= Messier 87 =

Messier 87 (also known as Virgo A or NGC 4486 , and generally abbreviated to M87) is a supergiant elliptical galaxy in the constellation Virgo . One of the most massive galaxies in the local universe , it is notable for its large population of globular clusters ? M87 contains about 12 @,@ 000 compared to the 150 @-@ 200 orbiting the Milky Way ? and its jet of energetic plasma that originates at the core and extends outward at least 1 @,@ 500 parsecs (4 @,@ 900 light @-@ years) , travelling at relativistic speed . It is one of the brightest radio sources in the sky , and is a popular target for both amateur astronomy observations and professional astronomy study .

French astronomer Charles Messier discovered M87 in 1781 , cataloguing it as a nebulous feature while searching for objects that would confuse comet hunters . The second brightest galaxy within the northern Virgo Cluster , M87 is located about 16 @.@ 4 million parsecs (53 @.@ 5 million light @-@ years) from Earth . Unlike a disk @-@ shaped spiral galaxy , M87 has no distinctive dust lanes . Instead , it has an almost featureless , ellipsoidal shape typical of most giant elliptical galaxies , diminishing in luminosity with distance from the centre . Forming around one sixth of M87 's mass , the stars in this galaxy have a nearly spherically symmetric distribution , their density decreasing with increasing distance from the core . At the core is a supermassive black hole , which forms the primary component of an active galactic nucleus . This object is a strong source of multiwavelength radiation , particularly radio waves . M87 's galactic envelope extends out to a radius of about 150 kiloparsecs (490 @,@ 000 light @-@ years) , where it has been truncated ? possibly by an encounter with another galaxy . Between the stars is a diffuse interstellar medium of gas that has been chemically enriched by elements emitted from evolved stars .

= = Observation history = =

In 1781 , French astronomer Charles Messier published a catalogue of 103 objects that had a nebulous appearance . This list was intended to identify objects that might be confused with comets . In subsequent use , each item in the catalogue was prefixed with an ' M ' . Thus , M87 was the eighty seventh member of Messier 's catalogue . During the 1880s , this nebula was included in the New General Catalogue as NGC 4486 . This compilation of nebulae and star clusters was assembled by the Danish @-@ Irish astronomer John Dreyer based primarily on the observations of English astronomer John Herschel .

In 1918 , American astronomer Heber Curtis of Lick Observatory observed that there was no spiral structure in M87 and he noticed a " curious straight ray ... apparently connected with the nucleus by a thin line of matter . " The ray appeared brightest at the inner end . The following year , a supernova within M87 reached a peak photographic magnitude of 21 @.@ 5 , although this event was not reported until photographic plates were examined by the Russian astronomer Innokentii A. Balanowski in 1922 .

American astronomer Edwin Hubble categorized M87 as one of the brighter globular nebulae , as it lacked any spiral structure but appeared to belong to the same family of non @-@ galactic nebulae as spiral nebulae . In 1926 he produced a new categorization of nebulae , with M87 being classified as a type of elliptical extra @-@ galactic nebula with no apparent elongation (class E0) . By 1931 , Hubble had identified M87 as a member of the Virgo cluster , for which he gave a provisional estimate of 1 @.@ 8 million parsecs from Earth . At the time it was the only known example of an elliptical nebula for which individual stars could be resolved . M87 continued to be called an extragalactic nebula for many years thereafter , but by 1956 it had been identified as an E0 @-@ type galaxy .

In 1947 , a prominent radio source was identified overlapping the location of M87 , and this was labeled Virgo @-@ A. This source was confirmed to be M87 by 1953 , and the linear relativistic jet emerging from the core of the galaxy was suggested as the cause . This jet extended from the core at a position angle of 260 ° to an angular distance of 20 ? with an angular width of 2 ? . In 1969 @-@ 70 , a strong component of the radio emission was found to closely align with the optical source of the jet .

In April 1965 , the US Naval Research Laboratory group launched an Aerobee 150 equipped with a pair of geiger counters . This flight discovered seven candidate X @-@ ray sources , including the first extragalactic X @-@ ray source ; Virgo X @-@ 1 was designated as the first X @-@ ray source detected in Virgo . A later Aerobee rocket launched from White Sands Missile Range on July 7 , 1967 , yielded further evidence that the source Virgo X @-@ 1 was the radio galaxy M87 . Subsequent X @-@ ray observations by the HEAO 1 and Einstein Observatory showed a complex source that included the active galactic nucleus of M87 . However , there is little central concentration of the X @-@ ray emission .

