Sky Maps and Constellations for Astronomy 110

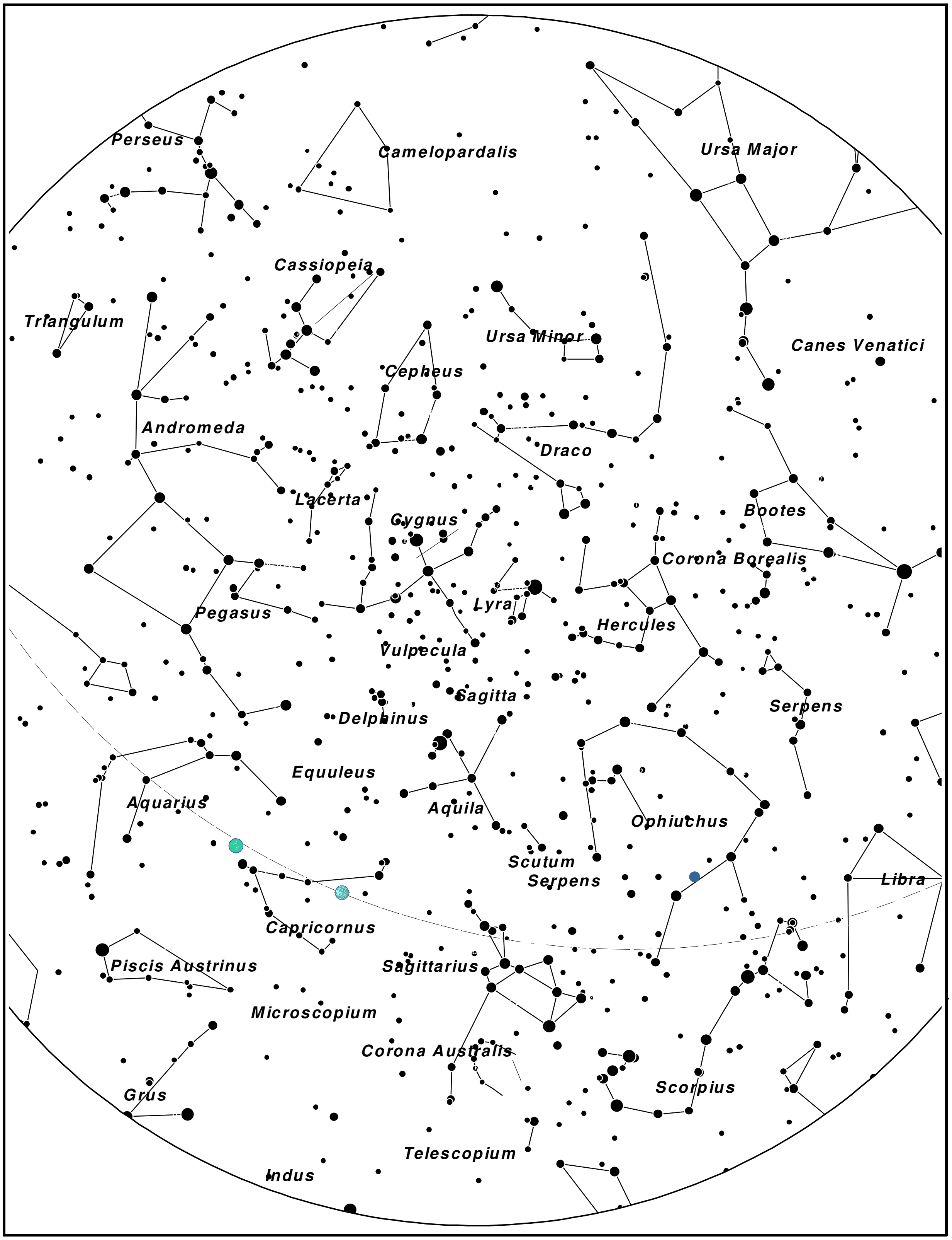
The following pages present star charts for the main months that NMSU is in session. For each of these months (September through May) there is a "all-sky" map showing the stars and constellations that are above the horizon as seen in Las Cruces at about 9 pm local time that month. In these maps, north is at the top of the page, and east is to the left. So, if you lay down on the grass, with your feet pointing towards the south, the star chart can be held above you, and you should be able to identify the major stars of each constellation.

Following each of the all-sky maps we highlight one of the major constellations found on that star chart. Here you will find a discussion of the constellation's mythology, as well as information about some of the stars or interesting objects located within this constellation. You should be able to view some of the brighter of these objects at the Campus Observtory.

We have compiled this document with information from three primary sources. The most authoritative source for the mythology of the constellations and for the origin of the various names that have been assigned to stars within those constellations is R. H. Allen's *Star Names and Their Meanings* (G. E. Stechert:NY 1899). A more readable account of constellation mythology can be found in J. D. W. Staal's book *The New Patterns in the Sky* (McDonald & Woodward Publishing Co.:Blacksburg, VA 1988). The final source for much of the information used in the following is *Burnham's Celestial Handbook* by R. Burnham Jr. (Dover:NY 1978). It has an exhaustive survey of just about all of the interesting objects that can be found in each of the various constellations. The star charts themselves have been produced using "TheSky" astronomy software by SoftwareBisque. There are numerous sources of information on the worldwide web. One of the best places to view the romantic interpretations of the constellations, however, is that dedicated to Johann Hevelius's *Uranographia* (http://albinoni.brera.unimi.it/HEAVENS/ATLAS/hevelius.html).

The Greek Alphabet					
Alpha	α	Iota	ι	Rho	ρ
Beta	β	Kappa	κ	Sigma	σ
Gamma	γ	Lambda	λ	Tau	τ
Delta	δ	Mu	μ	Upsilon	υ
Epsilon	ϵ	Nu	ν	Phi	ϕ
Zeta	ζ	Xi	ξ	Chi	χ
Eta	η	Omicron	o	Psi	ψ
Theta	θ	Pi	π	Omega	ω

Figure 1: The Sky Map for September



Constellation Highlight for September: Cygnus

Near the center of the sky map on the preceding page (Figure 1) can be found the constellation Cygnus, the "Swan". Early in the evening during September, Cygnus is almost directly overhead for residents of Las Cruces. Cygnus is also commonly known as the "Northern Cross", a figure that can be constructed by drawing lines connecting the five brightest stars in the constellation ($\alpha, \gamma, \beta, \epsilon$, and δ). A close-up view of the constellation Cygnus can be found on the next page (Figure 2), where the brightest stars are labeled with their names, and/or with their Greek letters.

Swans occur throughout the Greek myths, and were an animal form often assumed by one of the principal gods to seduce some attractive nymph, or desirable queen. Zeus, for example, felt he had a better chance with Leda (the King of Sparta's wife) if he assumed the form of a swan. So he briefly turned himself into a swan, and visited Leda on her wedding night. The result was Pollux, half-brother/twin of Castor (see the March constellation highlight).

The exact origin of the swan that is commemorated as Cygnus is not precisely known. It may be Cycnus, son of Poseidon (god of the seas, and a brother of Zeus). At birth, Cycnus had been left on the seashore to die. However, a swan took pity and flew down to care for the newborn. Cycnus went on to become the king of Colonae, a city north of Troy. But Cycnus was not an exceptionally good king. He set his own children adrift out to sea when he found out that his new wife had fallen in love with one of his sons (Tenes). He then killed his wife when she lied to him about their relationship. Cycnus defended Troy during the onslaught led by Achilles. In their individual struggle, however, Achilles proved much too strong, and he choked Cycnus to death. Poseidon grieved for his departed son and turned him into a swan.

Despite the myths, the constellation was known simply as "Ornis" (the Bird) to the Greeks. It was the Romans who named it Cygnus and who adopted the Greek myths to explain its name. The Arabs saw the constellation as a hen.

Alpha (α) Cygni, is the brightest star in the constellation Cygnus, and is known as "Deneb", which is derived from the Arabic word for "the hen's tail". Deneb is an extremely luminous *supergiant* star having about 50,000$\times$ the luminosity of the sun.

Beta (β) Cygni is known as Alberio. The origin of the name is obscure. Alberio, however, is well known to amateur astronomers due to the fact that it is a *double star*–two stars that are very close to each other in the sky (note the that the star has two names plotted: β_1 and β_2). There are many double stars in the sky, but few of them have the large color contrast of Alberio. The brighter of the two stars is yellow/orange (the star has a temperature of about 4200 K), while the fainter one is a hot blue star (temperature of 11,300 K). Alberio is an excellent target for small telescopes.

"The North American Nebula". Just to the east (left) of Deneb on our star chart is plotted an irregular black shape. This, and the other such features on our map, delineate regions of glowing hydrogen gas. As can be seen in Figure 3 on the picture on the page following the star chart for Cygnus, this particular region of glowing gas happens to bear some resemblance to the North American continent.

Figure 2: The Constellation Cygnus

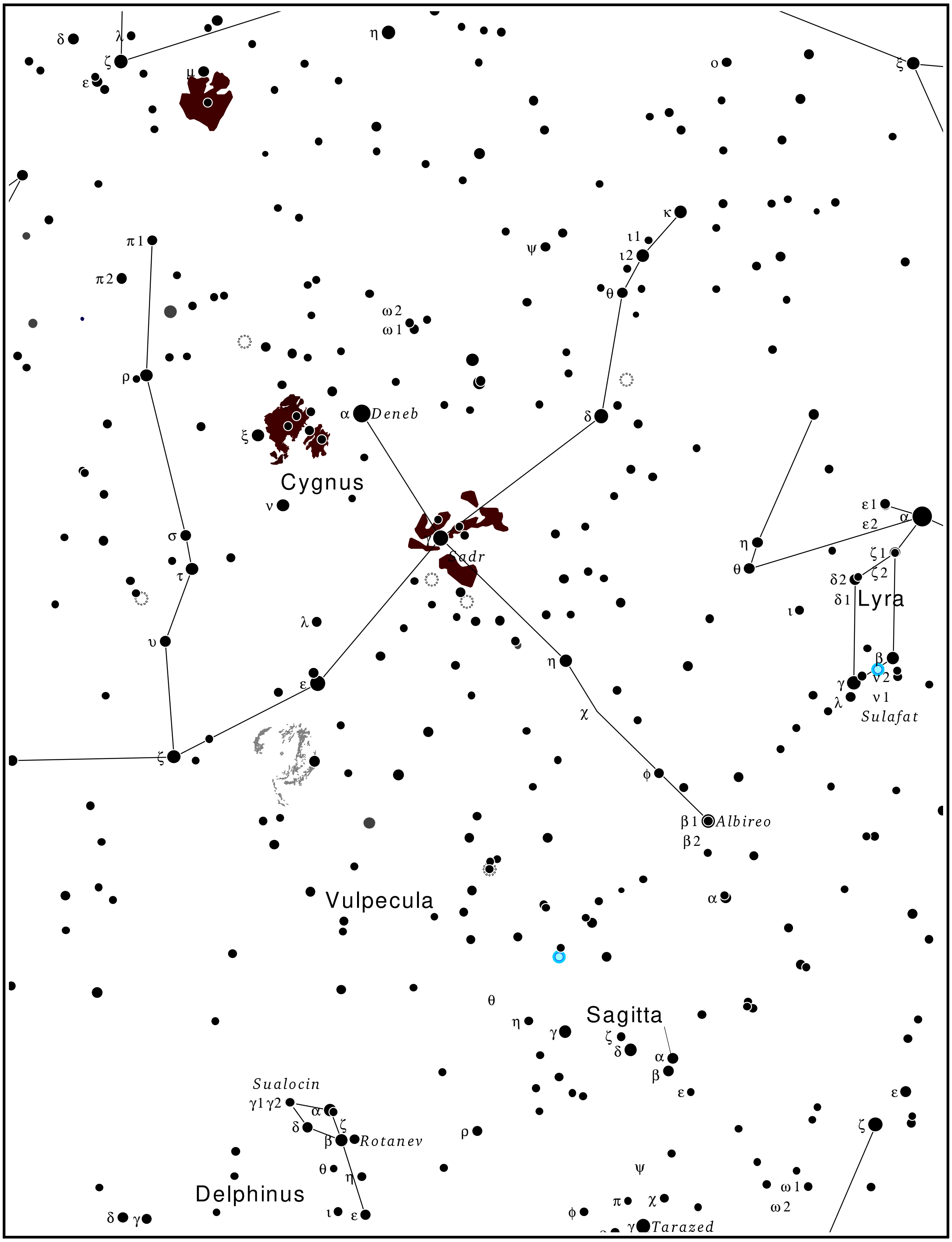
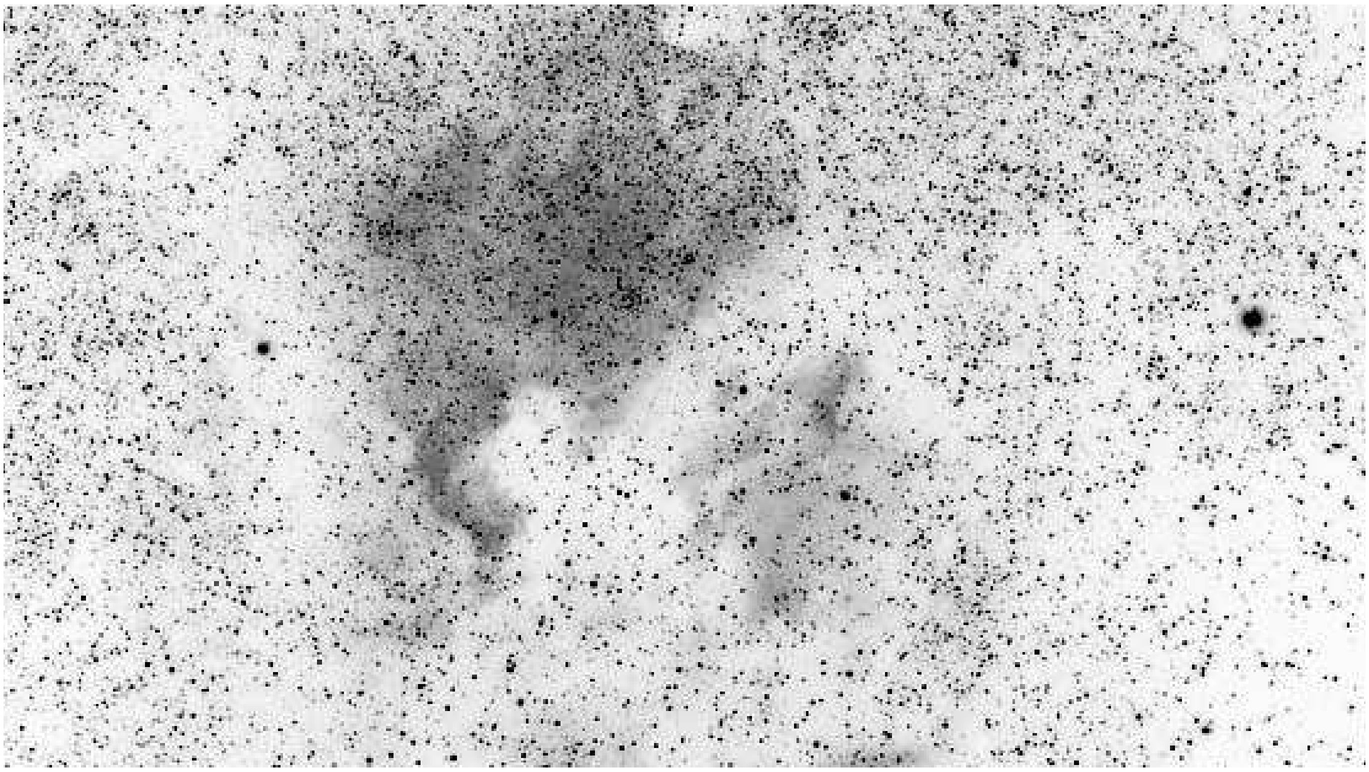
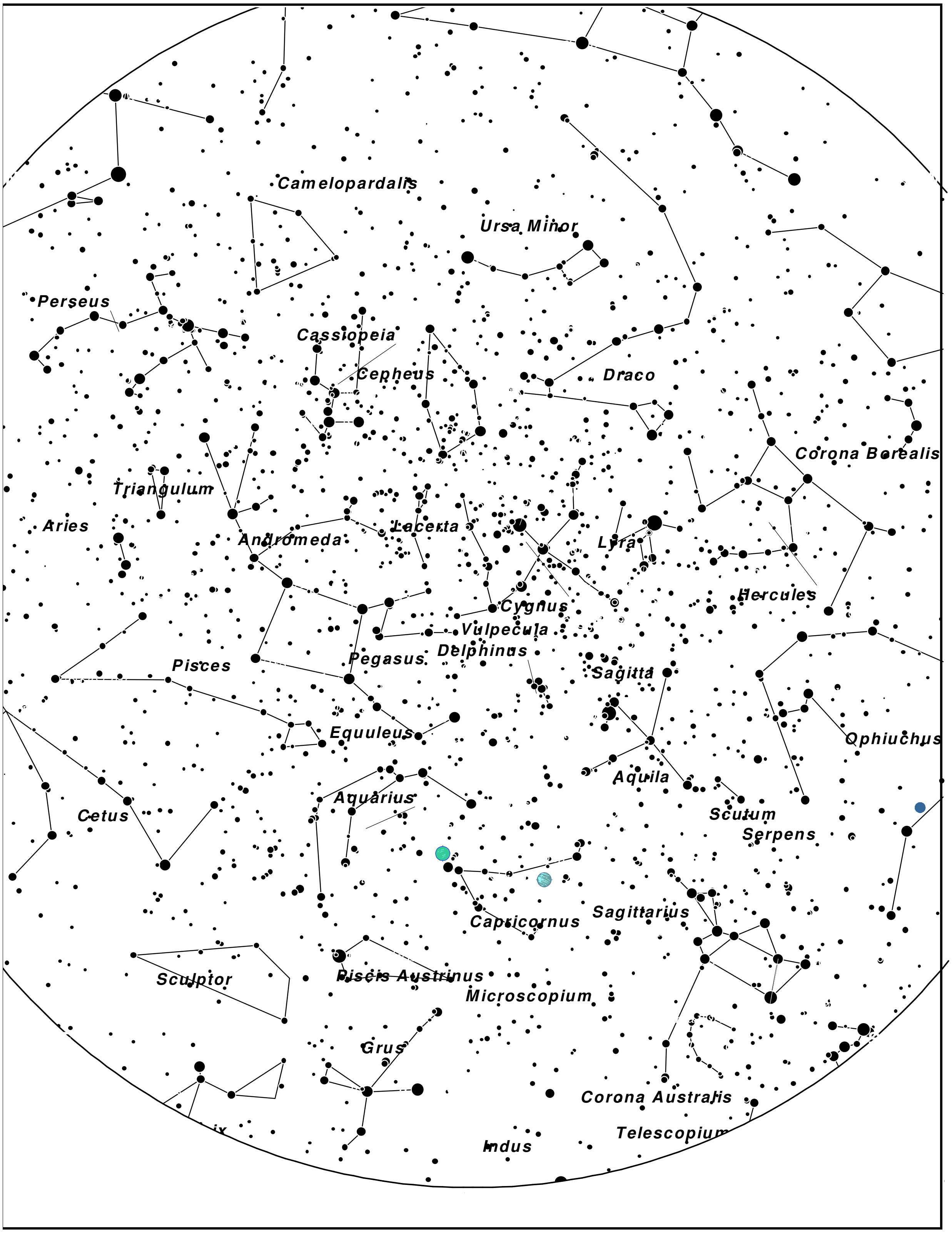


