NGC 147	00:33.2	+48:31	dE5 pec	9.5	15.0 x 9.4	+ 89	2400
And III	00:35.4	+36:31	dSph/E2	13.5p	4.5 x 3.0		2900:
NGC 185	00:39.0	+84:20	dE3 pec	9.2	14.5 x 12.5	+ 39	2300
M110	00:41.3	+41:41	E5 pec	8.5	19.5 x 12.5	- 1	2900
And VIII	00:42.3	+40:37	dSph pec	9.1	45 x 10	-250	2700:
M 32	00:42.7	+40:52	E2 (cE2)	8.1	11.0 x 7.3	+ 35	2900
M 31	00:42.7	+41:16	SA(s)b I-II	3.4	185.0 x 75.0	- 59	2900
And I	00:45.7	+38:00	dSph/E3 pec ?	13.2	2.5 x 2.5		2900:
SMC	00:51.7	-73:14	SB(s)m pec	2.3	280 x 160	- 30	210
Scl dw	01:00.0	-33:42	dSph/E3 pec	10.5p		+162	300:
LGS 3	01:03.8	+21:53	Irr	15.4p	2		3000:
IC 1613	01:05.1	+02:08	IAB(s)m V	9.2	20.0 x 18.5	-125	2900:
And V	01:10.3	+47:38	dSph	15.9			2900:
And II	01:16.4	+33:27	dSph/E0	13.5	3.6 x 2.5		2900:
M 33	01:33.9	+30:39	SA(s)cd II-III	5.7	67.0 x 41.5	+ 3	3000
Phe dw	01:51.1	-44:27	Irr	13.1	4.9 x 4.1		1600:
For dw	02:39.9	-34:32	dSph/E2	8.1	12.0 x 10.2		500
UGCA 92	04:32.0	+63:36	Irr ? S0 ?	13.8	2.0 x 1.0	+ 66	4700
LMC	05:19.7	-68:57	SB(s)m	0.1	650 x 550	+ 13	179
Car dw	06:14.6	-50:58	dSph/E3	20.9	23.5 x 15.5		360
CMa dw	07:15	-28	Irr		720		25
Leo A	09:59.4	+30:45	IBm V	12.9	5.1 x 3.1		2500
Sex B	10:00.0	+05:20	Ir+ IV-V	11.8	5.1 x 3.5		4700
NGC 3109	10:03.1	-26:09	Ir+ IV-V	10.4	16.0 x 2.9	+131	4500
Ant dw	10:04.1	-27:20	dSph/E3	14.8	2.0 x 1.5		4600
Leo I	10:08.5	+12:18	dE3	9.8	9.8 x 7.4		900
Sex A	10:11.1	-04:43	Ir+ V	11.9	5.9 x 5.0		5200
Sex dw	10:13.2	-01:37	dSph/E3	12.			320
Leo II	11:13.5	+22:10	dSph/E0 pec	12.6	12.0 x 11.0		750
GR 8	12:58.7	+14:13	Im V	14.5	1.2 x 1.1	+165	7900:
UMi dw	15:08.8	+67:12	dSph/E4	10.9	41.0 x 26.0		240
Dra dw	17:20.1	+57:55	dSph/E0 pec	9.9	51.0 x 31.0		280
Milky Way	17:45.6	-28:56	SAB(s)bc I-II ?		-	0	28
SagDEG	18:55	-30:30	dSph/E7			+168	88
SagDIG	19:30.1	-17:42	IB(s)m V	15.5	2.9 x 2.1		4200
NGC 6822	19:44.9	-14:49	IB(s)m IV-V	9.3	15.5 x 13.5	+ 66	1800
Aqr dw	20:46.8	-12:51	Im V	13.9	2.3 x 1.2		3400
Tuc dw	22:41.7	-64:25	dSph/E5	15.7	2.9 x 1.2		3200
UKS2323-326	23:26.5	-32:23	Irr	13.9	1.5 x 1.2		4700
And VII	23:27.8	+50:35	dSph		2.5 x 2.0		2600
Peg dw	23:28.6	+14:45	Im V	13.2	5.0 x 2.7		3000:
And VI	23:51.7	+24:36	dSph	11.2	3.5 x 3.5		2800

Possible further members:

Galaxy	RA	Dec	Type	m_v	dim	RV	Dist
UGCA 86	03:59.9	+67:08	Irr ? S0 ?	13.5	0.8 x 0.7	+262	6200
IC 5152	22:06.1	-51:17	IAB(s)m IV	10.6	4.9 x 3.0	+ 30	5800

Below we list some nearby but probably non-member field galaxies (which are also not members of one of the neighboring groups listed above), in the same format as above:

Nearby Non-Member (?) Galaxies

Galaxy	RA	Dec	Type	m_v	dim	RV	Dist
NGC 55	00:14.9	-39:11	Sc/SB(s)m	8.8	32.4 x 5.6	+129	7000
NGC 404	01:09.4	+35:43	E0	10.1	4.4 x 4.1	+178	8000:
Cam A	04:25.3	+72:48	Irr	14.8	3.7 x 2.1		6500::
NGC 1569	04:30.8	+64:51	Irp+ III-IV:	11.2v	2.9 x 1.5	+ 87	7500::
NGC 1560	04:32.8	+71:53	Sd	11.5v	9.8 x 2.0	+151	7500::
Argo dw	07:05.3	-58:31	Irr	14.2	3.5 x 1.7	+554	12000:
UGC 9128	14:15.9	+23:03	Irp+	14.4	1.7 x 1.3	+154	

Key:

RA, Dec:
: Right Ascension and Declination for epoch 2000.0

Type:
: Classification type from Tom Polakis' article, or elsewhere

m_v
: Apparent visual brightness in Magnitudes. A "p" indicates that only photographic magnitudes are available and given.

dim
: Angular dimension in arc minutes

RV:
: Radial velocity wrt galactic center in km/sec

Dist:
: Distance in 1000 light years (kly)

A colon following a number indicates this value is uncertain.

More data of and remarks on Local Group Galaxies

Galaxy	R	SG	Diam	Mass	Other names/Remarks
WLM	(*)	LGC	8	?	UGCA 444, DDO 221
IC 10		LGC			UGC 192
Cet dw		LGC			
NGC 147		M31			UGC 326, DDO 3
And III		M31			PGC 2121
NGC 185		M31			UGC 396
M 110		M31	17	10000	NGC 205
And VIII		M31	33		
M 32		M31	8	3000	NGC 221
M 31		M31	195	400000	NGC 224
And I		M31			PGC 2666
SMC		MW	25	6000	NGC 292, Nubecula Minor
Scl dw		MW			ESO 351- G 030, PCG 3589
LGS 3	(*)	M31/33			Psc dw, PCG 3792
IC 1613		M31/LC			UGC 668, DDO 8
And V		M31			
And II		M31			PGC 4601
M 33		M31/33	60	25000	NGC 598
Phe dw	(I)	MW/LGC			ESO 245- G 007, PGC 6830
For dw		MW			ESO 356- G 004, PGC 10093
UGCA 92	(I)	M31?			EGB 0427+63, PGC 15439
LMC		MW	30	20000	ESO 056- G 115, PGC 17223, Nubecula Major
Car dw		MW			ESO 206- G 220, ESO 206- GA020, PGC 19441
CMa dw		MW			
Leo A		M/3109			Leo III, UGC 5364, DDO 69
Sex B	(I)	N3109			UGC 5373, DDO 70
NGC 3109	(I)	N3109			UGCA 194, DDO 236
Ant dw	(I)	N3109	5		PGC 29194
Leo I		MW			UGC 5470, DDO 74, Harrington-Wilson 1, Regulus Galaxy
Sex A		N3109			UGCA 205, DDO 75
Sex dw		MW			
Leo II		MW			Leo B, UGC 6253, DDO 93, Harrington-Wilson 2
GR 8	(?)	GR8			UGC 8091, DDO 155, VV 558
UMi dw		MW			UGC 9749, DDO 199
Dra dw		MW			UGC 10822, DDO 208
Milky Way		MW	100	750000	
SagDEG	(*)	MW			Sgr dShp, Sgr I dw
SagDIG	(*)	LGC			Sgr dw, ESO 594- G 004, UKS 1927-177, PGC 63287, Kowal's Object
NGC 6822		LGC			IC 4895, DDO 209, Barnard's Galaxy
Aqr dw		LGC			DDO 210, PGC 65367
Tuc dw		LGC			PCG 69519
UKS2323-326		LGC			UGCA 438
And VII		M31			Cas dSph, Cas dw
Peg dw		LGC			UGC 12613, DDO 216, Peg DIG
And VI		M31			Peg dSph, Peg II

Possible members:

Galaxy	R	SG	Diam	Mass	Other names/Remarks
UGCA 86	(?)	M31/L?			PGC 14241
IC 5152	(?)	LGC?			ESO 237- G 027

Key:

R:
: Remarks: (*), (?) and (I); see below

SG:
: Subgroup (after Mateo 1999). MW=Milky Way subgroup, M31: M31 subgroup, M31/33: M33 subgroup (probably part of M31 subgroup), LGC: Local Group Cloud (vast cloud of dwarf irregulars), N3109: NGC 3109 subgroup (not counted to Local Group by Van den Bergh), GR8: GR8 group (LG membership in doubt), M/N3109: Either MW or NGC 3109 group

Diam:
: Diameter in 1000 light years (kly)

Mass:
: Mass in million solar masses

Remarks (*):

- "WLM" is "Wolf-Lundmark-Melotte"
- "LGS" stands for "Local Group (suspected)" (LGS 3)
- "SagDEG" is the "Sagittarius Dwarf Elliptical Galaxy" (discovered 1994, containing M54)
- "SagDIG" is the "Sagittarius Dwarf Irregular Galaxy"

Galaxies marked with "(?)" may be non-members as they are not in the list of Irwin et.al. 1997 (this list has 35 Local Group members), in particular:

- UGCA 86 may be a member of the Maffei 1 group
- GR8 and IC 5152 are listed as nearby non-member galaxies in Irwin's list. They may be lonely nearby non-members near the edges of the group.
- The Aquarius Dwarf is also listed by Irwin as non-member, but Van den Bergh (2000) reports its membership has now be confirmed.
- Leo A was also listed in Irwin's list of non-members, but recent distant re-determination confirmed its membership.

Galaxies marked with "(I)" are newly taken into the list from Irwin's list: Besides the newly discovered Antlia dwarf, these are the Phoenix dwarf, UGCA 92, Sextans B, and NGC 3109.

More Data on the Probable Nearby Non-Members listed above:

Galaxy	Other names/Remarks
NGC 55	ESO 293- G 050
NGC 404	UGC 718
Cam A	
NGC 1569	UGC 3056
NGC 1560	UGC 3060
Argo dw	PGC 20125
UGC 9128	DDO 187

Various sources have listed other, former Local Group candidates which however have not been confirmed:

"Galaxy"	listed	Rem
1010-27	McGraw	= Ant dw ?
DDO 187 (UGC 9128)	McGraw	Nearby probable non-member galaxy, see above
SDIG	KKT	Member of the Sculptor Group of Galaxies
LGS 2	Irwin	diffuse reflection nebulosity
And IV	vdB	Background galaxy, or open cluster in M31
Sex C (A 1003)	LGAA	globular cluster Palomar 3
UMa dw (A 1127)	dV,LGAA	globular cluster Palomar 4
Ser dw (A 1513)	dV	globular cluster Palomar 5
Cap dw (A 2144)	McGraw	globular cluster Palomar 12
Snickers candidate		Radio observations of 1975 indicated this nearby galaxy
NGC 6946	Hubble	Nearby non-member galaxy
IC 342	Hubble	Member of the Maffei 1 or IC 342 Group of Galaxies
Maffei 1	Maffei	Member of the Maffei 1 or IC 342 Group of Galaxies
Maffei 2	Maffei	Member of the Maffei 1 or IC 342 Group of Galaxies
2318-42	Irwin	

Sources:

dV:
: G. De Vaucouleurs 1975, Nearby Groups of Galaxies, ch. 4, The Local Group. Published in "Galaxies and the Universe," ed. by A. Sandage, M. Sandage and J. Kristian.

Hubble
: E.P. Hubble 1936, The Realm of the Nebulae, Yale University Press. Local group table on p. 126.

KKT:
: Kraan-Korteweg & Tammann, 1979. *Astronomische Nachrichten* **300**, p. 181

LGAA:
: Le Grand Atlas de L'Astronomie, Encyclopedia Universalis, 1986. German edition: "Der große JRO Atlas der Astronomie"

McGraw:
: McGraw-Hill Dictionary of Astronomy, by Sybil P. Parker (ed), p. 242

Maffei:
: P. Maffei 1968, *PASP* **80**, p. 618

vdB:
: S. van den Bergh 1972, Search for Faint Companions to M31. *ApJ*. **171**, p. L31-L33.
  Andromeda IV is probably not an independent Local Group galaxy, but either a large open cluster in M31 (Jones, 1993), or a more remote background galaxy (Ferguson *et.al.*, 2000)

As our Milky Way obscures parts of the sky, there is still a steady flow of new discoveries of galaxies, in low galactic latitudes (i.e., near the equatorial plane of our galaxy, where the obscuring dust is most dense). Also, some of the galaxies are of extreme low surface brightness, and it was only recently possible to detect them. Therefore, it must be expected that more Local Group members exist, obscured by dust, or extremely faint, and are still waiting for their detection somewhen in the future.

Jeff Bondono has compiled a comprehensive list of Local Group member and member candidate galaxies.

Links

You are invited to contribute more links which are of interest for this page; please contact the maintainer.

- Local Group Galaxies, images and more information on all known certain and possible member galaxies as well as all former candidates, at SEDS
- Bill Arnett's table of Local Group galaxies
- (Lengthy) article on the Local Group by George Lake
- Mike Irwin's Local Group page and Local Group Member list
- Brian Skiff's list of Local Group galaxies (based on Sidney van den Bergh's article in PASP May 2000 issue)
- Local Group Galaxies table from NED (from Mateo 1998)
- Local Group Survey, by Phil Massey Based on High Resolution Images from the KPNO and CTIO 4-m telescopes.
- Milky Way Satellite and Local Group pages (from An Atlas of the Universe, by Richard Powell)
- Local Group galaxy images from the Astronomical Picture of the Day archives
- Observing the Local Group by Tom Polakis; from Deep Sky Magazine #36.
- The Local Group of Galaxies map and list, and The Milky Way's Satellite Galaxies, from An Atlas of the Universe
- Distribution of Galaxies in the Local Group, an animated graphical 3D presentation by Wil Milan

References

- Annette M.N. Ferguson, J.S. Gallagher, and Rosemary F.G. Wyse, 2000. On the Nature of Andromeda IV. Astronomical Journal, Vol. 120, No. 2, p. 821-832 (08/2000)
- Joseph H. Jones, 1993. CCD photometry of Andromeda IV - Dwarf irregular galaxy or M31 open cluster? Astronomical Journal, vol. 105, no. 3, p. 933-7 (03/1993)
- Mario Mateo, 1998. Dwarf Galaxies of the Local Group. Annual Review of Astronomy and Astrophysics, Volume 36, 1998, p. 435-506. Available online [framed version] - table of Local Group galaxies (NED Level 5)
- Sidney van den Bergh, 1972. Search for Faint Companions to M31. *Astrophysical Journal*, vol. 171, p. L31-L33
- Sidney van den Bergh, 1994. The Outer Fringes of the Local Group. Astronomical Journal 107, No. 4, p. 1328-1332 (April 1994)
- Sidney van den Bergh, 2000. Updated Information on the Local Group. Publications of the Astronomical Society of the Pacific, Vol. 112, No. 770, p. 529-536 (April 2000)

- **Tom Polakis** has published an interesting article for observers of local group galaxies, *Observing the Local Group*, in the *Deep Sky* magazine (#36), which was reprinted in **David Eicher**'s book *Galaxies and the Universe*. (was also available online but disappeared)
- **Paul W. Hodge**, *Galaxies*. Harvard University Press, 1986. In particular Chapter 7: The Local Group.
- **Edwin P. Hubble**, *The Realm of the Nebulae*, Yale University Press, 1936 (in particular, pp. 124, 145)

This page has been used in the sci.astro FAQ

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 22 Nov 2003

M 31

Spiral Galaxy M31 *(NGC 224)*, type Sb, in Andromeda

Andromeda Galaxy

Right Ascension	00 : 42.7 (h:m)
Declination	+41 : 16 (deg:m)
Distance	2900 (kly)
Visual Brightness	3.4 (mag)
Apparent Dimension	178x63 (arc min)

Known to Al-Sufi about AD 905.

M31 is the famous *Andromeda galaxy*, our nearest large neighbor galaxy, forming the Local Group of galaxies together with its companions (including M32 and M110, two bright dwarf elliptical galaxies), our Milky Way and its companions, M33, and others.

Visible to the naked eye even under moderate conditions, this object was known as the "little cloud" to the Persian astronomer Abd-al-Rahman Al-Sufi, who described and depicted it in 964 AD in his *Book of Fixed Stars*: It must have been observed by and commonly known to Persian astronomers at Isfahan as early as 905 AD, or earlier. R.H. Allen (1899/1963) reports that it was also appeared on a Dutch starmap of 1500. Charles Messier, who cataloged it on August 3, 1764, was obviously unaware of this early reports, and ascribed its discovery to Simon Marius, who was the first to give a telescopic description in 1612, but (according to R.H. Allen) didn't claim its discovery. Unaware of both Al Sufi's and Marius' discovery, Giovanni Batista Hodierna independently rediscovered this object before 1654. Edmond Halley, however, in his 1716 treat of "Nebulae", accounts the discovery of this "nebula" to the French astronomer Bullialdus (Ismail Bouillaud), who observed it in 1661; but Bullialdus mentions that it had been seen 150 years earlier (in the early 1500s) by some anonymous astronomer (R.H. Allen, 1899/1963).

It was longly believed that the "Great Andromeda Nebula" was one of the nearest nebulae. William Herschel believed, wrongly of course, that its distance would "not exceed 2000 times the distance of Sirius" (17,000 light years); nevertheless, he viewed it at the nearest "island universe" like our Milky Way which he assumed to be a disk of 850 times the distance of Sirius in diameter, and of a thickness of 155 times that distance.

It was William Huggins, the pioneer of spectroscopy, who noted in 1864 the difference between gaseous nebula with their line spectra and those "nebulae" with star-like, continuous spectra, which we now know as galaxies, and found a continuous spectrum for M31 (Huggins and Miller 1864).

In 1887, Isaac Roberts obtained the first photographs of the Andromeda "Nebula," which showed the basic features of its spiral structure for the first time.