= = Visibility = =

M87 is located near the high declination border of the Virgo , next to the constellation of Coma Berenices . It lies along a line between the stars Epsilon Virginis and Denebola . At an apparent magnitude of 9 @.@ 59 , this galaxy can be readily observed using a small telescope with a 6 cm (2 @.@ 4 in) aperture , extending across an angular area of 7 @.@ 2 × 6 @.@ 8 arcminutes with a bright , 45 arcsecond core . Viewing the jet is a challenge without the aid of photography . Before 1991 , Russian @-@ American astronomer Otto Struve was the only person known to have seen the jet visually , using the 254 cm (100 in) Hooker telescope . In recent years , however , it has been observed in larger amateur telescopes under excellent conditions .

= = Properties = =

In the modified Hubble sequence galaxy morphological classification scheme of French astronomer Gérard de Vaucouleurs , M87 is categorized as an E0p galaxy . The E0 designation is used for an elliptical galaxy that displays no flattening ? that is , it appears spherical . A ' p ' suffix indicates a peculiar galaxy that does not fit cleanly into the classification scheme ; in this case , the peculiarity denotes the presence of the jet emerging from the core . M87 is considered a type @-@ cD galaxy , which is a supergiant D class galaxy . The latter category , first proposed by American astronomer William W. Morgan in 1958 , is a galaxy that has an elliptical @-@ like nucleus surrounded by an extensive , dustless , diffuse envelope .

The distance to M87 has been estimated using several independent techniques . These include measuring the luminosity of planetary nebulae , comparison with nearby galaxies whose distance has been estimated using standard candles such as cepheid variables , the linear size distribution of globular clusters , and the tip of the red giant branch method using individually resolved red giant stars , These measurements are consistent with each other , and their weighted average yields a distance estimate of 16 @.@ 4 ± 0 @.@ 5 megaparsecs (53 @.@ 5 ± 1 @.@ 63 million light @-@ years) .

This galaxy is one of the most massive in the local Universe . This galaxy spans a diameter of 120 @,@ 000 light years , about the same as the Milky Way . But M87 is a spheroid , not a flat spiral . So it contains close to 2 @.@ 7 trillion solar masses by some estimates . The mass of M87 within a radius of 9 ? 40 kiloparsecs (29 ? 130 thousand light @-@ years) from the core steadily increases roughly in proportion to r1.7 , where r is the radius from the core . Within a radius of 32 kiloparsecs (100 thousand light @-@ years) , the mass is (2 @.@ 4 ± 0 @.@ 6) × 1012 times the mass of the Sun , which is double the mass of the Milky Way galaxy . Only a fraction of this mass is in the form of stars , as M87 has an estimated mass to luminosity ratio of 6 @.@ 3 ± 0 @.@ 8 . That is , about one part in six of the galaxy 's mass is in the form of stars that are radiating energy . The total mass of M87 may be 200 times that of the Milky Way .

Gas is infalling into the galaxy at the rate of two to three solar masses per year , most of which may be accreted onto the core region . The extended stellar envelope of this galaxy reaches a radius of about 150 kiloparsecs (490 thousand light @-@ years) , compared to about 100 kiloparsecs (330 thousand light @-@ years) for the Milky Way . Beyond that distance the outer edge of the galaxy has been truncated by some means ; possibly by an earlier encounter with another galaxy . There is some evidence of linear streams of stars to the northwest of the galaxy , which may have been

created by tidal stripping of orbiting galaxies , or by small satellite galaxies falling in toward M87. as well as a filament of hot , ionized gas in the northeastern outer part of this galaxy that has been proposed to be the remnant of a small , gas @-@ rich galaxy that was disrupted by M87 and that could be feeding its active nucleus .

Using the Very Large Telescope to study the motions of about 300 planetary nebulae , it has been shown that M87 has absorbed a medium @-@ sized galaxy over the last billion years . The distinctive spectral properties of the planetary nebulae allowed astronomers to discover a chevron @-@ like structure in M87 's halo which was produced by the incomplete phase @-@ space mixing of a disrupted galaxy .

= = Components = =

At the core of this galaxy is a supermassive black hole (SMBH) with an estimated from (3 @.@ 5 ± 0 @.@ 8) × 109 times the mass of the Sun to (6 @.@ 6 ± 0 @.@ 4) × 109 M ? . This is one of the highest masses known for such an object . Surrounding the black hole is a rotating disk of ionized gas that is oriented roughly perpendicular to the relativistic jet . This disk is rotating at velocities of up to roughly 1 @,@ 000 km / s , and spans a maximum diameter of 0 @.@ 12 parsecs (0 @.@ 39 light @-@ years) . Gas is accreting onto the black hole at an estimated rate equal to the mass of the Sun every ten years (about 91 earth masses per day) .