Figure 3: The North American Nebula



The North American Nebula can be seen with the naked eye (or with binoculars) under perfect conditions (clear air in a very dark location). Part of the apparent shape of this object is governed by dust clouds that lie between us and the glowing cloud of hydrogen gas. These dust clouds act to dim and remove the light being emitted by the gas cloud. The dust clouds are easy to locate in this picture—just note where the number of stars in the background is lower than elsewhere! The North American Nebula is located about 1600 light years from Earth, and is about 45 light years in diameter. Deneb is at nearly the same distance as the cloud, but is located at least 70 light years from its western edge.

Figure 4: The Sky Map for October



Constellation Highlight for October: Pegasus

Pegasus is a large constellation that is near the center of the October sky map (Figure 4). Pegasus represents the winged horse of Greek mythology. As can be seen in Figure 5, The actual figure of Pegasus appears "upside down" in the sky (for skygazers in the northern hemisphere), with the head towards the southwest, the body to the northeast, and the front feet to the northwest. The hindquarters of Pegasus are actually part of a completely different constellation: Andromeda (see the constellation highlight for November).

The mythology of Pegasus is very rich. Pegasus was tamed by the goddess Athena, and she gave the winged horse to the Muses to provide poetic inspiration. Pegasus was also the bearer of Zeus' thunderbolts. Pegasus is most famous as the steed of the Greek hero Bellerophon, who slew the Chimera, a beast that was part lion, part goat, and part serpent! Bellerophon and Pegasus had a number of wild adventures, but when Bellerophon decided to ride Pegasus to the top of Mount Olympus, the winged horse threw him after being stung by an insect sent by the angry Zeus. Bellerophon was killed as he crashed back to Earth.

Pegasus has been associated with the hero Perseus, who slayed the Medusa, and rescued Andromeda, the daughter of Queen Cassiopeia and King Cepheus, from the sea monster Cetus. However, the association of Pegasus with Perseus appears to be of modern origin, and is not a part of the original Greek mythology. All five of these constellations (Perseus, Andromeda, Cassiopeia, Cepheus, and Cetus) are located close to Pegasus (as can been in the October sky chart), and it may be their proximity that caused this association by later writers. It is interesting to note that the constellation of Pegasus was considered to be the Horse of Nimrod by the ancient Jews.

The Great Square of Pegasus: The stars α Andromedae (Alpheratz), with β (Scheat), γ (Algenib), and α Pegasi (Markab) define the "The Great Square of Pegasus", a rectangle that is $18^o \times 14^o$ in size. Markab is Arabic for "saddle", Scheat for "foreleg", and Algenib for "the side" or "wing". All three stars are giants, having 95×, 300×, and 1900× the luminosity of the sun, respectively. Alpheratz, the "navel of the steed" is no longer technically part of Pegasus, having been officially assigned to the constellation Andromeda. Alpheratz is a binary star, a pair of stars that are in orbit around each other. In the case of Alpheratz, one complete orbit requires 97 days.

NGC7078 (Messier 15): Near ϵ Pegasi (Enif, the "nose of the horse") is plotted a special symbol with the number 7078 (number 7078 in the New General Catalogue of Non-Stellar Objects). Also known as Messier 15, this object is a globular cluster, a collection of many thousands of stars (see Figure 6) that are gravitationally bound (that is, all of the stars in the cluster orbit the cluster center-not unlike a swarm of bees around their queen). M15 is one of the brightest of the Milky Way's 100+ globular clusters, and is easily visible in binoculars. A practiced observer with a modest sized telescope can see hundreds of faint stars in M15. M15 is located about 40,000 light years from Earth, and has a total luminosity of 200,000× that of the Sun! There is some evidence that a massive black hole sits at the center of M15.

About 15^o due south of M15 is another globular cluster, NGC7089 in Aquarius (also known as Messier 2). NGC7089 is a little bit further away than Messier 15, with a distance of 50,000 light years. Globular clusters are arranged in a spherical distribution about the center of our Milky Way galaxy, and slowly orbit it just as planets orbit the sun. In this case, however, it takes many hundreds of millions of years to complete just one orbit around the center of our galaxy! Just about all large galaxies like the Milky Way have a family of globular clusters in orbit about them. Globular clusters contain very old stars, and probably formed early in the history of the universe.

