Chapter 2

The Messier Objects

M1 (NGC 1952)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Taurus	Supernova remnant	05 h 34.5 m, +22° 01′	December 24
Distance	**Age**	**Apparent size**	**Magnitude**
6,500 light years	1,000 years (created by a supernova in A.D. 1054)	6′ × 4′	8.4

Nicknamed the "Crab Nebula," this is one of the most well-studied objects in the sky. At its center is a pulsar, which is a rotating neutron star (about 10 km in diameter with a mass about twice that of the Sun) with a strong magnetic field that emits a narrow beam of radio emission. The Crab pulsar rotates about 30 times a second (i.e., its period is 33 ms), with its beacon pointing at us once each rotation (like a very rapidly rotating lighthouse beam). It is slowly spinning down, so that when the pulsar first formed in A.D. 1054 it is thought to have rotated more than 50 times a second. Of more than 1,000 known radio pulsars, this is one of only six whose pulses are visible in optical wavelengths (with professional telescopes). Pulsars are the remains of a star that went supernova. For the Crab pulsar, the progenitor star is thought to have had a mass about ten times that of our Sun. The Crab Nebula constitutes the remnants of the material ejected by the supernova event of this star, with several solar masses worth of material being present in the luminous portion of the nebula. The filaments in the nebula are moving outward at over 1,000 km/s.

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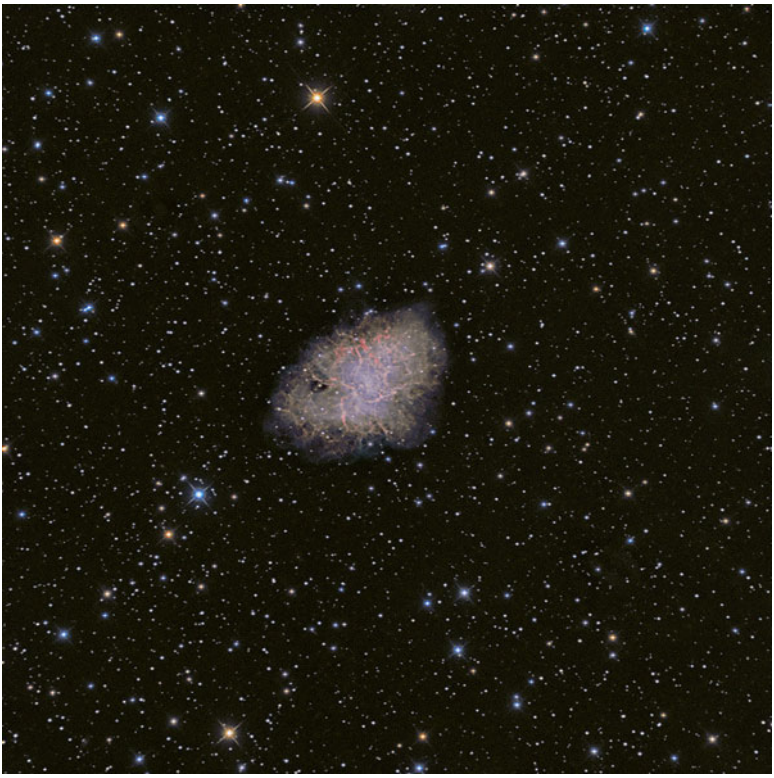

Fig. 2.1 Photo of M1; 9×15 min luminance, red, green, blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M2 (NGC 7089)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Aquarius	Globular cluster	21 h 33.5 m, –00° 49′	September 8
Distance	**Age**	**Apparent size**	**Magnitude**
40,000 light years	10–14 billion years	16′	6.6

The mass of this cluster is about 900,000 suns, but many of these stars are more massive than the Sun so that the total number of stars is about 150,000. Its size of 11.7′ gives it a diameter of about 130 light years. It lies in the halo of our galaxy. The halo is the region outside the spiral disk and bulge of our galaxy, extending out as a sphere with a radius of perhaps six times that of the spiral disk region and containing most of the galaxy's dark matter. M2 orbits the galaxy independently of the galactic disk on an inclined orbit that wanders out over 100,000 light years from the galactic center and then approaches within a few tens of thousands of light years of the galactic center, taking the better part of a billion years to complete one revolution around the galaxy. Its color magnitude diagram (CMD) has both a split sub-giant branch, where the two populations differ by a few tenths of magnitude, and a double red giant branch, where the two populations differ somewhat in color. These CMD features may reflect two sequential generations of star formation in this cluster.

Fig. 2.2 Photo of M2; 19×5 min exposures with Canon 40D camera, ISO 800, Astro-Tech 8″ f/4 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M3 (NGC 5272)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Canes Venatici	Globular cluster	13 h 42.2 m, + 28° 23′	May 11
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	18′	6.3

The mass here is about a half million suns. Its size of 18′ corresponds to a diameter of about 160 light years. It orbits the galaxy on a precessing elliptical path that is highly inclined with the plane of our galaxy and quite eccentric (minor axis to major axis ratio of 0:4). It takes about 300 million years to make one revolution of the galaxy, never straying farther than about 60,000 light years from the galactic center (we are about 27,000 light years from the galactic center, although we stay in the disk of our galaxy and M3 does not). M3 never approaches closer than about 10,000 light years from the galactic center, making it an inner halo cluster (so called since it doesn′t travel too far out in the halo – see M2 for the meaning of "halo"). It is considered intermediate in its richness of "metals" (elements heavier than helium), ranking just out of the top third in metallicity for globular clusters in our galaxy.

Fig. 2.3 Photo of M3; 9×10 min exposures with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M4 (NGC 6121)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scorpius	Globular cluster	16 h 23.6 m, –26° 31′	June 21
Distance	**Age**	**Apparent size**	**Magnitude**
7,000 light years	10–14 billion years	36′	5.4

This is the nearest globular cluster to us. Its size of 36′ corresponds to a diameter of about 70 light years. It has a mass of about 100,000 suns. It has two distinct stellar populations, which are thought to represent two different generations of stars that formed at different times in this cluster. The cluster lies toward the galactic center, within roughly 2,000 light years of the galactic central plane, so that interstellar material in the disk of our galaxy blocks out some of its light and makes it dimmer (by a few magnitudes) than it would otherwise appear. It follows an orbit that takes it in as close as 1,000 light years and out as far as 30,000 light years from the galactic center over a period of about 120 million years.

Fig. 2.4 Photo of M4; 3×10 min red, green, blue exposures with QSI540wsg camera, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M5 (NGC 5904)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Serpens Caput	Globular cluster	15 h 18.6 m, +02° 05′	June 5
Distance	**Age**	**Apparent size**	**Magnitude**
25,000 light years	10–14 billion years	23′	5.7

This has a mass of about 600,000 suns and its diameter is about 160 light years. Like most globular clusters, it does not orbit our galaxy with the galactic disk, as we do. Instead it follows an orbit that takes it out as far as 180,000 light years from the galactic center and then back in as close as a few thousand light years, on a path highly inclined to the galactic disk, taking almost a billion years to make one revolution around our galaxy (compare to the quarter-billion years our Sun takes to make one galactic revolution). M5 currently sits about 20,000 light years from the galactic center, which is much closer than its average orbital distance, since it is about to reach its closest approach to the galactic center.

Fig. 2.5 Photo of M5; 8×5 min luminance, 6×5 min red, green and blue exposures with a ST-10XME camera, Takahashi FSQ 106 mm f/5 telescope on AP900GTO mount. (Copyright Stuart Heggie)

M6 (NGC 6405)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scorpius	Open cluster	17 h 40.3 m, −32° 15′	July 10
Distance	**Age**	**Apparent size**	**Magnitude**
1,600 light years	95 million years	33′	4.2

This is nicknamed the "Butterfly Cluster," due to the shape of its apparent outline. It contains several chemically peculiar stars ("CP2" stars – see NGC 2169 for explanation). It lies in the direction of the center of our galaxy, less than 20 light years below the galactic central plane. Its size of 33′ corresponds to a diameter of about 15 light years. Professional telescopic studies have counted over 300 stars belonging to this cluster (only a small fraction of which are visible in amateur telescopes).

Fig. 2.6 Photo of M6; 25 min exposure on chilled Kodak Ektachrome 400 with 8″ f/6 Newtonian telescope. North is up and east is to the left. (Copyright John Mirtle)

M7 (NGC 6475)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scorpius	Open cluster	17 h 53.8 m, −34° 48′	July 14
Distance	**Age**	**Apparent size**	**Magnitude**
1,000 light years	300 million years	75′	3.3

First mentioned by Ptolemy over 2,000 years ago, it has a diameter of about 20 light years. Professional telescopic studies find that nearly 100 % of the stars in M7 are binary stars, an inordinately high frequency of binaries compared to the galactic field (where >50 % of main-sequence stars are binaries). It has a mass of about 700 suns. Like all open clusters, a good number of the stars in the field of this cluster (called "field stars") do not belong to the cluster. Instead, they just happen to lie in the line-of-sight of the cluster but are actually much closer or farther away from us than the cluster. This "contamination" by field stars can be seen in Fig. 3.7 of Chapter 3. (See M39 for further discussion of this.)

Fig. 2.7 Photo of M7; 13×30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 300 mm f/5 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M8 (NGC 6523)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Emission nebula	18 h 03.7 m, −24° 23′	July 16
Distance	**Age**	**Apparent size**	**Magnitude**
4,000 light years		45′ × 30′	5.0

Nicknamed the "Lagoon Nebula," the open cluster NGC 6530, with more than a thousand member stars, is embedded within this nebula. The stars in this cluster formed from the nebula in the past couple million years. It contains many pre-main sequence stars that are still contracting and have not yet begun burning hydrogen. The nebula itself is a large ionized hydrogen (or HII) region, within which young O-and B-type stars associated with the cluster are thought to still be triggering star formation. M8 is actually only a small "blister" on the surface of a giant molecular gas cloud that lies behind M8. The nebula is ionized (and thus made visible) largely by just three stars (primarily 9 Sgr, but also the binary HD 165052, and the multiple star Herschel 36) as shown in Fig. 3.8 of Chapter 3. Herschel 36 may be a triple-star system, perhaps consisting of a close binary pair that orbits a primary star whose mass is similar to that of the orbiting binary pair and is >20 suns. It is responsible for ionizing the brightest part of the nebula, a 15″ × 30″ patch in the center of the nebula. This patch is called the "Hourglass." The Hourglass is on the back side of the nebula, right on the edge of the giant molecular cloud from which NGC 6530 formed.

Fig. 2.8 Photo of M8; 10 × 2 min exposures, ISO 1600, with Canon 60Da camera, 200 mm Skywatcher f/5 Newtonian reflector with a Paracorr coma corrector. (Copyright Blair MacDonald)

M9 (NGC 6333)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	17 h 19.2 m, −18° 31′	July 5
Distance	**Age**	**Apparent size**	**Magnitude**
25,000 light years	10–14 billion years	12′	7.8

The mass of this cluster is about 300,000 suns. Its size of 12′ gives it a diameter of about 90 light years. It belongs to the central bulge of our galaxy (i.e., the central, spherically shaped region within about 15,000 light years of the galactic center) and lies a few thousand light years nearly directly above the galactic center. This is a metal-poor bulge cluster (metal-poor meaning it has a low abundance of elements heavier than helium), being in the bottom 20th percentile for metallicity of Milky Way globular clusters.

Fig. 2.9 Photo of M9; 21 × 30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 200 m f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M10 (NGC 6254)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	16 h 57.1 m, –04° 06′	June 30
Distance	**Age**	**Apparent size**	**Magnitude**
15,000 light years		20′	6.6

The mass here is 100,000–200,000 suns. The size of 20′ corresponds to a diameter of about 80 light years. This cluster stays within several thousand light years of the galactic central plane and has a velocity close to that of the material in the galactic disk. This is quite unusual for a moderately "metal-poor" cluster like this one ("metal-poor" meaning it has low amounts of elements heavier than helium), since stars in the galactic disk tend to have "metal" that was scattered by previous supernovae. Only a few percent of its stars are binaries, which is much lower than that seen on average in the Milky Way, but is expected given the high density of stars and resulting dynamical interactions between stars. About 120 blue stragglers are known in this cluster, which are stars that are paradoxically far more blue and luminous than expected, perhaps because of mass transfer between or coalescence of stars. (See NGC 6633).

Fig. 2.10 Photo of M10; 22×30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 200 m f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M11 (NGC 6705)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scutum	Open cluster	18 h 51.1 m, –06° 16′	July 29
Distance	**Age**	**Apparent size**	**Magnitude**
6,000–7,000 light years	200 million years	11′	5.8

This is nicknamed the "Wild Duck Cluster" after the V-shaped outline (pointed east) that some of its brighter members make. Its mass is several thousand suns, with 500 members brighter than mag. 14. Its size of 14′ corresponds to a diameter of about 25 light years. A person in the middle would see a night sky with several hundred first mag. stars, each separated by <1 light year. This is nearly as dense as some globular clusters. A significant number of field stars are present as foreground/background stars. (See M39.)

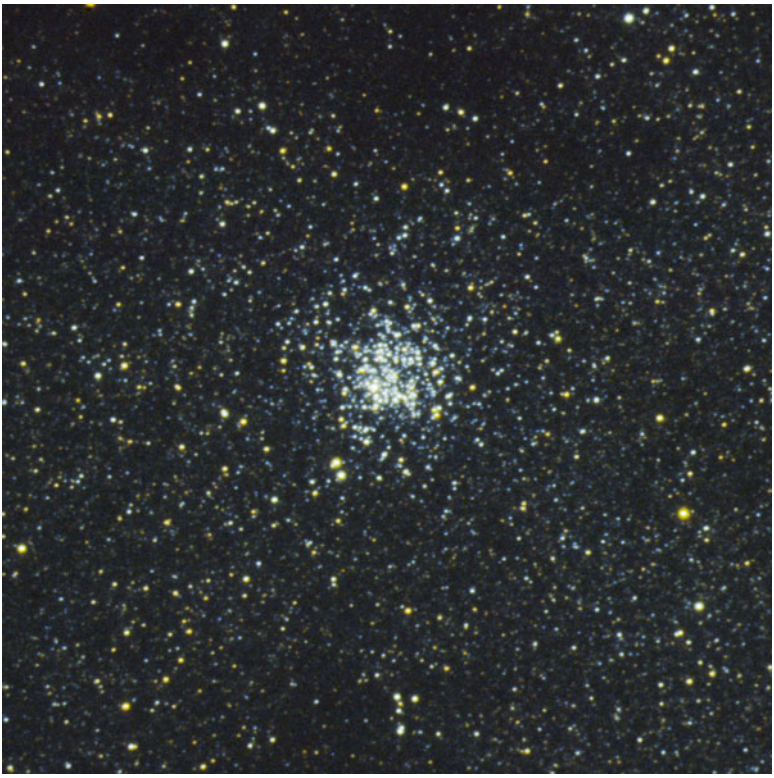

Fig. 2.11 Photo of M11; 20 min exposure on chilled Kodak Ektachrome 400 with 8″ f/6 Newtonian telescope. North is up and east is to the left. (Copyright John Mirtle)

M12 (NGC 6218)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	16 h 47.2 m, –01° 57′	June 27
Distance	**Age**	**Apparent size**	**Magnitude**
15,000 light years	10–14 billion years	16′	6.1

The size of 16′ here corresponds to a diameter of about 70 light years. Like M3 and M10, this is an inner halo cluster, so called since it doesn't travel too far out in the halo – see M2 for the meaning of "halo." M12 never strays farther than about 20,000 light years from the galactic center on an orbit inclined to the galactic central plane by 33° or so. M12 takes about 130 million years to complete one revolution around the galaxy, having just crossed the galactic central plane a few million years ago (lying 2,000 light years below it) on its way to a maximum excursion of 10,000–15,000 light years below the galactic plane. Its mass is about 100,000 suns, which is perhaps a fifth of its original mass, having been tidally stripped of stars by interactions with the Milky Way's gravitational potential over its lifetime, losing a mass of perhaps 5,000 suns each time it orbits our galaxy.

Fig. 2.12 Photo of M12; 22×30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 200 m f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M13 (NGC 6205)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Hercules	Globular cluster	16 h 41.7 m, +36° 28′	June 26
Distance	**Age**	**Apparent size**	**Magnitude**
25,000 light years	10–14 billion years	20′	5.8
This is nicknamed the "Hercules Cluster." Its 20′ size corresponds to a diameter of about 130 light years. It has a mass of about 500,000 suns. It orbits the galaxy independently of the material in the galactic disk on an inclined orbit that travels out to beyond 100,000 light years from the galactic center but approaches within 15,000 light years of the galactic center, taking a half billion or so years to complete one revolution.			

Fig. 2.13 Photo of M13; 5×10 min luminance, 9×5 min red and green, 4×5 min blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the left. (Copyright Stuart Heggie)

M14 (NGC 6402)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	17 h 37.6 m, –03° 15′	July 10
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	11′	7.6

The mass of this cluster is about 1.2 million times that of our Sun. Its size of 6.7′ corresponds to a diameter of about 100 light years. It is located in the central bulge of our galaxy (i.e., the central, spherically shaped region) and is relatively lacking in elements heavier than helium (i.e., "metals"), so that it may have formed in one of the earliest star-forming periods of our galaxy (see NGC 6287). It lies about 8,000 light years above the galactic central plane about 13,000 light years from the galactic center. It was only the second globular cluster (after M80) to have a nova discovered in it. It may have an extragalactic origin and been accreted by the Milky Way.