In 1912, V.M. Slipher of Lowell Observatory measured the radial velocity of the Andromeda "nebula" and found it the highest velocity ever measured, about 300 km/sec in approach. This already pointed to the extra-galactic nature of this object. According to Burnham, a better value is about 266 km/sec, but R. Brent Tully gives 298 km/sec, and NED has again 300 +/- 4 km/s as the modern value. Note that all the previous values describe the motion with respect to our Solar System, i.e. heliocentric motion, not that w.r.t. the Milky Way's Galactic Center. The latter value can be obtained by correcting for the motion of our Solar System around that center. The modern values for Galactic rotation and heliocentric radial velocity yield that the Andromeda Galaxy and the Milky Way are approaching each other at about 100 km/sec.

In 1923, Edwin Hubble found the first Cepheid variable in the Andromeda galaxy and thus established the intergalactic distance and the true nature of M31 as a galaxy. Because he was not aware of the two Cepheid classes, his distance was incorrect by a factor of more than two, though. This error was not discovered until 1953, when the 200-inch Palomar telescope was completed and had started observing. Hubble published his epochal study of the Andromeda "nebula" as an extragalactic stellar system (galaxy) in 1929 (Hubble 1929).

At modern times, the Andromeda galaxy is certainly the most studied "external" galaxy. It is of particular interest because it allows studies of all the features of a galaxy from outside which we also find in Milky Way, but cannot observe as the greatest part of our Galaxy is hidden by interstellar dust. Thus there are continuous studies of the spiral structure, globular and open clusters, interstellar matter, planetary nebulae, supernova remnants (see e.g. Jeff Kanipe's article in *Astronomy*, November 1995, p. 46), galactic nucleus, companion galaxies, and more.

Some of the features mentioned above are also of interest for the amateur: Even Charles Messier found its two brightest companions, M32 and M110 which are visible in binoculars and conspicuous in small telescopes, and created a drawing of all three. These two relatively bright and relatively close companions are visible in many photos of M31, including the one in this page. They are only the brightest of a "swarm" of smaller companions which surround the Andromeda Galaxy, and form a subgroup of the Local Group. At the time of this writing (September 2003), at least 11 of them are known: Besides M32 and M110 these are NGC 185, which was discovered by William Herschel, and NGC 147 (discovered by d'Arrest) as well as the very faint dwarf systems And I, And II, And III, possibly And IV (which may however be a cluster or a remote background galaxy), And V, And VI (also called the Pegasus dwarf), And VII (also Cassiopeia dwarf), and And VIII. It is still not clear if M33, the smaller spiral galaxy in Triangulum, and its probable companion LGS 3 belong to this subgroup, or the more remote Local Group member IC 1613, or one of the possible member candidates UGCA 86 or UGCA 92.

The Andromeda Galaxy is in notable interaction with its companion M32, which is apparently responsible for a considerable amount of disturbance in the spiral structure of M31. The arms of neutral hydrogene are displaced from those consisted of stars by 4000 light years, and cannot be continuously followed in the area closest to its smaller neighbor. Computer simulations have shown that the disturbances can be modelled by a recent close encounter with a small companion of the mass of M32. Very probably, M32 has also suffered from this encounter by losing many stars which are now spread in Andromeda's halo.

The brightest globular cluster of the Andromeda Galaxy M31, G1, is also the most luminous globular in the Local Group of Galaxies; its apparent visual brightness from Earth is still about 13.72 magnitudes. It outshines even the brightest globular in our Milky Way, Omega Centauri, and can be glimpsed even by better equipped amateurs under very favorable conditions, with telescopes starting at 10-inch aperture (see Leos Ondra's article in *Sky & Telescope*, November 1995, p. 68-69). The Hubble Space Telescope was used to investigate globular cluster G1 in mid-1994 (published April 1996). While the easiest, G1 is not the only M31 globular cluster which is in the reach of large amateur telescopes: Amateur Steve Gottlieb has observed 18 globular clusters of M31 with a 44cm telescope. With their 14-inch Newton and CB245 CCD camera, observers of the Ferguson Observatory near Kenwood, CA have photographed G1 and four fainter M31 globulars. Barmby *et.al* (1999) have found 435 globular cluster candidates in M31, and estimate the total number at 450 +/- 100.

The astrophotographer is even better off, as he can gather the fainter light of the fine detail in the spiral arms, as in our image: Amateurs can obtain most striking pictures even with inexpensive equipment, from wide-field exposures to detailed close-ups. Also in photography, better equipment pays off, as is demonstrated by our image, which was obtained by (and is courtesy of) Texas amateur Jason Ware, with a 6-inch refractor. More information on this image is available.

The brightest star cloud in the Andromeda galaxy M31 has been assigned an own NGC number: NGC 206, because William Herschel had taken it into his catalog as H V.36 on the grounds of his discovery observation of October 17, 1786. It is the bright star cloud at the upper left, just below a conspicuous dark nebula, in our photograph (very conspicuous in the larger photo).

Despite the large amount of knowledge we now have about the Andromeda Galaxy, its distance, though among the best known intergalactic distances, is not really well-known. While it is well established that M31 is about 15-16 times further away than the Large Magellanic Cloud (LMC), the absolute value of this measure is still uncertain, and in current sources, usually given between 2.4 and 2.9 million light-years - a consequence of the uncertainty in the LMC distance and thus the overall intergalactic distance scale. E.g., the semi-recent correction from data by ESA's astrometrical satellite Hipparcos has pushed this value up by more than 10 percent, from about 2.4-2.5 to the about 2.9 million light-years we use here.

Under "normal" viewing conditions, the apparent size of the visible Andromeda Galaxy is about 3 x 1 degrees (our acurate value, given above, is 178x63 arc minutes, while NED gives 190x60'). Careful estimates of its angular diameter, performed with 2-inch binoculars, by the French astronomer Robert Jonckhere in 1952-1953, revealed an extension of 5.2 times 1.1 degrees (reported by Mallas), corresponding to a disk diameter of over 250,000 light years at its distance of 2.9 million light years, so that this galaxy is more than double as large as our own Milky Way galaxy ! Its mass was estimated at 300 to 400 billion times that of the sun. Compared to the newer estimates for our Milky Way galaxy, this is considerably less than the mass of our galaxy, implying that the Milky Way may be much denser than M31. These results are confirmed by new estimates of the total halo masses, which turn out to be about 1.23 trillion solar masses for M31, compared to 1.9 trillion for the Milky Way (Evans and Wilkinson, 2000).

The Hubble Space Telescope has revealed that the Andromeda galaxy M31 has a double nucleus. This suggests that either it has actually two bright nuclei, probably because it has "eaten" a smaller galaxy which once intruded its core, or parts of its only one core are obscured by dark material, probably dust. In the first case, this second nucleus may be a remainder of a possibly violent dynamical encountering event in the earlier history of the Local Group. In the second case, the duplicity of Andromeda's nucleus would be an illusion causes by a dark dust cloud obstructing parts of a single nucleus in the center of M31.

Up to now, only one supernova has been recorded in the Andromeda galaxy, the Supernova 1885, also designated S Andromedae. This was the first supernova discovered beyond our Milky Way galaxy, on August 20, 1885, by Ernst Hartwig (1851-1923) at Dorpat Observatory in Estonia. It reached mag 6 between August 17 and 20, and it was independently found by several observers. However, only Hartwig realized its significance. It faded to mag 16 in February 1890.

- Historical Observations and Descriptions of M31
- Images of M31 from the Isaac Newton Telescope, by the INT Team and David Malin
- More images of M31
- Amateur images of M31
- IRAS investigated M31 in the infrared light
- Rosat has explored M31 in the X-ray light
- Chandra X-ray Observatory images of M31
- GALEX images of M31 in the ultraviolet light
- More images of M31 and M32
- Amateur images of M31 and M32

Animation explaining the structure of M31

Links

- Atlas of the Andromeda Galaxy by Paul W. Hodge. University of Washington Press, 1981.
- DIRECT: A project to directly determine the distances of M31 and M33 (by Kris Stanek, Harvard-Smithsonian CfA)
- John A. Blackwell's M-31 Atlas
- Jack Schmidling's M31 page

- Multispectral Image Collection of M31, SIRTF Multiwavelength Messier Museum
- SIMBAD Data of M31
- NED Data of M31
- Publications on M31 (NASA ADS)
- Observing Reports for M31 (IAAC Netastrocatalog)

References

- P. Barmby, J.P. Huchra, J.P. Brodie, D.A. Forbes, L.L. Schroeder and C.J. Grillmair, 1999. Preprint astro-ph/9911152.
- N.W. Evans and M.I. Wilkinson, 2000. The mass of the Andromeda galaxy. Monthly Notices of the Royal Astronomical Society, Volume 316, Issue 4, p. 929-942 (08/2000)
- Edwin P. Hubble, 1929. Astrophysical Journal, Vol. 69, p. 103-157 and plates III-VIII.
- William Huggins and W.A. Miller, 1864. On the Specta of some of the Nebulae. Philosophical Transactions, Vol. 154 (1864), p. 437.

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 18 September 2003

The Satellite Galaxy System of the Milky Way Galaxy

Galaxy	RA	Dec	Type	m_v	dim	RV	Dist
	h:m	d:m		mag	arc min	km/s	kly
SMC	00:51.7	-73:14	SB(s)m pec	2.3	280 x 160	- 30	210
Scl dw	01:00.0	-33:42	dSph/E3 pec	10.5p		+162	300:
Phe dw (?)	01:51.1	-44:27	Irr	13.1	4.9 x 4.1		1600:
For dw	02:39.9	-34:32	dSph/E2	8.1	12.0 x 10.2		500
LMC	05:19.7	-68:57	SB(s)m	0.1	650 x 550	+ 13	179
Car dw	06:14.6	-50:58	dSph/E3	20.9	23.5 x 15.5		360
CMa dw	07:15	-28	Irr				25
Leo A (?)	09:59.4	+30:45	IBm V	12.9	5.1 x 3.1		2500
Leo I	10:08.5	+12:18	dE3	9.8	9.8 x 7.4		900
Sex dw	10:13.2	-01:37	dSph/E3	12.			320
Leo II	11:13.5	+22:10	dSph/E0 pec	12.6	12.0 x 11.0		750
UMi dw	15:08.8	+67:12	dSph/E4	10.9	41.0 x 26.0		240
Dra dw	17:20.1	+57:55	dSph/E0 pec	9.9	51.0 x 31.0		280
Milky Way	17:45.6	-28:56	SAB(s)bc I-II ?		-	0	28
SagDEG	18:55	-30:30	dSph/E7		490 x 190	+168	88

.. more to come soon ..

- [The Local Group of Galaxies]

[Hartmut Frommert]
[Christine Kronberg]
[[contact]]

Last Modification: 8 Oct 2003

The Large Magellanic Cloud, LMC

Irregular Galaxy LMC, the Large Magellanic Cloud in Dorado

Right Ascension	5 : 23.6 (h:m)
Declination	-69 : 45 (deg:m)
Distance	179.0 (kly)
Visual Brightness	0.1 (mag)
Apparent Dimension	650x550 (arc min)

Known pre-historically on the Southern hemisphere. Mentioned 964 A.D. by Al Sufi. Probably mentioned by Amerigo Vespucci in 1503-4. Discovered by Magellan 1519.

The Large Magellanic Cloud, together with its apparent neighbor and relative, the Small Magellanic Cloud, are conspicuous objects in the southern hemisphere, looking like separated pieces of the Milky Way for the naked eye. They were certainly known since the earliest times by the ancient southerners, but these people produced little documents which are still preserved. The first preserved mention of the Large Magellanic Cloud was by Persian astronomer Al Sufi, who in 964 A.D., in his *Book of Fixed Stars* calls it **Al Bakr**, the White Ox, of the southern Arabs, and points out that while invisible from Northern Arabia and Baghdad, this object is visible from the Strait of Babd al Mandab, at 12deg 15' Northern latitude. Next, it was probably mentioned by Amerigo Vespucci in a letter written during his third voyage about 1503-4, as one of "three Canopes, two bright and one obscure;" Amerigo's bright "Canopes" are thought to be the Magellanic Clouds, while the obscure one is probably the Coalsack dark nebula. Eventually, it was Magellan and his discovery expedition who brought them to our knowledge in 1519.

Both Magellanic Clouds are irregular dwarf galaxies orbiting our Milky Way galaxy, and thus are members of our Local Group of galaxies. The Large Magellanic Cloud, at its distance of 179,000 light years, was longly considered the nearest external galaxy, until in 1994, the Sagittarius Dwarf Elliptical Galaxy was discovered at only about 80,000 light years. (Our current distance value takes into account the corrected Cepheid distance scale based on the Hipparcos satellite data published in early 1997.)

Although a small irregular galaxy, the LMC is full of interesting objects including diffuse nebulae (especially the Tarantula Nebula, NGC 2070, a giant H II region), globular and open clusters, planetary nebulae, and more.

- Some prominent LMC objects

On February 24, 1987, supernova 1987A occurred in the Large Magellanic Cloud, which was the nearest observed supernova since Keplers, which occured before the invention of the telescope. Supernova 1987A, peculiar and of type II, was one of the most interesting objects for the astrophysicists in the 1980s (some even say of this century).

In John Caldwell's observing list. In the Astronomical League's Southern Sky Binocular Club list.

The image in this page was obtained by *David Malin* with the Anglo-Australian Telescope. This image is copyrighted and may be used for private purpose only. For any other kind of use, including internet mirroring and storing on CD-ROM, please contact the Photo Permissions Department of the Anglo Australian Observatory.

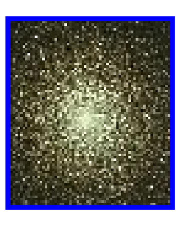
- More information on this image (David Malin)

- Donald R. Pettit's LMC astrophoto from the International Space Station, ISS (Feb 2003)

- Multispectral Image Collection of the Large Magellanic Cloud, SIRTF Multiwavelength Messier Museum
- NED data of LMC
- SIMBAD Data of LMC
- Observing Reports for the Large Magellanic Cloud - LMC (IAAC Netastrocatalog)

Hartmut Frommert
Christine Kronberg
[contact]

Globular Star Clusters



Click icon to view globular clusters of Messier's catalog

>> Messier's Globular Clusters; Links

The icon shows 47 Tucanae (NGC 104).

Globular clusters are gravitationally bound concentrations of approximately ten thousand to one million stars, spread over a volume of several tens to about 200 light years in diameter.

The first globular cluster discovered, but then taken for a nebula, was M22 in Sagittarius, which was probably discovered by Abraham Ihle in 1665. This discovery was followed by that of southern Omega Centauri (NGC 5139) by Edmond Halley on his 1677 journey to St. Helena. This "nebula" had been known but classified as star since ancient times. Next followed the discovery of M5 in Serpens Caput by Gottfried Kirch in 1702, and that of M13 in Hercules, again by Halley, in 1714. De Chéseaux's list of nebulae of 1746 contains, in addition, two new globular clusters, M71 and M4, while Jean-Dominique Maraldi discovered M15 and M2 in September of this year (1746). Abbe Lacaille's catalog of southern "nebula" of 1751-52 contains 8 globular clusters (among them 5 new ones), while Messier's catalog contains a total of 29 globulars, 20 of them new discoveries. Charles Messier was the first to resolve one globular cluster, M4, but still referred to the other 28 of these objects in his catalog as "round nebulae." Thus, in summer 1782, before William Herschel started his comprehensive deep sky survey with large telescopes, there were 33 globular clusters known. Herschel himself discovered 37 new globulars, bringing the number of known globulars to 70. He was the first to resolve virtually all of them into stars, and coined the term "globular cluster" in the discussion adjacent to his second catalog of 1000 deepsky objects (1789).

These early known globulars are all belonging to our Milky Way Galaxy, but some of them have been integrated, or have immigrated into the Galactic Globular Cluster system only recently, including M54 (noted 1994) and M79 (noted 2003).

Melotte's list of 1915 already lists 83 globulars, Shapley (1930) has 93, one of them in the Large Magellanic Cloud (NGC 1651). Helen Sawyer (Hogg, 1947) lists 99 Milky Way globular clusters, 97 of which are still considered as such; her 1959 list (Sawyer Hogg 1959) has 118 entries (115 real). Further lists of Arp (1965), Alcaino (1973) and Kukarkin (1974) have between 119 and 131 clusters. Becvar lists 100, the Sky Catalogue 2000.0 lists 138 globulars, a number given for 1987 also by Kenneth Glyn Jones (1991). The more recent compilations of Webbink (1985) and Djorgovski and Meylan (1993) have 154 and 143 (both 141 real), respectively. W.E. Harris' database of 1999 contains 147; the four further recent discoveries brings the number of currently known Milky Way globular clusters to 151. Of the 151 known globular clusters of our Milky Way galaxy, 104 are in the NGC catalog, and 3 more in the IC catalog of J.L.E. Dreyer.

Since their discovery and resolution, globular clusters were always *thought* or suspected to be physical objects, agglomerations or swarms of stars held together by their mutual gravity, all close together and at about the same distance. The proof for this correct guess, or working model, came only with spectroscopy, showing that the stars of these clusters have radial velocities as expected for such swarms, and perfectly match in color-magnitude or Hertzsprung-Russell diagram, i.e. they represent a population of stars of about same age (also see below), all at about the same distance.

The distribution of the globular clusters in our Milky Way galaxy is concentrated around the galactic center in the Sagittarius -- Scorpius -- Ophiuchus region: Of the 138 Milky Way globulars listed in the Sky Catalog 2000, these constellations contain 29, 18, and 24 globulars, respectively, so a total of 71 clusters, or 51.4 percent (though one must admit that of the 29 clusters listed in Sagittarius, probably four are members of the Sagittarius Dwarf Elliptical Galaxy discovered 1994, and not really of the Milky Way, among them M54; however, these are in process to be integrated into the Milky Way's halo). Current counting (June 2002) brings these numbers to 33, 19 and 25 globulars in Sagittarius, Scorpius and Ophiuchus, respectively, thus a total of 77 clusters of a total of 151, or 51.0 percent. Of the 88 constellations, only 43 or about half contain any globular cluster at all; Aquila follows with 7, Serpens with 5, Hercules and Ara with 4 clusters each, and no further constellation contains more than 3.

Of the 151 known clusters, 138 (91.4 percent) are concentrated in the hemisphere centered on Sagittarius, while only 13 globulars (8.6 percent) are on the opposite side of us (among them M79). Of these 13, four (including M79) are suspected to be members of the remnant globular cluster system of the Canis Major Dwarf galaxy discovered in 2003, which again is going to be integrated into the Milky Way's Galactic Halo.