Figure 5: The Constellation Pegasus

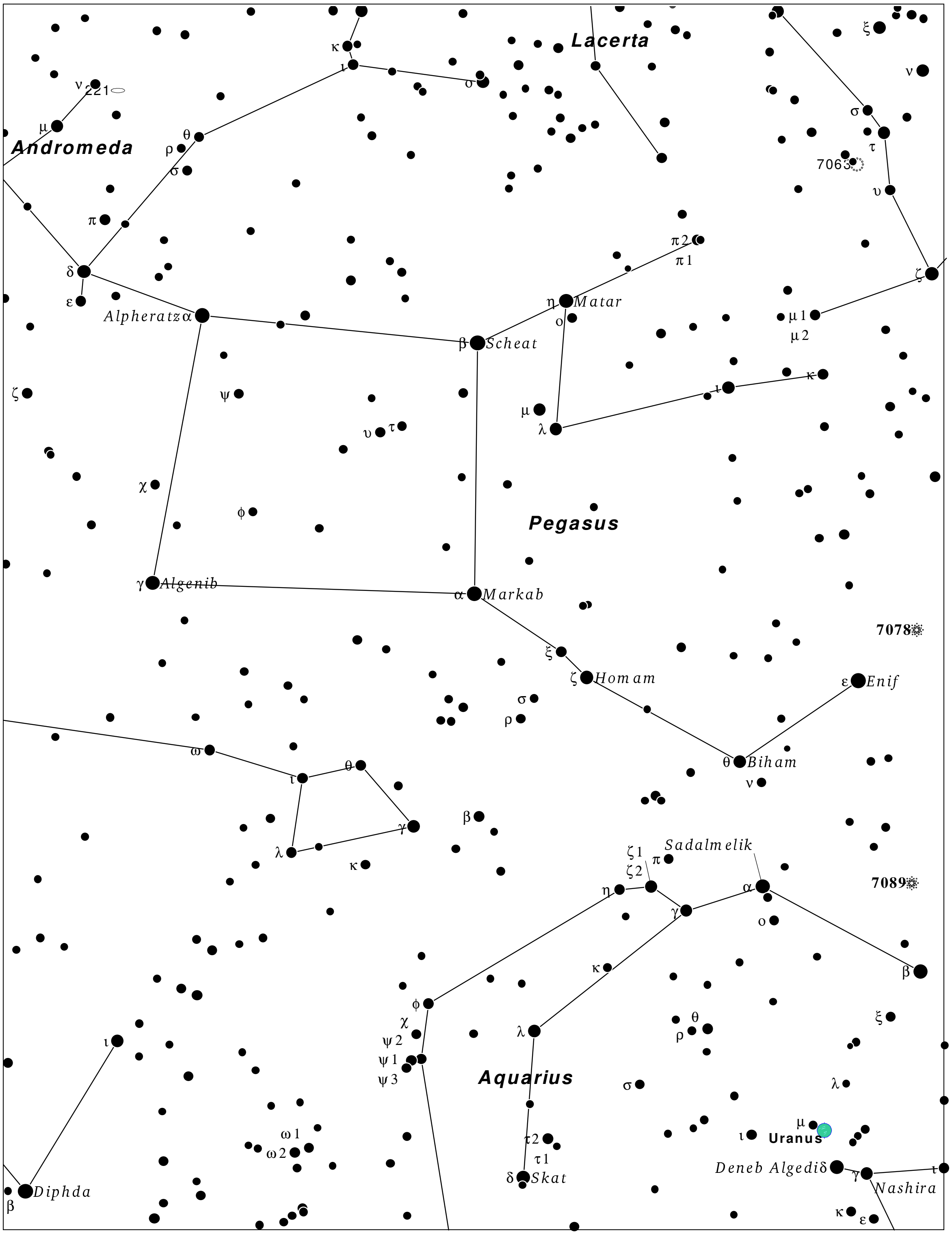


Figure 6: **The Globular Cluster NGC7078 = M15**

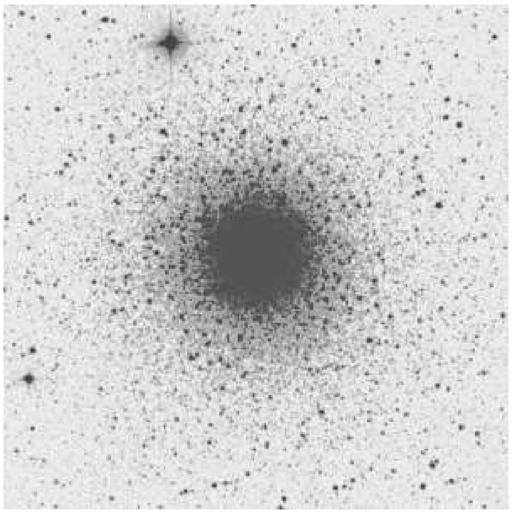
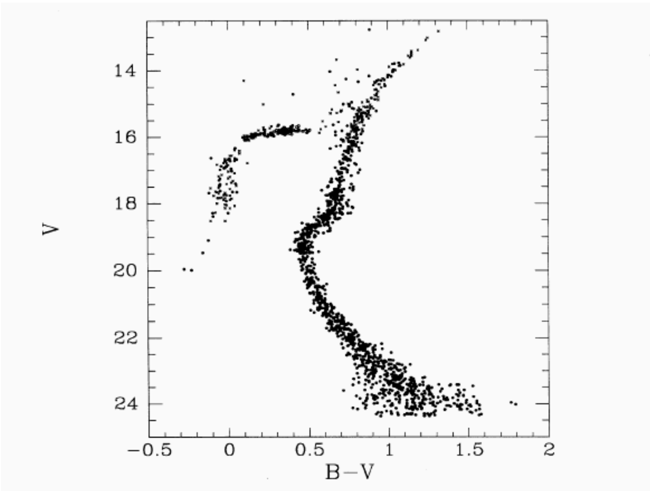
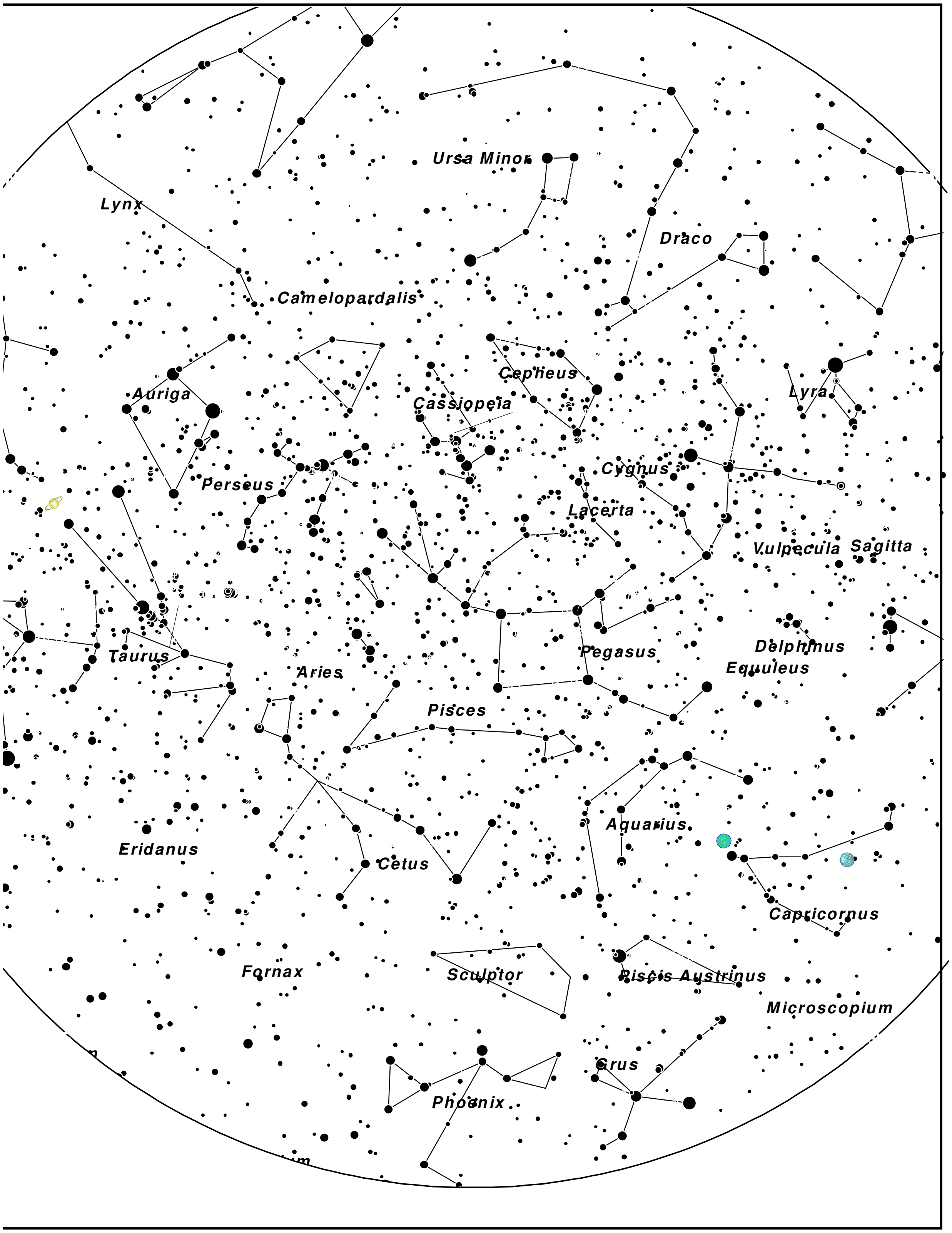


Figure 7: **The Color-Magnitude Diagram for M15 (from Durrell & Harris 1993)**



A color-magnitude (sometimes called a Hertzsprung-Russell, or "HR") diagram plots the brightnesses of the stars in a cluster versus a measure of stellar temperature. In the diagram above, the brightness is measured in visual ("V") magnitudes, while temperature is correlated with the "$B-V$" color of the star. If the Sun was in the globular cluster M15, it would show up in this plot at $B-V = 0.63$, V = 21. The lower group of stars, those with V $>$ 19 and $B-V > 0.4$, are "main sequence" stars. The curving arc to the upper right (that starts near V = 18) represents the red giants in M15, and these are generally the most luminous stars in the cluster. The most evolved, and once upon a time, the most massive stars, are those in the arc that starts near V = 16, and $B-V = 0.6$, and curves down to the lower left. The smaller the $B-V$, the hotter the star. Stars with $B-V < 0$ have temperatures above 10,000 K.

Figure 8: The Sky Map for November



Constellation Highlight for November: Andromeda

The constellation Andromeda, "the woman chained", is near the center of our sky map for November (Figure 8), but is not labeled (it is labeled on both the October and December sky maps, however). A close-up view of Andromeda is shown in Figure 9 (the areas shaded in gray here are the outlines of the ghostly glow of the Milky Way, which can be seen in very dark skies). Like many of the constellations in the sky, it takes considerable imagination to see the figure of a woman here. A stylized representation (by Hevelius) of the constellation is shown in Figure 10.

As discussed in the mythology section for Pegasus on last month's sky map, Andromeda was the daughter of Queen Cassiopeia and King Cepheus. Cassiopeia was said to be a beautiful queen, but she was also boastful. One day she claimed to be more beautiful than any of the Nereids (the water nymphs), who were known for their exquisite beauty. The Nereids heard this claim, and complained to their father Poseiden (aka. Neptune). Poseiden was infuriated, and sent the sea monster Cetus to ravage the kingdom. Consulting an oracle, Cepheus found out that to save his kingdom, he must sacrifice his daughter Andromeda. Andromeda was chained to the rocks on the shore so that she could not get away from Cetus. Just in the nick of time, the hero Perseus happened by (back from slaying the Medusa), and promised to save Andromeda if King Cepheus would let them marry. Perseus stood watch over Andromeda, and just when Cetus appeared, Perseus removed the head of the Medusa from the sack in which he carried it, and showed it to Cetus. The sea monster instantly turned to stone and sank into the sea. The myth of Andromeda and Perseus appears to have more ancient origins than most of the other Greek mythologies. R. H. Allen notes references for versions of this story that date back to Babylonian times. We will return to the legend of Perseus in our December constellation highlight.

γ Andromadae (Almach). The name Almach derives from the Arabic name for a small, badger-like animal common to Arabia, and has nothing to do with the Andromeda story. Presumably, the ancient Arabs had a different mythology for the stars here. The Chinese called the star *Tien Ta Tseang*, for "Heaven's Great General". γ Andromadae is one of the finest double stars in the sky. It has a large color contrast similar to that of Alberio (see September), with the brighter of the pair being of a yellow/golden hue, with the fainter star being blue, or bluish-green. The two stars are separated by 10 arcseconds, so a small telescope is necessary to split them. Interestingly, the blue star is a binary star, with an orbital period of 61 years. At the current time, the two stars are only separated by 0.35 arcseconds, requiring a large telescope, and exceptional observing conditions to see them as a pair of stars.

The Andromeda Galaxy (Messier 31, NGC 224). In a clear dark sky it is possible to see a faint, fuzzy patch about 1° degree west of ν Andromadae (represented by the small oval plotted on the sky chart). With binoculars, it is possible to trace the faint glow of this object out to a degree or more. The Andromeda galaxy, shown in close-up in Figure 11, is the closest large galaxy to our Milky Way, and is at a distance of 750,000 light years. It is slightly larger and more luminous than the Milky Way. The Andromeda and Milky Way galaxies are the anchors of a collection of some 35 much smaller galaxies that make up the "Local Group". The Local Group is a small, gravitationally-bound family of galaxies.

Like the Milky Way, the Andromeda galaxy is a *spiral* galaxy made up of at least a hundred billion stars. As you will learn, spiral galaxies have "arms", that are home to many young, hot stars, and numerous star formation regions. The spiral arms in the Andromeda galaxy are tightly wound, and only one is easily seen in Figure 11 (on the lower, right hand side of the galaxy). The spiral arms can be quite dusty, and most of the lighter (whiter) regions in our negative image of M31 are due to dust clouds absorbing the light of the stars in the spiral arms (just as they do in the case of the North American Nebula region discussed in Figure 3).