Fig. 2.14 Photo of M14; 10 × 1.5 min luminance, red, green, blue exposures with Atik 460EXM camera, Celestron 14″ telescope with Hyperstar lens corrector. North is up and east is to the left. (Copyright Dalton Wilson)

M15 (NGC 7078)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Pegasus	Globular cluster	21 h 30.0 m, +12° 10′	September 7
Distance	**Age**	**Apparent size**	**Magnitude**
34,000 light years	10–14 billion years	18′	6.3

The mass here is nearly a million suns. The size of 18′ corresponds to a diameter of about 180 light years. It is a halo cluster (see M2 for the meaning of "halo"), but never travels farther than about 45,000 light years from the galactic center on a path that is inclined by about 40° from the galactic disk. It revolves once around the galaxy every quarter billion years or so in a prograde orbit (like most globular clusters), meaning it revolves about the galaxy in the same direction as the galaxy's own rotation. The cluster is core collapsed (see NGC 6284 for explanation) and has one of the most concentrated centers (with more than 30 stars per square arc second in professional telescopes). M15 contains a planetary nebula (Pease 1, mag. 13), one of only four known globular clusters that share this distinction and the easiest planetary of the four to find in amateur telescopes (but recommended for a 12-in. or larger telescope, and requiring a detailed map of the field, optional nebula filter, and patience to discern Pease 1 among the myriad stars near it). M15 is the most metal-poor globular cluster in the Milky Way, meaning it has the least abundance of elements heavier than helium.

Fig. 2.15 Photo of M15; 10×3 min exposures with Canon 40D camera, ISO 800, Astro-Tech 8″ f/4 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M16 (NGC 6611)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Serpens Cauda	Open cluster with nebulosity	18 h 18.8 m, −13° 48′	July 20
Distance	**Age**	**Apparent size**	**Magnitude**
6,000 light years	1–3 million years	8′	6.0

The stellar mass of this open cluster is thought to be about 20,000 suns. The cluster's size of 8′ corresponds to a diameter of about 14 light years. It is embedded in a gas cloud from which the cluster formed and in which star formation is still going on. Young, hot stars in the cluster are ionizing the surrounding hydrogen gas cloud (making it a so-called HII region), thereby making it fluoresce as the emission nebula IC 4703, which is nicknamed the "Eagle Nebula" or the "Star Queen Nebula" after the appearance of part of this nebula in professional telescopic images and photographs. This namesake region is well known from the Hubble Space Telescope's "Pillars of Creation" photo of a 2′×2′ or so portion of it (which lies just SE of the open cluster's most concentrated area). This photo shows three large pillars (looking like "elephant trunks" or hoodoos) aligned in a SE-NW direction. The pillars are regions of dark molecular gas and dust that are being "eroded" by intense radiation from stars to their NW. Stars in NGC 6611 are thought to progress in age from younger (1 million years) in the northwest to older (3 million years) in the southeast, possibly because star formation in this region was progressively triggered by an encounter starting in the southeast several million years ago with a giant molecular shell created earlier by supernovae explosions.

Fig. 2.16 Photo of M16; 7 × 10 min H-alpha exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the left. (Copyright Stuart Heggie)

M17 (NGC 6618)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Emission nebula + open cluster	18 h 20.8 m, −16° 10′	July 21
Distance	**Age**	**Apparent size**	**Magnitude**
7,000 light years	1 million years	20′ × 15′	6.0

The appearance of this nebula in amateur telescopes leads to its various nicknames ("Swan Nebula," "Omega Nebula," among others). Its size of 20′ corresponds to a diameter of about 40 light years. Like M8 and M16, the nebula fluoresces due to an embedded open cluster, in this case containing thousands of stars that formed from the nebula. However, the stars in the open cluster are so heavily obscured by intervening gas and dust that only five of them have magnitudes brighter than 14 (with only two brighter than magnitude 10), making its appearance as a true "cluster" of stars essentially nonexistent in the eyepiece of an amateur telescope. Professional telescopes find many pre-main sequence stars in this cluster that are only a few hundred thousand years old. These young stars are still collapsing and have not yet begun nuclear fusion. Ongoing star formation is thought to be occurring, triggered by already formed large bright O-type stars that are irradiating the molecular cloud from which they formed.

Fig. 2.17 Photo of M17; 3 × 20 min H-alpha exposures with SBIG STL11000 camera, Takahashi FSQ 106 mm f/5 telescope on AP900GTO mount. North is down. (Copyright Stuart Heggie)

M18 (NGC 6613)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Open cluster	18 h 20.0 m, −17° 06′	July 21
Distance	**Age**	**Apparent size**	**Magnitude**
4,000 light years	30 million years	7′	6.9
This sparse cluster has a diameter of about 10 light years and has not been well studied. It has a mass of perhaps a little less than a couple hundred suns.			

Fig. 2.18 Photo of M18; 14×30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 200 m f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M19 (NGC 6273)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	17 h 02.6 m, −26″ 16′	July 1
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	17 ′	6.8

With a mass of about 1.2 million suns, this emits the 10th most visible light of all the globular clusters in our galaxy. It belongs to the central bulge of our galaxy (i.e., the central, spherically shaped region), lying a few thousand light years nearly directly above the galactic center. It is a metal-poor bulge cluster (meaning it has a low abundance of elements heavier than helium), being close to the bottom 20th percentile in metallicity for Milky Way globular clusters.

Fig. 2.19 Photo of M19; 5×5 min exposures with QSI540wsg camera, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M20 (NGC 6514)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Emission and reflection neb.	18 h 02.7 m, −22° 58′	July 16
Distance	**Age**	**Apparent size**	**Magnitude**
5,000 light years	300,000 years	20′	6.3

Light from very young stars that formed out of the surrounding gas ionize hydrogen in the nebula here, causing it to glow (making this a so-called HII region, although other elements are present, in particular oxygen, since the nebula benefits from a filter that lets in light from doubly ionized oxygen, i.e., OIII). This nebula is thought to be in a "pre-Orion-nebula" state, where young stars are violently ejecting matter, and protostars with jets are interacting with the nebula. The nebula is "lit up" mostly by the bright star in the middle of the nebula (HD 164492 or ADS 10991, mag. 7). ADS 10991 is a multiple star whose two brightest components have a separation of 10.6″ and position angle of 212°. It is found to consist of seven stars in professional telescopic studies. Dust grains are also present in the nebula (in the northern regions near the bright mag. 7.5 star there) that scatter the starlight, so that this nebula consists of both a reflection nebula (in the north) and an emission nebula (in the south). The nickname "Trifid Nebula" refers to the emission nebula and is derived from Latin (*trifidus,* meaning "split into three"), which refers to its three lobes that are separated by lanes of dust grains in the nebula that block its light from us. The entire nebula's size of 20′ corresponds to a diameter of about 30 light years.

Fig. 2.20 Photo of M20; 8×3 min red, 7×3 min green and blue exposures with SBIG XR-10XME camera, Takahashi FSQ 106 mm f/5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M21 (NGC 6531)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Open cluster	18 h 04.2 m, −22″ 29′	July 16
Distance	**Age**	**Apparent size**	**Magnitude**
4,000 light years	5–10 million years	16′	5.9
This cluster lies very close to the galactic central plane (being a few tens of light years below it). It has a mass of perhaps 800 suns. Of the 1,500 or so open clusters in our galaxy this is one of many that have not been well studied by professional telescopes.			

Fig. 2.21 Photo of M21; 15×30 s exposures, ISO 1600, Canon Rebel XT 350D camera with 200 m f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M22 (NGC 6656)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	18 h 36.4 m, −23° 54′	July 25
Distance	**Age**	**Apparent size**	**Magnitude**
10,000 light years	10–14 billion years	32′	5.2

Its mass is a few hundred thousand suns. It is the third brightest globular cluster in our night sky, after 47 Tuc (NGC 104) and ω Centauri (NGC 5139). It is also the third closest globular cluster to us (after M4 and NGC 6397). Along with M15, this is one of only four globular clusters that contains a planetary nebula, labeled GJJC 1. However, at mag. 15 and lying near the core of the cluster, finding GJJC 1 in an amateur telescope is exceptionally challenging (the one in M15 is easier to find – see M15). M22 never strays too far from the galactic disk in its orbit, staying within about 15,000 light years of the galactic central plane between about 50,000 and 10,000 light years from the galactic center, orbiting the galaxy once every 200 million years or so. It has two distinct stellar populations with unusually different abundances of heavy elements, the origin of which remains uncertain but may either be simply two generations of stars as occurs in most globular clusters or, more unusually, the cluster may have an extragalactic origin.

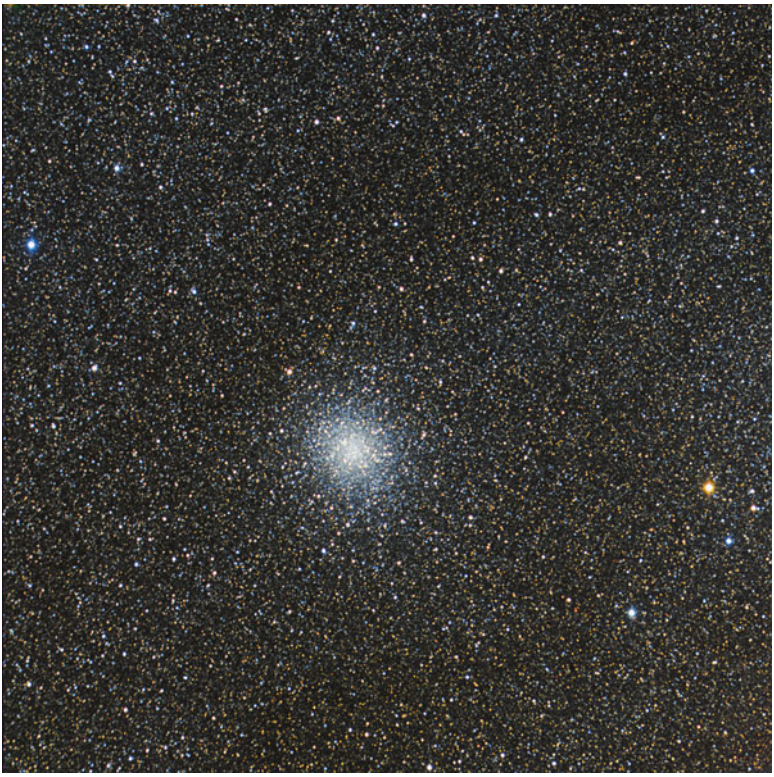

Fig. 2.22 Photo of M22; 3×1 min luminance, red, green, blue exposures with QSI540wsg camera, Celestron 14″ telescope with Hyperstar lens corrector. North is up and east is to the left. (Copyright Dalton Wilson)

M23 (NGC 6494)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Open cluster	17 h 57.1 m, −18° 59′	July 15
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years	300 million years	25′	5.5
The size of 25′ here corresponds to a diameter of about 15 light years. It has a mass of nearly 600 suns.			

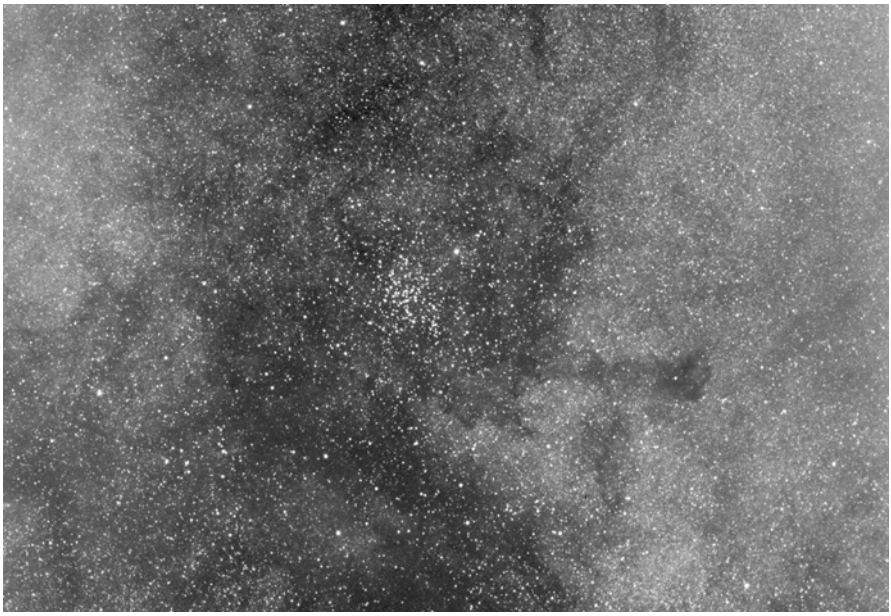

Fig. 2.23 Photo of M23; 5 min exposure on hypered Kodak Tech Pan with 8″ f/1.5 Schmidt camera. North is up and east is to the left. (Copyright John Mirtle)

M24 (IC 4715)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Star cloud	18 h 16.5 m, −18° 50′	July 15
Distance	**Age**	**Apparent size**	**Magnitude**
9,000–12,000 light years		1.6°×0.6°	4.6

This is a patch of the Milky Way seen through a hole in the foreground interstellar dust that obscures the surrounding sky, making the patch appear as a cluster to Messier even though it is not a true cluster. Nicknamed the "Small Sagittarius Star Cloud," the open cluster NGC 6603 (mag. 11.1, 9,000–12,000 light years away, 100–200 million years old) lies within M24 (probably on the near side of the star cloud that makes up M24) and is sometimes incorrectly labeled as M24.

Fig. 2.24 Photo of M24 (IC4715); 15 min exposure on Kodak film with 8″ f/1.5 Schmidt camera. North is up and east is to the left. (Copyright John Mirtle)

M25 (IC 4725)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Open cluster	18 h 31.8 m, −19° 07′	July 24
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years	70–100 million years	26′	4.6
This has a diameter of about 15 light years and has a mass of over 1,000 suns. It contains one Cepheid variable star (U Sgr, mag. 6.4 – see NGC 7790 for an explanation of Cepheid variables). It also contains six known Be stars (see M47 for explanation of Be stars).			

Fig. 2.25 Photo of M25 (IC 4725); 2×10 min luminance, red, green, blue exposures with QSI540wsg camera, Skywatcher 80 mm telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M26 (NGC 6694)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scutum	Open cluster	18 h 45.3 m, −09° 23′	July 27
Distance	**Age**	**Apparent size**	**Magnitude**
5,000 light years	100–200 million years	10′	8.0
This has a diameter of about 15 light years. It lies about 250 light years below the galactic central plane, which happens to be about the furthest extent our Sun travels from the galactic central plane (although the Sun currently sits within about 100 light years above the galactic central plane). In professional telescopes it has a mass of 300–400 suns.			

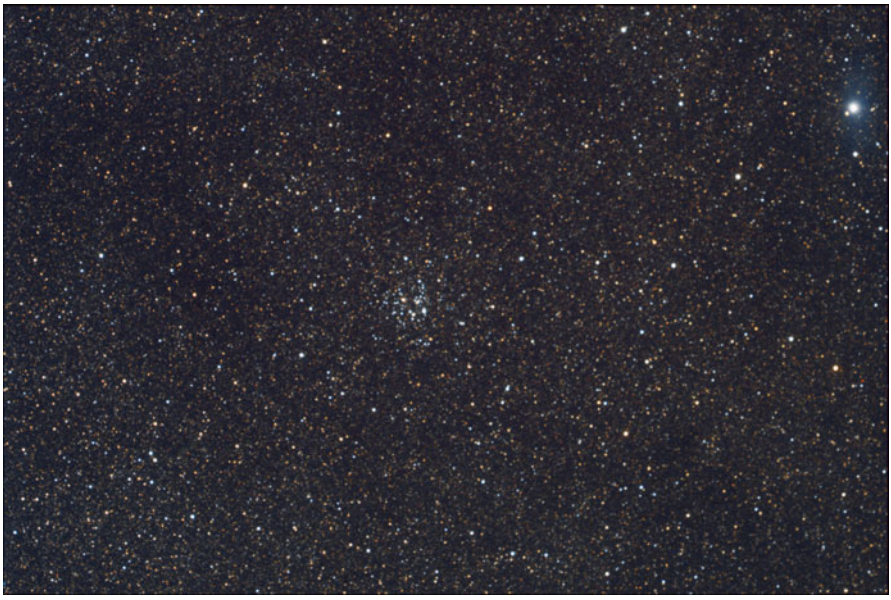

Fig. 2.26 Photo of M26; 3×5 min red, green, blue exposures with SBIG ST-8XE camera, Takahashi FSQ 106 mm f/5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M27 (NGC 6853)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Vulpecula	Planetary nebula	19 h 59.6 m, +22° 43′	August 15
Distance	**Age**	**Apparent size**	**Magnitude**
1,000 light years		5.8′	7.3

This is nicknamed the "Dumbbell Nebula," although a partially eaten apple might be a better description of its actual appearance in amateur telescopes. Planetary nebulae begin when an aging giant star gives off a large amount of gas in a "superwind" (traveling at 10 km/s, emitting 10^{-4} solar masses/year). Once the core of the old star is eventually exposed, a hot, fast wind (1,000 km/s, emitting 10^{-9} solar masses/year) slams into the previously emitted gas. This may explain the complex shapes of some planetary nebulae, but the presence of companion stars and magnetic fields may also play a role in some cases. The nebula is ionized by short wavelength, non-visible radiation from the central star and re-emits this radiation in visible wavelengths. The central star (mag. 13.8) lies at the narrowest part of the "bowtie" shape and has a temperature of about 110,000 K. The nebula is several thousand years old and still expanding (at several tens of km/s). In professional telescopes M27 is found to have an elliptical halo surrounding the main nebula, which itself is elliptical, and also contains an internal elliptical shell, so that the structure of this nebula consists of nested shells.

Fig. 2.27 Photo of M27; 51×15 min H-alpha, 12×10 min red, 4×10 min green, 3×10 min blue exposures with Apogee U16M camera, Planewave 12.5″ f/8 telescope on Paramount ME mount. North is to the right. (Copyright Stuart Heggie)

M28 (NGC 6626)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	18 h 24.5 m, −24° 52′	July 22
Distance	**Age**	**Apparent size**	**Magnitude**
20,000 light years		13′	6.9

The mass here is about 300,000 suns. Like M10 (NGC 6254), this cluster spends its time within a few thousand light years of the galactic central plane. This is quite unusual for a "metal-poor" cluster like this one (meaning it has low amounts of elements heavier than helium), since stars in the galactic disk tend to have "metal" that was scattered by previous supernovae. The origin of this cluster is thus uncertain. Its elliptical orbit takes it in as close as 2,000 light years (at perigalacticon) and out as far as 20,000 light years (at apogalacticon) from the galactic center, with an orbital period of about 50 million years. It is currently near apogalacticon. Interactions with the Milky Way's gravitational pull have resulted in mass loss and perhaps two tidal tails, one of which may be due to its last passage about 4 million years ago through the galactic central plane.