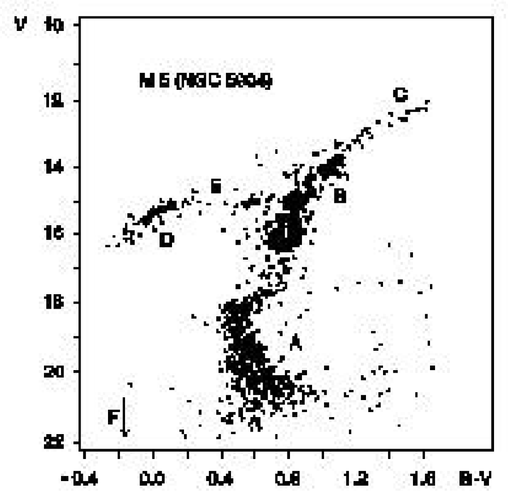
This pronounced anisotropy in the distribution of globular clusters was of historic importance when Harlow Shapley, in 1917, derived from it that the center of our galaxy is lying at a considerable distance in the direction of Sagittarius and not close to our solar system as had been thought previously (however, he significantly overestimated the size of the Milky Way as a whole, as well as the size of the globular cluster system and our distance from the Galactic Center).

Radial velocity measurements have revealed that most globulars are moving in highly excentric elliptical orbits that take them far outside the Milky Way; they form a halo of roughly spherical shape which is highly concentrated to the Galactic Center, but reaches out to a distance of several 100,000 light years, much more than the dimension of the Galaxy's disk. As they don't participate in the Galaxy's disk rotation, they can have high relative velocities of several 100 km/sec with respect to our solar system; this is what shows up in the radial velocity measurements.

Spectroscopic study of globular clusters shows that they are much lower in heavy element abundance than stars such as the Sun that form in the disks of galaxies. Thus, globular clusters are believed to be very old and consisted from an earlier generation of stars (*Population II*), which have formed from the more primordial matter present in the young galaxy just after (or even before) its formation. The disk stars, by contrast, have evolved through many cycles of starbirth and supernovae, which enrich the heavy element concentration in star-forming clouds and may also trigger their collapse.

Globular clusters typically contain a number of variable stars, in particular RR Lyrae stars which were once called "Cluster Variables" because of their abundance in globulars. Their frequency is varying from cluster to cluster. A small number of four globular clusters also contains planetary nebulae; these appear to be so rare because of the short liftime of planetary nebulae. They also contain a large number of white dwarfs and, at least in some cases, many neutron stars, some of which show up as pulsars.

The H-R diagrams for globular clusters (here shown for M5) typically have short main sequences and prominent horizontal branches, this again represents very old stars that have evolved past giant or supergiant phases.



Comparison of the measured HRD of each globular cluster with theoretical model HRDs derived from the theory of stellar evolution provides the possibility to derive, or estimate, the age of that particular cluster. It is perhaps a bit surprising that almost all globular clusters seem to be of about the same age; there seems to be a physical reason that they all formed in a short period of time in the history of the universe, and this period was apparently long ago when the galaxies were young. Semi-recent estimates yield an age of 12 to 20 billion years; the best value for observation is perhaps 12 to 16 billion (see e.g. the discussion at M92). As their age is crucial as a lower limit for the age of our universe, it was subject to vivid and continuous discussion since decades. In early 1997, the discussion of the age of the globular clusters got revived because of the general modifications of the distance scale of the universe, implied by results of ESA's astrometrical satellite Hipparcos: These results suggest that galaxies and many galactic objects, including the globular clusters, may be at a 10 per cent larger distance; therefore, the intrinsic brightness of all their stars must be about 20 % higher. Considering the various relations which are important for understanding stellar structure and evolution, they should also be roughly 15 % younger, in a preliminary off-hand estimate.

As globular clusters follow their orbits around the Milky Way's Galactic center through the billion years, they are subject to a variety of disturbations:

- some of their stars escape as they get randomly accelerated in mutual encounters,
- tidal forces from the parent galaxy acts on them, particularly heavy in that part of their orbit which is closest to the galactic center (near the periapsis),
- each passing through the galactic plane, as well as close encounters with greater masses like (any type of) clusters or big nebulous clouds contributes to disturbation,
- stellar evolutionary effects and loss of gas also contribute to increasing the rate of mass loss (and thus deflation) of the clusters

Although significantly slower compared to the less densely packed and less populated open clusters, these disturbations are tending to disrupt the clusters. The currently existing globulars are just the survivers of a perhaps significantly larger population, the rest of which has been disrupted and spread their stars throughout the Galactic halo. The process of destruction still works, and it was estimated that about half of the Milky Way globulars will cease to exist within the next 10 billion years.

Our galaxy has a system of perhaps about 180 to 200 globular clusters (including the 29 Messier globulars, of which two may have immigrated only recently: M54 and M79). Most other galaxies have globular cluster systems as well, in some cases (e.g., for M87) containing several thousands of globulars! A small number of the known extragalactic globulars is in the reach of larger amateur telescopes; see Jim Shield's Extragalactic Globulars webpage for examples.

While all the globulars in our Milky Way, and our big companion, the Andromeda Galaxy M31, are old, other Local Group galaxies as the Large and the Small Magellanic Cloud as well as the Triangulum Galaxy M33 also contain considerably younger globular star clusters, which can be concluded with certainty from spectroscopic investigations. These galaxies contain also extremely large diffuse nebulae with masses of the order of globular clusters, clear candidates for future young globulars currently in formation, notably the Tarantula Nebula NGC 2070 in the LMC and NGC 604 in M33. A large number of over 100 young globular clusters have been detected recently in M82, an irregular galaxy beyond the Local Group.

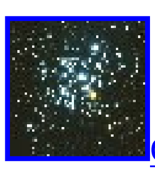
Messier's globular clusters: M2, M3, M4, M5, M9, M10, M12, M13, M14, M15, M19, M22, M28, M30, M53, M54, M55, M56, M62, M68, M69, M70, M71, M72, M75, M79, M80, M92, M107.
Other early known globular clusters: NGC 104 (47 Tucanae), NGC 4833, NGC 5139 (Omega Centauri), NGC 6397.

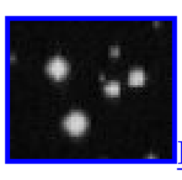
Links

- The Milky Way Globular Clusters
- Planetary Nebulae in Globular Clusters (in the Milky Way)
- Link to the most current globular cluster data file, compiled by W. E. Harris of the Physics and Astronomy department of McMaster University. We hold possibly older versions of the data file and the reference file at SEDS.
- Globular Cluster list by Brian Skiff
- Globular Cluster Catalogs List; Catalog List (Mikkel Steine)
- ARVAL Catalog of Bright Globular Clusters
- Globular Cluster Catalog: Info and references, by Leroy W.L. Guatney. Includes a Globular Observing "Club".
- A galactic globular cluster database, by Marco Castellani. Data (Harris), images (DSS) and color-magnitude diagrams.
- Virtual Tour of the Milky Way Globular Cluster system (Limber Observatory)
- Manos' Globular Cluster Page
- Faint globular hunting:
  - Barbara Wilson's Obscure Globular Clusters of the Milky Way: Terzan Clusters and UKS-1, Extreme Halo Globulars (NGC 2419; AM 1; Pal 3, 4, 14; Eri)
  - Palomar Globular Clusters, by Jim Shields, Barbara Wilson and Doug Snyder (including a Palomar Marathon)
- Globular Cluster List from An Atlas of the Universe
- Distribution of Milky Way Globular Clusters, an animated graphical investigation by Wil Milan
- Globular clusters in other galaxies:
  - Catalog of Globular Cluster Systems of Other Galaxies by W. E. Harris (we hold a possibly older copy - also see NED Level5 article); Globular Clusters in Other Galaxies (M. Kissler-Patig)
  - Extragalactic Globulars - The Brightest Globular Cluster in Eight Nearby Galaxies, hints for observers by Jim Shields
- Look at Globular Clusters in Messier's Catalog
- Also look at our collection of some significant non-Messier globulars

References

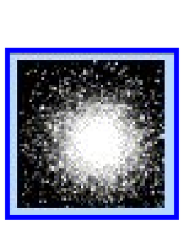
- Gonzalo Alcaino, 1973. *Atlas of galactic globular clusters with colour magnitude diagrams.* Universidad Catolica de Chile, Santiago.
- Halton C. Arp, 1965. *Globular Clusters in the Galaxy*. Ch. 19 in: *Galactic Structure*, ed. A. Blaauw, p. 401. Univ. of Chicago Press.
- Antonin Becvar, 1964. *Atlas of the Heavens - II, Catalogue 1950.0*. Publishing House of the Czechoslovak Academy of Sciences, Praha and Sky Publishing Corporation, Cambridge, Massachusetts. Fourth enlarged edition. Here: Globular Clusters, p. 289-292.
- S. Djorgovski and G. Meylan, 1993. In: G. Meylan and S. Djorgovski (eds.), *Structure and Dynamics of Globular Clusters*, ASP Conference Series 50, A.S.P., San Francisco, p. 325-336
- Kenneth Glyn Jones, 1991. *Messier's Nebulae and Star Clusters*. 2nd revised edition, Cambridge University Press.
- William E. Harris, 1996-2003. Milky Way Globular Clusters - current version (now Feb 2003). Also see: A Catalog of Parameters for Globular Clusters in the Milky Way. Astronomical Journal, vol. 112, p. 1487-1488 (10/1996)
- Alan Hirshfeld and Roger W. Sinnott (eds.), 1985. *Sky Catalogue 2000.0. Volume 2. Double Stars, Variable Stars and Nonstellar Objects*. Cambridge University Press and Sky Publishing Corporation, Cambridge, Massachusetts. Here Globular Clusters, p. 291-294, and introduction p. xxiii-xxiv.
- Kukarkin, 1974. Globular star clusters. The general catalogue of globular star clusters of our galaxy, concerning information on 129 objects known before 1974. Sternberg State Astron. Inst., Moscow
- P. Melotte, 1915. A catalogue of star clusters shown on the Franklin-Adams chart plates. Mem. R. Astron. Soc., 60, 175-186
- Helen B. Sawyer (Hogg), 1947. *A Bibliography of Individual Globular Clusters*. The University of Toronto Press.
- Helen B. Sawyer Hogg, 1959. Star Clusters. In: S. Flügge (ed.), *Handbuch der Physik* [Encyclopedia of Physics], Vol. LIII (53): Astrophysik IV: Sternsysteme [Astrophysics IV: Stellar Systems], p. 129-207.
- Harlow Shapley, 1930. *Star Clusters.* Harvard Observatory Monographs, No. 2. New York, 1930.
- R.F. Webbink, 1985. Structure parameters of galactic globular clusters. In: Dynamics of star clusters; Proceedings of the Symposium, Princeton, NJ, May 29-June 1, 1984. Dordrecht, D. Reidel Publishing Co., p. 541-577

Open Clusters

Binary Star Systems

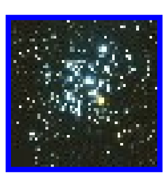
---

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 23 Nov 2003

Open Star Clusters

 Click icon to view open clusters of Messier's catalog

>> Messier's open clusters; Links

The icon shows the Southern open cluster NGC 3293.

Open clusters are physically related groups of stars held together by mutual gravitational attraction. Therefore, they populate a limited region of space, typically much smaller than their distance from us, so that they are all roughly at the same distance. They are believed to originate from large cosmic gas and dust clouds (diffuse nebulae) in the Milky Way, and to continue to orbit the galaxy through the disk. In many clouds visible as bright diffuse nebulae, star formation still takes place at this moment, so that we can observe the formation of new young star clusters. The process of formation takes only a considerably short time compared to the lifetime of the cluster, so that all member stars are of similar age. Also, as all the stars in a cluster formed from the same diffuse nebula, they are all of similar initial chemical composition.

Open clusters are of great interest for astrophysicists because of these properties:

1. the stars in a cluster are all at about *the same* **distance**
2. the stars have approximately *the same* **age**
3. the stars have about *the same* **chemical composition**
4. the stars have *different* **masses**, ranging from about 80-100 solar masses for the most massive stars in very young clusters to less than about 0.08 solar masses.

Therefore, they represent samples of stars of constant age and/or constant chemical composition, suited for study with respect to stellar structure and evolution, and to fix lines or loci in many state diagrams such as the color-magnitude diagram (CMD), or Hertzsprung-Russell diagram (HRD). Comparing the "standard" HRD, derived from nearby stars with sufficiently wellknown distances, or the theory of stellar evolution, with the measured CMD of star clusters, provides a considerably good method to determine the distance of star clusters. Comparing their HRD with stellar theory provides a reasonable way to estimate the age of star clusters. The result that all the cluster HRDs can be explained by the theory of stellar evolution gives convincing evidence for this theory, and moreover for the underlying physics including nuclear and atomic physics, quantum physics and thermodynamics.

Over 1100 open clusters are known in our Milky Way Galaxy, and this is probably only a small percentage of the total population which is probably some factor higher; estimates of as many as about 100,000 Milky Way open clusters have been given.

Most open clusters have only a short life as stellar swarms. As they drift along their orbits, some of their members escape the cluster, due to velocity changes in mutual closer encounters, tidal forces in the galactic gravitational field, and encounters with field stars and interstellar clouds crossing their way. An average open cluster has spread most of its member stars along its path after several 100 million years; only few of them have an age counted by billions of years. The escaped individual stars continue to orbit the Galaxy on their own as field stars: All field stars in our and the external galaxies are thought to have their origin in clusters quite probably.

The first open clusters have been known since prehistoric times: The Pleiades (M45), the Hyades and the Beehive or Praesepe (M44) are the most prominent examples, but *Ptolemy* had also mentioned M7 and the Coma Star Cluster (Mel 111) as early as 138 AD. First thought to be nebulae, it was *Galileo* who in 1609 discovered that they are composed of stars, when observing M44. As open clusters are often bright and easily observable with small telescopes, many of them have been discovered with the earliest telescopes: As seen in the list below, there are 27 in Messier's list, and 32 others were also known in summer 1782. Note that all these early known clusters belong to our Milky Way Galaxy.

In 1767, Reverend John Michell (Michell 1767) derived that clusters were most probable physically related groups rather than chance collections of stars, by calculating that it would be extremely improbable (1/496,000) to find even one cluster like the Pleiades anywhere in the sky, not to speak of the number of then-known open clusters; moreover he presumed that all or at least most then-known nebulous objects actually were composed of stars. The finding of common proper motion by Mädler for the Pleiades and other stellar groups, including the Ursa Major Moving Cluster by Proctor (Proctor 1869), further established the physical relationship between cluster stars. Finally, spectroscopy was needed to show the common radial motion (velocity) of the cluster stars, and to show that the stars perfectly match in a Hertzsprung-Russell diagram (HRD), indicating that they all lie at roughly the same distance. The final confirmation of the roughly common distance came only from the direct measurement of parallaxes for a number of nearby clusters, both from Earth-bound observatories and from ESA's astrometric satellite Hipparcos.

Eventually, the theoretical study of stellar evolution has provided convincing evidence that the stars of a cluster are all roughly of the same age, and thus have formed within a short period of time on the cosmic time scale, i.e. their HRDs represent isochrones, or pictures of stars of all the same age.

Open clusters are often typized according to a simple scheme which goes back to **Harlow Shapley**, which describes richness and concentration roughly:

c
: very loose and irregular

d
: loose and poor

e
: intermediately rich

f
: fairly rich

g
: considerably rich and concentrated

Another important and more sophisticated scheme was introduced by **R.J. Trumpler** (Trumpler 1930). This scheme consists of three parts, characterizing the cluster's degree of concentration, the range of brightness of its stars, and the richness, as follows:

Concentration

I
: Detached; strong concentration toward center

II
: Detached; weak concentration toward center

III
: Detached; no concentration toward center

IV
: Not well deteached from surrounding star field

Range in Brightness

1
: Small range in brightness

2
: Moderate range in brightness

3
: Large range in brightness

Richness

p
: Poor: Less than 50 stars

m
: Moderately rich: 50 to 100 stars

r
: Rich: More than 100 stars

A "**n**" following the Trumpler class indicates that there is nebulosity associated with the cluster.

Messier's open clusters: M6, M7, M11, M16, M18, M21, M23, M25, M26, M29, M34, M35, M36, M37, M38, M39, M41, M44, M45, M46, M47, M48, M50, M52, M67, M93, M103.
Moreover, the Milky Way starcloud M24 contains the open star cluster NGC 6603, and all diffuse nebulae in Messier's catalog contain very young open clusters, still in the process of formation.
Other early known open clusters: 752, 869 (h Per), 884 (Chi Per), 2244, 2362, 2451, 2477, 2516, 2546, 2547, 3228, 3293, 3532, 3766, 4755 (Kappa Cru), 5281, 5662, 6025, 6124, 6231, 6242, 6530, 6633, I2391 (Omicron Vel), I2488, I2602, I4665, Brocchi's Cluster (Cr 399), Alpha Persei Cluster (Mel 20), Hyades (Mel 25), Coma Star Cluster (Mel 111), Ursa Major Moving Cluster (Cr 285).

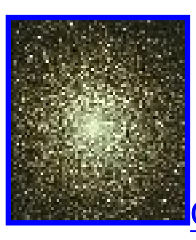
All the diffuse nebulae in Messier's catalog are associated with open clusters of young stars which have formed of the nebula's material in (astronomically) very recent times, and are still formed today in many cases.

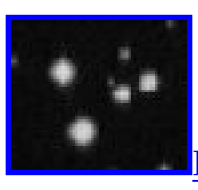
Links

- WEBDA: A Site Devoted to Stellar Open Clusters, by Jean-Claude Mermilliod. Presentation - Cluster list
- A Simulation of Star Cluster Evolution
- Open Cluster Catalogs List; Catalog List (Mikkel Steine)
- ARVAL Catalog of Bright Open Clusters
- Open Clusters List and Star Clusters and Nebulae within 10000 light years map from An Atlas of The Universe - also note their Map of the Orion Arm within 2000 light years for nearby open clusters
- Look at Open Clusters in Messier's Catalog
- Also look at our collection of some significant non-Messier open clusters

References

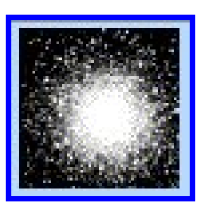
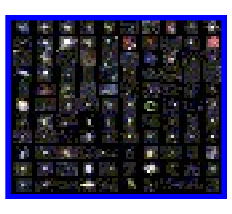
- Woldemar Götz, *Die offenen Sternhaufen unserer Galaxis* (The open star clusters of our Galaxy), Verlag Harri Deutsch, 1990
- John Michell, 1767. An Inquiry into the probable Parallax, and Magnitude, of the Fixed Stars, from the Quantity of Light which they afford us, and the particular Circumstances of their Situation. *Philosophical Transactions*, Vol. 57, p. 234-264.
- Richard A. Proctor, 1869. Preliminary Paper on certain Drifting Motions of the Stars. *Proceedings of the Royal Society of London*, Vol. 18, p. 169-171.
- Robert Julius Trumpler, 1930. Preliminary results on the distances, dimensions and space distribution of open star clusters. *Lick Observatory Bulletin*, Vol. **14**, p. 154

Globular Clusters

Binary Star Systems

---

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 29 Mar 1998, 20:00 MET

Diffuse Nebulae


Click icon to view a diffuse nebula from Messier's catalog

>> Messier's diffuse nebulae; Links

The icon shows reflection nebulae in Scorpius around Antares. The globular cluster at the lower right is M4.