Figure 9: **The Constellation Andromeda**

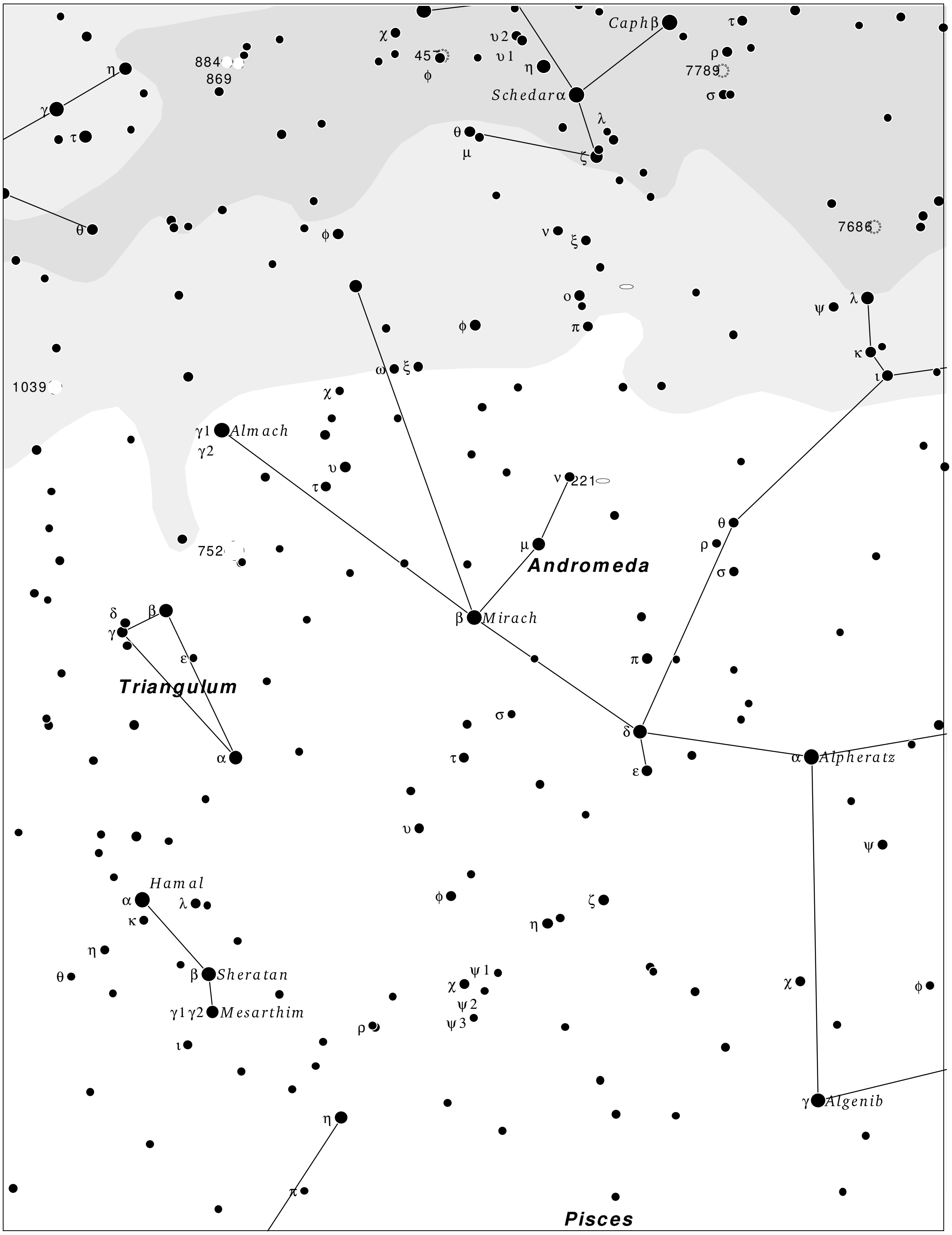


Figure 10: **A Fanciful Rendering of the Constellation Andromeda by Hevelius**

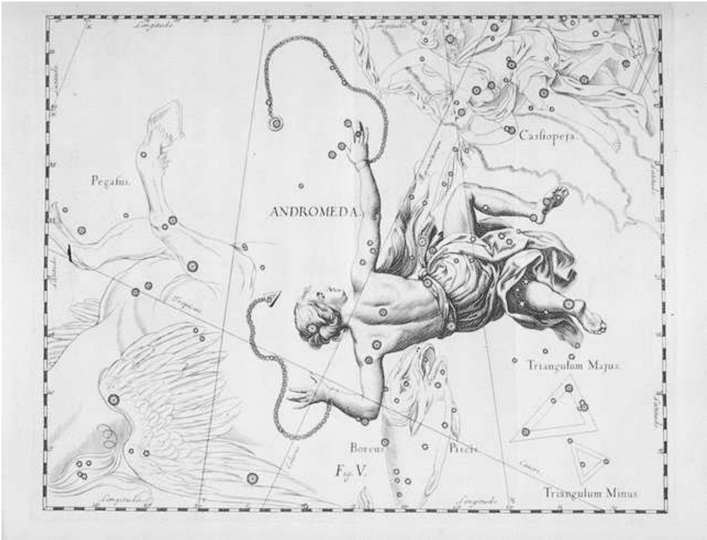
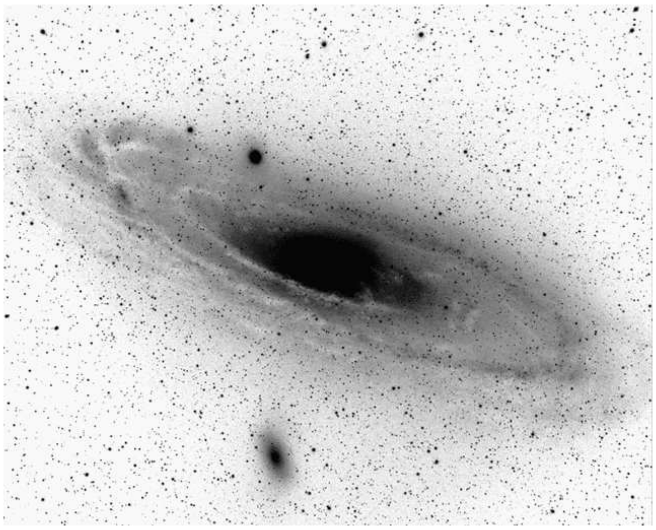
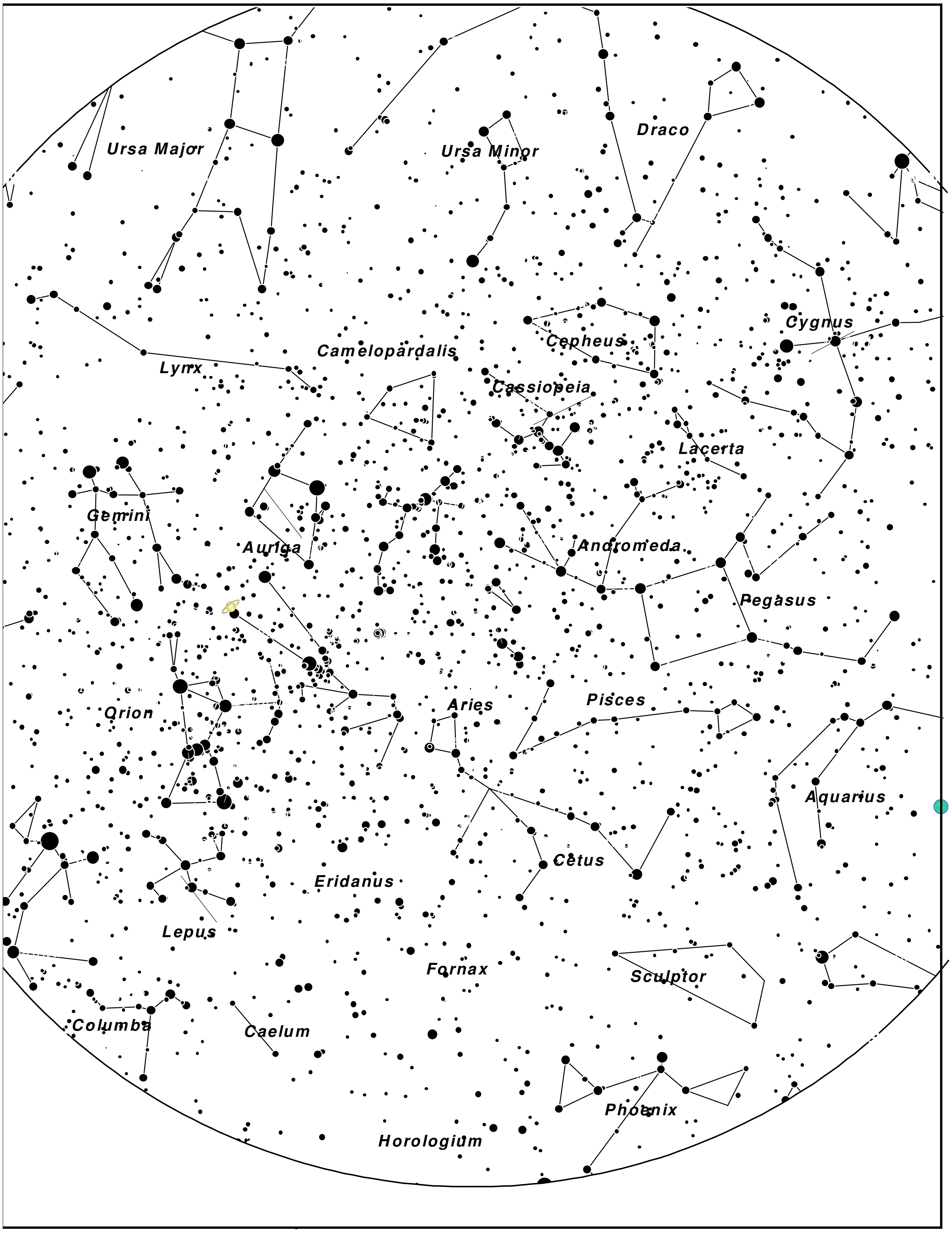


Figure 11: **The Andromeda Galaxy**



The Andromeda galaxy is usually considered the most distant object that can be seen with the naked eye. It is amazing to think that the photons of light detected by your eye started their journey 750,000 years ago! While this object was known at least as far back as the 10th century, it took the development of large telescopes to discover that the faint glow that made up the nebula was the result of the collected light from billions of individual stars. The two fuzzy objects, one above, and one below, the Andromeda galaxy are the two small "satellite" galaxies NGC 205 and NGC221. Both of these galaxies are small *elliptical* galaxies that orbit about the larger spiral galaxy.

Figure 12: The Sky Map for December



Constellation Highlight for December: Perseus

Perseus is the unlabeled constellation just east (left) of Andromeda in our December sky chart (Figure 12). In our close up view (Figure 13), it is apparent from the gray shading that the constellation of Perseus sits in the middle of the Milky Way. Many "open" clusters (see below) can be found in this region, and are denoted by the small, numbered "ringlets" plotted on this map (about one dozen of them are plotted here). We have already encountered part of the extensive mythology surrounding Perseus in our discussion of Andromeda. Perseus was the son of the union between Zeus and Danae, the daughter of King Acrisius of Argos. While Perseus was away on a trip to Samos, his mother was enslaved by King Polydectes of Seriphos. On his return, Perseus rescued his mother, and would have killed Polydectes, but the adopted father of Danae (Dictys) successfully convinced Perseus not to do so. Polydectes, realizing that Perseus would continue to cause him problems, decided to hold a banquet. Given that Perseus was very poor, he could not present the king with the customary gift at this banquet. The resulting ridicule by the guests and nobles made Perseus extremely angry, and he told them that he would bring them a gift–he would bring them the head of Medusa. At this King Polydectes ordered him off the island, and he was not to return without this "gift".

Perseus left the palace and went to pray to Minerva, the goddess of wisdom, to have her help him with his difficult task, for Medusa was said to be so ugly that if you were to stare into her face, you would turn to stone. Minerva told Perseus where to find Medusa, and showed him how to get close enough to kill her without becoming one of her stony victims. Donning his winged sandals, Perseus was off to find Medusa. On his way, he stopped by to visit with Atlas (who was charged with holding up the sky). Atlas promised to give Perseus a helmet that would make him invisible if on his return, Perseus would stop and show him the head of Medusa. Atlas wanted to be turned to stone–for he was growing old, and was very tired of holding up the sky. With this helmet in hand, Perseus once more set off for Hesperides, the home of Medusa and the other Gorgons. Once there, Perseus approached Medusa by using the reflection of her image in his shield to find his way. Once he was close enough, he chopped off her head, put it in a leather sack, and headed back for Seriphos (stopping on the way to turn Atlas to stone, and to rescue Andromeda). Once back, he found that King Polydectes was having another banquet; Perseus pulled Medusa's head from the sack, and turned the king and his court to stone.

β Persei (Algol). In most depictions of the figure of Perseus, β Persei represents the head of Medusa. The Hebrews knew this star as "Satan's Head", while the Chinese called it *Tseih She*, the "Piled-up Corpses". Obviously, it was one of the most feared stars in the sky. Algol is a variable star, an object whose brightness changes with time. In the case of Algol, the brightness changes by a factor of three over a period of 2.87 days. The cause of these brightness changes is an eclipse of a bright star by a dimmer companion that orbits it (see Figure 14). Algol is the brightest example of a family of objects called "eclipsing binaries". It is interesting to speculate whether this variability had anything to do with the association this star with Medusa's head (there is no apparent support, however, for such a connection).

The Double Cluster in Perseus (NGC 884 and 869). To the northwest (upper right) of the star η Persei are two little broken circles with the numbers 884 and 869. Here we find two spectacular "open clusters" very close together in the sky (see Figure 15). Open clusters are groups of dozens, hundreds, or occasionally, even thousands of stars that have condensed out of a single, large molecular gas cloud. Open clusters differ from globular clusters in that all of them have formed within the disk of our Milky Way galaxy and are much younger than the typical globular cluster. Over time, open clusters tend to disappear ("evaporate") as stars are ejected from the cluster due to gravitational interactions with other stars in the cluster, as well as with stars and molecular gas clouds the cluster encounters as it orbits around the center of our Milky Way galaxy. The Double Cluster is considered by many to be the most beautiful example of this type of object.

Figure 13: Constellation Highlight for December: Perseus

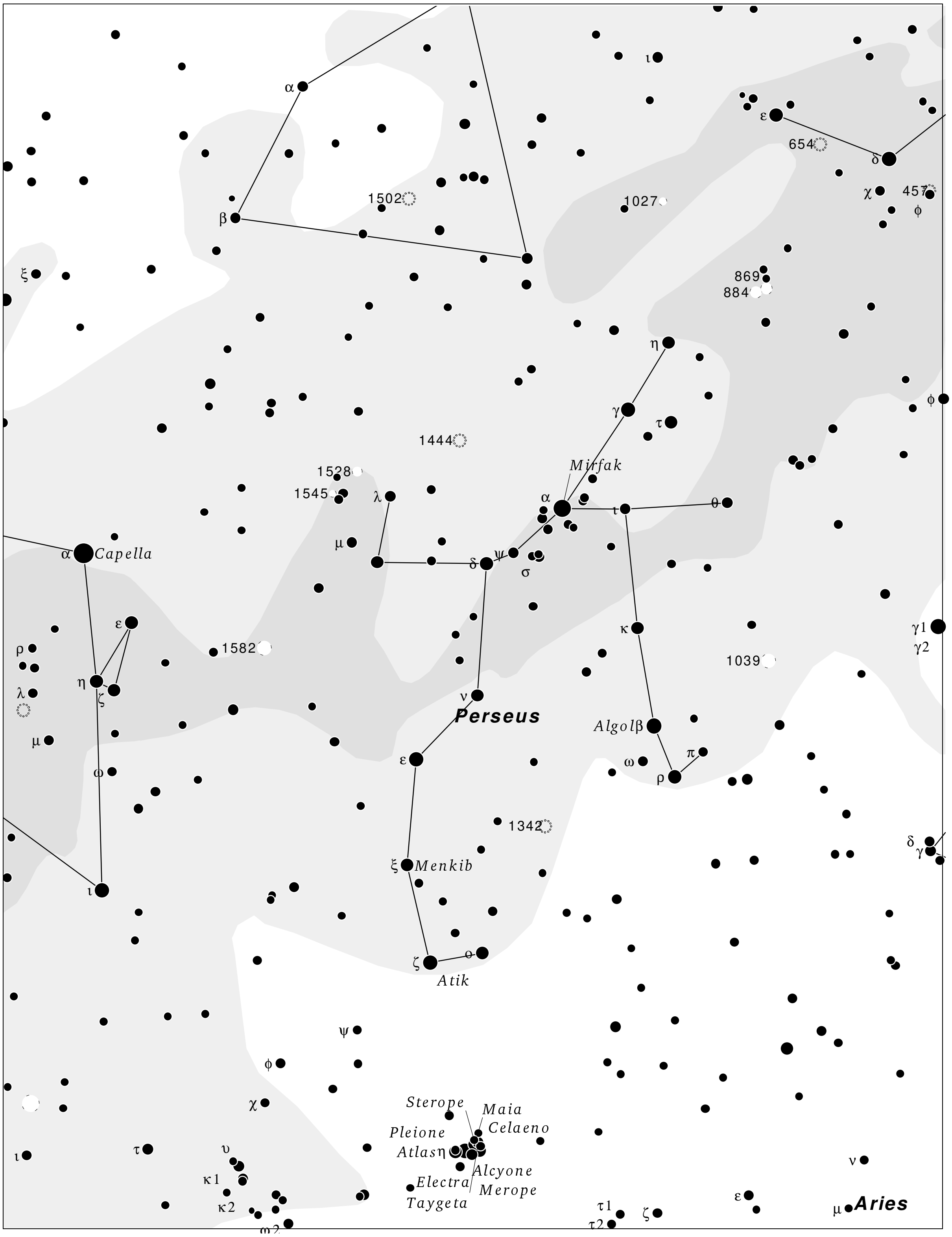
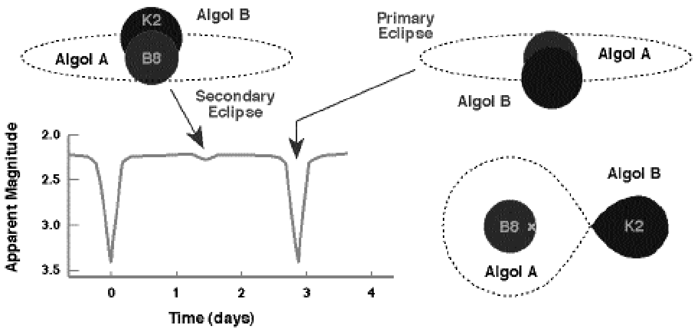
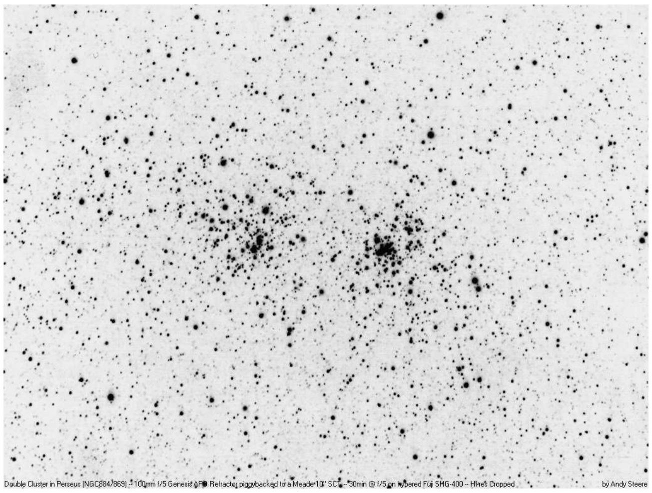