Fig. 2.28 Photo of M28; 8×4 min exposures with Canon 40D camera, ISO 800, Celestron 14″ telescope with Hyperstar lens corrector. North is up and east is to the left. (Copyright Dalton Wilson)

M29 (NGC 6913)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cygnus	Open cluster	20 h 23.9 m, +38° 32′	August 21
Distance	**Age**	**Apparent size**	**Magnitude**
3,000 light years	A few million years	10′	6.6
This has a diameter of less than 10 light years. It is heavily obscured by foreground dust that is very patchy (dimming some stars in the cluster by up to five magnitudes, but hardly dimming others). In professional telescopes this cluster is found to contain several hundred stars and a mass close to 1,000 suns.			

Fig. 2.29 Photo of M29; 2×5 min red and green, 2×11 min blue exposures with SBIG ST-8 camera, Vixen 8″ f/9 telescope. North is up and east is to the left. (Copyright John Mirtle)

M30 (NGC 7099)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Capricornus	Globular cluster	21 h 40.4 m, –23° 11′	September 9
Distance	**Age**	**Apparent size**	**Magnitude**
25,000 light years	10–14 billion years	12′	6.9

This has a mass of about 100,000–200,000 suns. It orbits the galaxy on a retrograde orbit that is inclined to the galactic disk (by 50°), taking about 160 million years to complete one revolution around the galaxy, never straying farther than about 30,000 light years from the galactic center, but never approaching closer than about 10,000 light years to the galactic center. The core of this cluster has "collapsed" (see NGC 6284), making its central region like a swarm of angry bees suddenly placed into a small container. Its size corresponds to a diameter of about 90 light years. It contains a high concentration of "blue straggler" stars. These are stars that are paradoxically far more blue and luminous than expected, perhaps because of mass transfer between or coalescence of stars (see NGC 6633), with almost 50 such stars known in this cluster.

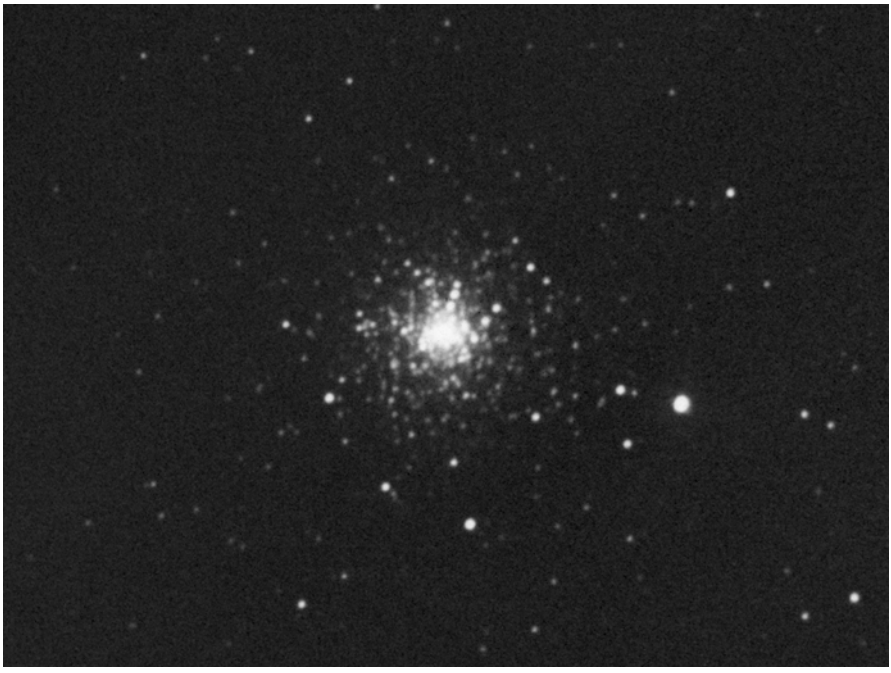

Fig. 2.30 Photo of M30; 20 min exposure on hypered Kodak Tech Pan film, with 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M31 (NGC 224)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Andromeda	Spiral galaxy	00 h 42.7 m, +41° 16′	October 26
Distance	**Age**	**Apparent size**	**Magnitude**
2.5 million light years		3.2° × 1.0°	3.5

Nicknamed the "Andromeda Galaxy," this is the nearest large galaxy to us and is the most luminous member of our Local Group of galaxies that contains about 40 galaxies in a radius of a few million light years. M31 is thought to have about the same mass as our galaxy. An apparent disk diameter of 3.2° corresponds to a diameter of 140,000 light years, although the diameter visible in telescopes is larger than this (and depends on the aperture and observing conditions). Professional telescopes show it has perhaps as many as 28 dwarf satellite galaxies, including NGC 205 (M110), which is prominent in amateur telescopes. Nearby M32 may be experiencing its first tidal encounter with M31, while M33 is thought to have had a close encounter with M31 a few billion years ago. M31 is rich in globular clusters for a spiral galaxy, with nearly 250 counted in professional telescopes. The brightest of these globular clusters can be observed in amateur telescopes. Some of them are thought to have come from dwarf galaxies that M31 accreted in past merger events. Professional telescopes find M31 has a double nucleus containing a black hole with a mass of about 50 million suns, the largest black hole in our Local Group of galaxies. The two nuclei are separated by 0.5″ and are thought to be part of an eccentric nuclear disk. The nucleus also contains a young blue star cluster with a mass of a few thousand suns that formed a couple of hundred million years ago. The galaxy is a LINER ("low-ionization nuclear emission region" – see M81/NGC 3031 for explanation). It is expected to collide with the Milky Way in a few billion years.

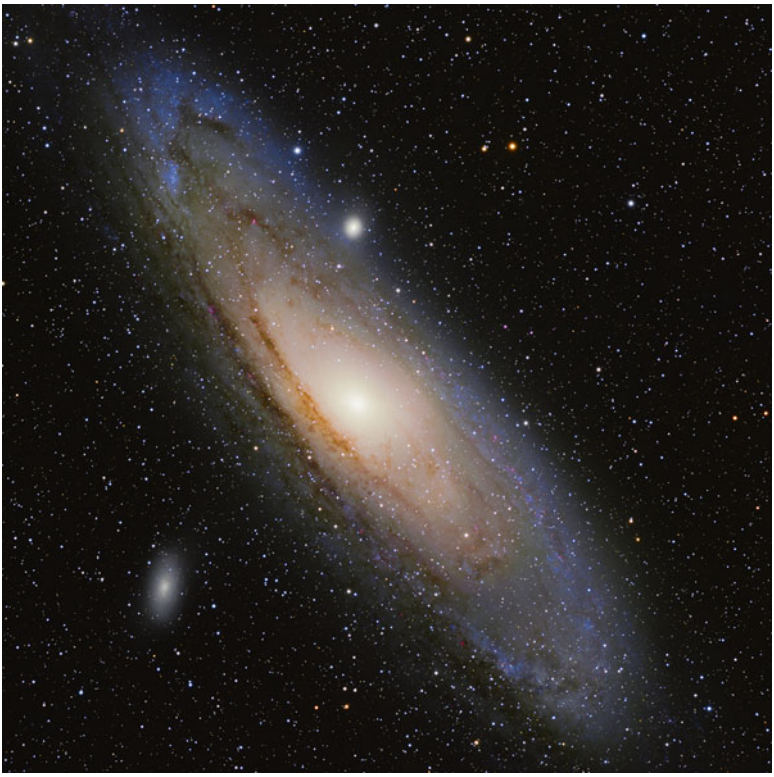

Fig. 2.31 Photo of M31; 17×10 min luminance, 10×10 min red, green and blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is down. (Copyright Stuart Heggie)

M32 (NGC 221)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Andromeda	Elliptical galaxy	00 h 42.7 m, +40° 52′	October 26
Distance	**Age**	**Apparent size**	**Magnitude**
2.5 million light years		8.5′ × 6.5′	8.1

This is a dwarf satellite galaxy of M31 and is M31's closest companion. M32 is a very unusual galaxy, referred to as a "compact elliptical" galaxy, having an inordinately bright and compact central core. Fewer than ten compact elliptical galaxies are known to exist within a distance of 300 million light years of our galaxy. Its origin remains uncertain, but one hypothesis suggests it was once a spiral galaxy that was stripped down to its bulge a few billion years ago by intense tidal interaction with M31. Alternatively, it may simply be a low-mass classical elliptical galaxy that happened by or else formed close to M31. Its stars are mostly older than a few billion years. A black hole with a mass of several million suns is thought to be present in the center of M32. M32 has an optical diameter of about 7,000 light years.

Fig. 2.32 Photo of M32; 2 × 10 min red, green, blue exposures with QSI540wsg camera, Celestron 14″ C14 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M33 (NGC 598)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Triangulum	Spiral galaxy	01 h 33.9 m, +30° 39′	October 24 (Standard Time)
Distance	**Age**	**Apparent size**	**Magnitude**
2.7 million light years		68.7′ × 41.6′	5.5

This is the third most luminous galaxy in our Local Group (which contains about 40 galaxies in a radius of a few million light years) after M31 and the Milky Way. It has an optical diameter of about 60,000 light years (about half that of the Milky Way), which is about average for a spiral galaxy. Its luminous mass is about 10 billion suns. It rotates clockwise from our viewpoint with a period of about 200 million years. The size of its central supermassive black hole (if one exists) is less than a couple of thousand solar masses. NGC 604, the largest known ionized hydrogen region (1,500 light years in diameter) and second most massive in our Local Group (after 30 Doradus), belongs to this galaxy and is visible as a knot in large amateur telescopes near the NNE edge; its stars are only a few million years old and in total have a mass of a few hundred thousand suns, with star formation still ongoing. M33 is thought to have had a close encounter with M31 a few billion years ago. It has about a tenth the mass of M31 and may be a satellite of M31, although M33 may have a dwarf spheroidal satellite galaxy of its own, labeled And XXII.

Fig. 2.33 Photo of M33; 9 × 5 min exposure ISO 1600, Canon 60Da camera, 200 mm Skywatcher f/5 Newtonian reflector with a Paracorr coma corrector. (Copyright Blair MacDonald)

M34 (NGC 1039)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Perseus	Open cluster	02 h 42.1 m, +42° 46′	November 10
Distance	**Age**	**Apparent size**	**Magnitude**
1,500 light years	200 million years	25′	5.2

This has a diameter of about 10 light years and was discovered in the middle of the seventeenth century by Giovanni Batista Hodierna. Its stars rotate at rates that are midway between those in the younger Pleiades cluster (100 million years old – see M45) and the older Hyades cluster (600 million years old). This is thought to be the result of rotational braking, whose effect on rotation rates becomes more pronounced with age. Such braking is believed to be due to angular momentum loss via magnetic coupling to the chromosphere (i.e., the star's atmosphere outside the bright photosphere). In professional telescopes, approximately 60 % of the 700 or so stars with magnitudes of between 14 and 24 in this region are cluster stars (the rest are field stars).

Fig. 2.34 Photo of M34; 2 × 10 min red, green, and blue exposures with SBIG ST-8XE camera, Takahashi FSQ 106 mm f/7 telescope. North is up and east is to the left. (Copyright John Mirtle)

M35 (NGC 2168)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Gemini	Open cluster	06 h 09.0 m, +24° 21′	January 2
Distance	**Age**	**Apparent size**	**Magnitude**
2,000–3,000 light years	100–200 million years	25′	5.1
This lies almost directly in the galactic anti-center direction (i.e., directly outward from us in the opposite direction from the center of the galaxy), about 100 light years above the galactic central plane. The open cluster NGC 2158 (see NGC 2158) lies only 24′ SW, but is not near M35 in space (NGC 2158 is roughly 10,000 light years farther away). The total mass of M35 is several thousand suns.			

Fig. 2.35 Photo of M35; 10×30 s exposures, ISO 1600, Canon Rebel XT 350D camera, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M36 (NGC 1960)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Auriga	Open cluster	05 h 36.3 m, +34° 08′	December 25
Distance	**Age**	**Apparent size**	**Magnitude**
4,000 light years	20 million years	10′	6.0

It is estimated to contain nearly 1,700 stars with masses between 0.1 and 7 times that of the Sun, although many of these are low mass stars, so that it contains less than 500 stars with mass 0.5–7 times the Sun. Although it is quite a young cluster, it is old enough that most of its stars have had time to lose their youthful circumstellar disks (that formed when the stars collapsed from the surrounding gas and dust – see NGC 2362). Its neighbors M37 (3° 45′ ESE) and M38 (2° 16′ NW) lie within 1,000 light years of M36.

Fig. 2.36 Photo of M36; 5×6 min exposures with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M37 (NGC 2099)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Auriga	Open cluster	05 h 52.3 m, +32° 33′	December 29
Distance	**Age**	**Apparent size**	**Magnitude**
5,000 light years	400–500 million years	15′	5.6
This has a diameter of about 20 light years. It lies close to M38 and M36 (see M36/NGC 1960). It is a rich cluster, with nearly 5,000 stars considered to be members in professional telescopic studies. No planets have yet been detected among its member stars, despite observations of nearly a third of its stars.			

Fig. 2.37 Photo of M37; 8×2 min exposures with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M38 (NGC 1912)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Auriga	Open cluster	05 h 28.7 m, +35° 51′	December 23
Distance	**Age**	**Apparent size**	**Magnitude**
5,000 light years	300 million years	15′	6.4

This has a diameter of about 20 light years and lies about 55 light years above the galactic plane. It contains more than 600 stars in professional telescopes. Physically it is close to M37 and M36 (see M36). NGC 1907, 32′ SSW, was once thought to perhaps be a coevolved twin to NGC 1907, but the two clusters are separated by more than 1,000 light years and are now thought to have had different birth environments and locations.

Fig. 2.38 Photo of M38; 2×6 min red, green, blue exposures with QSI540wsg camera, Celestron 14″ telescope with Hyperstar lens corrector. North is up and east is to the left. (Copyright Dalton Wilson)

M39 (NGC 7092)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cygnus	Open cluster	21 h 31.7 m, +48° 25′	September 7
Distance	**Age**	**Apparent size**	**Magnitude**
1,000 light years	300–400 million years	31′	4.6

This has a diameter of about 10 light years and a mass of a few hundred suns. This cluster lies in a rich field that is "contaminated" with field stars (i.e., stars that happen to lie along the same line-of-sight but which are foreground or background stars) from the Milky Way. This "contamination" worsens the fainter the stars that are being considered. For example, about 80–90 % of the mag. 8–10 stars are true cluster members, but only about 20 % of the mag. 11 stars in this cluster are actual cluster members (the rest being field stars), while fewer than 10 % of the mag. 12 stars are true cluster members. Distinguishing field stars from true open cluster members requires professional telescopic studies, but the fact that one is seeing a mix of field stars and true cluster members should be borne in mind when viewing an open cluster through the eyepiece.

Fig. 2.39 Photo of M39; 3×5 min red and green, 3×6 min flue exposures with SBIG ST-8XE camera, Takahashi FSQ 106 mm f/7 telescope. North is up and east is to the left. (Copyright John Mirtle)

M40

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Two stars	12 h 22.4 m, +58° 05′	April 21
Distance	**Age**	**Apparent size**	**Magnitude**
			8

This is simply two stars (mag. 9.7 and 10.1, separation 52″, position angle 81°, i.e., the two stars lie along a nearly E-W line), also known as Winnecke 4. The two stars are not believed to be orbiting each other, i.e., this is not a binary star. The brighter star lies about 500 light years away while the dimmer one lies about 2,000 light years away. Messier included this entry when looking for a nebula reported by Hevelius in this region.

Fig. 2.40 Photo of M40; 7×20 s exposures, ISO1600, Canon Rebel XT 350D camera, 300 mm f/5 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M41 (NGC 2287)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Canis Major	Open cluster	06 h 46.0 m, −20° 46′	January 11
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years	200–300 million years	39′	4.5

This has a diameter of about 20 light years. A large percentage (perhaps as high as 80 %) of its stars are binary stars. Open clusters are beasts of the galactic disk and are stripped of their stars over time by gravitational interaction with material in the disk as they jostle about it while rotating with it. For an open cluster in our vicinity of the galaxy, like this one, typical lifetimes are thought to be a little over half a billion years, so that this cluster is approaching middle age. The cluster has about 70 members with magnitudes brighter than 12, although our view of the cluster to this magnitude is "contaminated" by about as many field stars as cluster members (see M39).

Fig. 2.41 Photo of M41; 2×6 min red, green, blue exposures with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M42 (NGC 1976)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Orion	Emission and reflection nebula	05 h 35.3 m, −05° 23′	December 24
Distance	**Age**	**Apparent size**	**Magnitude**
1,400 light years		1°	4.0

Nicknamed the "Orion Nebula," this is the apparently brightest and one of the closest ionized hydrogen star-forming regions (or HII regions) in our sky. It is lit up by the stars in a very young cluster (less than a few million years old and referred to as the Orion Nebula Cluster) containing about 3,500 stars situated in the heart of the nebula. However, many of the stars in this cluster are obscured by material in the nebula. Light from these stars is both scattered off dust, particularly in the outer regions of the nebula, and re-emitted by gas, particularly in the inner regions, making this both a reflection and emission nebula. Four stars in the cluster form a quadrangle (with sides of about 10″–20″) called the "Trapezium" and are all part of the multiple star system θ^1 Orionis. Professional telescopic studies indicate θ^1 Orionis contains at least 14 stars, only six of which can be seen, including the four in the Trapezium, under good seeing conditions in moderate amateur telescopes. θ^1 Orionis is in fact a wide double star with θ^2 Orionis (itself a triple star, so that θ Orionis consists of at least 17 stars!). The brightest (and most southern) star in the Trapezium quadrangle (θ^1 Orionis C) is largely responsible for the ionization of the nebula. M42 is actually only a small "blister" on the near side of a much larger cloud of gas and dust (the Orion A complex) that has a mass of about 100,000 suns. The Orion A complex is itself part of an even larger group of giant molecular gas clouds (the Orion-Monoceros complex) that extend 30° in a SE-NW direction and sit about 500 light years below the galactic central plane. Formation of the Orion-Monoceros complex may have been triggered by a giant bubble blown out of the galactic plane by the open cluster Collinder 121. The 1° apparent dimension of M42 corresponds to a diameter of a little more than 20 light years.