Observations suggest that the black hole in M87 may be displaced from the galaxy center by a distance of about 25 parsecs (82 light @-@ years) . The displacement is in the opposite direction from the one @-@ sided jet , which may indicate that the black hole has been accelerated away from the center by the jet . Another possibility is that the displacement occurred during the merger of two SMBH . However care has to be taken with these findings . The study does not include any spectroscopic discrimination between the stellar and active galactic nucleus component . It is therefore possible that the seeming position of the galaxy center with respect to the black hole is misinterpreted by an optical flare of the jet itself . In 2011 , an analysis of M87 did not find any statistically significant displacement .

Active elliptical galaxies of a form similar to M87 are believed to form as a result of one or more mergers between smaller galaxies . There is now little dust remaining to form the diffuse nebulae where new stars are created , so the stellar population is dominated by old , population II stars that contain relatively low abundances of elements other than hydrogen and helium . The elliptical shape of this galaxy is maintained by random orbital motions of its member stars , in contrast to the more orderly rotational motions found in a spiral galaxy such as the Milky Way .

The space between the stars in the M87 galaxy is filled with a diffuse interstellar medium of gas , which has been chemically enriched by the elements ejected from stars as they passed beyond the end of their main sequence lifetime . Carbon and nitrogen is being continuously supplied by intermediate mass stars as they pass through the asymptotic giant branch . The heavier elements from oxygen to iron are primarily produced by supernova explosions within the galaxy . About 60 % of the abundance of these heavy elements was produced by core @-@ collapse supernovae , while the remainder came from Type Ia supernovae . The distribution of these elements suggests that early enrichment was from core @-@ collapse supernovae . The contribution from these sources was much lower in abundance than in the Milky Way . Type Ia supernovae have provided a continuous contribution to the interstellar medium of M87 throughout the history of the galaxy .

Examination of M87 at far infrared wavelengths shows an excess emission at wavelengths longer than 25 ?m . Normally such emission may be an indication of thermal emission by warm dust . However , in the case of M87 , the emission appears to be fully explained by synchrotron radiation from the jet . Within the galaxy , silicate grains are expected to survive for no more than 46 million years because of the X @-@ ray emission from the core . This dust may be destroyed by the hostile environment or expelled from the galaxy . The combined mass of dust in this galaxy is no more than 70 @,@ 000 times the mass of the Sun . By comparison , the Milky Way contains about a hundred million (108) solar masses worth of dust .

Within a 4 kpc (13 × 10 ^ 3 ly) radius of the core , the abundance of elements other than hydrogen

and helium ? what astronomers term the metallicity ? is about half the abundance in the Sun . Outside this radius , the abundance of metals steadily decreases with increasing distance from the core . Although this is classified as an elliptical galaxy and therefore lacks the dust lanes of a spiral galaxy , optical filaments have been observed in M87 . These filaments have an estimated mass of about 10 @,@ 000 times the mass of the Sun . Surrounding the galaxy is an extended corona with hot , low density gas .

M87 has an abnormally large population of globular clusters . A 2006 survey out to an angular distance of 25 ? from its core estimates that there are 12 @,@ 000 ± 800 globular clusters in orbit around M87 , as compared to the Milky Way 's 150 ? 200 . These clusters are similar in size distribution to the globular clusters of the Milky Way , with most having an effective radius between 1 and 6 parsecs . The size of the M87 clusters shows a gradual increase with distance from the galactic center . The first hypervelocity globular cluster , HVGC @-@ 1 , was discovered escaping M87 . The discovery of HVGC @-@ 1 suggests that the core of M87 holds not one but two supermassive black holes . The two supermassive black holes are the result of a long @-@ ago collision between two galaxies , which merged to form a single giant galaxy .

Ultra @-@ compact dwarfs resemble globular clusters but have a diameter of 10 parsecs (33 light @-@ years) or more , much larger than the 3 @-@ parsec (10 light @-@ year) maximum of globular clusters . Their nature is unclear as to whether they are dwarf galaxies captured by M87 or a new class of massive globular cluster . Almost a hundred have been identified from the thousands of globular clusters in M87 .