Diffuse nebulae, sometimes inacurately referred to as gaseous nebulae, are clouds of interstellar matter, namely thin but widespread agglomerations of gas and dust. If they are large and massive enough they are frequently places of star formation, thus generating big associations or clusters of stars. Some of the young stars are often very massive and so hot that their high energy radiation can excite the gas of the nebula (mostly hydrogene) to shine; such nebula is called *emission nebula*. If the stars are not hot enough, their light is reflected by the dust and can be seen as white or bluish *reflection nebula*. Note that many emission nebulae also have an additional reflection nebula component (as they usually also contain dust); a most impressive example for this is the Trifid Nebula M20.

Diffuse emission nebulae are often called H II regions because they are mainly consisted of ionized hydrogene, H II - the roman number after the element symbol (here H) designating the ionization level: `I' would stand for neutral atoms, the `II' here means first ionization, i.e. the hydrogene atoms have lost their single electron, and for other elements higher numbers (ionization levels, or numbers of lost electrons) would be possible (e.g., He III, O III or Fe V).

After some million years, the gas and dust of the nebula will have been used up for forming stars (and planets), or blown away by the stellar winds of the young hot stars. A newly born open star cluster will remain. From the physical viewpoint, the nebulae are an early stage of evolution of star clusters.

The first diffuse nebula discovered was the Orion Nebula, M42, observed telescopically in 1610 by N. Peiresc. The diffuse nebulae were longly be considered as distant, unresolved star clusters, or star clouds, until in the 1860s spectroscopy revealed their gaseous nature by showing line spectra, in particular due to the pioneering research of William Huggins. Eventually, in 1912, Vesto M. Slipher discovered that the nebulae in the Pleiades, M45, had the same spectra as the stars illuminating them, thus proving their nature as reflection nebulae. Of Messier's nebulae, M78 is the only pure reflection nebula, and the first of these objects to be discovered; its nature as a reflection nebula was revealed in 1919, again by V.M. Slipher.

While all of Messier's diffuse nebulae belong to our Milky Way galaxy, most other galaxies (especially all spiral and irregular galaxies) also contain such objects.

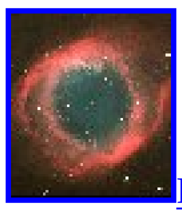
Messier's diffuse nebulae: M8, M17, M20, M42, M43, M78.
Moreover, open star cluster M16 (NGC 6611) is physically connected with the Eagle Nebula IC 4703, an H II region, and the Pleiades, M45, contain diffuse reflection nebulae.
Other early known diffuse nebulae: NGC 2070, NGC 3372.

Links

- Diffuse Nebulae Catalogs List
- ARVAL Catalog of Bright Nebulae (Diffuse and SNRs)
- Diffuse Nebulae list from An Atlas of the Universe
- Look at Diffuse Nebulae in Messier's Catalog
- Also look at our small collection of some significant diffuse nebulae not in Messier's catalog
- Interstellar Matter text (Scholar series at the MAA)

References

- James B. Kaler, *Cosmic Clouds*, Scientific American Library, W.H. Freeman, 1997 (German edition: Kosmische Wolken, 1998)


Planetary Nebulae


Supernova Remnants


Dark Nebulae

Hartmut Frommert
Christine Kronberg
[contact]



Last Modification: 23 Nov 2003

The Small Magellanic Cloud, SMC

Irregular Galaxy SMC, the Small Magellanic Cloud (NGC 292) in Tucana

Right Ascension	00 : 52.7 (h:m)
Declination	-72 : 50 (deg:m)
Distance	210.0 (kly)
Visual Brightness	2.3 (mag)
Apparent Dimension	280 x 160 (arc min)

Known pre-historically on the Southern hemisphere. Probably mentioned by Amerigo Vespucci in 1503-4. Discovered by Magellan 1519.

Like its larger apparent neighbor, the Large Magellanic Cloud, the Small Magellanic Cloud was certainly known to the ancient southerners, and was probably mentioned by Amerigo Vespucci in a letter written during his third voyage about 1503-4, but became known to us only when Magellan went on his journey around the world, in 1519. The main body of the Small Magellanic Cloud has been assigned NGC 292 in Dreyer's catalog, which is now sometimes used for this galaxy. In addition, many clusters and nebulae which are members of this galaxy have been given their own NGC numbers.

This galaxy looks like a piece of the Milky Way for the naked eye. It orbits our Milky Way galaxy at about 210,000 light years distance, which makes it the third-nearest external galaxy known (after the LMC and the 1994 discovered Sagittarius Dwarf Elliptical Galaxy). Our current distance value takes into account the corrected Cepheid distance scale based on the Hipparcos satellite data published in early 1997.

The SMC is of irregular type. It may be a distorted barred disk, deformed by the tidal gravitational forces of Milky Way and LMC, but this is not sure. It contains several nebulae and star clusters which can be seen in photographs and through telescopes.

Our small neighboring galaxy contains the same kinds of objects as our Milky Way, in particular open clusters, diffuse nebulae, supernova remnants, planetary nebulae, and one globular cluster, NGC 121. It is situated well outside the denser regions of the galaxy, slightly north but not far from the galactic foreground globular 47 Tucanae (NGC 104).

- Some prominent SMC objects

It was the Small Magellanic Cloud where Miss Henrietta Leavitt discovered the period-luminosity relation of Cepheid variables, which is since then the most reliable method available for determining large cosmic distances.

In John Caldwell's observing list. In the Astronomical League's Southern Sky Binocular Club list.

The image in this page was obtained by *David Malin* with the Anglo-Australian Telescope. This image is copyrighted and may be used for private purpose only. For any other kind of use, including internet mirroring and storing on CD-ROM, please contact the Photo Permissions Department of the Anglo Australian Observatory. The image also shows two remarkable foreground objects, globular clusters of our own Milky Way galaxy: Situated on the right is conspicuous 47 Tucanae (NGC 104), while in the left top is NGC 362. These are, of course, much closer to us than the galaxy.

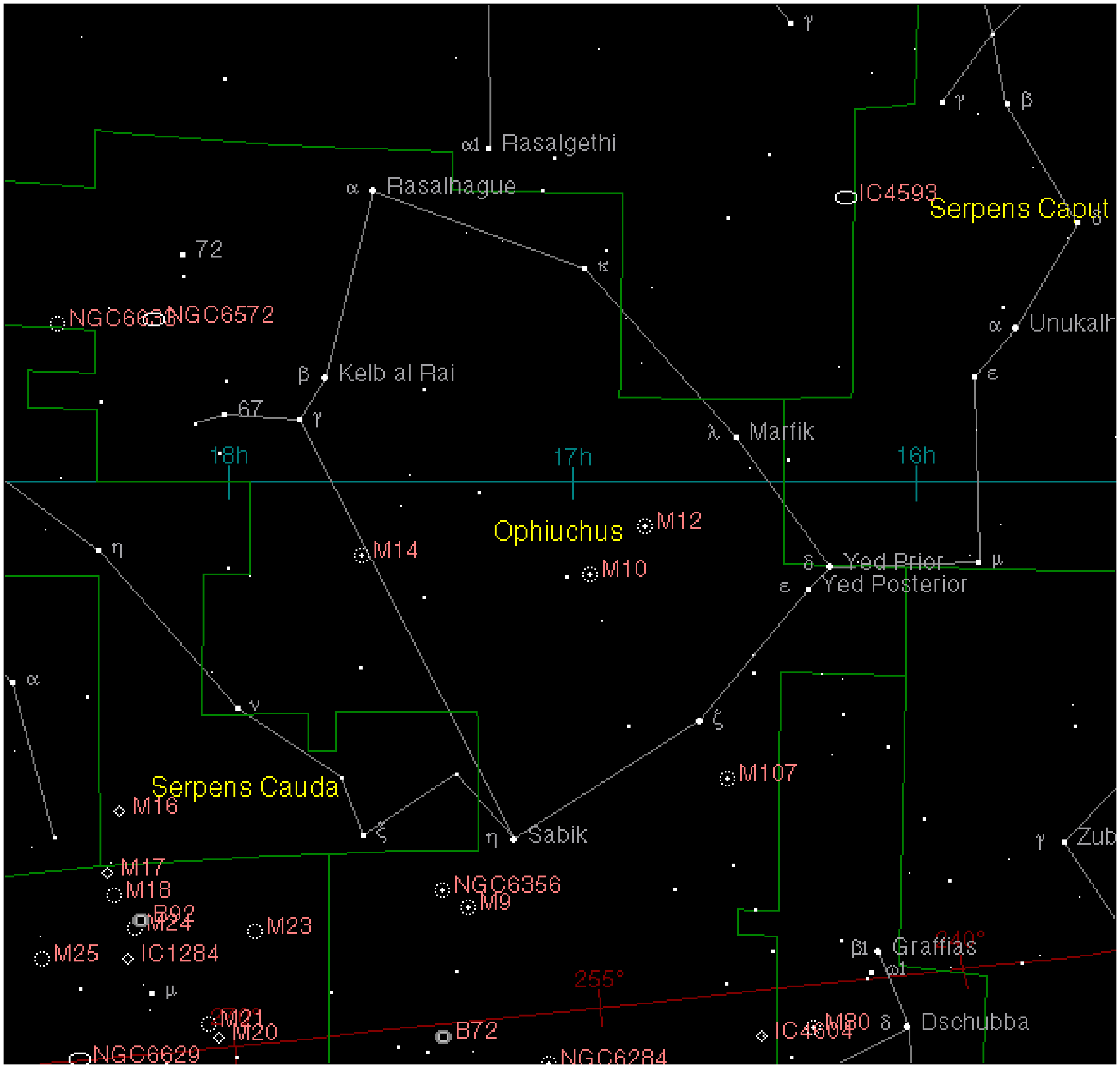
- More information on this image by David Malin

- Multispectral Image Collection of the Small Magellanic Cloud, SIRTF Multiwavelength Messier Museum
- NED data of SMC
- SIMBAD Data of the Small Magellanic Cloud (NGC 292)
- Observing Reports for NGC 292, Small Magellanic Cloud - SMC (IAAC Netastrocatalog)

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 29 Mar 1998

Ophiuchus



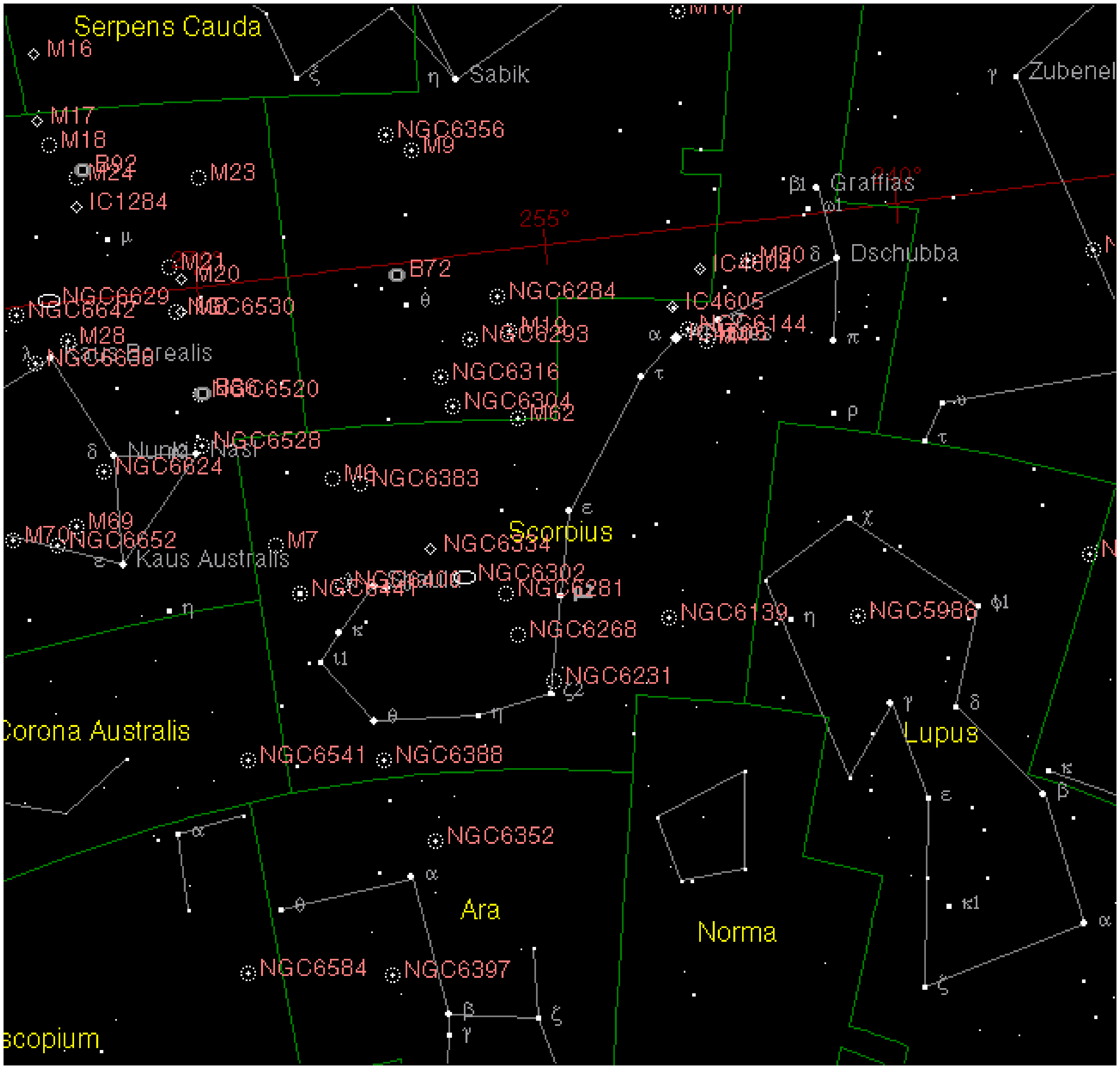
- [Download map]

Messier Objects in Ophiuchus: [M9], [M10], [M12], [M14], [M19], [M62], [M107]

- [Constellation index]
- [More on constellation Ophiuchus] [[MAA Original]]
- [More on Ophiuchus] (Chris Dolan)
- [Digital images - Constellation Ophiuchus page] (T. Credner/S. Kohle) [[unframed version]]

[Hartmut Frommert]
[Christine Kronberg]
[[contact]]

Scorpius



- Download map

Messier Objects in Scorpius: M4, M6, M7, M80

- Constellation index
- More on constellation Scorpius [MAA Original]
- More on Scorpius (Chris Dolan)
- Digital images - Constellation Scorpius page (T. Credner/S. Kohle) [unframed version]

Hartmut Frommert
Christine Kronberg
[contact]

Under construction!

Milky Way Spiral Structure

The disk of the Milky Way exhibits a spiral structure, which shows up in the distribution of the objects populating the disk component, i.e. population I stars and objects. These objects include, in particular, young stars, diffuse star-forming nebulae (H II regions) and open star clusters. Population I objects are very or rather young, in contrast to the very old population II objects of the Milky Way's Halo (globular clusters and old stars, including older planetary nebulae).

The origin of the spiral structure is thought to be in density waves which are triggered by gravitational disturbations, in particular during encounters with neighbor galaxies. The density waves first concern interstellar matter, which is compressed, forms diffuse nebulae which become starforming regions, and later form (open) clusters and associations of young stars, the most lumionous and conspicuous of which are massive, hot, blue and short-lived. Therefore, we see the most current density wave in the reddish H II regions, the elder next in the blueish clouds and associations of hot young stars, the next in age are characterized by type II (and Ib, Ic) supernova remnants and a bit older, less hot and blue open clusters. They can also be traced by the stars of the hotter spectral types, O, B, and A. The stars which are even older have dissipated into a more diffuse background; this includes intermediate population I stars, older star clusters and the younger representatives of the planetary nebulae.

The arms of the Milky Way, at least near the solar neighborhood in our Galaxy, are typically named for the constellations where (in the direction of which) more substantial parts of them are situated.

Our solar system is situated (by chance) in a smaller spiral arm, called the Local or Orion Arm, sometimes labelled "0". This small or intermediate arm connects the more substantial next inner arm and the next outer arm. The next inner arm, sometimes labelled "-I", is called the Sagittarius or Sagittarius-Carina Arm, the next outer arm, labelled "+I", is the Perseus Arm. At least one even outer arm, and two more inner arms have been identified.

A list of the Milky Way Spiral Arms follows, sorted from outside to inside near our solar neighborhood in the Galaxy:

- "+II", **Outer Arm**
- "**+I**", **Perseus Arm**
- "**0**", **Local Arm**, **Orion Arm**
- "**-I**", **Sagittarius Arm**, **Sagittarius-Carina Arm**
- "-II", **Scutum-Crux Arm**
- **Norma Arm**

These arms can be traced by deepsky objects, namely diffuse nebulae, open star clusters and associatons, (type II and Ib/Ic) supernova remnants, and main sequence stars of so-called "early" (hot) spectral types.