Fig. 2.42 Photo of M42; 10×4 min exposures for outer region and 20×20 s exposures for core, ISO 800 with Canon EOS 350D camera, 200 mm Skywatcher f/5 telescope. (Copyright Blair MacDonald)

M43 (NGC 1982)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Orion	Emission nebula	05 h 35.5 m, –05° 16′	December 24
Distance	**Age**	**Apparent size**	**Magnitude**
1,400 light years		20′	9.0

This is part of the same gas and dust cloud as M42 (the Orion A complex), lying just NE of M42, separated from M42 by a wall of dust between the two. M43 has relatively little dust, so its light is largely from gas emission (it is an ionized hydrogen, i.e., HII, region). The nebula is visible because it is ionized by the bright variable star NU Orionis (i.e., HD 37061, mag. 6.9) in its center. Professional telescopic studies find planet-forming ("protoplanetary") disks are present around several stars in M43 (as well as in M42), some of which contain water-ice.

Fig. 2.43 Photo of M43 (lower portion of photo, below M42); 8×5 min red, green, blue exposures, SBIG STL11000 camera, Guan Sheng Optics 8″ Ritchey-Chretien telescope. North is down. (Copyright Stuart Heggie)

M44 (NGC 2632)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cancer	Open cluster	08 h 40.6 m, +19° 40′	February 9
Distance	**Age**	**Apparent size**	**Magnitude**
600 light years	600 million years	1.2°	3.1

This is nicknamed the "Beehive Cluster" or "Praesepe" (which means "manger" in Latin, its common-use anglicized pronunciation being pree-SEE-pee). It contains perhaps 1,100 members. In professional telescopes its tidal diameter is 7°. It is one of only a few open clusters thought to have stars harboring planets, in this case two Jupiter-mass planets in low radius orbits ("hot Jupiters") having orbital periods of a few days. M44 and the Hyades (60° W) may be part of a single, moving group, although M44 is thought to be perhaps 50 million years younger than the Hyades.

Fig. 2.44 Photo of M44, 4×5 min red, green and blue exposures, Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the left. (Copyright Stuart Heggie)

M45

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Taurus	Open cluster	03 h 47.0 m, +24° 07′	November 27
Distance	**Age**	**Apparent size**	**Magnitude**
400 light years	100 million years	1.8°	1.2
Nicknamed the "Pleiades" (pronounced PLEE-ah-deez) or the "Seven Sisters" (although only six stars are visible with the naked eye in light polluted skies), this cluster has a mass of about 900 suns. The Orion Nebula cluster (see M42) is believed to be similar to what M45 was like when it was a few hundred thousand years old. The nebulosity around its stars that is apparent in photographs is thought to be foreground dust and is not material from the original giant molecular cloud that birthed the Pleiades.			

Fig. 2.45 Photo of M45; 15×5 min luminance, 12×10 min red, green and blue exposures, Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is up. (Copyright Stuart Heggie)

M46 (NGC 2437)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Puppis	Open cluster	07 h 41.8 m, −14° 49′	January 25
Distance	**Age**	**Apparent size**	**Magnitude**
5,000 light years	200 million years	20′	6.1
This has a mass of approximately 1,000 suns. It lies about 400 light years above the galactic central plane at a distance of about 30,000 light years from the galactic center. Although NGC 2438 lies on the NE edge of the open cluster M46 (see M46/NGC 2437), their differing relative velocities and the young age of M46 together suggest that NGC 2438 is not part of M46, despite them lying at a similar distance.			

Fig. 2.46 Photo of M46 (*left*) and M47 (*right*); 9 min exposure on 120 format Kodak Ektachrome 400, 6″ f/4.5 Newtonian telescope. NGC 2423 (see NGC 2423) is also visible (*middle right*), above M47. North is up and east is to the left. (Copyright John Mirtle)

M47 (NGC 2422)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Puppis	Open cluster	07 h 36.6 m, −14° 29′	January 24
Distance	**Age**	**Apparent size**	**Magnitude**
1,600 light years	100 million years	25′	4.4

This has a mass of a few hundred suns. Interstellar dust between us and the stars in this cluster cause its stars to appear dimmer by only a few tenths of a magnitude, which is much less than the average two magnitudes of dimming for every kiloparsec (3,260 light years) that is typical when light travels in the central plane of our galaxy. Several Be stars are known in this cluster, the brightest of which is HD 60856 at mag. 8 and is readily visible in amateur telescopes (see Fig. 3.6 of Chapter 3). Be stars are B-type stars that are peculiar because of hydrogen Balmer emission lines in their spectra, due to atomic transitions in material expelled by high rotational velocities into a circumstellar disk in the equatorial plane of the star.

See Fig. 2.46

M48 (NGC 2548)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Hydra	Open cluster	08 h 13.7 m, −05° 45′	February 2
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years	400 million years	1°	5.8

Of 750 stars brighter than mag. 15.0 in this region, about 300 are thought to be cluster members. It lies about 28,000 light years from the center of our galaxy and nearly 700 light years above the galactic central plane. Its current position is close to its maximum excursion of 800 light years from this plane, having crossed it perhaps ten times in its lifetime, while making a little less than two revolutions about the galactic center. It has a diameter of about 30 light years. Messier's discovery and subsequent listing of this object resulted in an error in its quoted position, so that its location in some old star charts (before T. F. Morris' correction of this error in 1959) is incorrect.

Fig. 2.48 Photo of M48; 10 min exposure on 120 format Kodak Ektachrome 400, 6″ f/4.5 Newtonian telescope. North is up and east is to the left. (Copyright John Mirtle)

M49 (NGC 4472)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 29.8 m, +08° 00′	April 23
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		10.2′ × 8.3′	8.3

This is a giant elliptical galaxy and the brightest member of the Virgo galaxy cluster, which is the nearest galaxy cluster to us. The Virgo galaxy cluster may contain nearly 2,000 galaxies, which are bunched into several subclusters with M87 and M49 being principal members of the two main subclusters. M49 lies perhaps a few million light years closer than M87. Occupying a roughly rectangular shape in the sky (8° E-W × 16° N-S), the major concentration of the Virgo cluster extends several tens of millions of light years around the cluster center near M87 (but, for simplicity, all its members are listed herein as being at the same distance). M49 is thought to be falling toward the center of the Virgo cluster at about 1,000 km/s. Much of the mass in the Virgo cluster is dark matter, with the total mass of the Virgo cluster being many hundreds of trillions of solar masses. The Virgo cluster lies at the center of the Virgo supercluster, an even larger gathering of galaxies with a diameter of about 100 million light years that includes our own Local Group. M49 contains about 6,000 globular clusters, which are mostly old (10 billion years). The center of M49 is thought to contain a supermassive black hole with a mass of about half a billion suns. The stellar mass of M49 is perhaps 200 billion suns, but its total mass (including dark matter in its halo) is more than a trillion suns. Its optical diameter is about 150,000 light years.

Fig. 2.49 Photo of M49; 4×10 min luminance, red, green and blue exposures with QSI583wsg camera, Astro-Tech 8″ f/4 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M50 (NGC 2323)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Monoceros	Open cluster	07 h 02.7 m, −08° 23′	January 15
Distance	**Age**	**Apparent size**	**Magnitude**
3,000 light years	130 million years	15′	5.9
This contains about 2,000 stars brighter than mag. 23, which is about half the number of stars in this region (the other half are field stars). Its apparent diameter corresponds to about 14 light years. The interstellar gas and dust in the disk of our galaxy is not uniformly distributed at light year length scales, but instead is clumped into patches with typical masses of a few hundred suns. Open clusters are thought to form from such interstellar clouds of gas and dust.			

Fig. 2.50 Photo of M50; 8.5 min exposure on 120 format Ektachrome 400, 6″ f/4.5 Newtonian telescope. North is up and east is to the left. (Copyright John Mirtle)

M51 (NGC 5194)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Canes Venatici	Spiral galaxy	13 h 29.9 m, +47° 12′	May 8
Distance	**Age**	**Apparent size**	**Magnitude**
25 million light years		11.2′ × 6.9′	8.1

This is nicknamed the "Whirlpool Galaxy." It is a grand-design spiral, meaning that it has two symmetrically placed spiral arms that extend over most its visible disk in professional telescopic images. What appears as a bridge connecting M51 to its nearby companion galaxy NGC 5195 (4′ NNE – see NGC 5195) is actually an optical illusion. A spiral arm of M51 is superimposed on NGC 5195 with NGC 5195 actually lying on the far side of M51 (by perhaps half a million light years), although the two galaxies have had perhaps two recent close encounters in the past (see NGC 5195). These gravitational interactions with NGC 5195 are thought to have triggered star formation in M51, with two peaks in star cluster formation occurring a few hundred million years ago, in addition to a recent peak a few million years ago. Almost 20,000 ionized hydrogen (HII) star-forming regions have been identified in M51, with diameters averaging about 30 light years and having masses up to several thousand suns. A number of these HII regions can be seen as bright knots in amateur telescopes. M51 is a Seyfert galaxy (see NGC 3372 for explanation) and has an optical diameter of about 80,000 light years. It is part of the M51 galaxy group of perhaps nine gravitationally bound galaxies.

Fig. 2.51 Photo of M51; 12 × 10 min luminance, 3 × 10 min red, green and blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the left. (Copyright Stuart Heggie)

M52 (NGC 7654)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cassiopeia	Open cluster	23 h 24.8 m, +61° 36′	October 6
Distance	**Age**	**Apparent size**	**Magnitude**
4,000–5,000 light years	100 million years	16′	6.9

This is a relatively rich cluster. At magnitudes brighter than 15.0, there is nearly one star for every square arc second of sky in its densest parts (although about one in ten of these is a field star and not a cluster member – see M39). To magnitude 14.5, a total of about 130 stars belong to the cluster (with only about 30 field stars "contaminating" the cluster), with these cluster members having masses about two to five times that of our Sun. To magnitude 19.5, over 6,000 stars belong to the cluster (with about the same number of field stars present), with most of these dimmer cluster members having masses near that of our Sun. The stars in this cluster appear to have a much larger spread of ages (tens of millions of years) than most open clusters (where the stars are typically only a few million years apart in age). Gas and dust between us and the cluster dim the stars in this cluster considerably (by a few magnitudes).

Fig. 2.52 Photo of M52; 5 × 5 min exposures with Canon EOS 350D camera, 1600 ISO, Meade 8″ f/4 Schmidt Newtonian telescope. M52 is on the *bottom* and NGC 7635 (see NGC 7635) can be seen in the *mid-upper right*. (Copyright Blair MacDonald)

M53 (NGC 5024)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Globular cluster	13 h 12.9 m, +18° 10′	May 4
Distance	**Age**	**Apparent size**	**Magnitude**
60,000 light years	10–14 billion years	13′	7.7

The mass here is about 0.5 million suns. It lies nearly directly "above" us from the galactic central plane in the halo of our galaxy (see M2/NGC 7089 for the meaning of "halo"). Its orbit keeps it out in the halo, with a period of close to a billion years. It follows a path that takes it well over 100,000 light years from the galactic center and never closer than about 35,000 light years to the galactic center. Its orbit is highly inclined (by about 60°) to the disk of our galaxy. M53's apparent size corresponds to a diameter of about 230 light years. The nearby globular cluster NGC 5053 (1° ESE) lies nearly directly "below" M53 in three-dimensional space, being 1,600 light years closer to us (in a direction nearly perpendicular to the disk of our galaxy).

Fig. 2.53 Photo of M53; 3 × 10 min red, 4 × 10 min green, 4 × 10 min blue exposures with SBIG ST-8XE camera, Takahashi FSQ 106 mm f/5 telescope on AP900GTO mount. M53 is *upper right* while NGC 5053 (see NGC 5053) is at *lower left*. North is up and east is to the left. (Copyright John Mirtle)

M54 (NGC 6715)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	18 h 55.1 m, −30° 29′	July 30
Distance	**Age**	**Apparent size**	**Magnitude**
85,000 light years	10–14 billion years	12′	7.7

This globular cluster is not part of our galaxy, but instead belongs to a nearby satellite galaxy (which goes by the cumbersome name "Sagittarius Dwarf Elliptical Galaxy"), embedded in its nucleus. This companion galaxy is in the process of being gravitationally disrupted by our galaxy. Models predict that it, along with M54, will collide with the disk of our galaxy in several tens of millions of years, having had a past such collision about 200 million years ago. M54 is the second most massive known Milky Way globular cluster (after ω Centauri/NGC 5139) with a mass of about 1.5 million suns (which is about 1/40 the mass of the galaxy it belongs to). Its size of 12′ corresponds to a diameter of about 300 light years.

Fig. 2.54 Photo of M54; 23 × 30 s exposure with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M55 (NGC 6809)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	19 h 40.0 m, −30° 58′	August 10
Distance	**Age**	**Apparent size**	**Magnitude**
18,000 light years	10–14 billion years	19.0′	6.3

This has a mass of about 100,000–200,000 suns and a diameter of about 100 light years. It takes a little over 100 million years or so to complete an orbit about our galaxy, always staying within about 25,000 light years of the galactic center but swinging within a few thousand light years, all in a path that is highly inclined to the disk of our galaxy. It contains 65 identified "blue stragglers" (see NGC 6633), which are stars that are paradoxically far more blue and luminous than expected, perhaps because of mass transfer between or coalescence of stars. It is metal poor, being near the bottom 10th percentile for metallicity of Milky Way globular clusters.

Fig. 2.55 Photo of M55; 24×30 s exposure with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M56 (NGC 6779)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Lyra	Globular cluster	19 h 16.6 m, +30° 11′	August 4
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	8.8′	8.4

This has a mass of about 200,000 suns and a diameter of about 80 light years. Although its orbit is roughly circular and lies nearly in the galactic disk (inclined by only about 15° to the central plane), like almost all globular clusters in our galaxy, it does not orbit with the disk material at a constant radius from the galactic center. Instead its path is thought to take it out as far as about 50,000 light years away from the galactic center and within a few thousand light years of the galactic center, although it takes about the same amount of time to complete an orbit as our Sun does (i.e., about a quarter of a billion years). It is a metal-poor halo cluster, meaning it contains lower amounts of compounds heavier than helium (i.e., "metals"), being near the bottom 10th percentile in metallicity of Milky Way globular clusters.

Fig. 2.56 Photo of M56; 17×10 min exposure with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M57 (NGC 6720)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Lyra	Planetary nebula	18 h 53.6 m, +33° 02′	July 29
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years		3.0′ × 2.4′	8.8

This is nicknamed the "Ring Nebula," It is thought to have been created a few thousand years ago when an old star blew off its outer layers. In professional telescopes the nebula extends out to nearly 4′ in diameter (with its outer halo 5,000 times dimmer in surface brightness than the ring). Its three-dimensional structure is thought to consist of an ellipsoidal shell (like the skin of an airship/dirigible as in the Hindenburg or the Goodyear blimp) that we are looking at nearly end-on. This shell is thought to be encircled at its midsection (half-way along the "dirigible") by a torus of material so that the ring we see is merely a donut of denser material at the mid-section of the ellipsoidal shell. The denseness of the ring is thought to be a relic of the preferential ejection of mass by the central star in its equatorial plane (in a "superwind" – see M27). The shell is expanding outward at a few tens of km/s. Invisible (UV) radiation from the hot central star ionizes the atoms in the shell, and electrons recombining with these ionized atoms cause optical photons to be emitted that make the nebula visible to us.

Fig. 2.57 Photo of M57; 90 min exposure from urban light polluted setting with Canon 60Da camera, ISO 1600, 200 mm Skywatcher f/5 reflector telescope. (Copyright Blair MacDonald)

M58 (NGC 4579)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Barred spiral galaxy	12 h 37.7 m, +11° 49′	April 25
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		6.0′ × 4.8′	9.6

This is part of the Virgo galaxy cluster (see M49/NGC 4472). M58 has a mass of about 300 million suns. It is a LINER galaxy (see M81) in which emission from the nucleus is thought to occur due to accretion of matter onto a supermassive central black hole with a mass of about 50 million suns. It has a nuclear ring with a diameter less than 1,000 light years. Its optical diameter is about 100,000 light years.

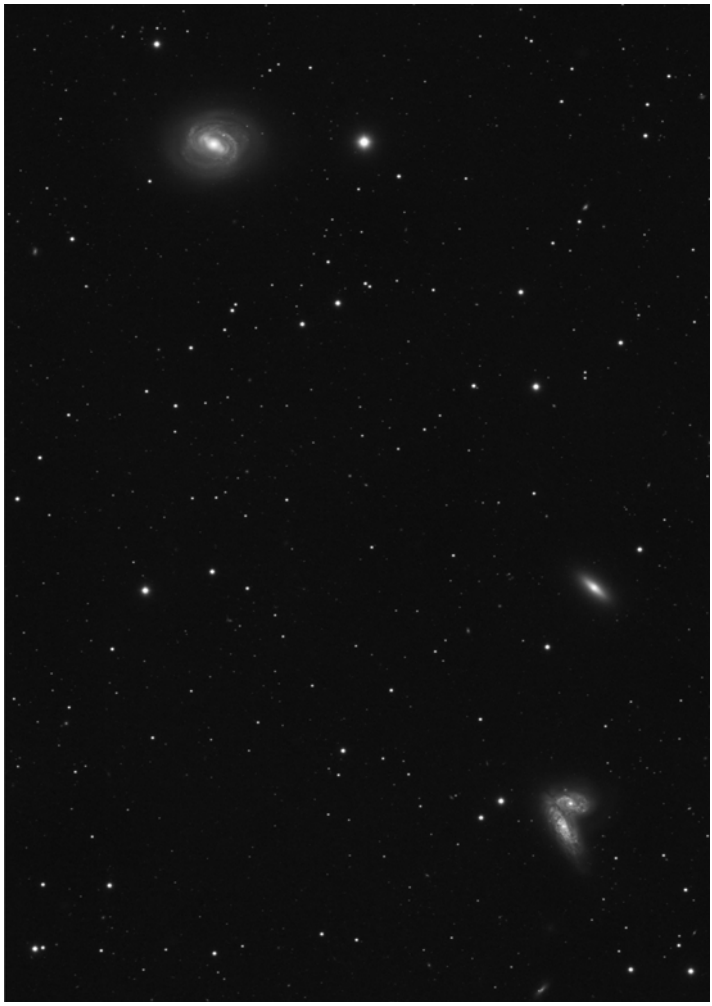

Fig. 2.58 Photo of M58; 15 × 10 min exposure with SBIG STF-8300M camera, Astrophysics AP130EDT f/8.35 telescope. M58 is at *upper left*, NGC 4567/4568 (see NGC 4567) is at *lower right*, while NGC 4564 is in the *middle right*. North is up and east is to the left. (Copyright John Mirtle)

M59 (NGC 4621)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 42.0 m, +11° 39′	April 26
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		5.4′ × 3.7′	9.7

This is part of the Virgo galaxy cluster (see M49/NGC 4472). The inner core of this galaxy is unusual because it is thought to be counter-rotating from the rest of the galaxy as well as having a different chemical makeup from, and being younger than, the rest of the galaxy, perhaps due to dynamics driven by a bar, or else by a past accretion event. This inner core has a diameter of several hundred light years and apparent size of about an arc second. Professional telescopes find M59 has a disk that emits about 16 % of the light from this galaxy. M59 also has a circumnuclear disk (diameter of 5″–7″) in professional telescopic studies. The center of this galaxy is believed to contain a supermassive black hole (with a mass of about 300 million suns). M59 contains about 2,000 globular clusters.