Figure 14: **A Diagram of the Eclipsing Binary Algol**



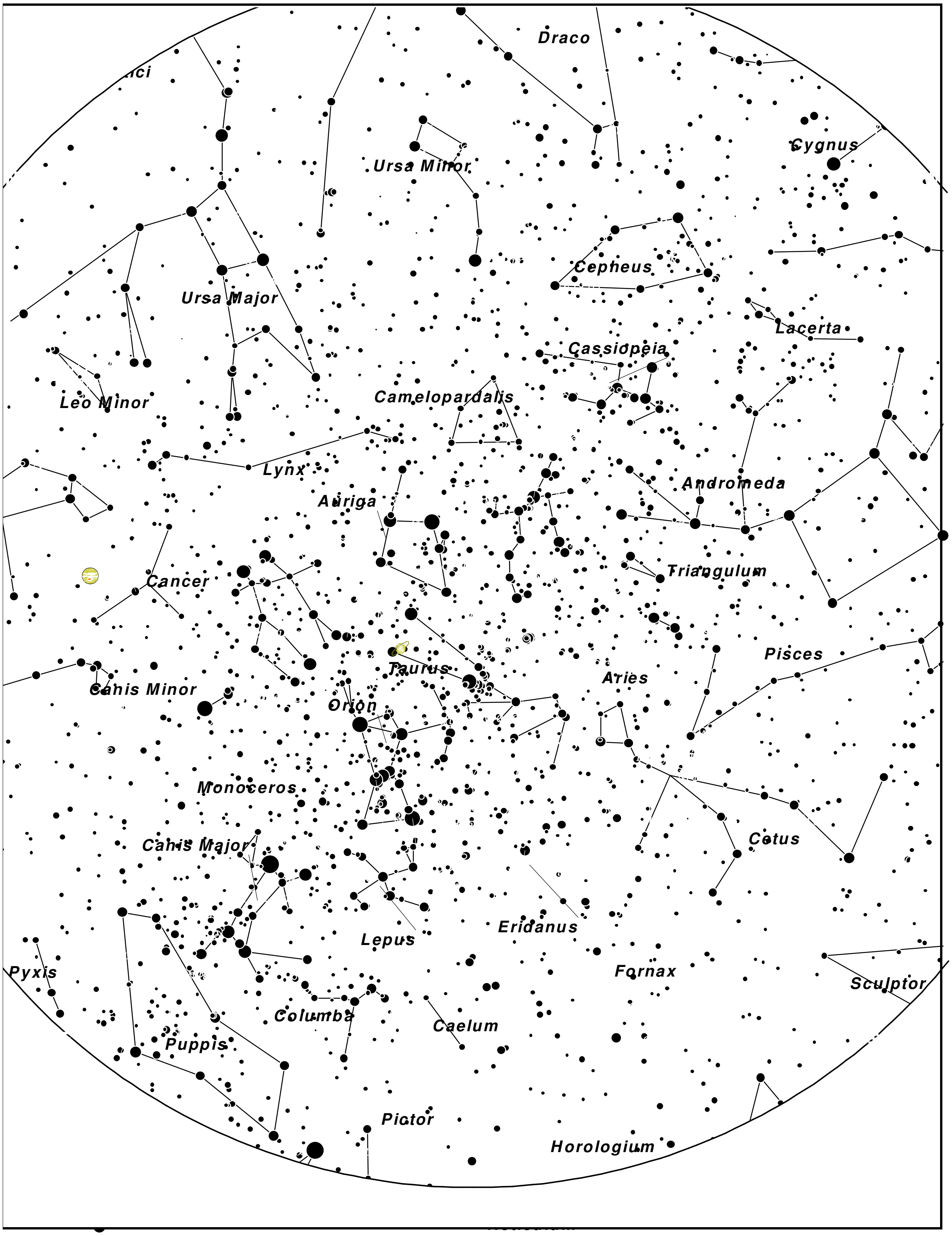
Every 2.87 days, the star Algol appears to dim by 1.2 magnitudes (corresponding to a factor of three in brightness). If you plot the brightness of Algol versus time, you end up with a light curve (shown in lower left hand corner of the figure above). The cause of this dimming is an eclipse of the primary star in Algol by a fainter companion star. Algol A is a hot (T = 11,000 K, "B8") main sequence star orbited by a cooler (5000 K, "K2") giant star Algol B. These two stars orbit around each other with a period of 2.87 days. Due to random chance, we see the orbit "edge on", and thus, the two stars appear to pass in front of each other once per orbital period. Because it has only one third the luminosity of the hot star, when the cool star is in front of the hot star, the apparent brightness of the binary drops (termed "primary eclipse").

Figure 15: **The Double Cluster in Perseus**



The Double Cluster in Perseus is composed of two separate open clusters (NGC 869 and 884). The clusters are each composed of about 500 stars, and are located about 7500 light years from Earth. They are both about 12 million years old. Both clusters can be seen with the naked eye, and are an amazing sight in a small telescope.

Figure 16: The Sky Map for January



Constellation Highlight for January: Taurus

Taurus, "the bull", is one of twelve Zodiacal constellations and is at the center of our chart for January. Taurus (see Figure 17) contains two open clusters that are visible to the naked eye: the Pleiades and the Hyades. During 2002-2003, the planet Saturn will be found among the stars of Taurus.

The figure of the front part of a bull in the stars of Taurus is rather easy to envision, and it appears this association dates back to at least 4000 BC. The Roman mythology for Taurus is rather brief, and commemorates two stories that have Jupiter (Zeus) attempting to seduce two different women, Europa and Io (*eye-O*). Europa was the beautiful daughter of Agenor, the King of Sidon. One day Europa was playing at the beach with friends when she noticed a stunning white bull amongst her father's herd. She went up to the bull, stroked it, and put a wreath of flowers around its neck. The bull was so docile, that she decided to climb on its back for a ride. As soon as she did, however, the bull (Jupiter in disguise) charged into the sea and swam all of the way to the island of Crete. Europa eventually had a child, Minos, who went on to become the King of Crete and started the Minoan, bull-centered culture (home of the Minotaur and its Labyrinth).

In the other story, Jupiter had fallen in love with Io, the daughter of the River God Inachos, and a priestess in Juno's temple. When Juno (Jupiter's wife) found out about this infatuation, she turned Io into a white heifer, and ordered Argos (the giant with 100 eyes) to keep watch on her. Jupiter decided to attempt to free Io, and sent the fleet-footed Mercury to kill Argos. Mercury succeeded, and Io escaped to Egypt where she became ruler of the Nile valley.

Aldebaran (α Tauri). The Arabic equivalent of Aldebaran means "the follower", and is usually attributed to the fact that Aldebaran rises after the Pleiades, and follows them across the sky. Aldebaran is the 13^{th} brightest star in the sky, and is a red giant that is 40 times the size of the sun, and 125 times more luminous. It is 68 light years from Earth.

The Hyades and Pleiades. These two naked-eye open clusters are of great importance to astronomers. The Hyades is one of the closest open clusters, and has been used to calibrate the "cosmic distance scale ladder" used by astronomers to estimate the size and age of the universe. The main part of the cluster forms a "V" shape that forms the head of the bull, and includes Aldebaran on its southeastern end (though Aldebaran is closer than the cluster). The Hyades contains about 300 stars and formed about 400 million years ago. The Pleiades, on the other hand, is much younger, having formed about 100 million years ago. It still contains several hot blue stars. The Pleiades cluster is located 410 light years from Earth, about three times the distance of the Hyades. Both the Hyades and Pleiades have their own mythology. One of the oldest, and most common stories associated with the Pleiades is of the "lost Pleiad". The story usually involves seven sisters, one of which becomes lost. Versions of this story exist in a variety of cultures beyond the Greeks, including the Japanese, Australian Aborigines, and natives of both the Gold Coast of Africa, and of Borneo. Whether one of the stars has actually disappeared (or merely faded from view) since ancient times has not been ascertained. However, Pleione (see Figure 18) is a variable star that might have undergone a major event at sometime in the past.

The Crab Nebula. The Crab Nebula is located a little over a degree to the northwest of ζ Tauri (at the eastern tip of the southern horn). It was discovered in 1731 by John Bevis. The origin of the "crab" in its name refers to the filamentary gas streams that can be best seen in photographs (see Figure 19). This cloud of glowing gas is in fact the remnant of a supernova that erupted in 1054 AD. The Chinese recorded the event as a "guest" star in July of that year. At its brightest, it rivaled Venus, and could be seen during the daytime. There are several Native American pictographs that have been associated with this event, one of them in New Mexico (at Chaco canyon). Strangely, no European records of this event have been found. The Crab is a rather unimpressive object in small telescopes.

Figure 17: Constellation Highlight for January: Taurus

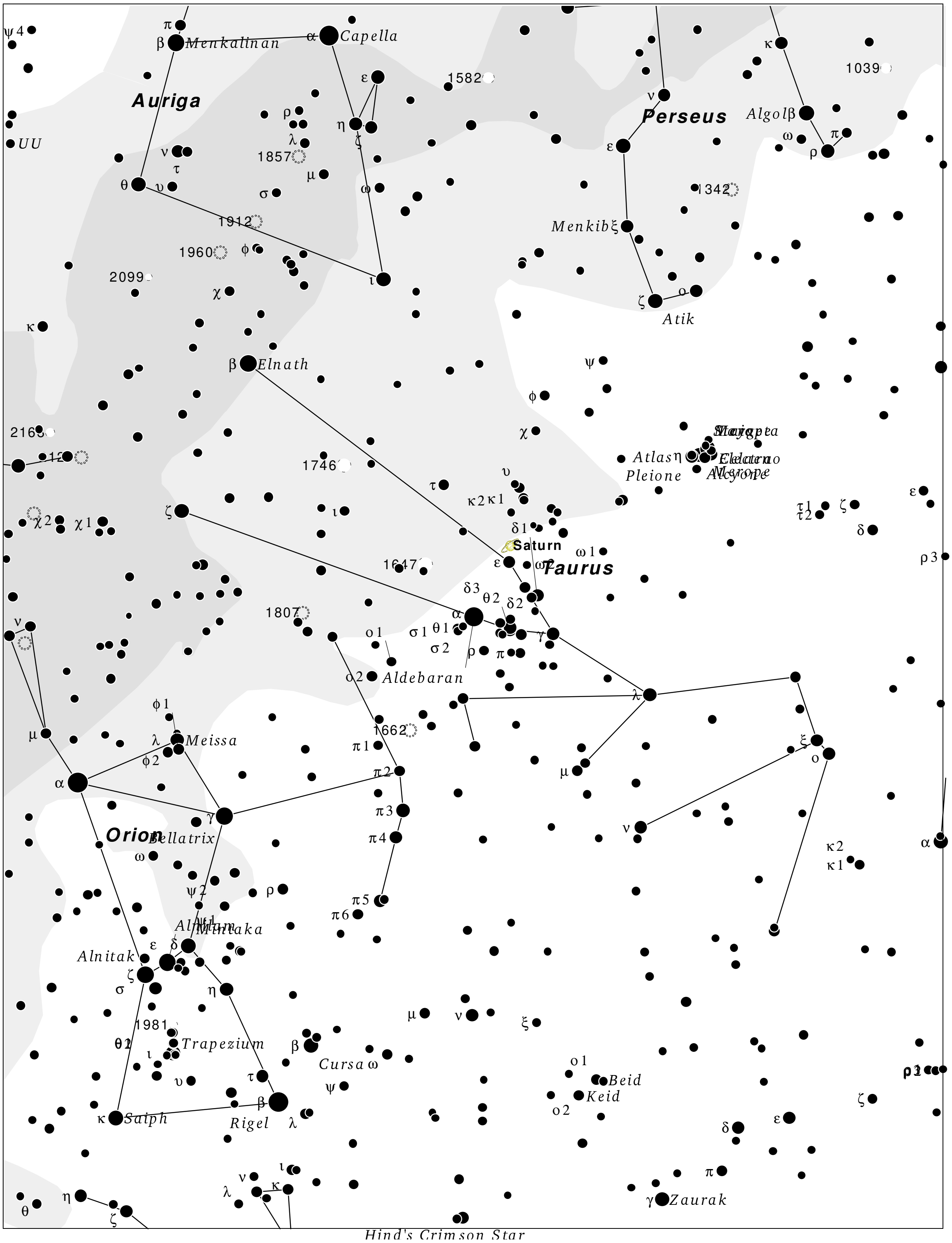
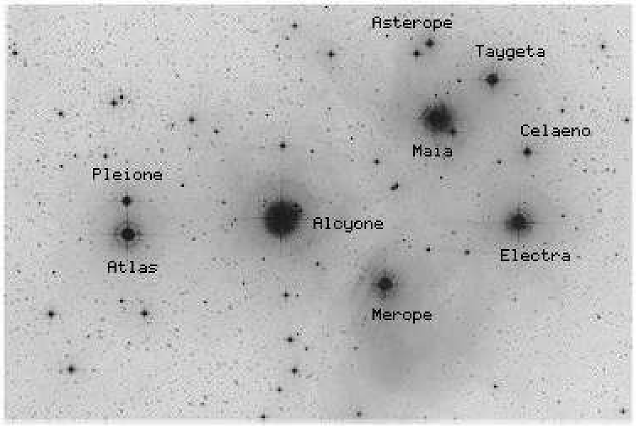
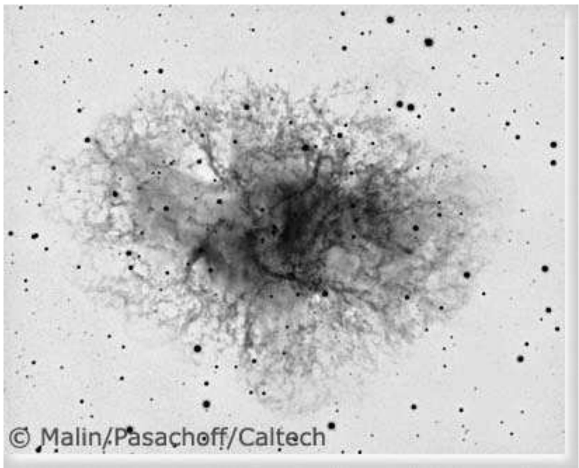


Figure 18: **The Pleiades**



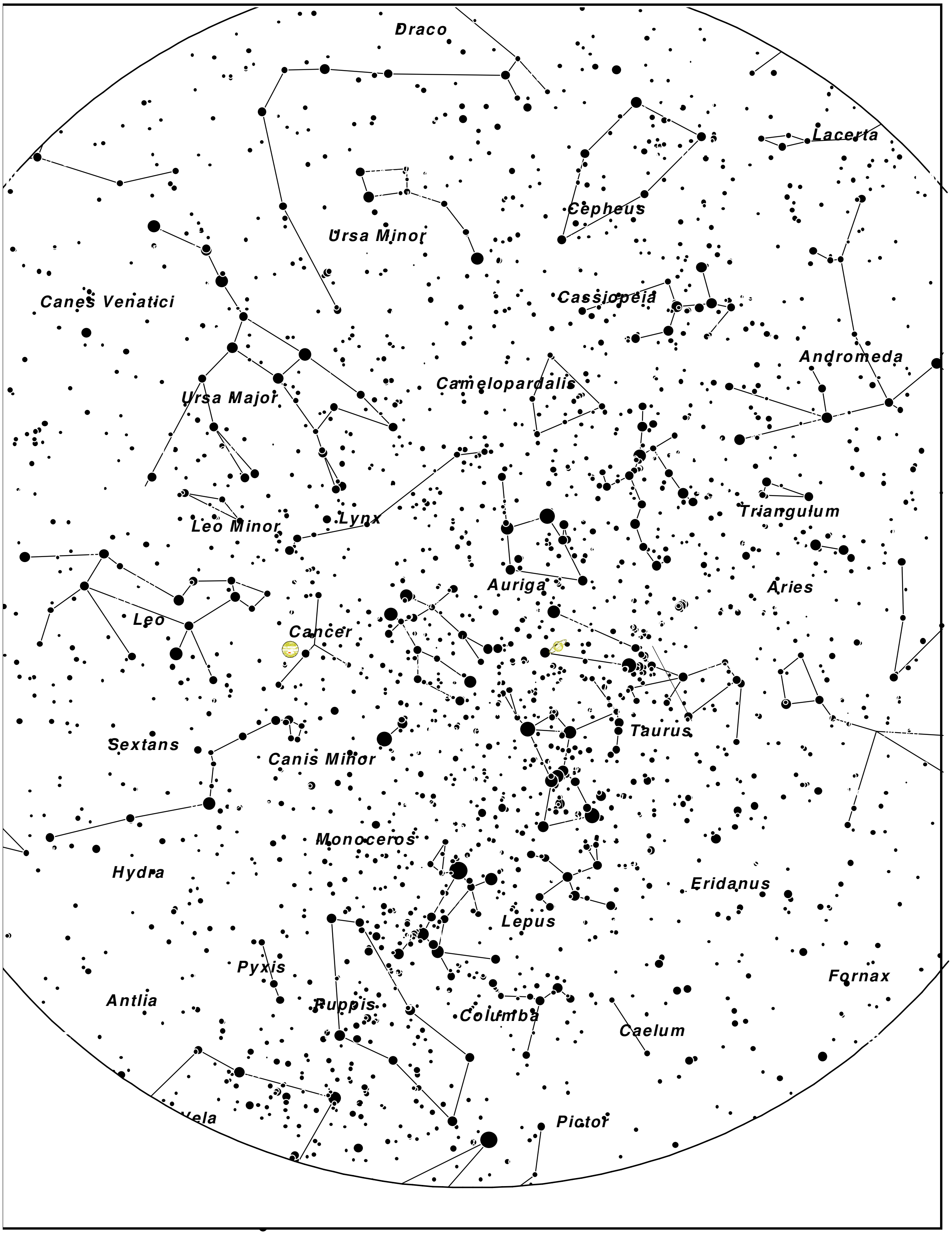
The Pleiades is a relatively nearby open cluster of several hundred stars. The name appears to be derived from the Greek word *plein*, “to sail”. The names of the brightest of the stars in the cluster are those of the daughters of Pleione and Atlas. The Seven Sisters escaped from the hunter Orion after being turned into doves by Zeus. The cluster still contains remnants of the dust from the formation process when the cluster was deeply embedded inside a dusty cloud of molecular gas. This dust lends the wispy-ness seen around the brighter stars in the photograph. This *reflection nebulosity* can be observed in a modest size telescope under good conditions.