Perseus Arm

Object		Con	Type	RA (2000)	Dec	dist
M 52	NGC 7654	Cas	OC	23:24.2	+61:35	5.0
M103	NGC 581	Cas	OC	01:33.2	+60:42	8.0
	NGC 869	Per	OC	02:19.0	+57:09	7.1
	NGC 884	Per	OC	02:22.4	+57:07	7.4
M 38 *	NGC 1912	Aur	OC	05:28.4	+35:50	4.2
M 1	NGC 1952	Tau	SNR	05:34.5	+22:01	6.3
M 36 *	NGC 1960	Aur	OC	05:36.1	+34:08	4.1
M 37 *	NGC 2099	Aur	OC	05:52.4	+32:33	4.4

Orion Arm

Object		Con	Type	RA (2000)	Dec	dist
M 6	NGC 6405	Sco	OC	17:40.1	-32:13	2
M 7	NGC 6475	Sco	OC	17:53.9	-34:49	0.8
M 23	NGC 6494	Sgr	OC	17:56.8	-19:01	2.15
M 25	IC 4725	Sgr	OC	18:31.6	-19:15	2
M 57	NGC 6720	Lyr	PN	18:53.6	+33:02	2.3
M 27	NGC 6853	Vul	PN	19:59.6	+22:43	1.25
M 29	NGC 6913	Cyg	OC	20:23.9	+38:32	4.0
M 73	NGC 6994	Aqr	OC?	20:58.9	-12:38	2.0
M 39	NGC 7092	Cyg	OC	21:32.2	+48:26	0.825
M 76	NGC 650	Per	PN	01:42.4	+51:34	3.4
M 34	NGC 1039	Per	OC	02:42.0	+42:47	1.4
M 45		Tau	C+N	03:47.0	+24:07	0.38
M 42	NGC 1976	Ori	DN	05:35.4	-05:27	1.6
M 43	NGC 1982	Ori	DN	05:35.6	-05:16	1.6
M 78	NGC 2068	Ori	DN	05:46.7	+00:03	1.6
M 35	NGC 2168	Gem	OC	06:08.9	+24:20	2.8
M 41	NGC 2287	CMa	OC	06:46.0	-20:44	2.3
M 50	NGC 2323	Mon	OC	07:03.2	-08:20	3
M 47	NGC 2422	Pup	OC	07:36.6	-14:30	1.6
M 46	NGC 2437	Pup	OC	07:41.8	-14:49	5.4
M 93	NGC 2447	Pup	OC	07:44.6	-23:52	3.6
M 48	NGC 2548	Hya	OC	08:13.8	-05:48	1.5
M 44	NGC 2632	Cnc	OC	08:40.1	+19:59	0.577
M 67	NGC 2682	Cnc	OC	08:50.4	+11:49	2.7
M 97	NGC 3587	UMa	PN	11:14.8	+55:01	2.6
M 40		UMa	DS	12:22.4	+58:05	0.51

Sagittarius Arm

Object		Con	Type	RA (2000)	Dec	dist
M 20	NGC 6514	Sgr	DN	18:02.6	-23:02	5.2
M 8	NGC 6523	Sgr	DN	18:03.8	-24:23	5.2
M 21	NGC 6531	Sgr	OC	18:04.6	-22:30	4.25
M 24	IC 4715?	Sgr	MWP	18:16.9	-18:29	10-15
	NGC 6603	Sgr	OC	18:18.4	-18:25	10
M 16	NGC 6611	Ser	C/N	18:18.8	-13:47	7
M 18	NGC 6613	Sgr	OC	18:19.9	-17:08	4.9
M 17	NGC 6618	Sgr	DN	18:20.8	-16:11	5
M 26	NGC 6694	Sct	OC	18:45.2	-09:24	5
M 11 *	NGC 6705	Sct	OC	18:51.1	-06:16	6

Notes:

- "*****": Listed as in the Orion Arm in

References:

-

[Hartmut Frommert](#)
[Christine Kronberg](#)
[[contact]](#)


Last Modification: 7 Dec 2000

Supernovae observed in the Milky Way: Historical Supernovae

Similar to other galaxies (including the Messier galaxies), there occur supernovae in our Milky Way at irregular intervals of time.

If they are not too heavily obscurred by interstellar matter, they can be seen as very spectacular events in the sky. Unfortunately, though, none of them has been well visible since the invention of the telescope, although modern estimates predict that every few decades one supernova should occur in a galaxy like the Milky Way.

Here we list the supernovae (sometimes only candidates, indicated by question marks) which have been recorded through the history of humanity.

Year	Date	Con	mag	Remnant	Observed/Comments
2241 BC ??		?	-10		Dubiously listed in some source
352 BC ?					Chinese; "first such record" according to Hellemans/Bunch
185 AD		Cen	-2	SNR 185	Chinese
369 ?					Chinese
386 ?					Chinese
393/396		Sco	-3	SNR 393	Chinese
437 ?		Gem			
827 ?		Sco/Oph	-10		
902 ?		Cas	0		
1006	Apr 30	Lup	-9+-1	SNR 1006	Arabic; also Chinese, Japanese, European
1054	Jul 4	Tau	-6	M1	Chinese, North American (?); also Arab, Japan
1181	Aug 6	Cas	-1	3C 58	Chinese and Japanese
1203 ?		Sco	0		
1230 ?		Aql			
1572	Nov 6	Cas	-4	Tycho SNR	Tycho Brahe's SN
1604	Oct 9	Oph	-3	Kepler SNR	Johannes Kepler's SN
1680? 1667?		Cas		Cas A	Flamsteed ? not seen ?

Key: Year/Date: Time of observation/occurrance, Con: Constellation, mag: estimated apparent magnitude in brightness maximum, Remnant: Identification of the supernova remnant

Restricting to the more or less safe supernova events, this table reduces significantly, most probably because of poor recording of our ancestors, to only 8 supernovae, one of which (185 AD) was even questioned recently:

Year	Date	Con	RA	Dec	mag	Comment/SNR
185 AD		Cen	14:43.1	-62:28	-2	(-6 mag acc. to Sky Catalog 2000) SNR: G135.4-2.3/RCW 86
393/396		Sco	17:14	-39.8	-3	3 radio sources candidates for SNR
1006	Apr 30	Lup	15:02.8	-41:57	-9+-1	SNR: PKS 1459-41
1054	Jul 4	Tau	05:34.5	+22:01	-6	M1
1181	Aug 6	Cas	02:05.6	+64:49	-1	3C 58 Chinese and Japanese
1572	Nov 6	Cas	00:25.3	+64:09	-4	Tycho
1604	Oct 9	Oph	17:30.6	-21:29	-3	Kepler
1680? 1667?		Cas	23:23.4	+58:50	6?	Cas A SN

Key: Year/Date: Time of observation/occurrance, Con: Constellation, RA/Dec: Right Ascension and Declination (2000.0) mag: estimated apparent magnitude in brightness maximum

Even for the 185 AD event, doubts have been brought up on its nature as a supernova (Y.-N. Chin and Y.-L. Huang 1994, "Identification of the Guest Star of AD 185 as a Comet Rather than a Supernova", *Nature* **371**, 398).

A notable event with some similarity to a supernova occurred with the star Eta Carinae in 1843, when it brightened to mag -0.8 and became the second brightest star in the heavens after Sirius, although it is at the great distance of 10,000 light years.

Only two supernovae have been discovered in other galaxies of the Local Group: SN 1885 or S Andromedae in the Andromeda Galaxy M31, and SN 1987A in the Large Magellanic Cloud.

Links:

- Michael Richmond's Information on the historical supernovae
- Historical Records of Supernovae (Cornell Univ., Astro 201) [Lists also SN 386 AD]

References:

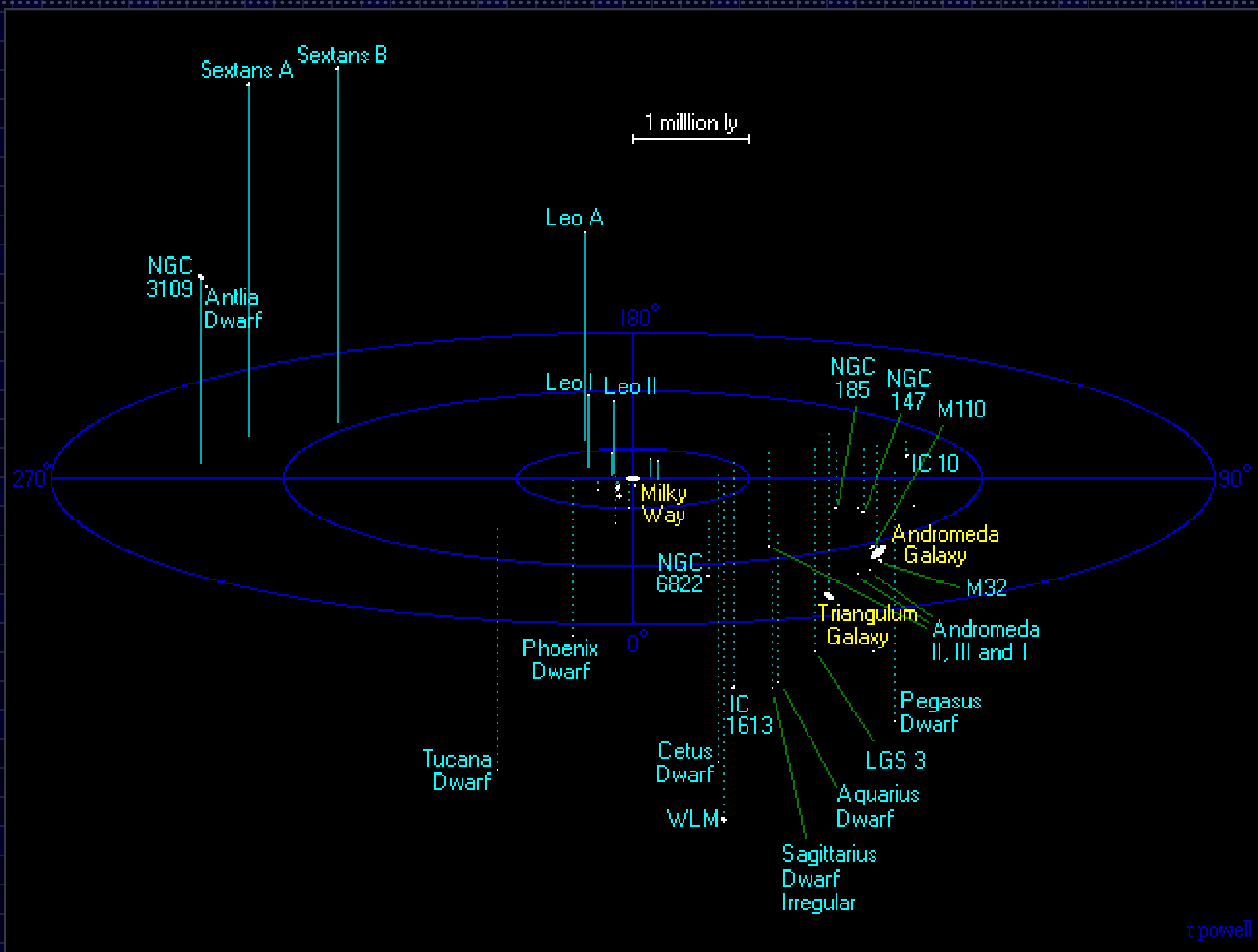
- The Historical Supernovae, by D.H. Clark and F.R. Stephenson, Pergamon Press, 1977
- Historical Supernovae, by F.R. Stephenson and D.H. Clark, *Scientific American*, Vol. 234, June 1976, p. 100-107.
- F. Richard Stephenson and David A. Green, 2003. A Millennium of Shattered Stars - Our Galaxy's Historical Supernovae. Sky and Telescope, Vol. 105, No. 5 (May 2003), p. 40-48.

- Please report me any errors, remarks and comments related to this list !

Hartmut Frommert
Christine Kronberg
[contact]


Last Modification: 2 May 17:00 MET

The Universe within 5 million Light Years
The Local Group of Galaxies



Zoom In x10 | Home | Zoom Out x20

- Number of large galaxies within 5 million light years = 3
- Number of dwarf galaxies within 5 million light years = 37
- Number of stars within 5 million light years = 700 billion

About the Map

The Milky Way is one of three large galaxies belonging to the group of galaxies called the Local Group which also contains several dozen dwarf galaxies. Most of these galaxies are depicted on the map, although most dwarf galaxies are so faint, that there are probably several more waiting to be discovered.

Data and Catalogs

The Local Group
There are at least 40 galaxies in the local group plus several more lying on on the borders. Here is a list of all the known members of the local group of galaxies.

Some of the galaxies in the Local Group

Shown below are four of the galaxies in the Local Group. The Triangulum galaxy (left) is a spiral galaxy and the third largest galaxy in the local group, it contains 50 billion stars. NGC 147 (top centre) is a dwarf elliptical galaxy and IC 10 (top right) is a dwarf irregular galaxy, they both contain tens of millions of stars. NGC 3109 (bottom right) is another dwarf irregular galaxy of several hundred million stars and it is also the largest member of a small sub-group of galaxies within the Local Group.




Home

Nearby Dwarf Galaxy Leo I
Credit: Anglo-Australian Telescope photograph by David Malin

Explanation: Leo I is a dwarf spheroidal galaxy in the Local Group of galaxies dominated by our Milky Way Galaxy and M31. Leo I is thought to be the most distant of the eleven known small satellite galaxies orbiting our Milky Way Galaxy. Besides the LMC and the SMC, all Milky Way satellite galaxies are small, dim, dwarf spheroidals, including the closest galaxy - the Sagittarius Dwarf. Leo I is most distant than most of them, thought to be about 250 kpc away. Analysis of stars in Leo I show it contains many stars only about 3 billion years old - much younger than in most galaxies.

Age of the Universe

There are at least 3 ways that the age of the Universe can be estimated. I will describe

- The age of the chemical elements.
- The age of the oldest star clusters.
- The age of the oldest white dwarf stars.

The age of the Universe can also be estimated from a cosmological model based on the Hubble constant and the densities of matter and dark energy. This model-based age is currently 13.7 +/- 0.2 Gyr. But this Web page will only deal with actual age measurements, not estimates from cosmological models. The actual age measurements are consistent with the model-based age which increases our confidence in the Big Bang model.

The Age of the Elements

The age of the chemical elements can be estimated using radioactive decay to determine how old a given mixture of atoms is. The most definite ages that can be determined this way are ages since the solidification of rock samples. When a rock solidifies, the chemical elements often get separated into different crystalline grains in the rock. For example, sodium and calcium are both common elements, but their chemical behaviours are quite different, so one usually finds sodium and calcium in different grains in a differentiated rock. Rubidium and strontium are heavier elements that behave chemically much like sodium and calcium. Thus rubidium and strontium are usually found in different grains in a rock. But Rb-87 decays into Sr-87 with a half-life of 47 billion years. And there is another isotope of strontium, Sr-86, which is not produced by any rubidium decay. The isotope Sr-87 is called *radiogenic*, because it can be produced by radioactive decay, while Sr-86 is non-radiogenic. The Sr-86 is used to determine what fraction of the Sr-87 was produced by radioactive decay. This is done by plotting the Sr-87/Sr-86 ratio versus the Rb-87/Sr-86 ratio. When a rock is first formed, the different grains have a wide range of Rb-87/Sr-86 ratios, but the Sr-87/Sr-86 ratio is the same in all grains because the chemical processes leading to differentiated grains do not separate isotopes. After the rock has been solid for several billion years, a fraction of the Rb-87 will have decayed into Sr-87. Then the Sr-87/Sr-86 ratio will be larger in grains with a large Rb-87/Sr-86 ratio. Do a linear fit of

```
Sr-87/Sr-86 = a + b*(Rb-87/Sr-86)
```

and then the slope term is given by

$$b = 2^x - 1$$

with *x* being the number of half-lives that the rock has been solid. See the talk.origins isochrone FAQ for more on radioactive dating.

When applied to rocks on the surface of the Earth, the oldest rocks are about 3.8 billion years old. When applied to meteorites, the oldest are 4.56 billion years old. This very well determined age is the age of the Solar System. See the talk.origins age of the Earth FAQ for more on the age of the solar system.

When applied to a mixed together and evolving system like the gas in the Milky Way, no great precision is possible. One problem is that there is no chemical separation into grains of different crystals, so the absolute values of the isotope ratios have to be used instead of the slopes of a linear fit. This requires that we know precisely how much of each isotope was originally present, so an accurate model for element production is needed. One isotope pair that has been used is rhenium and osmium: in particular Re-187 which decays into Os-187 with a half-life of 40 billion years. It looks like 15% of the original Re-187 has decayed, which leads to an age of 8-11 billion years. But this is just the mean formation age of the stuff in the Solar System, and no rhenium or osmium has been made for the last 4.56 billion years. Thus to use this age to determine the age of the Universe, a model of when the elements were made is needed. If all the elements were made in a burst soon after the Big Bang, then the age of the Universe would be t_o = 8-11 billion years. But if the elements are made continuously at a constant rate, then the mean age of stuff in the Solar System is

$$(t_o + t_{SS})/2 = 8\text{-}11 \text{ Gyr}$$

which we can solve for the age of the Universe giving

$$t_o = 11.5\text{-}17.5 \text{ Gyr}$$

Radioactive Dating of an Old Star

A very interesting paper by Cowan *et al.* (1997, ApJ, 480, 246) discusses the thorium abundance in an old halo star. Normally it is not possible to measure the abundance of radioactive isotopes in other stars because the lines are too weak. But in CS 22892-052 the thorium lines can be seen because the iron lines are very weak. The Th/Eu (Europium) ratio in this star is 0.219 compared to 0.369 in the Solar System now. Thorium decays with a half-life of 14.05 Gyr, so the Solar System formed with Th/Eu = $2^{4.6/14.05}$*0.369 = 0.463. If CS 22892-052 formed with the same Th/Eu ratio it is then 15.2 +/- 3.5 Gyr old. It is actually probably slightly older because some of the thorium that would have gone into the Solar System decayed before the Sun formed, and this correction depends on the nucleosynthesis history of the Milky Way. Nonetheless, this is still an interesting measure of the age of the oldest stars that is independent of the main-sequence lifetime method.

A later paper by Cowan *et al.* (1999, ApJ, 521, 194) gives 15.6 +/- 4.6 Gyr for the age based on two stars: CS 22892-052 and HD 115444.

A another star, CS 31082-001, shows an age of 12.5 +/- 3 Gyr based on the decay of U-238 [Cayrel, *et al.* 2001, Nature, 409, 691-692]. Wanajo *et al.* refine the predicted U/Th production ratio and get 14.1 +/- 2.5 Gyr for the age of this star.