Fig. 2.59 Photo of M59 (*middle, right*), with M60 and its nearby companion NGC 4647 (*middle, left*); 40 min exposure on hypered Kodak Tech Pan, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M60 (NGC 4649)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 43.7 m, +11° 33′	April 26
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		7.6′ × 6.2′	8.8

This is a giant elliptical galaxy. It is part of the Virgo galaxy cluster (see M49/NGC 4472). M60 is thought to contain a supermassive central black hole (with a mass of perhaps 4.5 billion suns). Its nearby companion galaxy NGC 4647 (barred spiral galaxy, 2.5′ NW, mag. 11.4) is possibly a few million light years away from M60, and not thought to have interacted significantly with M60 yet. M60 contains perhaps 15,000 globular clusters (about 100 times as many as in our galaxy).

See Fig. 2.59

M61 (NGC 4303)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Barred spiral galaxy	12 h 21.9 m, +04° 28′	April 21
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		6.5′ × 5.8′	9.3

This has a total mass of about 70 billion suns. It has an active galactic nucleus containing a central supermassive black hole with a mass of a few millions suns. Its nucleus also contains a few million year-old starburst cluster with a mass of about 100,000 suns and has a massive circumnuclear star-forming disk (with a diameter of about 10″ and a mass of about 50 million suns) that itself has a bar and spiral structure. This galaxy has a diameter of about 100,000 light years. It is part of the Virgo cluster (see M49/NGC 4472) and is a grand-design spiral, meaning that it has two symmetrically placed spiral arms that in professional telescopic images extend over most its visible disk. Many giant, ionized hydrogen (star-forming) regions are present along its spiral arms, giving the arms an uneven brightness along their length in large amateur telescopes. The total star-formation rate in this galaxy is probably 1–2 solar masses/year (which is similar to that occurring in our galaxy, but our galaxy is more than ten times as massive). It is probably interacting with nearby NGC 4303A (10′ NE, mag. 13) and NGC 4292 (12′ NW, mag. 12.2).

Fig. 2.61 Photo of M61; 10×5 min exposures with Canon 40D camera, ISO 800, Celestron 14″ telescope with Hyperstar lens corrector. North is up and east is to the left. (Copyright Dalton Wilson)

M62 (NGC 6266)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	17 h 01.2 m, −30° 07′	July 1
Distance	**Age**	**Apparent size**	**Magnitude**
25,000 light years	10–14 billion years	15′	6.4

This has a mass of almost a million suns. Its size of 15′ corresponds to a diameter of about 110 light years. It lies on the edge of the galactic disk, in the direction of the galactic center from us and is a "bulge cluster" (meaning it spends its time orbiting within the central 15,000-light year diameter bulge of our galaxy). It is one of only a few Milky Way globular clusters that might host a black hole, in this case with an intermediate mass of at most a couple thousand suns. The core of M62 is thought to be "collapsed." (See NGC 6284 for explanation.)

Fig. 2.62 Photo of M62; 20 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M63 (NGC 5055)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Canes Venatici	Spiral galaxy	13 h 15.8 m, +42° 02′	May 4
Distance	**Age**	**Apparent size**	**Magnitude**
25 million light years		12.6′ × 7.2′	8.5

Nicknamed the "Sunflower Galaxy," this is part of a gravitationally bound group of perhaps nine galaxies that includes M51 (NGC 5194) and NGC 5023 (spiral galaxy, mag. 12.1, 2° NNW). M63 is a so-called "flocculent" spiral galaxy, meaning that it lacks any obvious azimuthally symmetric spiral arm pattern (see NGC 3521 for further explanation). It has a mass of a couple hundred billion suns and is a "low-ionization nuclear emission region" galaxy (or "LINER" – see M81/NGC 3031 for an explanation). It has an optical diameter of a little over 90,000 light years. Beyond its optically visible regions the galaxy consists of a neutral hydrogen (HI) disk (not visible in amateur telescopes) that is "warped" so that the far outer edge of its HI disk lies in a plane that is skewed by perhaps about 20° from the rest of the galaxy. Warps occur in the HI distribution of most galaxies that have significant HI extending beyond their optical disks, perhaps because of misalignment, relative to the disk, of the angular momentum of accreted material. Professional telescopes also find a giant loop extending out 14′ on the eastern side of this galaxy, which is thought to be a stellar tidal stream created by the accretion, within the past few billion years ago, of a dwarf galaxy with a mass of a few hundred thousand suns.

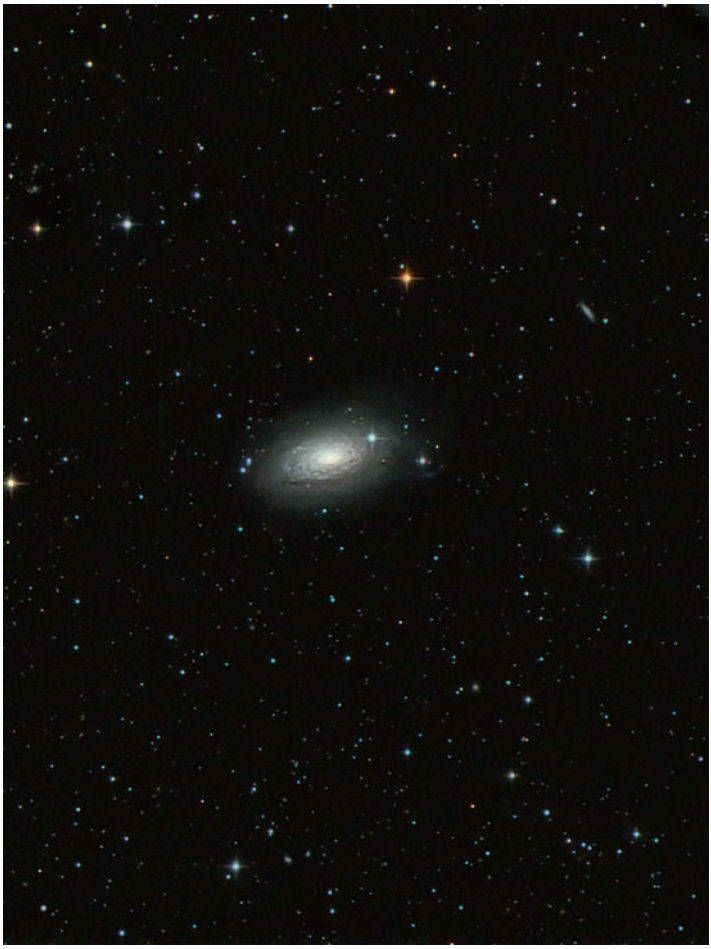

Fig. 2.63 Photo of M63; 5×5 min red, green, blue exposures with QSI583wsg, Astro-Tech 8″ f/4 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M64 (NGC 4826)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Spiral galaxy	12 h 56.7 m, +21° 41′	April 30
Distance	**Age**	**Apparent size**	**Magnitude**
15 million light years		10.0′ × 5.4′	8.5

This is nicknamed the "Black-Eye Galaxy" because of a dark arc-shaped dust region on its NE side, which is a challenge to discern in amateur telescopes. It has an optical diameter of about 50,000 light years. The nucleus of this galaxy is chemically different from the rest of the galaxy (and is said to be "chemically decoupled"). In addition, the gas in the outer disk (radii > about 1′ and containing 100 million solar masses) counter-rotates from rest of the galaxy, including the stars (which all rotate the same way). This highly unusual situation may have its origin in the past accretion of a gas-rich dwarf satellite galaxy. The dust that gives the galaxy its "black eye" rotates with the stars. M64 is thought to be a LINER galaxy driven by a starburst in its nucleus (see M81/NGC 3031 for an explanation).

Fig. 2.64 Photo of M64; 8×2 min exposures with Canon Rebel XT 350D camera, ISO 1600, 300 mm f/5 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M65 (NGC 3623)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Leo	Barred spiral galaxy	11 h 18.9 m, +13° 05′	April 5
Distance	**Age**	**Apparent size**	**Magnitude**
35 million light years		9.8′ × 2.9′	9.2

M65 is nearly edge-on with its rotation axis inclined by 71° from our line-of-sight. It has an optical diameter of about 100,000 light years. It is part of a gravitationally bound group of galaxies that includes NGC 3593 (1° SW), as well as nearby M66 (see M66/NGC 3627) and NGC 3628 (see NGC 3628) with which it forms the "Leo Triplet." Its stars are unusually similar in age (0.7–0.9 billion years) across its central bulge and disk regions, perhaps because of central bulge star formation induced by past interaction with its fellow Leo triplets.

Fig. 2.65 Photo of M65 (*upper right*), M66 (*lower right*), and NGC 3628 (*left*, see NGC 3628); 24 × 5 min exposures with Canon 60Da camera, ISO 1600, 200 mm Skywatcher f/5 Newtonian reflector with a Televue Paracorr coma corrector. (Copyright Blair MacDonald)

M66 (NGC 3627)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Leo	Barred spiral galaxy	11 h 20.3 m, +12° 59′	April 5
Distance	**Age**	**Apparent size**	**Magnitude**
35 million light years		9.1′×4.1′	8.9

M66 is part of the "Leo Triplet" that includes nearby M65 (see M65/NGC 3623) and NGC 3628, which form a gravitationally bound group of four galaxies (the fourth member being nearby NGC 3593), and which are part of the Leo I galaxy group (see M96/NGC 3368). Professional telescopes find a quarter million light year (40′) long plume of stars and gas extending to the east of NGC 3628, with a mass of hundreds of millions of suns, that is thought to be the result of an interaction with M66 nearly a billion years ago. Distortions in the disk and arms within M66 itself may be the result of a dwarf galaxy careening in from the SE and colliding with M66 within the past few tens of millions of years. M66 has an optical diameter of about 90,000 light years and has an active galactic nucleus (AGN) of either LINER (see M81/NGC 3031) or Seyfert type (where a supermassive object in this galaxy's center accumulates nearby material and produces strong emission). It has an 12″ long inner bar nested inside its large-scale 1.4′ long outer bar, with a 45° angle between the two bars.

See Fig. 2.65

M67 (NGC 2682)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cancer	Open cluster	08 h 51.3 m, +11° 48′	February 11
Distance	**Age**	**Apparent size**	**Magnitude**
3,000 light years	4 billion years	25′	6.9

This is one of the oldest open clusters known. Indeed, most open clusters disassociate within a few hundred million years of their formation. M67's large initial mass and distance from the galactic center have allowed it to reach its old age, although it is thought to have lost more than three quarters of its original stellar mass, and it is reaching its end of life as a bound cluster. As clusters age, mass segregation of stars (see NGC 2506) results in star mass decreasing with radial distance from the cluster center, and M67 is no exception. Professional telescopes find 1,400 members (down to magnitude 23) in this cluster. Its size of 30′ corresponds to a diameter of about 20 light years.

Fig. 2.67 Photo of M67; 30 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright Blair MacDonald)

M68 (NGC 4590)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Hydra	Globular cluster	12 h 39.5 m, −26° 45′	April 26
Distance	**Age**	**Apparent size**	**Magnitude**
34,000 light years	10–14 billion years	11′	7.3

This has a mass of a few hundred thousand suns. Its size of 11′ corresponds to a diameter of over 100 light years. Like most globular clusters, it does not orbit our galaxy with the galactic disk as we do. Instead it follows an orbit that takes it out as far as about 170,000 light years from the galactic center and then back in as close as about 30,000 light years on an elliptical path (with eccentricity 0.5) inclined to the galactic disk (by about 30°), taking about a half billion years to make one revolution around our galaxy. It is very "metal poor" (meaning it is sparse in elements heavier than helium), being among the 25 most metal-poor globular clusters in our galaxy.

Fig. 2.68 Photo of M68; 9×5 min exposures with Canon 40D camera, ISO 800, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M69 (NGC 6637)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	18 h 31.4 m, −32° 21′	July 24
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	7.1′	8.3

This lies almost directly below the galactic center (about 5,000 light years below the galactic central plane), about 3,000 light years on the other side of the galactic center from us. It has a mass of about 300,000 suns, and its size corresponds to a diameter of about 60 light years. It is thought to be a "bulge cluster" (meaning it spends its time orbiting around the central, ball-like, 15,000 light year diameter bulge of our galaxy). It is a "metal-rich" cluster (meaning it contains significant amounts of elements heavier than helium). About a quarter of the globular clusters in our galaxy are considered metal-rich, and NGC 6637 is just within the top 25th percentile for metallicity of Milky Way globular clusters.

Fig. 2.69 Photo of M69; 24×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M70 (NGC 6681)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	18 h 43.2 m, −32° 17′	July 27
Distance	**Age**	**Apparent size**	**Magnitude**
30,000 light years	10–14 billion years	8.0′	7.8

This has a mass of about 200,000 suns and a diameter of about 70 light years. Like its neighbor M69, this is thought to be a "bulge cluster" (meaning it spends its time orbiting around the bulge of our galaxy – see M69/NGC 6637). Its core is thought to have "collapsed," the result of an instability that causes the stars in its core to confine themselves to an unusually small region (see NGC 6284).

Fig. 2.70 Photo of M70; 20×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M71 (NGC 6838)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagitta	Globular cluster	19 h 53.8 m, +18° 47′	August 14
Distance	**Age**	**Apparent size**	**Magnitude**
13,000 light years	10–14 billion years	7.2′	8.4

This is the eighth closest globular cluster to us. With a mass of only a few tens of thousands of suns and a diameter of a little over 25 light years, this is a sparse globular cluster. It has an elliptical shape with an aspect ratio (minor to major axis ratio) of about 0.7, its flattened shape possibly caused by its recent passage through the galactic central plane about 16 million years ago. Its orbit is highly elliptical (with a minor to major axis ratio of 0.2), and it takes about 160 million years to complete one orbit around our galaxy, never straying far from the galactic disk.

Fig. 2.71 Photo of M71; 22×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M72 (NGC 6981)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Aquarius	Globular cluster	20 h 53.5 m, −12° 32′	August 30
Distance	**Age**	**Apparent size**	**Magnitude**
55,000 light years	10–14 billion years	6.6′	9.2
This has a mass of about 200,000 suns and a diameter of about 100 light years. It lies in the halo of our galaxy. (See M2 for the meaning of "halo.") It rotates about our galaxy in a retrograde direction (i.e., opposite to the Sun's motion around the galaxy), which has led to the suggestion that it was adopted in a merger with another galaxy.			

Fig. 2.72 Photo of M72; 25×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M73 (NGC 6994)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Aquarius	Asterism	20 h 58.9 m, −12° 38′	August 31
Distance	**Age**	**Apparent size**	**Magnitude**
		1.4′	8.9
The four stars at this location are not a cluster but are simply an asterism (i.e., a pattern of physically unrelated stars in the sky).			

Fig. 2.73 Photo of M73; 7×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M74 (NGC 628)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Pisces	Spiral galaxy	01 h 36.7 m, +15° 47′	October 25 (Standard Time)
Distance	**Age**	**Apparent size**	**Magnitude**
25 million light years		10.5′ × 9.5′	9.1

This has a mass of about 330 billion suns and an optical diameter of about 80,000 light years. It is nearly face-on (its inclination angle, which is the angle between its axis of rotation and our line-of-sight, is less than 10°). Hundreds of ionized hydrogen (HII) star-forming regions (like M42) have been identified in this galaxy in professional telescopes, some of which can be seen as bright knots in large amateur telescopes. In addition, within its inner 0.5′ is a circumnuclear ring of star formation. All told, these star-forming regions produce several new stars per year. M74 is thought to be part of a gravitationally bound group of perhaps six galaxies that includes NGC 660 (2° 38′ SE) as well as several dimmer galaxies (the brightest of which, at mag. 13, are UGC 1195, 22′ NNW of NGC 660 and UGC 1200, 29′ S of NGC 660), although it has not interacted with any galaxies for more than a billion years. Professional telescopic studies show that beyond its optically visible disk is an extended ring of atomic hydrogen reaching out to more than twice its optical diameter. This extended ring is warped, perhaps as the result of two high velocity clouds that are accreting onto the disk.

Fig. 2.74 Photo of M74; 3×15 min luminance, red, green, blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and East is to the left. (Copyright Dalton Wilson)

M75 (NGC 6864)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Sagittarius	Globular cluster	20 h 06.1 m, −21° 55′	August 17
Distance	**Age**	**Apparent size**	**Magnitude**
70,000 light years	10–14 billion years	6.8′	8.6
This has a mass of about half a million suns and a diameter of about 140 light years. Its horizontal branch (HB), composed of stars immediately following their red giant stage, has two gaps in it, giving three HB populations that differ in temperature. It lies on the other side of the galaxy from us, well below the galactic central plane (by about 30,000 light years).			