Figure 19: **The Crab Nebula**



The Crab Nebula is the remnant of the supernova of 1054 AD. As a star ages, it begins to run out of fuel. Depending on its mass, there are several paths that it then can follow. For massive stars, like the progenitor to the Crab, the result is a supernova–the core begins a rapid collapse because it is no longer supported by nuclear burning. This collapse generates an explosion that rips the star apart, ejecting the stellar atmosphere at high velocity (10,000 km/s!). It is this gas that forms the glowing nebula we see today. At the very center of the explosion, some of the core material continues to collapse. Usually an object called a *neutron star* is formed, an object that is entirely composed of neutrons, and that has the incredible density of a billion tons per cubic inch (10^{14} gm/cm^3)! If the mass of the progenitor star is higher, the core can collapse to form a black hole. In the case of the Crab, a very hot (1 million degree) neutron star sits at the center of the nebula.

Figure 20: The Sky Map for February



Constellation Highlight for February: Orion

Orion, "the Hunter", is a wintertime constellation that is familiar to most people. In February, Orion is almost due south at the onset of darkness. The figure of Orion is composed of a number of bright stars, including the first magnitude beacons Betelgeuse (*beetle-juice*) and Rigel, while the belt of Orion points (southeast) to the brightest star in the night time sky, Sirius (the "dog star" of great importance to the Egyptians). Seeing the figure of a giant or hunter in the stars of Orion was widespread among ancient peoples ranging from the Arabs and Greeks, to the Norse, the Saxons, and the early people of Ireland. In Babylonian and Hindu legends, the constellation was associated with great winter storms. The classical mythology for Orion, however, is somewhat brief, suggesting that Orion was a minor figure. Orion was the son of the god Neptune and the nymph Euryale. He was a giant of a man, and feared no creature. He even threatened to rid the Earth of all of its animals. When the Goddess of the Earth, Gaia, heard this boast she sent a scorpion to kill Orion. Orion was mortally wounded, but the great healer, Ophiuchus (a summertime constellation near Scorpius), gave him the antidote and saved his life. This story has been commemorated by placing the constellations of the two mortal enemies, Orion and Scorpius, opposite to each other in the sky, so that when Orion is setting, Scorpius is rising, and vice versa. There are several other stories about Orion in Greek mythology, including one that involves the Pleiades mentioned last month, as well as a story about the hunting goddess Diana accidently killing Orion with her bow.

To the ancient Egyptians, the constellation of Orion was interpreted as the God of Light, Osiris. Osiris and his brother, *Set*, the God of Darkness, were in a never ending battle for supremacy. In an attempt to settle this battle, Set constructed a beautiful box. This box would be given to the brother of his that could fit within it. Of course, Set had built the box to fit Osiris exactly. When Osiris took his turn, Set slammed the lid shut, eventually suffocating poor Osiris. When Osiris' wife, Isis, found out, she went to seek help. In the meantime, however, Set chopped the body of Osiris into fourteen pieces, and scattered them in all directions. Isis went about collecting the pieces, finding thirteen of them. The missing member, she constructed of wood, reassembled all of the pieces, breathed life into them, and Osiris rose into the sky.

Betelgeuse (α Orionis). Betelgeuse is a *red supergiant* star located about 600 light years from Earth. The name derives from the Arabic for "the armpit of the giant". Betelgeuse is a massive star very near the end of its life, and will eventually erupt as a supernova. It has truly enormous dimensions, being about 750 times the size of the sun! If placed at the center of our solar system, the orbits of the planets Mercury, Venus, Earth, and Mars would be contained *within* the atmosphere of Betelgeuse. It emits 10,000 times the luminosity of the sun.

Rigel (β Orionis). Anchoring the opposite corner of the figure of Orion from Betelgeuse is the *blue* supergiant star Rigel, the 7^{th} brightest star in the sky. Rigel is even more luminous than Betelgeuse, having nearly 60,000 times the luminosity of the sun! It is located about 900 light years from the Earth. While Betelgeuse is relatively cool at 3,000 K, Rigel is hot, with a temperature of 12,000 K.

The Orion and Horsehead Nebulae. Orion is famous for two objects, the great "Orion Nebula", and the Horsehead Nebula. The Orion nebula (Figure 21) is a glowing cloud of hydrogen gas that is being energized by a very young, hot cluster of stars (the "Trapezium"). It can be seen with the naked eye as a pinkish star in the sword of Orion (the sword of Orion is the line of three stars due south of the middle belt star ϵ Orionis). It is a fascinating sight in a small telescope. The Horsehead nebula is a dark, dusty cloud of gas between us and a background emission nebula that has the shape of a horse's head (Figure 22). It can be found just south of the eastern-most belt star Alnitak (ζ Orionis). While easily photographed, the Horsehead Nebula is very difficult to see in a telescope because the background nebula is not very bright.

Figure 21: Constellation Highlight for February: Orion

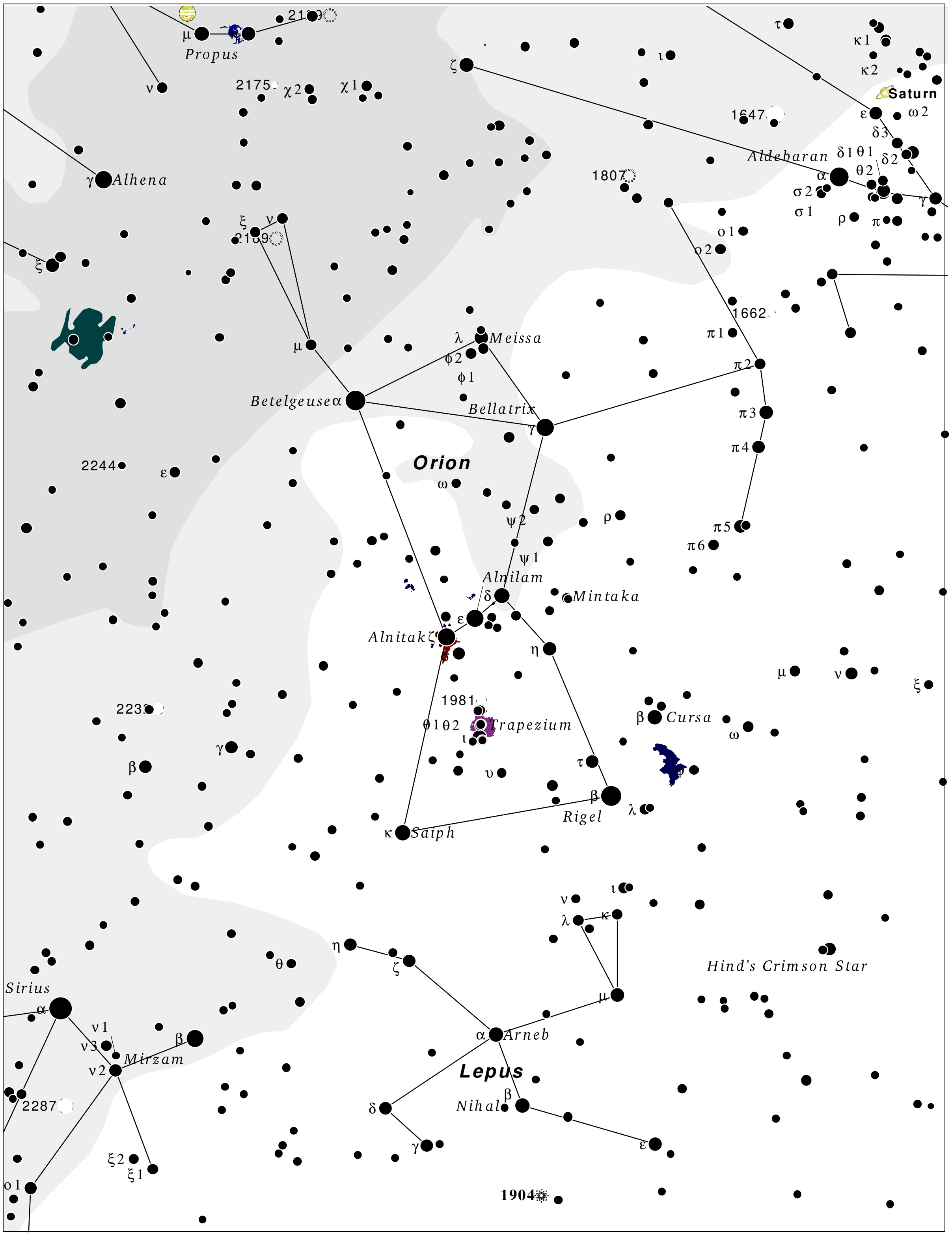
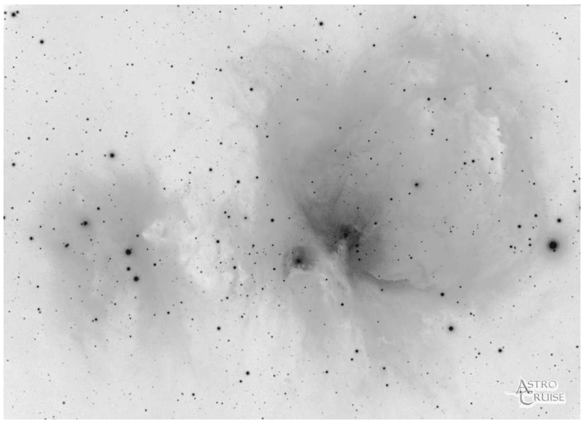


Figure 22: **The Orion Nebula**

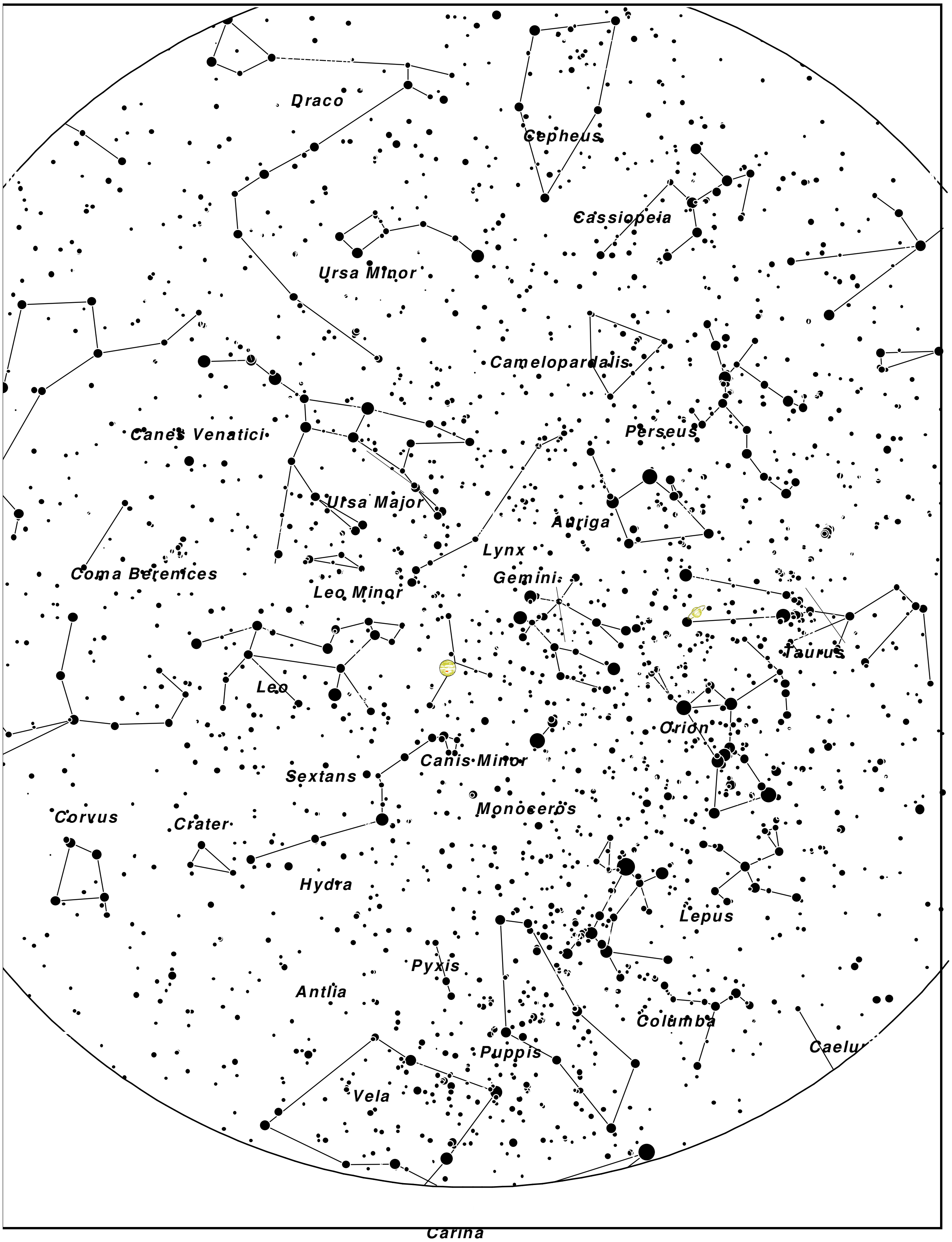


The Orion Nebula is what astronomers call an "HII region". HII stands for ionized hydrogen (unionized hydrogen is represented by "HI"). The hydrogen gas is being ionized by a number of very hot luminous young stars that have recently formed out of a giant molecular cloud complex that covers much of the eastern part of Orion, and which contains several other *star forming regions.* The group of the hottest, and brightest stars that sit at the center of the Orion nebula, and at the center of a future open cluster with many hundreds of stars, is called the Trapezium. The Trapezium stars are very young, only a few million years old. The nebula and the Trapezium are located about 1,500 light years from Earth. The diameter of the brightest portion of the nebula is about 40 light years.