The Age of the Oldest Star Clusters

When stars are burning hydrogen to helium in their cores, they fall on a single curve in the luminosity-temperature plot known as the H-R diagram after its inventors, Hertzsprung and Russell. This track is known as the main sequence, since most stars are found there. Since the luminosity of a star varies like M^3 or M^4, the lifetime of a star on the main sequence varies like t=const*M/L=k/$L^{0.7}$. Thus if you measure the luminosity of the most luminous star on the main sequence, you get an upper limit for the age of the cluster:

$$\text{Age} < k/L(\text{MS\_max})^{0.7}$$

This is an upper limit because the absence of stars brighter than the observed L(MS_max) could be due to no stars being formed in the appropriate mass range. But for clusters with thousands of members, such a gap in the mass function is very unlikely, the age is equal to k/L(MS_max)$^{0.7}$. Chaboyer, Demarque, Kernan and Krauss (1996, Science, 271, 957) apply this technique to globular clusters and find that the age of the Universe is greater than 12.07 Gyr with 95% confidence. They say the age is proportional to one over the luminosity of the RR Lyra stars which are used to determine the distances to globular clusters. Chaboyer (1997) gives a best estimate of 14.6 +/- 1.7 Gyr for the age of the globular clusters. But recent Hipparcos results show that the globular clusters are further away than previously thought, so their stars are more luminous. Gratton *et al.* give ages between 8.5 and 13.3 Gyr with 12.1 being most likely, while Reid gives ages between 11 and 13 Gyr, and Chaboyer *et al.* give 11.5 +/- 1.3 Gyr for the mean age of the oldest globular clusters.

The Age of the Oldest White Dwarfs

A white dwarf star is an object that is about as heavy as the Sun but only the radius of the Earth. The average density of a white dwarf is a million times denser than water. White dwarf stars form in the centers of red giant stars, but are not visible until the envelope of the red giant is ejected into space. When this happens the ultraviolet radiation from the very hot stellar core ionizes the gas and produces a planetary nebula. The envelope of the star continues to move away from the central core, and eventually the planetary nebula fades to invisibility, leaving just the very hot core which is now a white dwarf. White dwarf stars glow just from residual heat. The oldest white dwarfs will be the coldest and thus the faintest. By searching for faint white dwarfs, one can estimate the length of time the oldest white dwarfs have been cooling. Oswalt, Smith, Wood and Hintzen (1996, Nature, 382, 692) have done this and get an age of 9.5+1.1-0.8 Gyr for the disk of the Milky Way. They estimate an age of the Universe which is at least 2 Gyr older than the disk, so $t_o > 11.5$ *Gyr*.

Hansen et al. have used the HST to measure the ages of white dwarfs in the globular cluster M4, obtaining 12.7 +/- 0.7 Gyr. In 2004 Hansen et al. updated their analysis to give an age for M4 of 12.1 +/- 0.9 Gyr, which is very consistent with the age of globular clusters from the main sequence turnoff. Allowing allowing for the time between the Big Bang and the formation of globular clusters (and its uncertainty) implies an age for the Universe of 12.8 +/- 1.1 Gyr.

Glossary of Astronomical and Cosmological Terms

absorption line: a more or less narrow range of wavelengths in a spectrum that is darker than neighboring wavelengths. Absorption lines are seen in stars.

angles: are measured in degrees or arcminutes (denoted by a single quote) or arcseconds (denoted by a double quote) or radians. 1 radian = 180/pi = 57.2958 degrees, 1 degree = 1º = 60 arcminutes = 60' = 3600 arcseconds = 3600".

baryon: a massive elementary particle made up of three quarks. Neutrons and protons are baryons.

blackbody: an object with a constant temperature that absorbs all radiation that hits it.

Cepheid: a type of pulsating variable star with a luminosity that can be determined from the period of its variation: Cepheids with long pulsation periods are bigger and thus more luminous than short period Cepheids.

cold dark matter: a type of dark matter that was moving at much less than the speed of light 10,000 years after the Big Bang. (see dark matter)

continuum: a smooth spectrum without emission or absorption lines. Some sources like tungsten lamps or blackbodies are purely continuum sources, while in sources with lines the continuum is a smooth spectrum drawn through the points between the lines.

CMB: Cosmic Microwave Background radiation, also CMBR, CBR and the "3 K blackbody radiation". Radiation left over from the hot Big Bang which has cooled by expansion to a temperature slightly less than 3 degrees above absolute zero.

cosmological constant: a term in Einstein's general relativity equations that leads to an acceleration of the expansion of the Universe. Usually denoted by the capital Greek letter Lambda when expressed with units of inverse length squared, or by the lower-case Greek lambda when normalized to the critical density like Omega.

critical density: the density of the Universe necessary so the expansion rate of the Universe is just barely sufficient to prevent a recollapse. Numerically the critical density is $3*H_o^2/[8*pi*G]$ or $19*[H_o/100]^2*10^{-30}$ gm/cc.

dark matter: a form of matter that does not emit light, absorb light, or scatter light. Its only interactions are gravitational.

density: the amount of matter in a volume divided by the volume, so the units are grams per cubic centimeter. Water has a density of 1 gram per cubic centimeter. The lower case Greek letter rho is usually used the symbolize density in equations.

dipole: a pattern with one hot side of the sky and one cold side of the sky.

Doppler: 19th century physicist who discovered the variation in the wavelength of waves caused by motion of the source.

electromagnetic force: one of the four forces of nature. Electromagnetic interactions hold electrons in atoms, hold atoms in molecules, and are used in all electronic devices.

electroweak: a unified force that combines the electromagnetic and weak nuclear interactions. Predicted by Weinberg and Salam, experimentally verified by Rubbia and van der Meer.

emission line: a more or less narrow range of wavelengths in a spectrum that is brighter than neighboring wavelengths. Emission lines are seen in quasars.

energy: the ability to do work, with units of *ergs* or *Joules*. One Joule is 10,000,000 ergs. One erg is the kinetic energy of a 2 gram mass moving at one cm/sec. Energy per unit time is power, and 1 Watt of power is 1 Joule per second.

escape velocity: the minimum velocity that will allow an object to escape from a gravitational field.

fine structure constant, usually denoted as the lower case Greek *alpha*, is the dimensionless ratio $e^2/(hbar*c) = 1/137.03599976...$ [in cgs units, or $e^2/(4*pi*epsilon_o*hbar*c)$ in MKS units], which gives the strength of the electromagnetic interaction. Here *e* is the electron charge, *hbar* is Planck's constant divided by 2*pi, and *c* is the speed of light.

flux: power per unit area. The flux from the Sun at the Earth is 1367 Watts per square meter. This total power is often divided up into different frequency or wavelength bands, giving for example Watts per square meter per Hertz or ergs per square cm per second per micron. 1 Jansky is 10^{-26} Watts per square meter per Hertz.

fluence: energy per unit area. Fluence is time times flux.

gamma ray: a very high energy photon, more energetic than an X-ray.

Gyr: gigayear, or one billion years. See for a table of all the metric prefixes from yocto (10^{-24}) to yotta (10^{24}).

grand unified theory: a model for unifying the strong nuclear force, the weak nuclear force, and the electromagnetic force into a single interaction. Several such GUTs have been proposed, but not yet experimentally verified.

gravitational potential: the gravitational energy per unit mass of a particle, equivalent to the acceleration of gravity times the height in ordinary circumstances on the surface of the Earth.

homogeneous: the same at all locations. Homgenized milk is not separated into cream and milk.

horizon: the edge of the visible Universe, but not the edge of the Universe since the Universe has no edge.

Hot Big Bang: A model of the Universe beginning at very high density and temperature, which expands and cools to become like the Universe we observe now.

hot dark matter: a type of dark matter that was moving at close to the speed of light 10,000 years after the Big Bang. (see dark matter)

Hubble constant: or H_o, the ratio of velocity to distance in the expansion of the Universe, so v = HD. The "o" [pronounced "naught"] on H_o means the current value, since the Hubble "constant" changes with time (but it is the same everywhere in the Universe at a given time). The measured value of H_o has also changed dramatically since even before Hubble's work, as shown in Huchra's H_o history.

inflationary scenario: a modification of the Big Bang model in which a large cosmological constant exists temporarily early in the history of the Big Bang, leading to a rapid accelerating expansion of the Universe, which is then followed by the normal Big Bang model with a decelerating expansion.

isotropic: the same in all directions. Anisotropic - not isotropic. Anisotropy - difference between different directions. In the standard color scheme for CMB anisotropy maps measured by the COBE DMR, red shows areas of the sky that are warmer, while blue shows the cooler regions.

Lambda: the upper case Greek Lambda is usually used to denote Einstein's cosmological constant. A non-zero Lambda indicates a non-zero vacuum energy density and causes a long-range repulsive effect which leads to the accelerating expansion of the Universe.

Lyman alpha line: the strongest line in the spectrum of the most common atom in the Universe, hydrogen. It is emitted at a wavelength of 122 nm. The general formula for the wavelength of hydrogen lines is

```
1/wavelength = [n^-2 - m^-2]/91.2
```

where *n = 1, 2, 3,* ... is the lower state quantum number and *m = n+1, n+2,* ... is the upper state quantum number. When *n = 1*, these lines with *m = 2, 3,* ... are called Lyman alpha, Lyman beta, ... and form the Lyman series. When *n = 2*, these lines with *m = 3, 4,* ... are called H-alpha, H-beta, ... and form the Balmer series.

MACHO: MAssive Compact Halo Object, and also one of projects searching for MACHOs by looking for gravitational microlensing: the other projects are EROS and OGLE. A MACHO is an object with a mass from about 10 billion tons to solar masses. If it is made out neutrons and protons then it is baryonic dark matter, but primordial black holes are a non-baryonic dark matter version of MACHOs.

magnitude: a scale used by astronomers to measure flux. Each 5 units on the magnitude scale corresponds to a 100-fold decrease in the flux. The Sun has magnitude -26.5. Sirius, the brightest star in the night sky, has magnitude -1.6. The faintest stars visible with the naked eye have magnitude 6.

micron: one micrometer, 0.000001 meters. Visible light has wavelengths between 0.4 and 0.7 microns. 1 micron is 10,000 Angstroms, or 1000 nanometers (nm). 1 nanometer is 0.000000001 meters.

nanowatt or nW: one billion'th of a watt.

neutralino: a particle predicted by supersymmetry models of the forces of nature. These models predict that each type of known particle will have a supersymmetric partner. The neutralino is the lightest electrically neutral supersymmetric partner, and it is a candidate for cold dark matter. As of 1999, no supersymmetric partner particles of any kind have been observed experimentally. A neutralino is one type of WIMP.

non-baryonic: not made up of neutrons, protons and electrons, and thus not like any of the known chemical elements.

Nucleon: a neutron or a proton - one of the particles inside an atomic nucleus.

Omega: the ratio of the density of the Universe to the critical density.

omega: the lower case Greek omega is often used to denote Omega*h^2, where $h=H_o/[100$ km/sec/Mpc]. Since Omega is the density divided by the critical density, and the critical density is $3*H_o^2/[8*pi*G]$, this combination is just proportional to the physical density. omega=1 corresponds to $19*10^{-30}$ gm/cc, or in SI: 19 yoctograms per cubic meter.

parsec: a unit of distance used by astronomers, corresponding to a parallax of one arc-second. Equal to $3.085678x10^{13}$ kilometers, or 3.26 light-years. kpc: 1000 parsecs; Mpc: 1 million parsecs.

QSO: quasi-stellar object. The first discovered QSO's were radio sources, leading to the name quasi-stellar radio sources, or QSRS, or *quasars*. These objects look like stars on an image of the sky, but their spectra show strong emission lines at high redshift. The redshift means that quasars are very far away, and are thus the most luminous objects in the Universe.

quadrupole: a type of pattern on the sky which generally has two high spots and two low spots.

quantum fluctuations: the uncertainty principle in quantum mechanics leads to all allowed interactions occuring with some probability.

quark: An elementary, strongly interacting constituent of matter. Quarks come in six flavors: up, down, charm, strange, top and bottom. The up, charm and top quarks have electric charges of +(2/3)e, while the down, strange and bottom quarks have charges of -(1/3)e. The proton which has a charge of +e is constructed of two up quarks and one down quark: (uud), while the neutron is (udd).

redshift: the Doppler shift for objects receding from the Earth causes the wavelengths of light to get longer, and hence shift into the red part of the spectrum. Because of the expansion of the Universe, objects with high redshift are far away, and we see them as they were a long time ago.

spectrum: result of spreading out light by wavelengths. A rainbow is a natural spectrum. The eye is sensitive to waves from violet at 380 nm wavelength to red at 700 nm wavelength, but astronomers now study electromagnetic radiation from gamma rays through X-rays, ultraviolet, violet, blue, green, yellow, orange, red, infrared and radio waves.

Steady State: a model of the expanding Universe with constant density and physical properties. Matter must be continually created to maintain the constant density.

steradian: the unit of solid angle. There are 4*pi steradians in the entire celestial sphere. One square degree is $(1/57.3)^2$ steradians because one degree is (1/57.3) radians.

strong nuclear force: one of the four forces of nature. The strong nuclear force holds the particles in the nucleus of atoms together.

time dilation: in special relativity, moving clocks appear to run slowly when compared to stationary clocks. This clock slowing is called time dilation.

vacuum energy density: Quantum theory requires empty space to be filled with particles and anti-particles being continually created and annihilated. This could lead to a net density of the vacuum, which if present, would behave like a cosmological constant.

weak nuclear force: one of the four forces of nature. The weak nuclear force is responsible for radioactive decay as well as the fusion reactions in the Sun that provide heat and light for the Earth.

WIMP: a Weakly Interacting Massive Particle, a possible form for cold dark matter.

zero point energy: the uncertainty principle does not allow a quantum mechanical system to have a definite position and definite velocity at the same time. Thus a *harmonic oscillator* like a pendulum or a mass on a spring has a minimum energy that is larger than zero, since zero energy would require a definite position to zero the potential energy and a definite (zero) velocity to zero the kinetic energy. This minimum energy is $0.5*h*f$, where *h* is Planck's constant and *f* is the frequency of the oscillator.

Groups and Clusters of Galaxies with Messier objects

Galaxies are usually members of groups or clusters, and those listed in Messier's catalog are no exceptions. Below please find those groups containing Messier galaxies.

Groups of Galaxies containing at least two Messier objects

Ordered roughly by Right Ascension.

Local Group of Galaxies
: Messier objects: The Andromeda Galaxy M31 and its satellites M32 and M110, as well as the Triangulum galaxy M33. Other members (over 30 in all) include our Milky Way Galaxy, the Large and the Small Magellanic Cloud (LMC and SMC), as well as several smaller galaxies. It is also somehow associated with the group around the large elliptical Maffei1.

M81 group
: Messier objects: M81 and M82. This group is very nearby, only some 11 million light-years distant. Other members include NGC 3077 and NGC 2976, an outlying member of the group is NGC 2403.

M96 group (Leo I group)
: Messier objects: M95, M96, M105. There are many more galaxies in this group, including NGC 3384 in the same field as M105.

Leo triplett (M66 group)
: M65 (NGC 3623), M66 (NGC 3627) and NGC 3628. Probably physically related to the M96 group.

Ursa Major Cloud
: Messier objects (probable members): M108, M109. A large and vast cloud of galaxies of at least 79 member galaxies.

Virgo Cluster of Galaxies (or Coma-Virgo Cluster)
: Messier objects: M49, M58, M59, M60, M61, M84, M85, M86, M87, M88, M89, M90, M91, M98, M99, and M100. The Virgo Cluster with its some 2000 member galaxies dominates our intergalactic neighborhood, as it represents the physical center of our Local Supercluster, and influences all the galaxies and galaxy groups by the gravitational attraction of its enormous mass. Our Local Group has experienced a speed-up of 100..400 km/sec towards this cluster (the Virgo-centric flow), and it is still unclear if at one time it will fall and merge into the cluster. HST observations of Cepheids in M100, together with the work of Nial R. Tanvir on the M96 group extrapolated to this cluster, indicate that the Virgo cluster is at a distance of some 60 million light-years.

M51 group
: Messier objects: M51, M63.

M94 Group, CVn I Cloud
: Messier objects: M64, M94. This vast and loose group or cloud of galaxies is listed by various sources but not in R. Brent Tully's *Nearby Galaxies Catalog*.

Further Messier galaxies contained in groups

The following list contains the Messier galaxies which are members of groups but not listed above; usually, some info on the corresponding groups is included in the object pages for these galaxies. It is ordered roughly by Right Ascension again.

- M74 is probably the chief member of a small physical group of galaxies (the **M74 group**)
- M77 is the dominating member of a small but remarkable group of galaxies, the **M77 group** (sometimes also called the NGC 1068 group).
- M106 is the brightest member of the **Canes Venatici II (CVn II) group** or **M106 group** of galaxies
- M104 is the dominating member of a small group called the **M104 group** or NGC 4594 group of galaxies.
- M83 forms the **M83 group** together with some conspicuous but quite southern galaxies, including *Centaurus A* (NGC 5128) and the unusual galaxy NGC 5253. This group is sometimes also referred to as Centaurus A group or NGC 5128 group.
- M101 forms the **M101 group** of at least 9 galaxies with several faint companions. Some sources suppose some physical connection with the M51 group but this is doubtful.
- The M102 candidate NGC 5866 is the brightest member of a conspicuous group of galaxies in Draco, the **NGC 5866 group**, which contains (besides NGC 5866) the bright edge-on spiral NGC 5907, NGC 5879, and a lot of fainter galaxies.

Links:

- A List of Nearby Galaxy Groups and The major Groups and Clusters of Galaxies within 200 million ly from An Atlas of the Universe

---

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: November 14, 2004

Groups and Clusters of Galaxies

Click icon for an index of galaxy groups and clusters containing galaxies of Messier's catalog

Our icon shows a region near the center of the Virgo Cluster of galaxies, near the large lenticulars M84 and M86.

Galaxies do not usually occur as isolated "island universes" in space which which float lonely through an otherwise empty universe, but normally form groups of several individuals, in a wide range from few or few dozens of galaxies to large clusters of up to several thousands. The galaxies of these groups are in mutual gravitational interaction which may have significant influence on their appearance.

Messier's galaxies are no exceptions, but in virtually all cases members of groups and clusters of galaxies; moreover, Messier had even discovered the nearest big cluster of galaxies, the Virgo Cluster, although at his time, the nature of galaxies was not recognized; thus he wrote of a concentration of nebulae, of which he had cataloged 16. This huge agglomeration contains several dozens of large and thousands of small galaxies.

Our own galaxy, the Milky Way, is also a member of a smaller group of galaxies, the Local Group, which contains three large and over 30 small galaxies. Together with most nearby galaxy groups (and field galaxies), the Local Group is part of the so-called Local or Virgo Supercluster, which is dominated by the big Virgo Cluster.

Big clusters like Virgo have a tendency to attract and finally incorporate the small groups and individual galaxies in their immediate neighborhood as time goes by. Besides accumulating mass, the cluster also grows in volume because of the following process: The incoming galaxies are accelerated by the cluster's gravity, and fall in with high velocities. Having reached the cluster, they transfer their kinetic energy during encounters to member galaxies, and thus "heat" the cluster. Like a gas, the heated cluster expands to a larger volume.