Fig. 2.75 Photo of M75; 22×30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M76 (NGC 650/651)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Perseus	Planetary nebula	01 h 42.3 m, +51° 34′	October 27 (Standard Time)
Distance	**Age**	**Apparent size**	**Magnitude**
4,000 light years	6,000 years	3.1′	10.1
This is nicknamed the "Little Dumbbell Nebula." Although different parts are expanding at different rates, typical expansion velocities are a few tens of km/s. It has a diameter of about 3 light years. The two lobes of the "bowtie" shape are each three-dimensional expanding bubbles, inclined at about 75° from our line-of-sight with the NW lobe pointing toward us.			

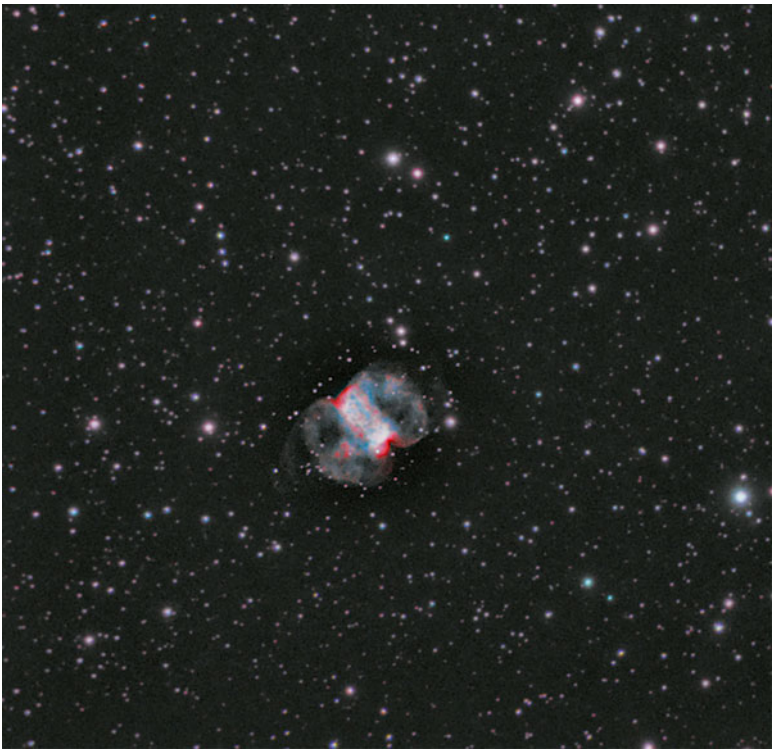

Fig. 2.76 Photo of M76; 9×4 min luminance, red, green, blue exposures with QSI540wsg camera, Celestron C14 telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M77 (NGC 1068)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cetus	Spiral galaxy	02 h 42.7 m, –00° 01′	November 11
Distance	**Age**	**Apparent size**	**Magnitude**
50 million light years		7.1′ × 6.0′	8.9

This is a well-known Seyfert galaxy, in which emission from the nucleus is thought to occur due to accretion of matter onto a massive central black hole (which is thought to have a mass of about 20 million suns in this galaxy). The galaxy's inner region is complex. It has a 4″ diameter circumnuclear disk containing 300 million year old stars throughout, but with a ring of 30 million year old stars. Its nucleus also has a bar of stars (0.5′ in length) from which emanate two tightly wound spiral arms (0.5′ in radius) that nearly form a ring, in which intense star formation is occurring. M77 also contains water-vapor "masers" in its central region. Maser stands for "microwave amplification by stimulated emission of radiation," the physics of which is the microwave equivalent of a laser, except that lasers are usually designed to produce a beam, while astronomical masers yield emission that radiates from a roughly spherical region. M77 is part of a gravitationally bound group of perhaps 11 galaxies that includes NGC 1055 (30′ NNW), NGC 1073 (1° 25′ N), as well as the much dimmer, mag. 13, UGC 2275 and UGC 2302. M77 has an optical diameter of about 100,000 light years.

Fig. 2.77 Photo of M77; 3×15 min luminance, red, green, blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M78 (NGC 2068)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Orion	Reflection nebula	05 h 46.8 m, +00° 05′	November 11
Distance	**Age**	**Apparent size**	**Magnitude**
1,400 light years		8′	8

M78 is a star-forming region. Its size of 8′ corresponds to a diameter of a few light years. It is illuminated by the triple star labeled HD 38563. M78 is part of the giant molecular cloud Orion B, also known as LDN (Lynds Dark Nebula) 1630, that has a size of about 8° in professional telescopic studies (that also includes the fellow star-forming regions NGC 2071, NGC 2023 and NGC 2024) and is part of the much larger Orion-Monoceros complex (see M42).

Fig. 2.78 Photo of M78; 18×5 min luminance, 6×5 min red, green and blue exposures with a ST-10XME camera, Takahashi FSQ 106 mm f/5 telescope on AP900GTO mount. North is up. (Copyright Stuart Heggie)

M79 (NGC 1904)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Lepus	Globular cluster	05 h 24.2 m, −24° 31′	December 22
Distance	**Age**	**Apparent size**	**Magnitude**
40,000 light years	10–14 billion years	9.6′	7.7

This has a mass of about 300,000 suns and a diameter of a little over 100 light years. It may contain a central intermediate mass black hole, with a mass of 3,000 suns. Like most globular clusters, it does not orbit our galaxy with the galactic disk as we do. Instead it follows an orbit that takes it out as far as 90,000 light years from the galactic center and then back in as close as about 5,000 light years, on a path inclined to the galactic disk (by about 45°), taking about 400 million years to make one orbit around our galaxy. It has been hypothesized that NGC 1904, along with NGC 1851, NGC 2298 and NGC 2808, were once part of the now accreted Canis Major dwarf galaxy.

Fig. 2.79 Photo of M79; 13 × 15 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M80 (NGC 6093)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Scorpius	Globular cluster	16 h 17.0 m, −22° 58′	June 21
Distance	**Age**	**Apparent size**	**Magnitude**
33,000 light years	10–14 billion years	10′	7.3
This has a mass of about 300,000 suns and a diameter of about 100 light years. It was the first globular cluster to have a nova discovered in it. M80 is a bulge cluster (meaning it orbits inside the central bulge of our galaxy – see M9/NGC 6333) and has one of the shortest orbital periods of the globular clusters in our galaxy. Indeed, it only takes about 70 million years to complete one revolution about the galaxy, in an orbit that is highly inclined to the galactic central plane.			

Fig. 2.80 Photo of M80; 21 × 30 s exposures with Canon Rebel XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M81 (NGC 3031)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Spiral galaxy	09 h 55.6 m, +69° 04′	February 28
Distance	**Age**	**Apparent size**	**Magnitude**
12 million light years		24.9′ × 11.5′	7.0

M81 is a LINER (low-ionization nuclear emission region) galaxy, which is a low-luminosity class of "active galactic nuclei" (AGN). The mechanism for LINERs varies, but in some galaxies it may be due to a supermassive black hole in the nucleus that is accreting gas and stars, resulting in photoionization of surrounding gas. (Indeed, some suggest that LINER galaxies represent an evolutionary stage between quasars and ordinary galaxies.) Alternatively, some LINERs may instead be caused by intense star-formation activity in the nucleus (a "starburst"). M81 is thought to be in the former class (a LINER whose emission is associated with a central black hole), with its supermassive black hole estimated to contain perhaps 70 million solar masses. About one-third of all galaxies are LINERs. M81 is the namesake member of the M81 group of about 30 gravitationally bound galaxies that includes NGC 2403 (14° W), NGC 2976 (1° 23′ SW), IC 2574 (3° E), NGC 4236 (12° E), in addition to nearby M82/NGC 3034 and NGC 3077, with which M81 has had strong past interactions (see NGC 3077 and M82/NGC 3034). M81 has an optical diameter of about 90,000 light years and a mass roughly similar to the Milky Way. To date, 144 globular clusters have been identified in M81.

Fig. 2.81 Photo of M81 (*left*), M82 (*right*); 20×5 min exposures with Canon 60Da camera, ISO 1600, 200 mm Skywatcher f/5 Newtonian reflector with a Televue Paracorr coma corrector. (Copyright Blair MacDonald)

M82 (NGC 3034)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Barred spiral galaxy	09 h 55.9 m, +69° 41′	February 28
Distance	**Age**	**Apparent size**	**Magnitude**
13 million light years		11.2′ × 4.3′	8.6

This is the prototypical starburst galaxy (in which intense star formation is occurring in its central region). Indeed, about ten new stars are formed every year in the center of this galaxy (within a radius of about 0.5′ of this galaxy's center), which is several times the rate at which stars form in the entire Milky Way. Supernovae occur in this starburst region about once a decade (which is several times the rate for the entire Milky Way). These supernovae blow material out of the center of this galaxy in a superwind (moving at speeds up to more than 1,000 km/s) that forms two jets perpendicular to the plane of the galaxy. These jets (which pick up material on their way out, possibly by turbulent shear layer mixing and by evaporating nearby gas in the galaxy), are believed to be slamming into gas outside the galaxy's disk. This gas is thought to be left over from earlier gravitational interactions with nearby M81. Material in the superwind jets is thought to be moving faster than the escape velocity of the galaxy and so will become intergalactic material. M82 is part of the M81 group of gravitationally bound galaxies (see M81/NGC 3031) and is thought to have had strong interactions with M81 over the last several hundred million years that have triggered the starburst in M82. Associated with the bright star-forming regions, over 1,000 "super star clusters" are known in M82, containing several hundred thousand suns each. The optical diameter of M82 is about 40,000 light years and its mass is roughly 10 billion suns.

See Fig. 2.81

M83 (NGC 5236)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Hydra	Barred Spiral galaxy	13 h 37.0 m, −29° 52′	May 11
Distance	**Age**	**Apparent size**	**Magnitude**
15 million light years		12.9′ × 11.5′	7.5

This is a grand-design spiral, meaning that it has two symmetrically placed spiral arms that extend over most its visible disk in professional telescopic images. It is also a starburst galaxy (meaning it has intense star formation occurring – see M82/NGC 3034) with the star formation concentrated in a half-ringlet occupying the region 3″–7″ from the galaxy center that contains hundreds of star clusters. About 30 of these star clusters have masses of more than 20,000 suns and are less than 10 million years old. An extremely massive star cluster, with a mass of about 10 million suns, formed about 100 million years ago from a previous starburst and lies just a few arc seconds away from the kinematical center of this galaxy, giving the galaxy the appearance of a double nucleus in professional telescopes. M83 is part of a gravitationally bound group of galaxies that includes nearby NGC 5264 (1° E) and NGC 5253 (1° 53′ SSE), the latter having its closest approach to M83 1 or 2 billion years ago. M83 has an optical diameter of about 60,000 light years and is nearly face-on (with an inclination angle of 24° i.e., it rotates about an axis that is inclined from our line-of-sight by 24°). It contains more than 1,000 massive Wolf-Rayet stars (see NGC 2403 for an explanation).

Fig. 2.83 Photo of M83; 60 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M84 (NGC 4374)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 25.1 m, +12° 53′	April 23
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		6.5′ × 5.6′	9.2

This is part of the Virgo galaxy cluster (see M49/NGC 4472) and a physically close companion to M86. M84 lies at one end of the "Markarian Chain" of galaxies that lies along a "chain" NE of M84 and includes eight galaxies: M84 (NGC 4374), M86 (NGC 4406), NGC 4435, NGC 4438, NGC 4461, NGC 4458, NGC 4473 and NGC 4477. These galaxies are moving like a rigid chain thrown away from Earth at several hundred km/s with the chain tumbling so that the west side of the chain (M84) is actually moving toward us while the east side (NGC 4477) is moving doubly fast away from us. The nucleus of M84 is an AGN ("active galactic nucleus"), in which energetic emission is caused by accretion onto a massive central object, which for M84 is thought to be a black hole with a mass of around a billion suns. This AGN powers the two jets and associated lobes that are evident in the nuclear region (the inner few arc seconds) in professional telescopes at radio wavelengths, the radio waves being due to synchrotron emission of high-speed electrons gyrating wildly in a magnetic field. This galaxy contains about 1,800 globular clusters.

Fig. 2.84 Photo of M84 (*right*) with M86 (*middle right*) along with several dimmer galaxies that are also part of the Markarian Chain. 3×20 min luminance, 2×20 min green, 2×20 min blue exposures with SBIG ST-8XE camera, Takahashi FSQ 106 mm f/5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M85 (NGC 4382)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Elliptical galaxy	12 h 25.4 m, +18° 11′	April 23
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		7.1′×5.5′	9.1

M85 is at the northern edge of the Virgo galaxy cluster (see M49/NGC 4472) and is a close physical companion to NGC 4394 (7′ ENE). It is viewed nearly face-on and is unusual for an elliptical galaxy because it contains young stars (i.e., less than a few billion years old) in its inner regions, which may have arisen from a past merger with another galaxy or because of interaction with nearby NGC 4394. It is thought to have an eccentric stellar disk in its nucleus, which gives it the appearance of a double nucleus (with 0.25″ separation) in professional telescopes.

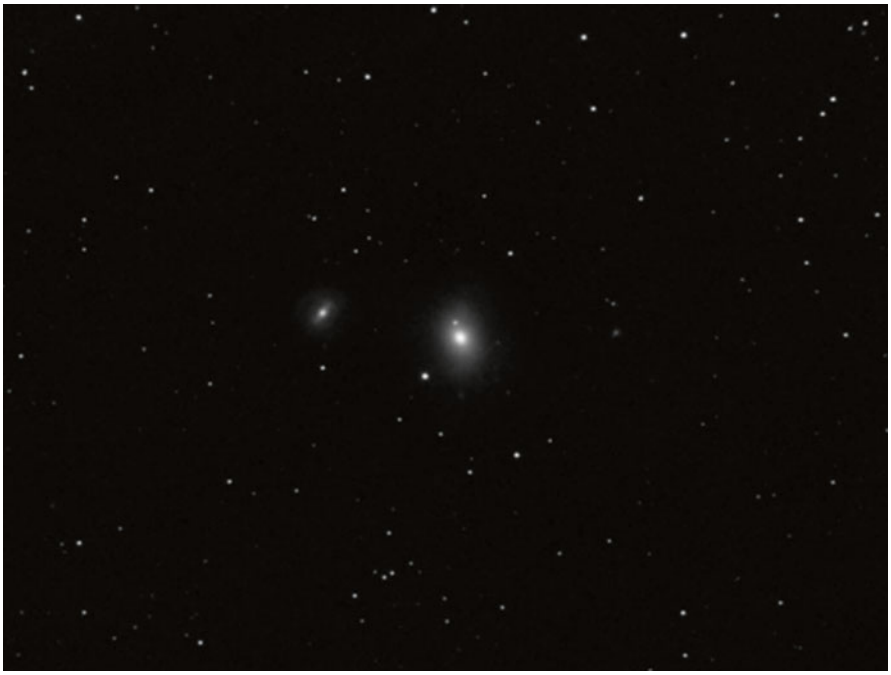

Fig. 2.85 Photo of M85 and the dimmer, nearby NGC 4394; 40 min exposure on hypered Kodak Tech Pan film, 8 f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M86 (NGC 4406)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 26.2 m, +12° 57′	April 23
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		8.9′ × 5.8′	8.9

It is part of the Virgo galaxy cluster (see M49/NGC 4472) and may anchor one of three subgroups in this cluster, the other two larger subgroups being associated with M87 (NGC 4486) and M49 (NGC 4472). Along with its close physical companion M84, it is part of the "Markarian Chain" of galaxies (see M84/NGC 4374). M86 is moving rapidly toward us compared to the rest of the Virgo cluster, resulting in M86 having a high speed (over 1,000 km/s) relative to the material between galaxies in the cluster (the "intracluster medium"). This galaxy's high-speed supersonic movement through the intracluster medium is thought to have caused gas to be stripped from the galaxy (so-called "ram-pressure stripping"), resulting in a tail of gas extending out from this galaxy more than a million light years and having a mass of about a billion suns. Professional telescopes have found several thousand globular clusters in this galaxy. It is thought to have undergone a collision with NGC 4438 (see NGC 4438) in the past.

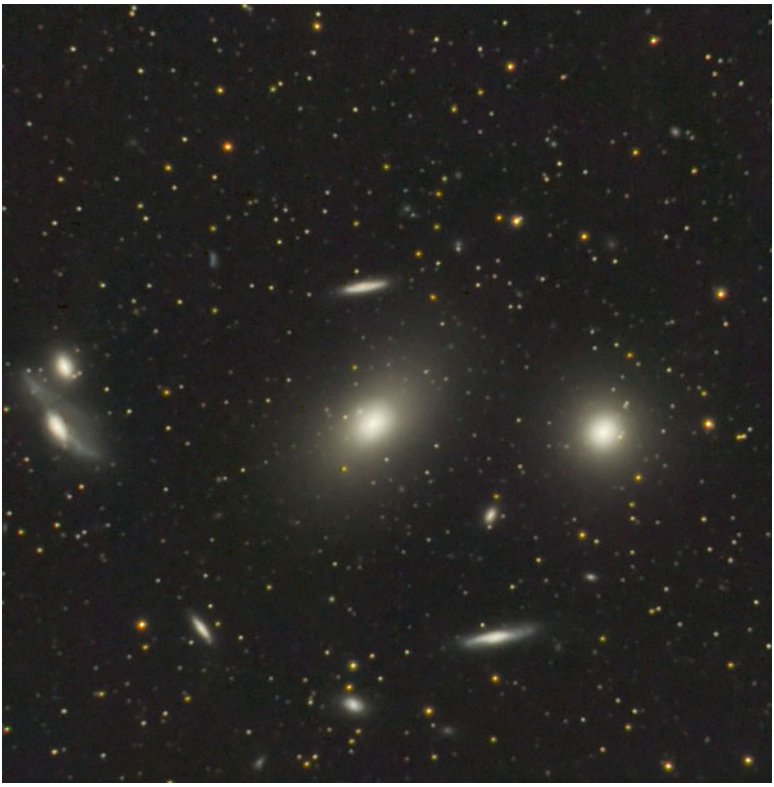

Fig. 2.86 Photo of M86 (*center*) with M84 (*left*) along with several dimmer galaxies that are also part of the Markarian Chain. 2×15 min red, green, and blue exposures with QSI540wsg camera, Skywatcher Equinox 120 mm f/7.5 telescope. North is up and east is to the left. (Copyright Dalton Wilson)

M87 (NGC 4486)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 30.8 m, +12° 23′	April 23
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		8.3′ × 6.6′	8.6

Lying near the center of the Virgo galaxy cluster (see M49/NGC 4472), this is a heavyweight in the world of galaxies. Its mass is several trillion solar masses (although more than 90 % of this is dark matter, with less than a trillion suns due to stellar mass). This is many hundreds of times more massive than the average galaxy. M87 lies at the heart of the largest of the two major subclusters within the Virgo cluster (the other being associated with M49/NGC 4472), while a third smaller clump may be associated with M86/NGC 4406. The M87 clump of the Virgo cluster has a mass of several hundred trillion suns. The center of M87 is thought to contain a supermassive black hole with a mass of several billion suns. This black hole is believed to be what drives the active galactic nucleus (in which energetic emission is caused by accretion onto the massive central black hole) that gives rise to the optically one-sided jet in M87. This jet is the major part of the radio source known as Virgo A, the radio waves being due to synchrotron emission of high-speed electrons gyrating wildly in a magnetic field. It extends for thousands of light years (its brightest parts extending out about 25″), with material in the jet traveling at significant fractions of the speed of light. M87 has one of the largest numbers of globular clusters of any galaxy, with more than perhaps 16,000 (compare to the Milky Way's 150 or so). The optical diameter of M87 is about 130,000 light years (which is more than twice the diameter of the average galaxy), but it extends out several times this distance in professional telescopic studies.