Figure 23: **The Horsehead Nebula**

Like the North American Nebula discussed in September, the Horsehead Nebula is formed by a dark dust cloud that obscures the light from a background HII region. In this case the dust cloud just happens to have the shape of a horse's head. The background HII region is at roughly the same distance as the Orion Nebula. The dark cloud that forms the head is roughly one light year across.

Figure 24: The Sky Map for March



Constellation Highlight for March: Gemini

Gemini, the "twins", is a Zodiacal constellation found near the center of our March sky chart (Figure 24). During the winter of 2002-2003, Jupiter can be found in the constellation Cancer, just to the southeast of Castor and Pollux, the two brightest stars in Gemini. Jupiter is labeled and plotted near the left hand edge of the chart for Gemini (Figure 25). Pluto was discovered near δ Geminorum in 1930 by Clyde Tombaugh, a former faculty member at NMSU.

The twins, Castor and Pollux, were the sons of Leda and Zeus, and were important to mariners who thought the twins capable of protecting sailors from storms. In Homer's Odyssey, the twins helped guide and protect Jason and the Argonauts in their quest for the golden fleece. The twins have been attributed with founding Thebes by the Greeks, and occasionally with the twins Romulus and Remus, the founders of Rome. Of the two twins, Pollux was an immortal, while Castor was not. One day, Castor was killed in a fight that erupted over the ownership of some cattle. Pollux was heartbroken, as the two twins were inseparable. Pollux begged Jupiter to let him also die, so as to be with Castor in Hades. But since he was immortal, that was not possible. Jupiter, however, allowed Pollux to spend one day among the gods, and the next in Hades with Castor. This intense brotherly love would be forever commemorated in the sky by the constellation Gemini.

To the Tewa indians of New Mexico, the stars of Orion, and Castor and Pollux, were incorporated into the story of Long Sash, an ancient Tewa warrior. Long Sash lead his people along the Endless Trail (denoted by the Milky Way) to escape the quarreling neighbors of their homeland. Along the way, his people became restless, and began to argue among themselves. He told them they must be able to live together in peace. Castor and Pollux represent the place of decision, where two paths were presented to them, and they had to decide for themselves which path in life to follow.

Castor (α Geminorum). Is the 23$^{\rm rd}$ brightest star in the sky, is located at a distance of 45 light years, and has a total luminosity of 36 suns. When viewed through a small telescope, Castor is easily split into two stars of similar brightness, Castor "A" and "B". Castor A and B form a true binary star system, and complete an orbit around each other once every 400 years. Both A and B are, in turn, binary stars! In both cases, the stars are in very tight orbits around each other, and cannot be resolved with normal telescopes. The orbital period of the Castor A binary is 9.2 days, while Castor B has an binary period of 2.9 days. One arcminute ($1/60^{\rm th}$ of a degree) to the south-southeast of Castor A and B is a further companion of this system, "Castor C". Castor C is also a binary star, composed of two *red dwarfs* (stars smaller and cooler than the sun) that orbit each other once every 19 hours. Thus, Castor is an actual *sextuple* star system!

Pollux (β Geminorum). Compared to Castor, Pollux is a rather mundane object. The name probably originates from the word for "Boxer", as Pollux was renown for his boxing skills. Pollux is a cool (4500 K) giant star with 30 times the luminosity of the sun, and is about 35 light years away.

The "Eskimo Nebula" (NGC2392). Located to the southeast of Wasat (δ Geminorum) is plotted a small circle with the number 2392. This object is a *planetary nebula.* The name planetary nebula stems from the fact that to early users of telescopes, these objects showed little disks or rings that sort of resembled planets. We now know that the disks and rings are actually composed of glowing gas excited by a small, but very hot star that sits at the center of the nebula. The gas that is excited to form the planetary nebula is the remnant of the atmosphere of a *low mass* star that has reached the end of its life. When massive stars die (those with 10 or more times sun's mass), they generally explode as supernovae, ejecting their atmospheres at high velocity. Stars with masses below this limit, however, shed their outer atmospheres more gently as their core collapses. The result is a complex (see Figure 26) volume of gaseous material that is illuminated by the hot *white dwarf* remnant.

Figure 25: Constellation Highlight for March: Gemini

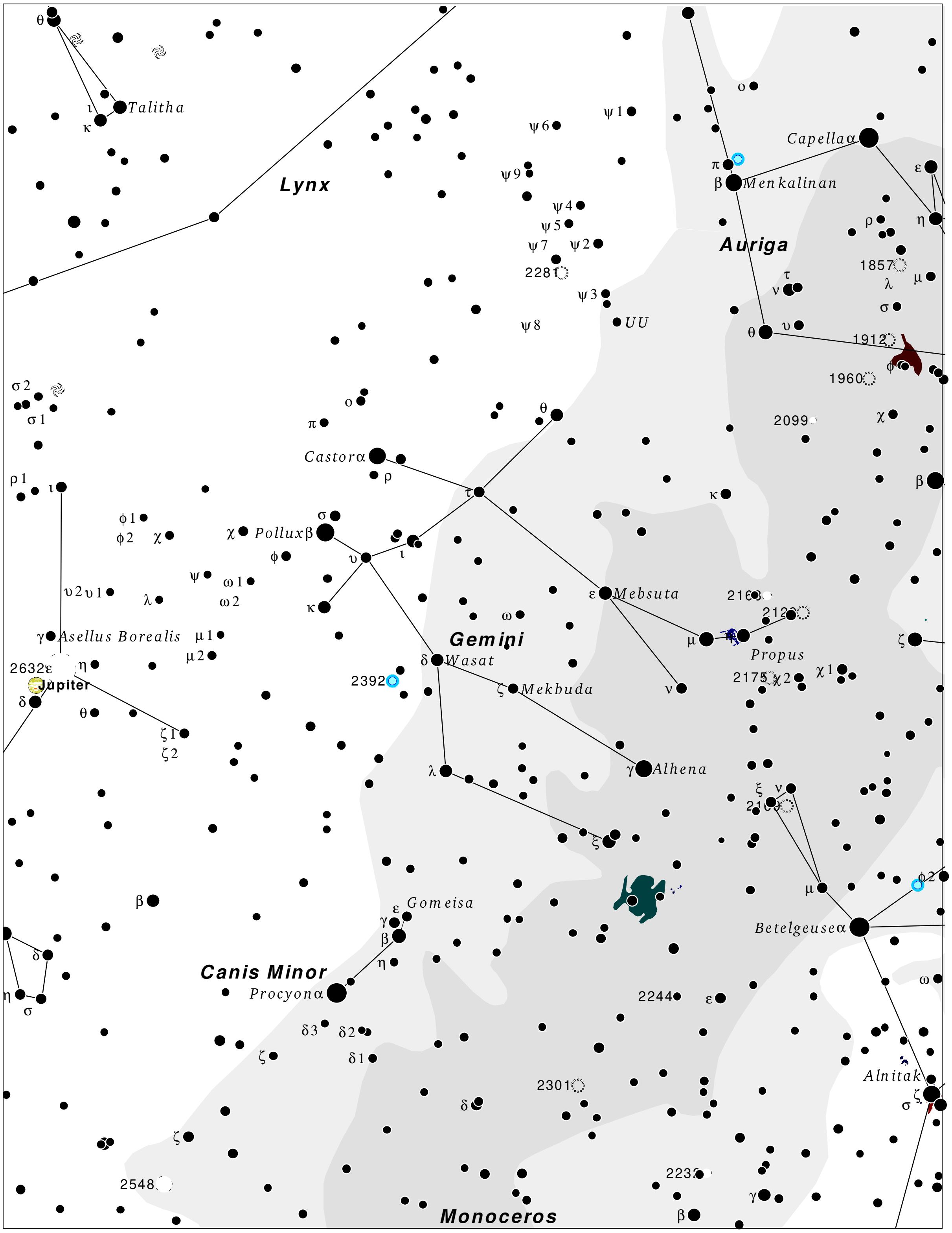
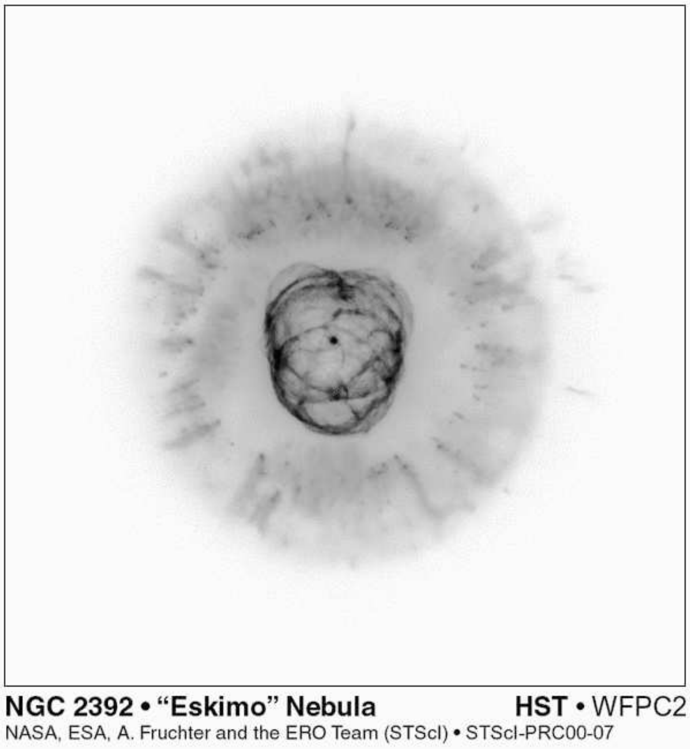


Figure 26: An HST Image of the Eskimo Nebula in Gemini



Using the Hubble Space Telescope, the Eskimo nebula is resolved into a complex of bubbles of gas in the interior, and illuminated streamers of gas in the outer regions of the nebula (these streamers have been nicknamed "cometary globules" due to the fact that they seem to have *heads* and *tails* that resemble those of comets). At this resolution, the "Eskimo" referred to in the name is difficult to discern. In the ground-based image below (Figure 27), however, the fringe of the parka (due to the cometary globules), and something resembling a face, is more easily seen. This is closer to the visual appearance of this object as seen in a large telescope.

Figure 27: **Ground-Based Image of the Eskimo Nebula**

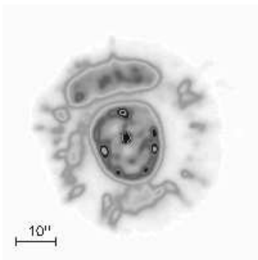
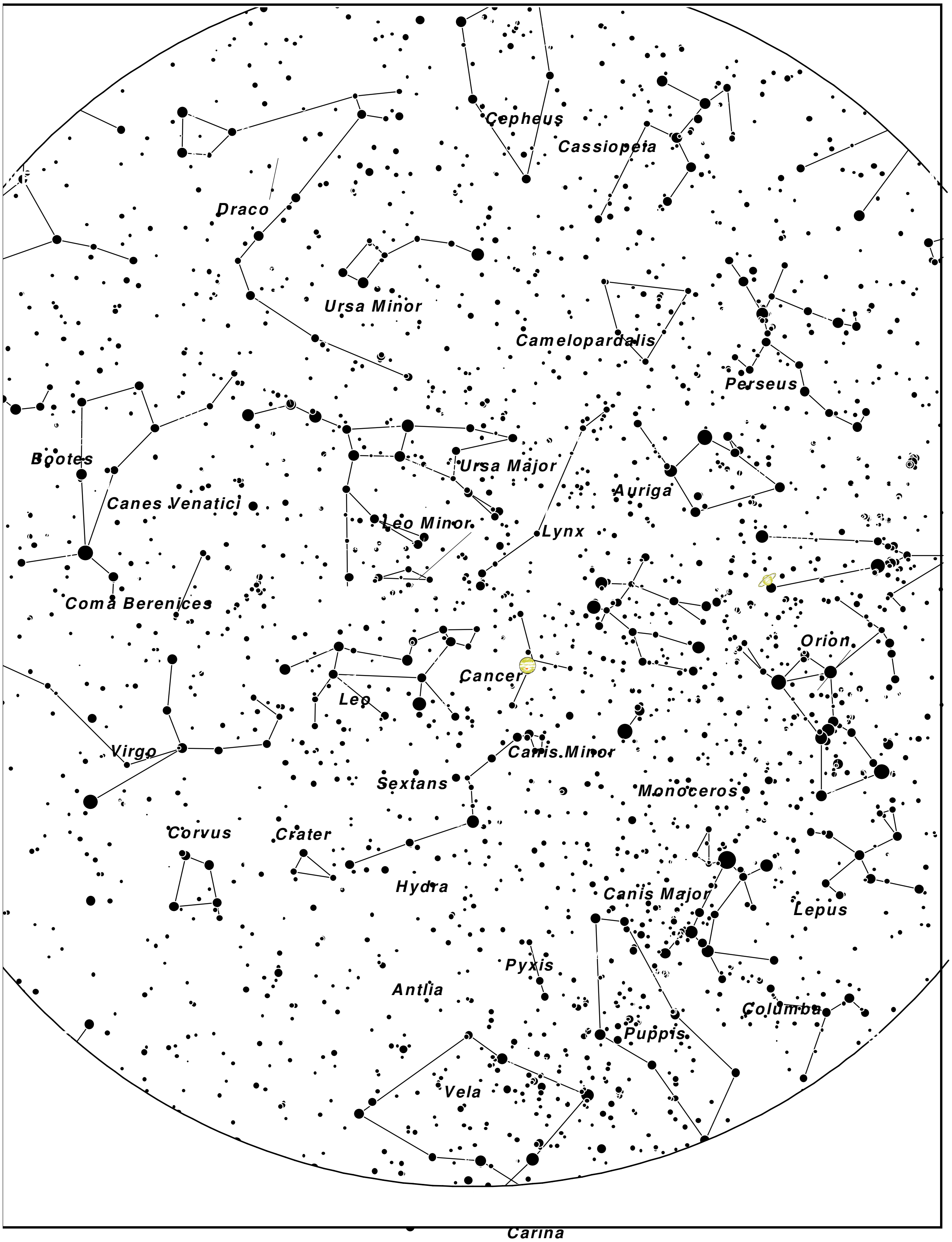


Figure 28: The Sky Map for April



Constellation Highlight for April: Ursa Major

Our constellation for April, Ursa Major (the "great bear") is certainly the most well-known of all, as the main body of the figure is comprised of the stars that form the "Big Dipper": A star-group most people learn as children—at least those in the Northern Hemisphere! You are also probably familiar with the fact that a line drawn through the two stars at the end of the bowl of the Big Dipper (α and β Ursae Majoris) points to the north star, Polaris (α Ursae Minoris). Because Ursa Major is located far from the crowded, and dusty plane of the Milky Way galaxy, it was chosen as the ideal site to peer deep into space to look back at an epoch when galaxies were first forming. To accomplish this, the *Hubble Space Telescope* obtained a large number of long exposure images at a variety of wavelengths over an eleven day span. The result is the "Hubble Deep Field" that forms the core of Lab exercise #11 (see Figure 11.2 on page 108).