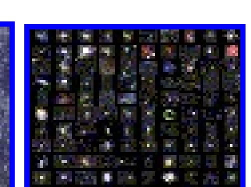
It is not yet clear if our Local Group will at one time be "eaten" by the Virgo cluster.

Links

- Galaxy Cluster optical and x-ray images (White, U. Alabama)
- Galaxy Cluster Catalogs List
- The Abell Catalogue of Clusters of Galaxies is available online thanks to Mikkel Steine
- Groups and Clusters of Galaxies containing Messier Objects
- Look at our collection of other significant clusters and groups of galaxies

---

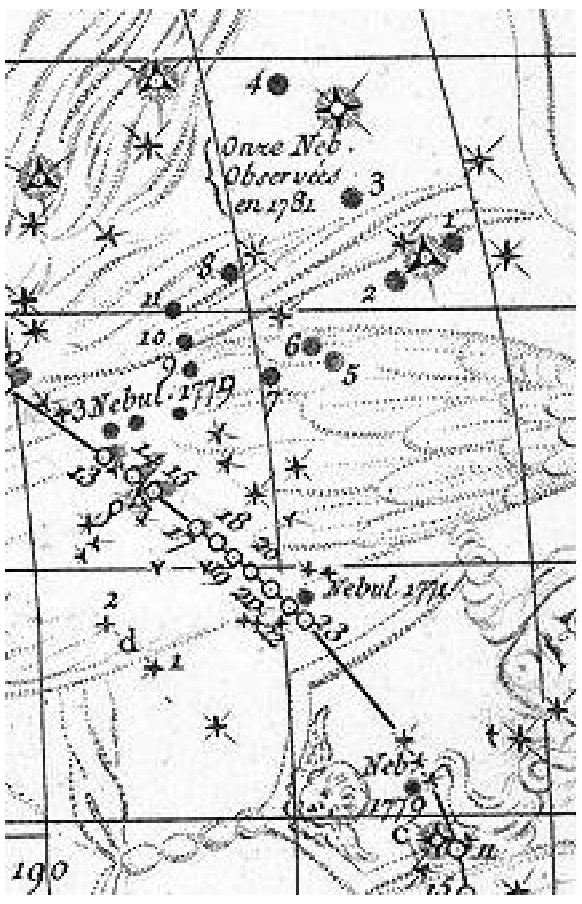
Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: January 25, 1998

The Virgo Cluster of Galaxies

Also: **Coma-Virgo cluster of Galaxies**



This giant agglomeration of galaxies is the nearest big cluster of galaxies, the largest proven structure in our intergalactic neighborhood, and the most remote cosmic objects with a physical connection to our own small group of galaxies, the Local Group, including our Milky Way galaxy. This structure is another discovery by Charles Messier, who noted behind his entry for M91 (here quoted from Kenneth Glyn Jones' book):

> ``The constellation Virgo and especially the northern wing is one of the constellations which encloses the most nebulae. This catalog contains 13 which have been determined, viz. Nos. 49, 58, 59, 60, 61, 84, 85, 86, 87, 88, 89, 90 and 91. All these nebulae appear to be without stars and can be seen only in a good sky and near meridian passage. Most of these nebulae have been pointed out to me by M. Méchain."

Together with his later entries, 98, 99, and 100, Messier had cataloged 16 members of the Virgo cluster which he viewed as a 'cluster of nebulae'. Pierre Méchain, in a letter of 1783, stated that he had seen even more "Nebulae" in this region which "Messier had not seen;" unfortunately, no records are known indicating which galaxies this may have been.

Our image shows a star chart drawn by Messier, cropped from a larger chart he published with his observations of the comet of 1779 (all 16 Messier objects are marked in this drawing). This discovery occured in 1781, significantly more than a century before the true nature of galaxies was realized in the 1920s ! A long history of exploration still had to pass until its nature as a physical cluster of galaxies became obvious.

Messier galaxies which are Virgo cluster members: M49, M58, M59, M60, M61, M84, M85, M86, M87, M88, M89, M90, M91, M98, M99, and M100.

The Virgo Cluster with its some 2000 member galaxies dominates our intergalactic neighborhood, as it represents the physical center of our Local Supercluster (also called Virgo or Coma-Virgo Supercluster), and influences all the galaxies and galaxy groups by the gravitational attraction of its enormous mass. It has slowed down the escape velocities (due to cosmic expansion, the `Hubble effect') of all the galaxies and galaxy groups around it, thus causing an effective matter flow towards itself (the so-called *Virgo-centric flow*). Eventually many of these galaxies have fallen, or will fall in the future, into this giant cluster which will increase in size due to this effect. Our Local Group has experienced a speed-up of 100..400 km/sec towards the Virgo cluster. Current data on the mass and velocity of the Virgo cluster indicate that the Local Group is probably not off far enough to escape, so that its recession from Virgo will probably be halted at one time, and then it will fall and merge into, or be eaten by the cluster, see our Virgo Cluster & Local Group page.

Because of the Virgo Cluster's enormous mass, its strong gravity accelerates the member galaxies to considerably high peculiar velocities, up to over 1500 km/sec, with respect to the cluster's center of mass. Investigations over the past decades have revealed a quite complex dynamic structure of this huge irregular aggregate of galaxies. The Virgo cluster is close enough that some of its galaxies, which happen to move fast through the cluster in our direction, exhibit the highest blue-shifts (instead of cosmological redshifts) measured for any galaxies, i.e. are moving toward us: The record stands for IC 3258, which is approaching us at 517 km/sec. As the cluster is receding from us at about 1,100 km/sec, this galaxy must move with over 1,600 km/sec through the Virgo Cluster's central region. Analogously, those galaxies which happen to move fastest away from us through the cluster, are receding at more than double redshift than the cluster's center of mass: The record is hold by NGC 4388 at 2535 km/sec, so that this galaxy moves peculiarly in the direction away from us at over 1,400 km/sec.

Our image shows the central portion of the Virgo Cluster of Galaxies, and is centered on the giant elliptical galaxy M87 which is considered to be the dominant galaxy of the whole giant cluster, situated close to its physical center. The two bright galaxies on the right (west) are (right-to-left) M84 and M86; starting from these two, a chain of galaxies ("Markarian's chain") stretches well to the upper (northern) middle of our image (and beyond, well to M88 which is slightly outside above the sky area photographed our image). The appealing group around these two giant lenticulars is described with M84, and in our collection of images with M84 and M86; we also have images of M87 together with Markarian's chain around M84 and M86. To the left (east) of M87, the considerably bright elliptical (type E0) M89 occurs (on roughly the same declination as M87), above it and slightly more left is the inclined and conspicuous spiral M90, while below (south) and left of M89 there is M58, sitting just on the edge of our image.

- Read a more detailed discussion of our image, identifying some of the fainter NGC galaxies.
- View the Virgo Cluster in X-ray light, or
- Compare the visual and X-ray appearance or an enlargement of the central part around M87.
- View an X-ray/Radio Overlay image of the Virgo Cluster
- Look at our table of Virgo Cluster members, showing some brighter non-Messier members also
- Limber Observatory near San Antonio, Texas, provides a clickable map of the Virgo cluster with links to images of the Messier galaxies.
- Observing the Virgo Cluster of Galaxies - our hints for observers
- Scott D. Davis' sketch of Virgo cluster galaxies around M84, M86, M87 and many fainter galaxies
- Bill Ferris' Virgo Cluster chart and observations page; he also features Markarian's chain
- The Virgo Mainline: Galaxy Hopping "Markarian's Chain", by Steve Gottlieb
- The Virgo Supercluster within 100 million Light Years from An Atlas of the Universe
- Identify galaxies in the heart of the Virgo cluster interactively

As the Virgo Cluster is such an important object in our wider intergalactic neighborhood, its distance from us is of great interest, also for the determination of the cosmic distance scale, and for cosmological issues. Semi-recent HST observations (from the 1990s) of Cepheids in M100, as well as estimates from the globular cluster luminosity in M87, together with the work of Nial R. Tanvir and, again, HST observations, on the M96 group, extrapolated to this cluster, indicate that the Virgo cluster is at a distance of some 60 million light-years. Historically, the Virgo Cluster distance has been subject of controversial discussion since Hubble's earliest (and systematically too small) estimates.

References for further reading:

- Bruno Binggeli, 1999. The Virgo Cluster - Home of M87. in: Proceedings of a workshop held at Ringberg Castle, Tegernsee, Germany, 15-19 September 1997, by Hermann-Josef Röser, Klaus Meisenheimer (eds.), Springer, Berlin & New York. Available online - framed version

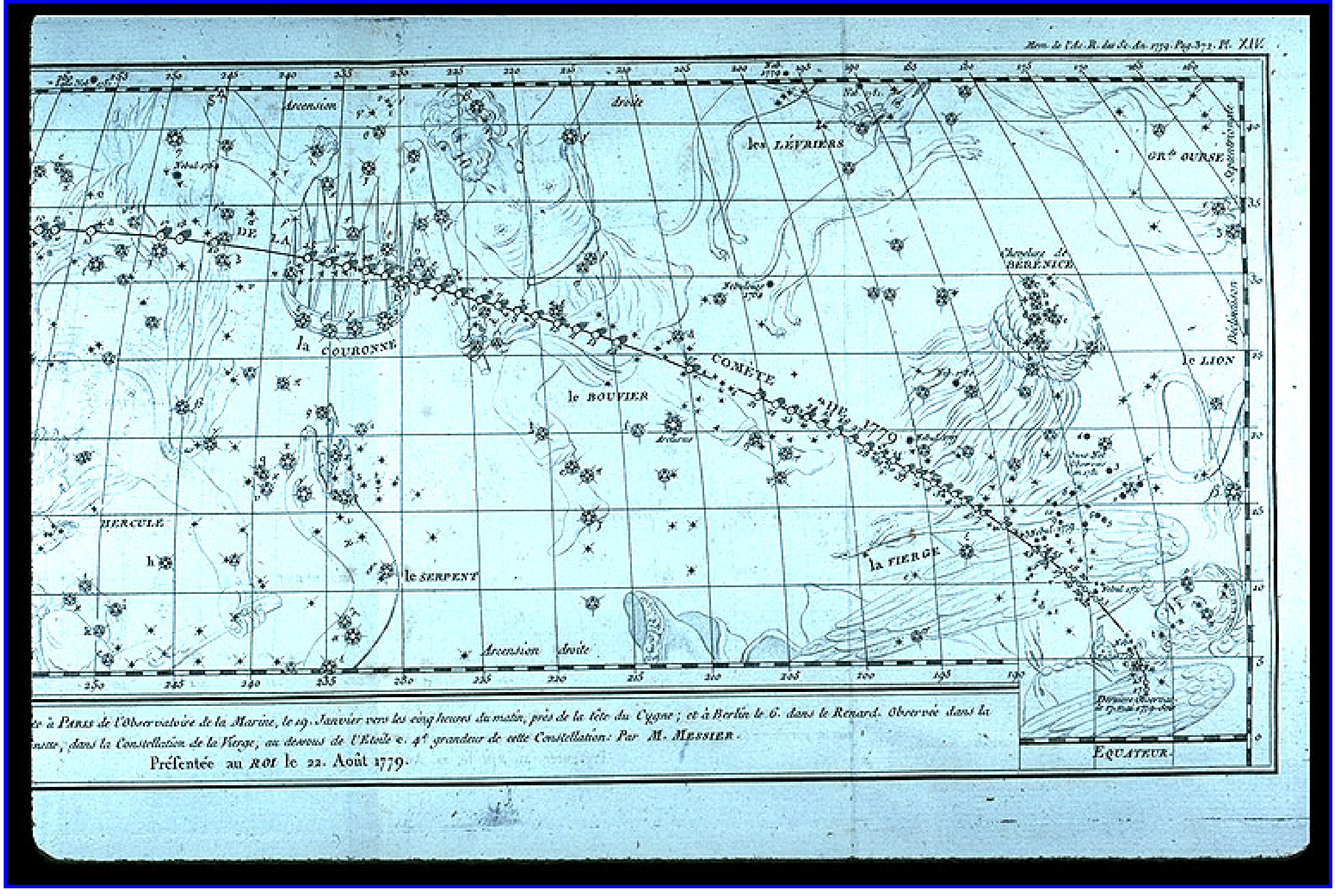
---

- Virgo cluster optical and x-ray images (White, U. Alabama)

- An ESO Workshop, held in Garching, September 4-7, 1984, was completely devoted to the Virgo Cluster of Galaxies. See ESO Conference and Workshop Proceedings No. 20, 1985, edited by O.-G. Richter and B. Binggeli.

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: May 11, 2005

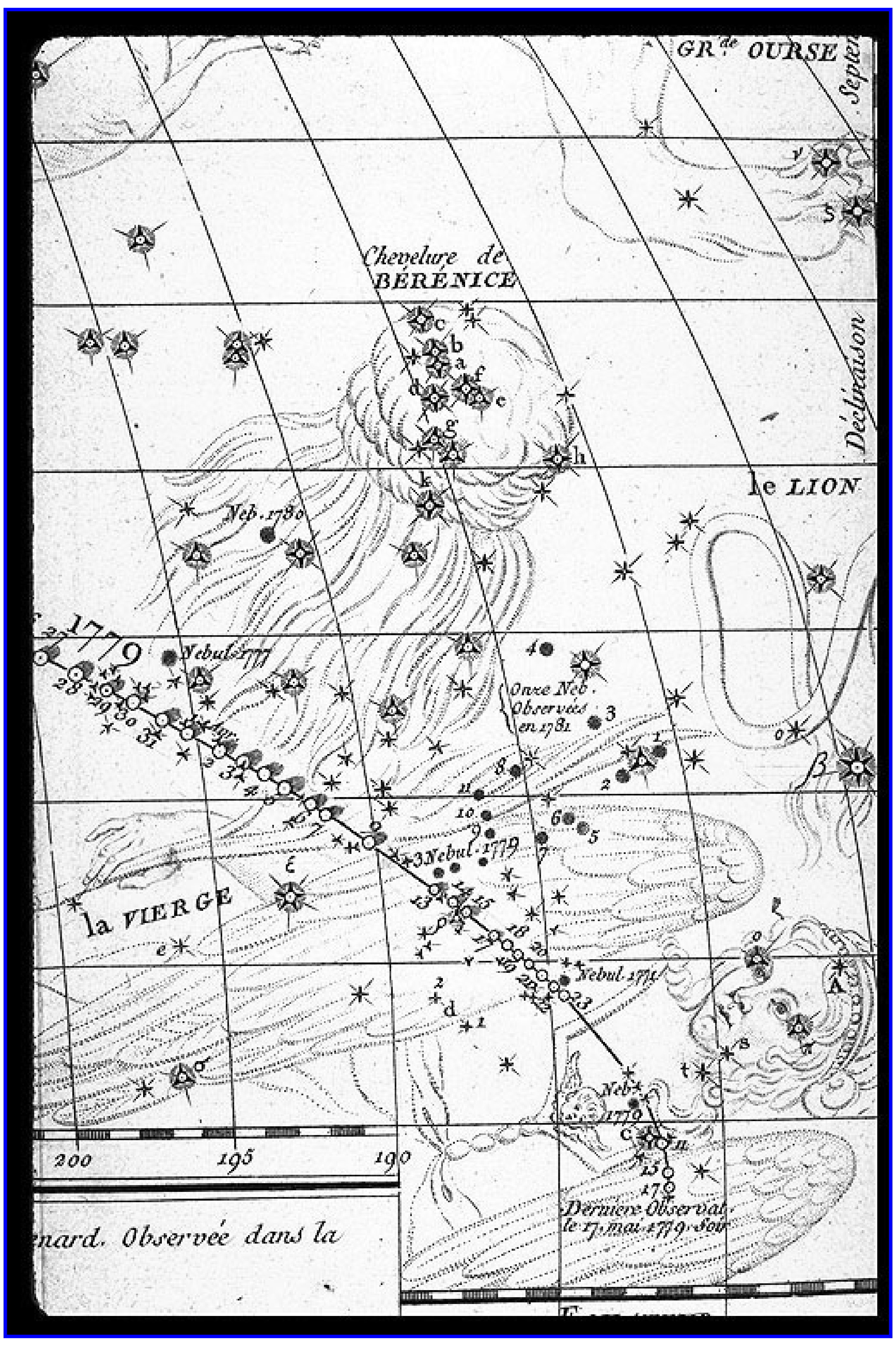


Besides being a considerably successful comet hunter and deep-sky discoverer, Charles Messier was also a skilled carthographer of the heavens. This was of particular importance for him, because for every comet discovery, he published a map of the comet's trajectory in the Memoirs of the French Academy of Sciences. These maps, although not intended to be so, were also some of the most up-to-date star charts available.

Our map presents the path of the comet of 1779 from the constellation Hercules thru Corona and Bootes to Coma Berenices and Virgo.

If we look carefully at the detail of the region around Coma at the right, we see a number of nebulous objects with labels like "nebula 1777" or "nebula 1780." These are some of the nebulae that Messier was publishing almost simultaneously in his famous nebula catalog of 1781. There are no less than 28 Messier objects depicted in the full comet map, many of them for the first time.

Messier's chart of the Coma-Virgo Region



The path of the comet in the first week of April, 1779, is charted at lower left. There are a number of nebulae depicted in Coma, indicated by the letters a,b,c, etc. as well as several others identified by their year of discovery. There is also a cluster of eleven newly discovered nebulae at lower right, numbered 1 to 11. These are part of the famous Virgo cluster of nebulae.

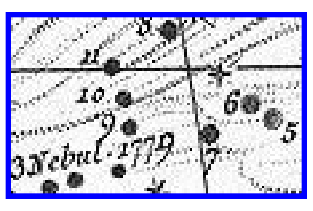
In this chart, the following Messier objects can be identified:

- M49 = "Nebul. 1771",
- M58--M60 = "3 Nebul. 1779" (r-to-l),
- M61 = "Neb. 1779",
- M84--M91 and M98--M100 = "Onze Neb. Observees en 1781", labeled with numbers as follows:
  - M84 = 5,
  - M85 = 4,
  - M86 = 6,
  - M87 = 7,
  - M88 = 8,
  - M89 = 9,
  - M90 = 10,
  - M91 (wrong position) = 11,
  - M98 = 1,
  - M99 = 2,
  - M100 = 3.

For his star charts, Messier used the plates in the Fortin edition of *John Flamsteed*'s *Atlas celeste* of 1776.