Fig. 2.87 Photo of M87; 60 min exposure on hypered Kodak Tech Pan, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M88 (NGC 4501)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Spiral galaxy	12 h 32.0 m, +14° 25′	April 24
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		6.8′ × 3.7′	9.4

M88 is part of the Virgo galaxy cluster (see M49/NGC 4472) and is a Seyfert galaxy (where a black hole in this galaxy's center, in this case with a mass of 80 billion suns, accumulates nearby gas, resulting in strong emission from the nucleus). It has an optical diameter of about 110,000 light years. The nucleus of this galaxy (within a radius of about 4″) has a different chemical makeup than the rest of the galaxy. The galaxy is a "flocculent" spiral, meaning that it lacks any obvious azimuthally symmetric spiral arm pattern (see NGC 3521). It is traveling through the Virgo cluster's intracluster medium, which causes "ram pressure" compression of its western side and removal of its atomic hydrogen gas.

Fig. 2.88 Photo of M88; 45 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M89 (NGC 4552)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Elliptical galaxy	12 h 35.7 m, +12° 33′	April 24
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		3.5′ × 3.5′	9.9

This is part of the Virgo galaxy cluster (see M49/NGC 4472). A supermassive object in this galaxy's center (thought to be a black hole with a mass of many hundreds of millions of suns) accumulates nearby gas resulting in emission from the nucleus as a LINER ("low-ionization nuclear emission region" – see M81/NGC 3031) galaxy. The galaxy's supersonic motion relative to the Virgo intracluster medium has resulted in ram pressure stripping of gas from this galaxy. A recent nuclear outburst, perhaps in the past couple million years, is thought to have produced a powerful shock wave that is causing X-ray emission in two ring-shaped regions within the center of this galaxy, with diameters of a few thousand light years. It contains 1,400 globular clusters within a radius of 10′ from its center. It has a complex structure of plumes, tails and shells in its outer regions that may be remnants from one or more past galaxy mergers or accretions.

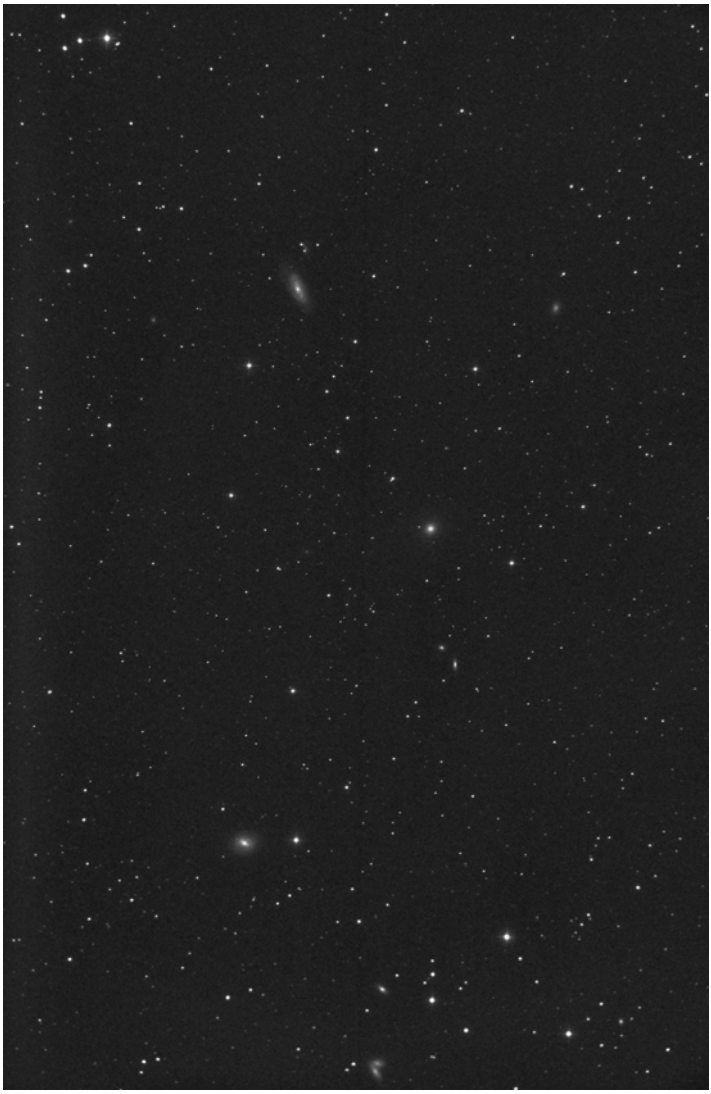

Fig. 2.89 Photo of M89 (*upper middle*), M90 (*middle right* and like a bright fuzzy star), M58 (*lower middle left*), as well as NGC 4567/4568 (*bottom middle* – see NGC 4567); 45 min exposure on hypered Kodak Tech Pan film, 6″ f/5.5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M90 (NGC 4569)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Barred spiral galaxy	12 h 36.8 m, +13° 10′	April 26
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		9.5′ × 4.4′	9.5

This is part of the Virgo cluster (see M49/NGC 4472). It is a LINER galaxy ("low-ionization nuclear emission region" – see M81/NGC 3031), but its nuclear emission is thought to be dominated by intense star formation and supernovae (i.e., a starburst, see M82/NGC 3034), rather than by accretion onto a central black hole. About two new stars form every year in this galaxy (about the same as form yearly in the Milky Way). The galaxy rotates about an axis that is inclined to our line-of-sight by about 64° with the western edge of the galaxy closest to us. Although the galaxy IC 3583 (6′ NNW) is nearby in the sky and is also a Virgo cluster member, the two are not thought to be interacting strongly. Because of M90's high speed relative to the Virgo cluster (over 1,000 km/s, which is locally supersonic), it is thought to have lost 90 % of its atomic hydrogen (HI) gas to "ram-pressure stripping" (see M91/NGC 4548) that peaked about 300 million years ago.

See Fig. 2.89.

M91 (NGC 4548)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Barred spiral galaxy	12 h 35.4 m, +14° 30′	April 24
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		5.2′ × 4.2′	10.1

This galaxy is part of the M87 clump of the Virgo galaxy cluster (see M49/NGC 4472). It is a LINER galaxy (see M81/NGC 3031). Like many spirals in galaxy clusters, this galaxy has much less atomic hydrogen gas than average for spirals in general. This is thought to be caused by stripping of this gas (so-called "ram-pressure stripping") from the galaxy due to the galaxy's motion relative to the material between galaxies in the cluster (the "intracluster medium"). Most of this galaxy rotates at about 250 km/s about an axis inclined to our line-of-sight by about 35°. It has a low star formation rate for a spiral galaxy. Stars in its nucleus have much higher "metal" content, meaning they are abundant in elements heavier than hydrogen and helium, than the rest of this galaxy.

Fig. 2.91 Photo of M91 (*upper middle*) and NGC 4571 (*lower left*); 50 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M92 (NGC 6341)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Hercules	Globular cluster	17 h 17.1 m +43° 08′	July 6
Distance	**Age**	**Apparent size**	**Magnitude**
27,000 light years	10–14 billion years	12′	6.4

This is one of the oldest globular clusters known and is the second most metal-poor Milky Way globular cluster, after M15/NGC 7078. It has a mass of about 200,000–300,000 suns. Its size of 12′ corresponds to a diameter of about 100 light years. It orbits the galaxy on a path that is somewhat inclined to the disk (by a little more than 20°) that takes it a maximum of about 25,000 light years away from the galactic central plane, traveling between typically a few thousand and 40,000 light years from the galactic center. It completes one revolution around the galaxy about once every 200 million years.

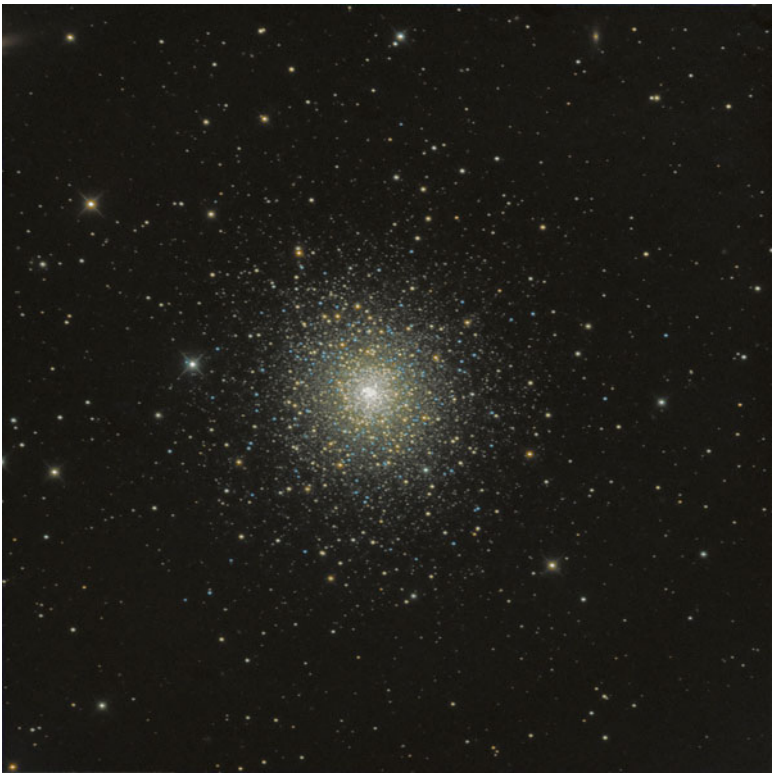

Fig. 2.92 Photo of M92; 6×10 min luminance, red, green, blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M93 (NGC 2447)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Puppis	Open cluster	07 h 44.5 m, −23° 51′	January 26
Distance	**Age**	**Apparent size**	**Magnitude**
3,000 light years	400 million years	10′	6.2
This lies just above the galactic central plane (by a few light years) a couple of thousand light years farther from the galactic center than we are. It has a diameter of about 10 light years and a mass of about 700 suns.			

Fig. 2.93 Photo of M93; 8.5 min exposure on 120 format Ektachrome 200 film, 6″ f/4.5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M94 (NGC 4736)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Canes Venatici	Barred spiral galaxy	12 h 50.9 m, +41° 07′	April 29
Distance	**Age**	**Apparent size**	**Magnitude**
15 million light years		14.4′ × 12.1′	8.1

This has a mass of perhaps 30–40 billion suns, an optical diameter of about 70,000 light years, and contains a central black hole with a mass of about 7 million suns. Professional telescopes find M94 has an inner ring (between 35″ and 48″ in radius) that is undergoing intense star formation (i.e., it is a "starburst" ring) and is the result of ring-bar dynamics. Star formation is also occurring in its outer disk. About one new star is formed every year in M94. Most of the galaxy rotates at approximately 150 km/s about an axis inclined to our line-of-sight by about 40°. M94 is a LINER galaxy (see M81/NGC 3031) and is part of the M94 group (also called the Canes Venatici I galaxy group) of perhaps 40 gravitationally associated galaxies. A counter-rotating component found in this galaxy may be the result of a past merger event.

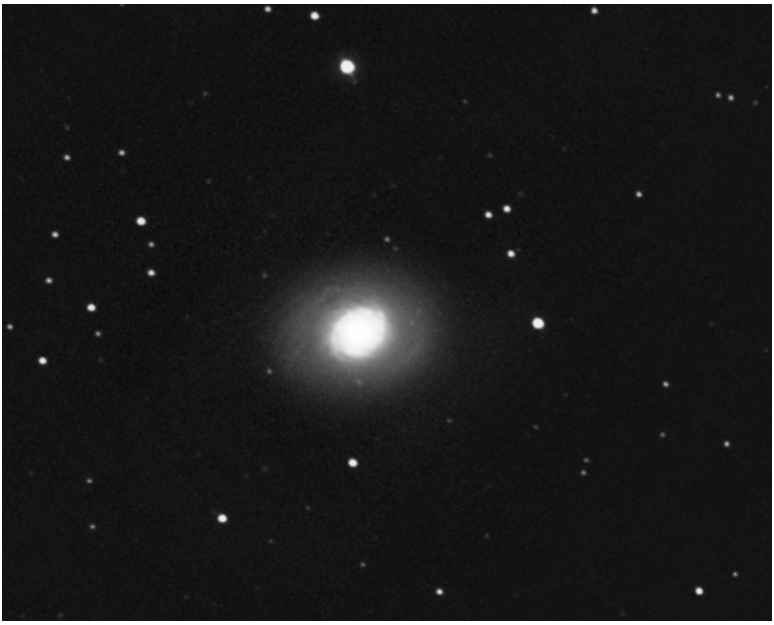

Fig. 2.94 Photo of M94; 30 min exposure, 16″ f/4.5 telescope. North is up and east is to the left. (Copyright John Mirtle)

M95 (NGC 3351)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Leo	Barred spiral galaxy	10 h 44.0 m, +11° 42′	March 27
Distance	**Age**	**Apparent size**	**Magnitude**
35 million light years		7.4′ × 5.0′	9.8

This is part of the M96 (NGC 3368) galaxy group – see M96/NGC 3368. It is a nuclear starburst galaxy. Indeed, professional telescopes find that M95 has an inner ring (7″ in radius) containing ionized hydrogen (HII) star-forming regions each with millions of suns divided among several clusters and being the result of orbital resonant interactions with this galaxy's bar, which itself is about 1.6′ long. M95 has an optical diameter of about 80,000 light years.

Fig. 2.95 Photo of M95 (*left*) and M96 (*right*); 30 min exposure, 16″ f/4.5 telescope. (Copyright John Mirtle)

M96 (NGC 3368)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Leo	Barred spiral galaxy	10 h 46.8 m, +11° 49′	March 28
Distance	**Age**	**Apparent size**	**Magnitude**
35 million light years		7.8′ × 5.2′	9.3

The nucleus of this galaxy harbors a black hole with a mass of about 7.5 million suns, and a nuclear bar with a radius of 5″. It is thought to also have a separate outer bar with length of 1′, as well as an inner disk with a diameter of about 0.5′. It is the namesake member of the M96 (NGC 3368) group of about a dozen galaxies that includes NGC 3299, NGC 3351 (M95), NGC 3377 (see NGC 3377), M105 (NGC 3379), NGC 3384 (see NGC 3384), NGC 3412 (see NGC 3412), and NGC 3489 (see NGC 3489). This group is part of the larger Leo I group that includes M65 and M66. M96 has an optical diameter of about 80,000 light years and is a LINER galaxy (see M81/NGC 3031).

See Fig. 2.95

M97 (NGC 3587)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Planetary nebula	11 h 14.8 m, +55° 01′	April 4
Distance	**Age**	**Apparent size**	**Magnitude**
2,000 light years		3.8′	9.9

This is nicknamed the "Owl Nebula" because it resembles two owl's eyes in a round disk when viewed at high power in large amateur telescopes. The nebula is expanding at a few tens of km/s and has a mass of perhaps a couple tenths that of our Sun (not including the central star, whose mass is about two-thirds that of the Sun and is a challenging object in amateur telescopes). In professional telescopic studies the three-dimensional structure of this nebula is complex, although the "owl's eyes" are thought to be a bipolar ("hourglass") cavity (inclined from our line-of-sight by about 30°) that is inside three separate elliptical shells. The inner shell of the three gives rise to the round outer shape visible in amateur telescopes.

Fig. 2.97 Photo of M97 (*upper left*) and M108 (*lower right*); 24 × 10 min luminance, 13 × 10 min red, 4 × 10 min green and blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the right. (Copyright Stuart Heggie)

M98 (NGC 4192)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Barred spiral galaxy	12 h 13.8 m, +14° 54′	April 20
Distance	**Age**	**Apparent size**	**Magnitude**
50 million light years		9.8′ × 2.8′	10.1

M98 is part of the Virgo galaxy cluster (see M49/NGC 4472), near its western edge and thought to be lying toward the front of this cluster. It has a mass of about 200 billion suns and an optical diameter of about 150,000 light years. It is nearly edge-on (with its axis of rotation inclined by about 80° from our line-of-sight). It has emission from its nucleus (perhaps from a LINER that is powered by both a star-burst and accretion onto a massive central object – see M81/NGC 3031).