= = Jet = =

The relativistic jet of matter emerging from the core extends at least 1 @.@ 5 kiloparsecs (5 thousand light @-@ years) from the nucleus of M87 and is made up of matter ejected from the galaxy by a supermassive black hole . This jet is highly collimated , appearing constrained to an angle of 60 ° within 0 @.@ 8 parsecs (2 @.@ 6 light @-@ years) of the core , about 16 ° at a distance of 2 parsecs (6 @.@ 5 light @-@ years) and an angle of 6 ? 7 ° at a distance of 12 parsecs (39 light @-@ years) . The jet 's base has the diameter of 5 @.@ 5 ± 0 @.@ 4 Schwarzschild radii . The jet is probably powered by a prograde accretion disk around a spinning supermassive black hole . It is surrounded by a lower velocity , non @-@ relativistic component . There is evidence of a counter jet , but this feature remains unseen from the Earth due to relativistic beaming . The jet is precessing , causing the outflow to form a helical pattern out to a distance of 1 @.@ 6 parsecs (5 @.@ 2 light @-@ years) . Lobes of matter from the jet extend out to a distance of 77 kiloparsecs (250 thousand light @-@ years) . German @-@ American astronomer Walter Baade found that the light from the jet is plane polarized , which suggested that the energy was being generated by the acceleration of electrons moving at relativistic velocities in a magnetic field . The total energy output of these electrons was estimated as 5 @.@ 1 × 1056 ergs (or 5 @.@ 1 × 1049 joules or 3 @.@ 2 × 1068 eV) . For comparison , the entire Milky Way galaxy output is estimated at 5 × 1036 joules per second (watts) .

In pictures taken by the Hubble Space Telescope in 1999 , the motion of M87 's jet was measured at four to six times the speed of light . This motion is presumably an optical illusion caused by the relativistic velocity of the jet , and not true superluminal motion . However , detection of such motion supports the theory that quasars , BL Lac objects and radio galaxies may all be the same phenomenon , known as active galaxies , viewed from different perspectives . It has been proposed M87 could actually be a BL Lacertae object (with a low @-@ luminosity nuclei compared with the brightness of its host galaxy) seen from an unfavorable angle to appreciate the properties of that kind of galaxies .

Observations made by Chandra X @-@ ray Observatory indicate the presence of loops and rings in the hot X @-@ ray emitting gas that permeates the cluster and surrounds M87 . These loops and rings are generated by pressure waves . The pressure waves are caused by variations in the rate at which material is ejected from the supermassive black hole in jets . The distribution of loops suggests that minor eruptions occur every six million years . One of the rings , caused by a major

eruption , is a shock wave 26 kiloparsecs (85 thousand light @-@ years) in diameter around the black hole . Other features observed include narrow X @-@ ray emitting filaments up to 31 kiloparsecs (100 thousand light @-@ years) long , and a large cavity in the hot gas caused by a major eruption 70 million years ago . The regular eruptions prevent a huge reservoir of gas from cooling and forming stars , implying that M87 ? s evolution may have been seriously affected , preventing it from becoming a large spiral galaxy . The observations also imply the presence of sound waves , 56 octaves below middle C for the minor eruptions and 58 to 59 below middle C for the major eruptions .

M87 is a very strong source of gamma rays , which are the most energetic rays of the electromagnetic spectrum . Gamma rays coming from M87 have been observed since the late 1990s , but in 2006 , using the HESS Cherenkov telescopes , scientists have measured the variations of the gamma ray flux coming from M87 , and found that the flux changes over a matter of days . This short period makes the immediate vicinity of the supermassive black hole in M87 the most promising source for these gamma rays . In general , the smaller the diameter of the emission source , the faster the variation in flux , and vice versa .

A knot of matter in the jet , designated HST @-@ 1 , has been tracked by the Hubble Space Telescope and the Chandra X @-@ ray Observatory . This knot is about 65 parsecs (210 light @-@ years) from the core . By 2006 , the X @-@ ray intensity of this knot had increased by a factor of 50 over a four @-@ year period . This X @-@ ray emission has since been decaying in a variable manner .

= = Environment = =

This supergiant elliptical galaxy is located near the center of the Virgo Cluster . This rich cluster has about 2 @,@ 000 members and it forms the core of the larger Virgo Supercluster , of which the Local Group , and hence the Milky Way galaxy , is an outlying member . The cluster is organized into at least three distinct subsystems that are associated with the three galaxies M87 , M49 and M86 , with the one centered around M87 known as Virgo A and the one around M49 as Virgo B. There is a preponderance of elliptical and S0 galaxies around M87 , with a chain of elliptical galaxies aligned with the jet . In terms of mass , M87 is a dominant member of the cluster , and hence appears to be moving very little relative to the cluster as a whole . Indeed , M87 is defined as the cluster center . The cluster has a sparse gaseous atmosphere that emits X @-@ rays that decrease in temperature toward the middle , where M87 is located . The combined mass of the cluster is estimated to be (0 @.@ 15 ? 1 @.@ 5) × 1015 solar masses .

Measurements of the motion of intracluster planetary nebulae between M87 and M86 suggest that these two galaxies are moving toward each other and this may be their first encounter . M87 may have encountered M84 in the past , as evidenced by the truncation of the outer halo of the former from tidal effects . However , another possible cause of this truncation is a contraction due to an unseen mass falling into M87 from the rest of the cluster , which , in particular , may be the hypothesized dark matter . A third possibility is that the halo formation was truncated as a result of early feedback from the active galactic nucleus at the core of M87 .