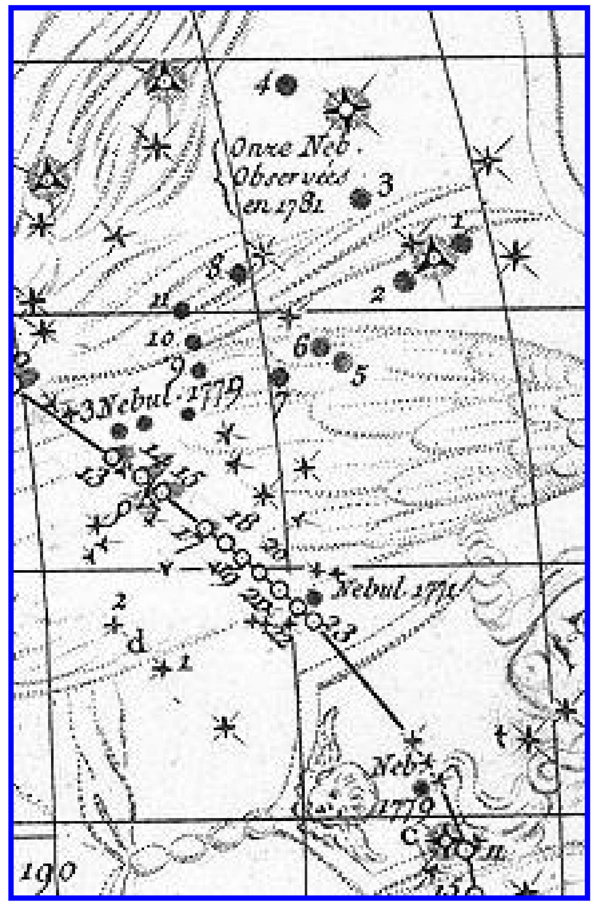
From the **Out of This World: *The Golden Age of the Celestial Atlas*** Exhibition of Rare Books from the Collection of the Linda Hall Library.

Hartmut Frommert
Christine Kronberg
[contact]



Last Modification: 7 Feb 1998

Messier Objects in the Virgo Cluster



In this chart of the Virgo Cluster region by Charles Messier, he has marked the positions of all 16 Messier Objects in this region:

- Near the bottom and in the right half, "Neb. 1779" is M61
- Below the image's center, "Nebul. 1771" is M49
- Left of the image's center, "3 Nebul. 1779" are, from left to right: M60, M59, and M58.
- The "Onze Neb. Observees en 1781" (Eleven Nebulae Observed in 1781) are M84--M91 and M98--M100:
    - M98 = 1,
    - M99 = 2,
    - M100 = 3,
    - M85 = 4,
    - M84 = 5,
    - M86 = 6,
    - M87 = 7,
    - M88 = 8,
    - M89 = 9,
    - M90 = 10,
    - M91 (wrong position) = 11,

Hartmut Frommert
Christine Kronberg
[contact]

Last Modification: 26 Jan 2001

M 91

[Spiral Galaxy](#) M91 (NGC 4548), type SBb, in Coma Berenices

Right Ascension	12 : 35.4 (h:m)
Declination	+14 : 30 (deg:m)
Distance	60000 (kly)
Visual Brightness	10.2 (mag)
Apparent Dimension	5.4x4.4 (arc min)

Discovered most probably by Charles Messier in 1781. Independently rediscovered by William Herschel in the on April 8, 1784.

On March 18, 1781, Charles Messier discovered the unusually large number of 8 nebulous objects, all in the region of today's border of the constellations Virgo and Coma Berenices, i.e. Virgo Cluster galaxies (plus one additional object, globular cluster M92 in Hercules). The last of these eight objects was cataloged by him as M91, but his position was erroneous.

Thus, for a long time, M91 was a missing Messier object, as Messier had determined its position from M89 while he thought it was from M58, as the Texas amateur William C. Williams of Fort Worth has figured out in 1969 (Williams 1969). Thus, the identity of M91 with NGC 4548, which had been cataloged H II.120 by William Herschel on April 8, 1784, was finally uncovered. Previous opinions have been that M91 had either been a comet which the great comet hunter Messier mistook for a nebula, and Owen Gingerich had suspected that it had been a duplicate observation of M58. William Herschel had not found M91 at Messier's erroneous position and suspected that it might have been NGC 4571 (his H III.602), a beautiful but faint 11.3 mag barred spiral (NGC 4571 came into discussion in summer 1994 when a group of astronomers at the Canada France Hawaii Telescope (CFHT) used observations of 3 Cepheids in this galaxy for a determination of the Hubble constant).

The barred spiral galaxy M91 is an appealing member of the Virgo Cluster of Galaxies. It is of type SBb and its bar is very conspicuous, lying at position angle 65/245 degrees (as measured from the North direction to the East). As its recession velocity is only about 400 km/sec, it has a considerable peculiar velocity toward us through the Virgo cluster, about 700 km/sec, as the cluster's recession velocity is about 1100 km/sec.

The membership of Messier 91 in the Virgo Cluster of Galaxies was confirmed by a recent measurement of its distance as 52 +/- 6 million light years by detecting Cepheid variables. These measurements were done by the Hubble Space Telescope H0 Key Project Team (paper XX, 1997). This coincides well with the value for other Virgo galaxies, including M100. The difference of their to our value is mainly due to another distance of the Large Magellanic Cloud assumed by them - the Hipparcos correction would increase their distance to about 58 Mly.

For the moderately equipped amateur, M91 is one of the most difficult Messier objects. Suggestions of this bar may be seen at medium power even in smaller telescopes, if the viewing conditions are good enough to see the galaxy at all. Photos show the bar more clearly, and show the spiral arms emanating from the ends of the bar.

Messier had described M91 as "Nebula without stars, fainter than M90". John Herschel described it as bright, large, little elongated, little brighter in the middle in his *General Catalogue*, while in his earlier observations, he describes its shape once as "pretty much elongated" and twice as "round". This is probably because of different viewing conditions: Under poor conditions, only the bright elongated bar region of this galaxy shows up, while under good conditions the spiral arms show up and exhibit an almost round to slightly elongated shape. This effect can be reproduced to some degree with amateur instruments.

- Historical Observations and Descriptions of M91
- Hubble Space Telescope images of M91
- More images of M91
- Amateur images of M91

- SIMBAD Data of M91
- NED Data of M91
- Publications on M91 (NASA ADS)
- Observing Reports for M91 (IAAC Netastrocatalog)

References

- H0 Key Project materials on M91:
  - The HST Key Project Archives - M91
  - John A. Graham *et.al.*, 1997. The Hubble Space Telescope Key Project on the Extragalactic Distance Scale. XX. The Discovery of Cepheids in the Virgo Cluster Galaxy NGC 4548. The Astrophysical Journal, Volume 516, Issue 2, p. 626-646.
- William C. Williams, 1969. Letter to the Editor. Sky & Telescope, Vol. 38, No. 6, December 1969, p. 376. Available online.

Hartmut Frommert
Christine Kronberg
[contact]

Pierre Méchain's Letter of May 6, 1783

Pierre Méchain has contributed a number of deepsky object discoveries to the Messier Catalog, but also discovered some more "nebulae", which he communicated to Bernoulli in Berlin in a letter dated May 6, 1783. This letter was published in German language in the *Astronomisches Jahrbuch* for 1786, p. 231-237.

From: *Astronomisches Jahrbuch für das Jahr 1786. nebst einer Sammlung der neuesten in die astronomischen Wissenschaften einschlagenden Abhandlungen, Beobachtungen und Nachrichten* [Astronomical Yearbook for the Year 1786. in addition to a collection of the newest treatises, observations and news], edited by J.E. Bode. Berlin, 1783.
[16.] *Ueber die Bahn des zweyten Kometen von 1781. Entdeckung einiger Nebelsterne; die Elemente der Bahn des neuen Planeten und astronomische Beobachtungen* [On the orbit of the second comet of the year 1781. Discovery of some nebulous stars; the elements of the orbit of the new planet and astronomical observations], by Mr Méchain, in Paris, p. 231-237.

Translated from German by H. Frommert

>> Comets
>> Nebulae -- M105 -- M102 -- M104 -- M108/M109 -- M106 -- M107
>> Uranus
>> Observations

On the Orbit of the second Comet

of the Year 1781. Discovery of some Nebulous Stars; the Elements of the Orbit of the new Planet and astronomical Observations.

by Mr. *Méchain* in Paris, from a letter of him to Mr. *Bernoulli*, of May 6, 1783.

[On cometary orbits]
Herewith follow the elements requested by Mr. *Bode* of the orbits of the two last comets which appeared in the year 1781, and equally the positions of the new nebulous stars discovered by me.

The elements of the orbit of the first comet of the year 1781, are given in the Connoissance des tems [sic] for 1784. page 365, I think, that I have sent you such [elements] more than a year ago, and without doubt, you or Mr. Bode will have the volume for 1784. at hand. (*)

The main pieces of the orbit of the second comet of 1781 (**) I give here, as they have been calculated by me after the very beautiful method of Mr. de la Place, which will be published in the Memoirs of the Academy for 1780.

```
The ascending node                     2s 17d 22' 55"
The inclination of hte orbit              27  12   4
Longitude of perihelion in the orbit   0  16   3   7
Distance at perihelion                     0.9609951
Average time of the
  perihelion passage     the 29th of Nov. 12h 42' 46"
```

The motion is retograde. (***)

These elements differ only insignificantly from thise which I have found by the conventional methods. I have found most of my observations obtained from Octob. 9 to Dec. 25, acurate to 1 minute with this theory, and the largest deviations never exceed 2 minutes. Meanwhile the apparent path of this comet in the sky extended for almost 170 degrees. In its true orbit, it traversed an arc of 97d 20' and the heliocentric latitude changed by 27d 22' from the day I discovered it to Dec. 25. On Nov. 9 at 6 1/4 o'clock in the evening, it passed only 40 min near the north pole of the ecliptic. (****) It has passed its ascending node on Octob. 10. On Dec. 25, when its northern geocentric latitude was only 16d 30' yet, it was standing almost in opposition to the place where it had been discovered. At the end of October and the beginning of November it was visible to the naked eye. The tail was steadily quite short and almost only recognizable in the telescope.

(*) These elements are already printed in the Jahrbuch 1785. page 166.

(**) See astronom. Jahrbuch f. 1785. page 164 166 and following.

(***) Simultaneously, look at my [Bode's] main pieces of the orbit of this comet found by a casual drawing in the Jahrbuch for 1785. page 168.

(****) See astronomisches Jahrbuch for 1785. page 167. and Fig. 1 on the 3rd table.

[On nebulous objects]
Concerning the nebulous stars or nebulous patches, I'm not able to satisfy Mr. *Bode*['s] request, because up to now I was lacking time to determine the acurate positions of allthose I have discovered. Therfore, I only want to give the positions of some which are not included in the Connoissance des tems [sic] f. 1784 [Messier's Catalog], and will indicate the others in such a manner that one will be able to recognize them. (**)
[M105] Mr. *Messier* mentions there on page 264 and 265 two nebulous stars, which I have discovered in the Lion [Leo; M95 and M96]. I find nothing to correct for the given positions which I have determined by comparison of their situation with respect to Regulus. There is, however, a third one, somewhat more northerly, which is even more vivid [brighter] than the two preceding ones. I discovered this one on March 24, 1781, 4 or 5 days after I had found the other two. On April 10, I compared its situation with Gamma Leonis from which followed its right ascension 159d 3' 45" and its northern declination of 13d 43' 58".

[M102] On page 267 of the Connoissance des tems [sic] f. 1784. Mr. Messier lists under No. 102 a nebula, which I have discovered between Omicron [actually Theta] Bootis and Iota Draconis; but this is a mistake. This nebula is the same as the preceding No. 101. Mr. Messier, caused by an error in the sky charts, has confused this one in the list of my nebulous stars communicated to him.

[M104] On May 11, 1781, I discovered a nebula above the Raven [Corvus], which did not appear to me to contain any single star. It is of a faint light and difficult to find when the wires of the micrometer are illuminated. I have compared it on this day and the following with Spica in the Virgin and from this derived its right ascension 187d 9' 42" and its southern declination 10d 24' 49". It does not appear in the Connoissance des tems.

[Virgo Cluster] On page 262 and 263, Mr. Messier mentions various nebulae, which I indicated to him. There are, however, in that region some others also, which he has not seen and the positions of which I intend to determine, as soon as I will have a comfortable observing place, which will not be delayed for long any more.

[M108, M109] Page 265 No. 97 [M97]. A nebula near Beta in the Great Bear. Mr. Messier mentions, when indicating its position, two others, which I also have discovered and of which one is close to this one [M108], the other is situated close to Gamma in the Great Bear [M109], but I could not yet determine their positions.

[M106] In July 1781 I found another nebula close to the Great Bear near the star No. 3 of the Hunting Dogs and 1 deg more south, I estimate its right ascension 181d 40' and its northern declination about 49d. I will be going to determine the more acurate position of this one shortly.

[M107] In April 1782 I discovered a small nebula in the left flank of Ophiuchus between the stars Zeta and Phi, the position of which I have not yet observed any closer.

This is, up to what is included in the mentioned Connoissance des tems [sic], all I have done concerning the nebulous stars. I will make up a separate memoir about that, and closer determine their positions and appearances.

(**) See the list of nebulous stars observed by Mr. Messier and Mr. Méchain since 1771. Page 164 [of the same *Jahrbuch*].

[On the new planet]
Now I will report to you a little bit about the new planet of Mr. *Herschel*, which I have busily observed from April 25, 1781 to now. I have tried on different occasions to find a circular orbit, which meets the requirement of my observations and always noticed, that it was necessary with the progress of time to assume a smaller radius vector; for that given by Mr. de la Place was always too large. In the month of July 1782, I undertook the attempt to obtain an ellipse from 4 selected observations, of which the outermost two were about a year apart, by which I obtained an impression of the elements of the orbit. Aftr the last opposition, Mr. de la Place requested 4 acurate observations from me, of which the two outermost would lie as far apart as I ever had them; but the two others should just include the oppositions of 1781 and 1782. Consequently he has thought up a very simple and meaningful method, by which he has found the measures of an ellipse which represents the four observations mentioned above very well, and which leaves only an error of 8 to 9 seconds for the observation of April 26, 1782. For my part, I have made use of a very simple method which Mr. *Boskovich* has communicated to me, which is based on the same 4 observations, of which the outermost are 594 days apart. I have calculated an ellipse, according to which the outermost observations agree exactly, and the two between them differ only 4 or 8 seconds more. Just this exact agreement also occurs for the other observations. Eventually, this ellipse gives the longitude only 7 seconds larger that the observation of the last April 26 [1783], 121 days after the last which it was based upon. The planet has not yet traversed a sufficiently large piece of arc and the deviation of its motion is too insignificant to be able to find more acurate elements of the orbit. But I believe, however, that the elements derived by Mr. de la Place and myself approach the truth, or are at least sufficient to get a general impression of the extension and situation of the orbit. A more comprehensive series of observations will closer inform us about this.

Here follow the elements of the elliptical orbit I calculated for the new planet:

```
Place of perihelion, May 11, 1781       5s 22d 13' 17"
Time of passage of the perihelion,
  November 7, 1799 at 7h 0m average time on the Paris meridian
Distance in perihelion                       18.25870
Distance in aphelion                         19.89938
Major half axis                              19.07904
Period of siderial revolution        83 years 4 months
Place of the ascending node             2s 11d 49' 17"
Inclination of the orbit                        43  35
Heliocentric longitude, on May 11
  1781 at 8h 47' average time           2  28  11  24 1/2
Average anomsly, taken from the
  perihelion, for this time             2  19   9  55
```

The first observation, which was used for calculating this orbit, is from May 11, 1781; the others have been improved with respect to the precession of the equinoxes, aberration and nutation, to have the true places and the siderial motion since May 11, 1781, as is required here.

[Observations]
At the transit of Mercury on November 12 of last year 1782, weather in Paris was so fine as one can always only wish. (*)

I noticed the full entry of Mercury or the first inner contact of the edges at 3h 2' 8" true time.

The second inner contact of the edges on exit was at 4h 17' 46".

I have also measured various distances of the center of Mercury from the Sun's limb, abd calculated, that the true conjunction occured at 4h 3' 18" true time in 7s 20d 26' 39 1/2". The tables of Mr. de la Lande, give 11 sec. more in longitude and in latitude, for which I found 15' 52.1", only 1 sec less than the observation (**). Other observers have noticed the first contact later; but I coincide up to triffle with Mr. *le Monnier*, *Dagelet* and another one. Moreover also the observations most deviating from mine only give a difference of 6 sec. in view of the geocentric longitude of Mercury.

(*) Here at us [in Berlin] the whole day was covered air and very foggy.

(**) Theerefore, they coincide very well with observation for this planet. My calculations of the transit, according to these tables, appears in the Ephemeris for 1782, p. 158. The calculation therein according to Halley's tables, as it appears in the 2nd volume of the Berlin collection of astronomical tables, therefore shows, that for entry and exit 21 minutes in time are missing.

This remarkable difference has its origin primarily in that Halley's tables put the ascending node of Mercury 10 minutes more east, and thus give the geocentric latitude 37" less; the chord, however, which Mercury traverses in front of the sun, is so close to the solar limb, that a small difference in latitude produces a very large one in duration and consequently in the times of entry and exit of Mercury.

At the occultation of the Pleiades by the Moon on February 9, 1783 the sky was less favorable; therefore, I have only been able to observe the entries of 3 stars:

Entry of *Merope* or d Plei. 6h 50m 45 1/2s true time, a good observation.
-- of *Atlas* or f Plei. 8h 22m 52s acurate to 3 or 4s.
-- of *Pleione* or h Plei. 8h 38m 1s rather acurate.

On the latitude of 48d 51' 50" and 2" time, west of the meridian of the Royal Observatory.

Also, we have observed the latest total lunar eclipse of March 18 of the year [1783] very well; (*) But because from such an event not much important can be derived and the indication of the entry and exit of separate patchesis loose, I only want to give here the phases mentioned, as I have observed them at Paris in the Cabinet of the King 14" west of the Royal Observatory.

(*) At Berlin, because of the cloudy sky, almost nothing of this eclipse could be seen. At the entry the Moon appeared between the clouds for a few minutes, but afterwards disappeared completely. At the time of total eclipse between 9 1/2 and 11 o'clock, the darkness of the night was exceptional. In the following night the moon was shining bright, and also the nights before the eclipse have been clear. Anyway it is strange, that of *seven* lunar eclipses rising over the Berlin horizon, since 1775 to now (Aug. 1783), not one has been visible in clear air.

- More on Pierre Méchain

Hartmut Frommert
Christine Kronberg
[contact]