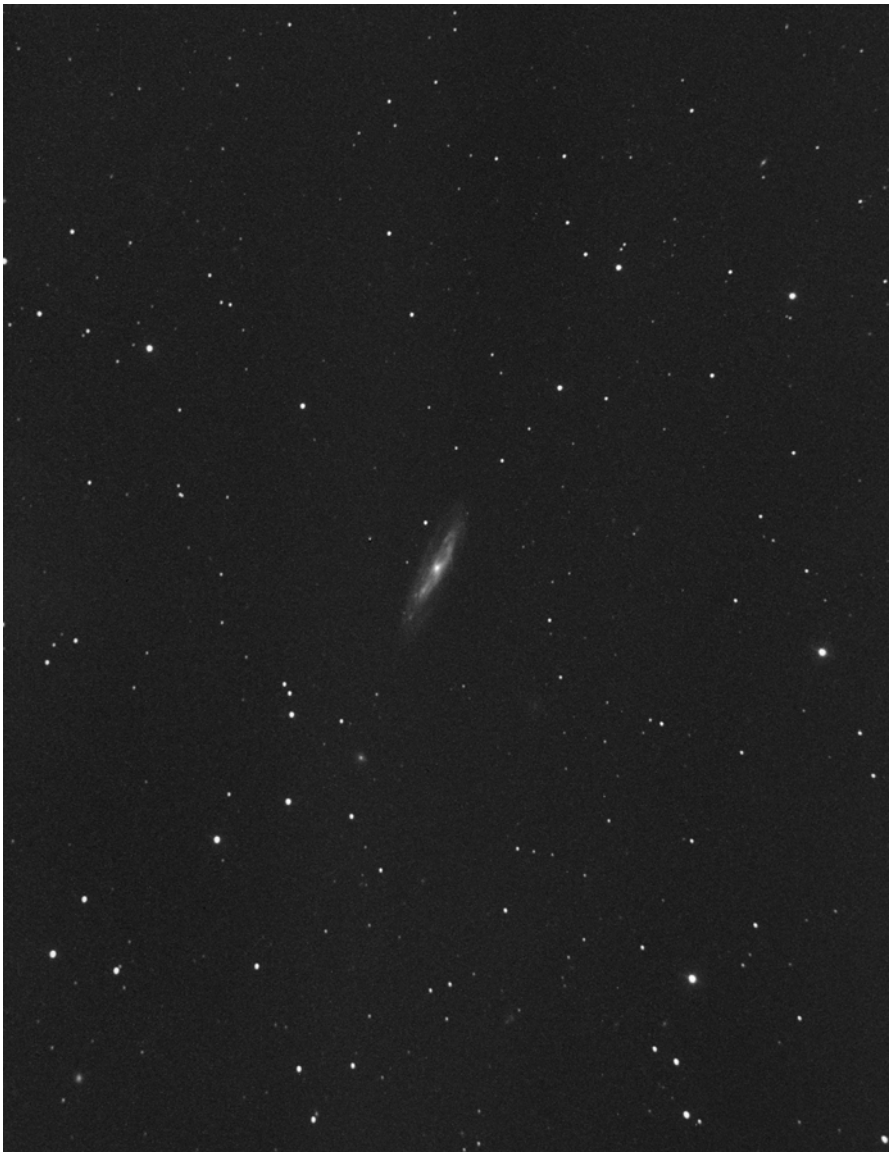

Fig. 2.98 Photo of M98; 60 min exposure on hypered Kodak Tech Pan film, 8″ f/6 telescope. North is up and east is to the left. (Copyright John Mirtle)

M99 (NGC 4254)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Spiral galaxy	12 h 18.8 m, +14° 25′	April 21
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		5.3′ × 4.6′	9.7

This is one of several galaxies whose nickname is the "Pinwheel Galaxy" (due to its multiple spiral arms evident in professional telescopic images). It is part of the Virgo galaxy cluster (see M49/NGC 4472) and may be a new entry to this cluster. It has a mass of a little under 200 billion suns and an optical diameter of about 90,000 light years. Vigorous star formation is occurring throughout this galaxy. In professional telescopes, one of this galaxy's spiral arms is much more pronounced, possibly caused by a close encounter with a massive galaxy, perhaps NGC 4162 (0.5° NNE, spiral galaxy, mag. 12.0), a few hundred million years ago. A huge cloud of neutral hydrogen (HI) with a mass of about 200 million suns lies about half a million light years from NGC 4254 and has been hypothesized to be tidal debris from a previous high velocity encounter with M98 (see NGC 4192/M98) a little less than a billion years ago.

Fig. 2.99 Photo of M99; 18 × 1 min exposures with Canon Rebel XT 350D camera, ISO 1600, 300 mm f/5 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M100 (NGC 4321)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Barred spiral galaxy	12 h 22.9 m, +15° 49′	April 22
Distance	**Age**	**Apparent size**	**Magnitude**
55 million light years		7.5′ × 6.1′	9.3

This is part of the Virgo galaxy cluster (see M49/NGC 4472), being the brightest and largest spiral galaxy in the Virgo cluster. It is a "grand-design spiral," meaning that it has two symmetrically placed spiral arms that extend over most of its visible disk in professional telescopic images. Resonance associated with the bar and the "Lindblad resonances" (where the speed of density waves resonantly amplifies oscillations in the orbits of matter in the disk) are thought to be triggering a ring of star formation (a "starburst") in the central region of M100. This ring has a radius of 7.5″–20″ and its stars vary in age progressively around the ring from less than 10 million years old to several hundred million years old, formed in a succession of a few intense periodic star formation episodes. M100 has a mass of about 200 billion suns and an optical diameter of about 120,000 light years.

Fig. 2.100 Photo of M100 from a light polluted urban site; 12 × 5 min exposures, Canon 350D camera, ISO 200, Meade Schmidt Newtonian 8″ f/4 telescope. North is up and east is to the left. (Copyright Blair MacDonald)

M101 (NGC 5457)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Spiral galaxy	14 h 03.2 m, +54° 21′	May 17
Distance	**Age**	**Apparent size**	**Magnitude**
20–25 million light years		28.8′ × 26.9′	7.5

This galaxy is nearly face-on. It has a diameter of almost 200,000 light years. Many ionized hydrogen (HII) star-forming regions are present in M101, some of which can be seen as bright knots in amateur telescopes. Several of these knots have their own NGC numbers, e.g. NGC 5461, 5462, 5471, the latter of which is a hundred times larger and brighter than any HII region in our galaxy. Some of these supersized HII regions have masses of tens of millions of suns (e.g., NGC 5461 and 5471), and although they appear as a single knot in amateur telescopes, they are made up of many individual giant molecular clouds (GMCs) that have masses of several hundred thousands of suns (similar to the masses of GMCs in our galaxy). M101 is the namesake member of the M101 group of gravitationally bound galaxies that includes NGC 5474 (44′ SSE), NGC 5585 (3° 21′ NE), NGC 5204 (6° NW), NGC 5477 (22′ ENE) and Holmberg IV (UGC 8837, 1° 19′ WSW). Tidal interactions with several group members in the past few hundred million years (perhaps including NGC 5477, NGC 5474 and Holmberg IV) are thought to have distorted M101. These interactions may have induced the formation of some of the HII regions, e.g., NGC 5471.

Fig. 2.101 Photo of M101; 34×10 min luminance, 5×10 min red, 8×10 min green and blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. North is to the left. (Copyright Stuart Heggie)

M102 (NGC 5866)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Draco	Lenticular galaxy	15 h 06.5 m, +55° 46′	June 2
Distance	**Age**	**Apparent size**	**Magnitude**
40 million light years		6.5′ × 3.1′	9.9

This is a lenticular galaxy (given the label S0 in classification schemes), meaning it has a disk and central bulge like a spiral galaxy but lacks the spiral arms. Lenticulars usually contain very little gas, dust or young stars, consisting almost entirely of old stars. It contains about 340 globular clusters. This galaxy is sometimes called the "Spindle Galaxy," although NGC 3115 also has this nickname. It is nearly edge-on (inclination angle of 86°, meaning it rotates about an axis that is inclined at 86° from our line-of-sight) with about 60 % of its light coming from its bulge and 40 % from its disk. It has an optical diameter of 80,000 light years (the diameter of our galaxy is about 100,000 light years). It is the namesake member of the NGC 5866 group of perhaps five galaxies that includes nearby NGC 5907 and NGC 5879, which are within several million light years of NGC 5866. Messier's original M102 is believed to be a duplicate entry of M101 (NGC 5457) rather than being NGC 5866, but in order to have 110 different objects in the Messier list, many amateur astronomers informally attach the label M102 to NGC 5866.

Fig. 2.102 Photo of M102; 3 × 2 min exposures with Canon XT 350D camera, ISO 1600, 300 mm f/5 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M103 (NGC 581)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Cassiopeia	Open cluster	01 h 33.4 m, +60° 39′	October 24 (Standard Time)
Distance	**Age**	**Apparent size**	**Magnitude**
7,000 light years	20 million years	6.0′	7.4

Of 228 stars with magnitude 14.5 and brighter that have been examined in professional telescopic studies in the cluster region, 77 are known to be actual cluster members, the rest being field stars (see M39/NGC 7092 for further discussion). The brightest star in the cluster region (a double star, Struve 131, mag. 7.3 and 10.5 with separation 13.8″ along a SE-NW direction) is not a cluster member but is a field star (in the foreground). M103's size of 6′ corresponds to a diameter of about 15 light years.

Fig. 2.103 Photo of M103; 20×30 s exposures with Canon XT 350D camera, ISO 1600, 200 mm f/6 telescope. North is up and east is to the left. (Copyright Tenho Tuomi)

M104 (NGC 4594)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Virgo	Spiral galaxy	12 h 40.0 m, −11° 37′	April 25
Distance	**Age**	**Apparent size**	**Magnitude**
30 million light years		8.6′ × 4.2′	8.3

This is nicknamed the "Sombrero Galaxy." Its well-known dust lane, which actually has a ring shape (like Saturn's rings), contains a mass of about 16 million suns of dust grains that are submicron in size. The dust lane may owe its existence to the gravitational interaction of a now-defunct bar with the interstellar medium. The disk in this galaxy is about a quarter as massive as this galaxy's large spheroidal bulge (whereas in our galaxy the disk has a mass of about seven times that of the bulge). This galaxy has a stellar mass of about a quarter of a trillion suns. It harbors a central black hole with a mass of many hundreds of millions of suns, onto which a few percent of a solar mass is accreted every year. It is a LINER (see M81/NGC 3031) galaxy, is nearly edge-on (inclination angle of 84°) and contains nearly 2,000 globular clusters. An ultra-compact dwarf galaxy similar to a globular cluster, but with a mass of about 30 million suns, orbits M104.

Fig. 2.104 Photo of M104; 10×3 min exposures with Canon EOS 350D camera, ISO 800, Meade Schmidt Newtonian 8″ f/4 telescope. North is up and east is to the left. (Copyright Blair MacDonald)

M105 (NGC 3379)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Leo	Elliptical galaxy	10 h 47.8 m, +12° 35′	March 28
Distance	**Age**	**Apparent size**	**Magnitude**
35 million light years		5.3′ × 4.8′	9.5

This is part of the M96 (NGC 3368) group of galaxies (see M96/NGC 3368). It has a stellar mass of about 100 billion suns, but its total mass including dark matter is about ten times this value. Its nucleus contains a supermassive black hole with a mass of perhaps as much as 400 million suns. Nearly 300 globular clusters are thought to orbit this galaxy, which is about twice as many as the Milky Way. NGC 3384 is nearby (see NGC 3384), as is the dimmer NGC 3389 (spiral galaxy, 10′ ESE, mag. 11.8, with a mass similar to M105). However, NGC 3389 is actually a background object and is instead about twice as far away and part of the NGC 3338 group of galaxies that includes NGC 3338, NGC 3389 and NGC 3346.

Fig. 2.105 Photo of M105 (*right*) and its companion NGC 3384 (*middle* – see NGC 3384), along with the background galaxy NGC 3389 (*below* and *left*); 4×15 min red, green, and blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M106 (NGC 4258)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Coma Berenices	Barred spiral galaxy	12 h 19.0 m, +47° 18′	April 20
Distance	**Age**	**Apparent size**	**Magnitude**
25 million light years		18.6′ × 7.2′	8.3

This is a Seyfert galaxy (see NGC 3227) and is thought to harbor a central black hole with a mass of about 40 million suns that is accreting much less than one solar mass per year. This galaxy has bipolar nuclear jets, driven by the central black hole. These jets are thought to emanate from the nucleus at about a 30° angle from the plane of the disk and interact with material in the disk that appear as "anomalous arms" in professional telescopic studies. The nucleus of this galaxy also contains water masers (see NGC 3079) contained in a thin warped disk with diameter of only 10 light years. This galaxy has an optical diameter of about 130,000 light years. It is at the north end of the NGC 4258 (M106) group of about 15 gravitationally bound galaxies that includes NGC 4144 (1° 45′ WSW), NGC 4242 (1° 42′ S), NGC 4460 (3° SE), NGC 4490 (6° SSE – see NGC 4490), NGC 4485 (6° SSE – see NGC 4485), NGC 4618 (7° SE – see NGC 4618), NGC 4625 (7° SE) and possibly NGC 4248 (14′ WNW).

Fig. 2.106 Photo of M106; 9 × 10 min luminance, 3 × 10 min red, green and blue exposures with Apogee U16M camera, Astrophysics 155 EDF 4″ f/7 telescope on Paramount ME mount. Several other moderately dim galaxies can also be seen in the photo, including NGC 4217 (*lower right*), NGC 4346 (*lower left*), and NGC 4220 (*far upper right*) which are all mag. 11.3. The dimmer NGC 4238 (mag. 12.4) is at 2 o'clock to M106 and just to the *right* of that is the very dim NGC 4232 (mag. 13.7) with star-like NGC 4231 (mag. 13.6) *right above* it. North is up. (Copyright Stuart Heggie)

M107 (NGC 6171)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ophiuchus	Globular cluster	16 h 32.5 m, −13° 03′	June 23
Distance	**Age**	**Apparent size**	**Magnitude**
20,000 light years	10–14 billion years	13′	7.8

This has a mass of about 100,000 suns and a diameter of about 80 light years. It is a bulge cluster (i.e., it orbits in the central ball-like bulge of our galaxy) with a period of about 100 million years. Its orbital path is inclined by about 45° to the galactic disk and is a very flattened ellipse. It was not noted by Messier, but instead is a recent (1947) addition to the Messier catalog suggested by H. S. Hogg.

Fig. 2.107 Photo of M107. North is up and east is to the left. 23×30 s exposures with Canon XT 350D camera, ISO 1600, 200 mm f/6 telescope. (Copyright Tenho Tuomi)

M108 (NGC 3556)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Spiral galaxy	11 h 11.5 m, +55° 40′	April 3
Distance	**Age**	**Apparent size**	**Magnitude**
40 million light years		8.6′ × 2.4′	9.9

Professional telescopic studies find that this galaxy has two giant loops of atomic hydrogen gas, one at the east and one at the west end. These loops have diameters of 10,000–20,000 light years, have masses around 50 million suns and are expanding outward but parallel to the disk of the galaxy at 40–50 km/s. They are thought to have originated about 50 million years ago. The loops may be the result of the rapid expansion of material shot outward from an active galactic nucleus, with the jets "flaring" into shells as they reach the less dense outer regions of the galaxy. The nuclear activity has since largely subsided. The galaxy is nearly edge-on (having an inclination angle of about 75°, meaning that it rotates about an axis inclined at 75° from our line-of-sight) and has an optical diameter of about 100,000 light years. It is thought to have nearly 300 globular clusters. Its stellar mass is estimated to be a little over 100 billion suns, and its nucleus harbors a supermassive black hole with a mass of 20–30 million suns.

Fig. 2.108 Photo of M108; 5 × 10 min luminance, 5 × 20 min red, green, and blue exposures with QSI540wsg camera, Astro-Tech 10″ f/8 Ritchey-Chrétien telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M109 (NGC 3992)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Ursa Major	Barred spiral galaxy	11 h 57.6 m, +55° 22′	April 15
Distance	**Age**	**Apparent size**	**Magnitude**
70 million light years		7.5′ × 4.4′	9.8

This has a mass of about 250 billion suns and a diameter of about 130,000 light years. It is part of the Ursa Major galaxy cluster which contains nearly 300 galaxies, one of only three major galaxy clusters within 150 million light years of us (the others being the Virgo cluster and the Fornax cluster). The Ursa Major cluster contains about 1/30 the mass of the Virgo cluster and is part of the Virgo supercluster (see see M49/NGC 4472). The Ursa Major cluster is an unusual cluster in that it consists almost entirely of late-type galaxies (e.g., Sc and SBc and later galaxies in Hubble's galaxy classification scheme; Sc and SBc spirals are "late-type" spirals that have prominent, loosely wound spiral arms and only a very small central bulge relative to an extended disk). In contrast, most galaxy clusters consist of "early-type" galaxies (i.e., elliptical and lenticular, and early-type spirals, the latter having relatively tightly wound spiral arms and a large central bulge). Indeed, three-quarters of the Virgo cluster galaxies are early-type. M109 is the namesake member of the M109/NGC 3992 galaxy group of about 30 gravitationally bound galaxies that is a subgroup of the Ursa Major cluster.

Fig. 2.109 Photo of M109; 4 × 10 min red, green, and blue exposures with QSI540wsg camera, Celestron 14″ C14 telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

M110 (NGC 205)

Constellation	Object type	RA, Dec	Approx. transit date at local midnight
Andromeda	Elliptical galaxy	00 h 40.4 m, +41° 41′	October 26
Distance	**Age**	**Apparent size**	**Magnitude**
2.6 million light years		20′ × 12′	7.9

This is a dwarf galaxy about 15,000 light years in optical diameter, and having a mass of perhaps 100 million suns. It is in our Local Group and close to M31. The mass of interstellar gas in this galaxy, a million suns' worth, is restricted essentially to its inner 1′ diameter core and is much less than expected theoretically. The galaxy underwent a burst of star formation for a few hundred million years, ending less than a hundred million years ago, which created the young blue star cluster with mass of a few hundred thousand suns that professional telescopes find in its 1′ diameter central region.

Fig. 2.110 Photo of M110; 3×12 min luminance, red, green and blue exposures, with QSI540wsg camera, Celestron 14″ C14 telescope on Celestron CGE Pro mount. North is up and east is to the left. (Copyright Dalton Wilson)

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