Like many other Roman myths, the story of Ursa Major begins with Jupiter lusting after a beautiful woman. In this case, it was Callisto, the daughter of King Lycaon of Arcadia. Callisto had devoted her life to serving the Goddess of the Hunt, Artemis. Jupiter had descended to Earth to restore it after it had become scorched by the falling to Earth of Phaethon (after his brief, and fateful ride in the Chariot of the Sun God, Helios). As Jupiter wandered the woods of Arcadia, admiring his restoration efforts, he came upon Callisto. He was immediately taken with the beautiful Callisto. To insure his success in seducing her, Jupiter transformed himself into Artemis, and he approached Callisto. Happy to see Artemis, Callisto jumped up to greet the goddess. Much to her surprise, however, Artemis suddenly became Jupiter, and even though she attempted to resist his advances, she could not. Nine months passed, and this immoral deed soon became quite apparent to the wood nymphs, and Callisto was driven from the service of Artemis. Not long after, Juno became aware of this tryst, and of Callisto's son Arcas. Juno became very angry and punished Callisto by turning her into a bear. Callisto remained in the Arcadian woods for many years until one day, when she happened to cross paths with Arcas, who was out hunting. Happy to see him, she charged towards Arcas to greet him (forgetting the fact she looked like a bear!). Surprised by this event, Arcas raised his bow to kill the charging bear. In the nick of time, Jupiter intervened, and raised them both up to heaven to form the Large and Small Bears (Ursa Major and Minor).

Given the fact that bears do not have long tails, it is remarkable that this group of stars has almost universally represented a bear. This was the case even well beyond the influence of the Greco-Roman world, for the Iroquois, Algonquin, Narragansett, and Illinois tribes of North America also envisioned this star pattern as a bear. For some of these tribes, however, the "bowl" of the Big Dipper (and stars to the south and west) formed the figure of the bear, while the stars in the "handle" represented three hunters. In England, the Big Dipper is known as the Plough, and in Germany it is seen as a wagon.

Mizar (ζ Ursae Majoris) and Alcor. If you have excellent eyesight, the middle star of the Dipper's handle can be split into two stars: Mizar and Alcor. If you point a small telescope at these two stars, you quickly find out that Mizar is itself a binary star. The two stars are separated by 14 arcseconds. Mizar is considered one of the finest of all double stars, and with Alcor, is an excellent object for small telescopes. As in the case of Castor, both components of Mizar are also binary stars! Thus, Mizar is a quadruple star system. Alcor shares the motion of Mizar across the sky, suggesting that both stars formed in roughly the same place, though Mizar and Alcor cannot form a true binary, since Alcor is at least 0.25 light years from Mizar (beyond the gravitational pull of Mizar). Mizar and Alcor, along with most of the stars that comprise the Big Dipper, appear to be the remnants of an open cluster that has become unrecognizable as such. Included in this *moving group* of stars is Sirius. Thus, the solar system appears to be moving through the outskirts of a very old open cluster!

Figure 29: Constellation Highlight for April: Ursa Major (the "Big Dipper")

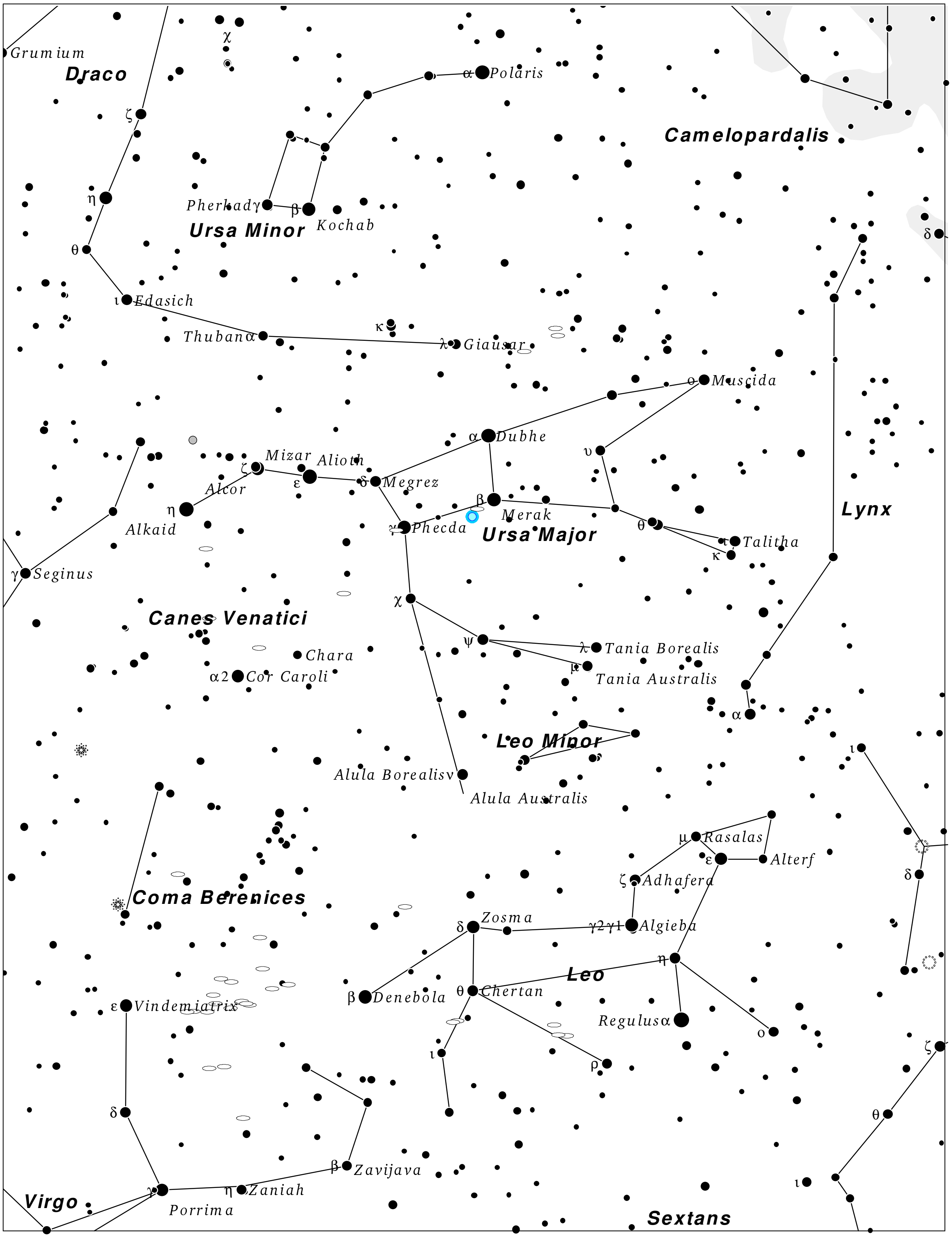
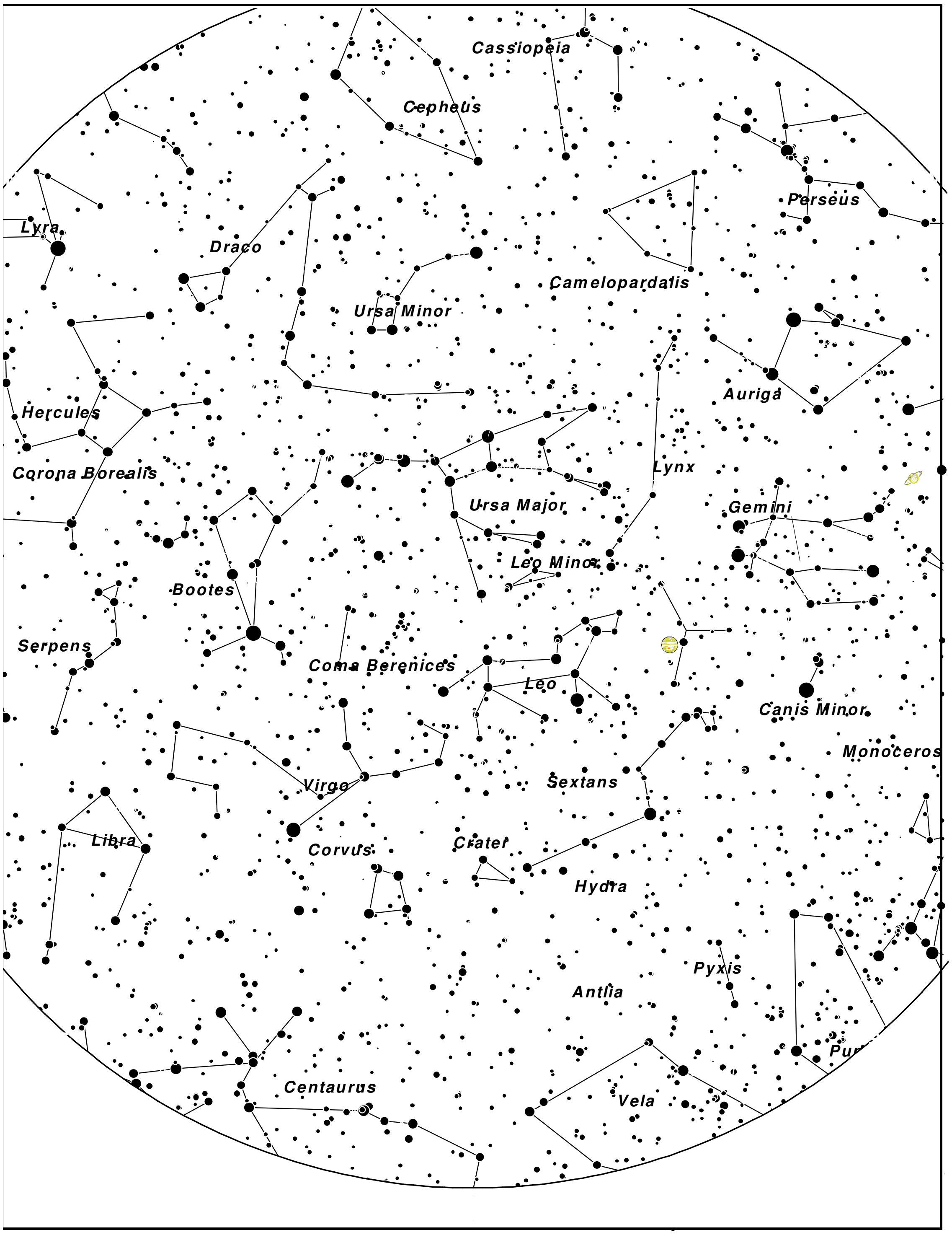


Figure 30: The Sky Map for May



Constellation Highlight for May: Virgo

In our sky chart for May (Figure 30), we can find the sprawling constellation of Virgo (the "virgin" or "maiden"), well to the southwest of Ursa Major and Leo the "lion". The brightest star in Virgo, Spica, can be found by using the handle of the Big Dipper. If you follow the arc of the handle for about 25 degrees you come to the bright star Arcturus, α Bootes (pronounced Bow-Oaties). Continuing on this arc, you will eventually encounter Spica. Virgo, shown in close-up in Figure 31, is one of the twelve Zodiacal constellations.

Virgo is usually identified with Proserpina, the daughter of Ceres, the Goddess of the Fields and Crops. One fine spring day, Pluto (God of the Underworld) was out riding in his black chariot surveying the bountiful fields of growing crops when he came across Proserpina, who was in the fields playing with her friends. Taken with her beauty, he grabbed her up, and took her home with him to the Underworld. With the loss of her daughter, Ceres became extremely depressed–so much so that all of the crops died, and nothing would grow. Faced with a global famine, Jupiter ordered Pluto to allow Ceres to visit with Proserpina in the Underworld for six months each year. This is why there are six months in the growing season, for Virgo can be seen from March until September. During the six months when Ceres is visiting with Proserpina in the Underworld, nothing grows. Some writers have postulated that this story derives from even earlier times when the beginning of spring occurred when the sun entered Virgo (due to the precession of the polar axis of the Earth, the locations associated with the start of each season slowly shift against the background stars on a 23,000 year cycle). If this were true, the association of Virgo with Spring would have had its genesis some 15,000 years ago!

Spica (α Virginis). In modern depictions of Virgo, Spica represents an ear of corn. But the name derives from the Latin for "Ear of Wheat" (since corn is a more recent introduction to Europe). Spica is a binary star composed of two stars with eight and eleven times the mass of the sun that orbit each other with a period of 4 days. The total luminosity of the binary system is 2,300 times that of the sun, and they are located 275 light years from Earth.

Porrima (γ Virginis). The name honors the "Goddess of Prophecy". Porrima has been an excellent target for small telescopes for more than a hundred and fifty years, as it is a binary star comprised of two identical stars that orbit each other once every 171 years. But with *periastron* (closest approach) occurring in 2007, the two stars are now very difficult to split, being separated by only 0.5 arcseconds: A stringent test for the optics of a 12 inch telescope, and an excellent example of binary star motion.

The Virgo Cluster. To the north of Porrima, in the middle of the upper part of the Y-shaped portion of the constellation of Virgo, are plotted eighteen small ovals. These ovals represent the brightest members located near the center of the great Virgo cluster of galaxies (see Figure 32). The Virgo Cluster is the nearest example of a large cluster of galaxies. The Virgo Cluster contains more than 2,000 individual galaxies. The gravitational pull of the cluster is so large, that it is actually pulling on the the Milky Way and the Local Group with enough force that we will eventually "fall into" the cluster−even though we are 60 million light years away! The estimated mass of the cluster is 5×10^{14} times that of the sun. Of this enormous number, however, the visible galaxies only comprise 1% or so of the cluster's mass. The majority of the rest of this mass appears to be "dark matter", whose true nature is still undetermined.

Messier 87. Near the center of the Virgo Cluster sits the giant *elliptical* galaxy Messier 87 (see Figure 33). Elliptical galaxies differ from spiral galaxies in that they do not have disks, or spiral arms. Elliptical galaxies also appear to have lower levels of active star formation when compared to the typical spiral galaxy. Messier 87 is a truly enormous object, having about 100 times the mass of the Milky Way galaxy. At the heart (*nucleus*) of M87 sits a super-massive black hole.

Figure 31: Constellation Highlight for May: Virgo

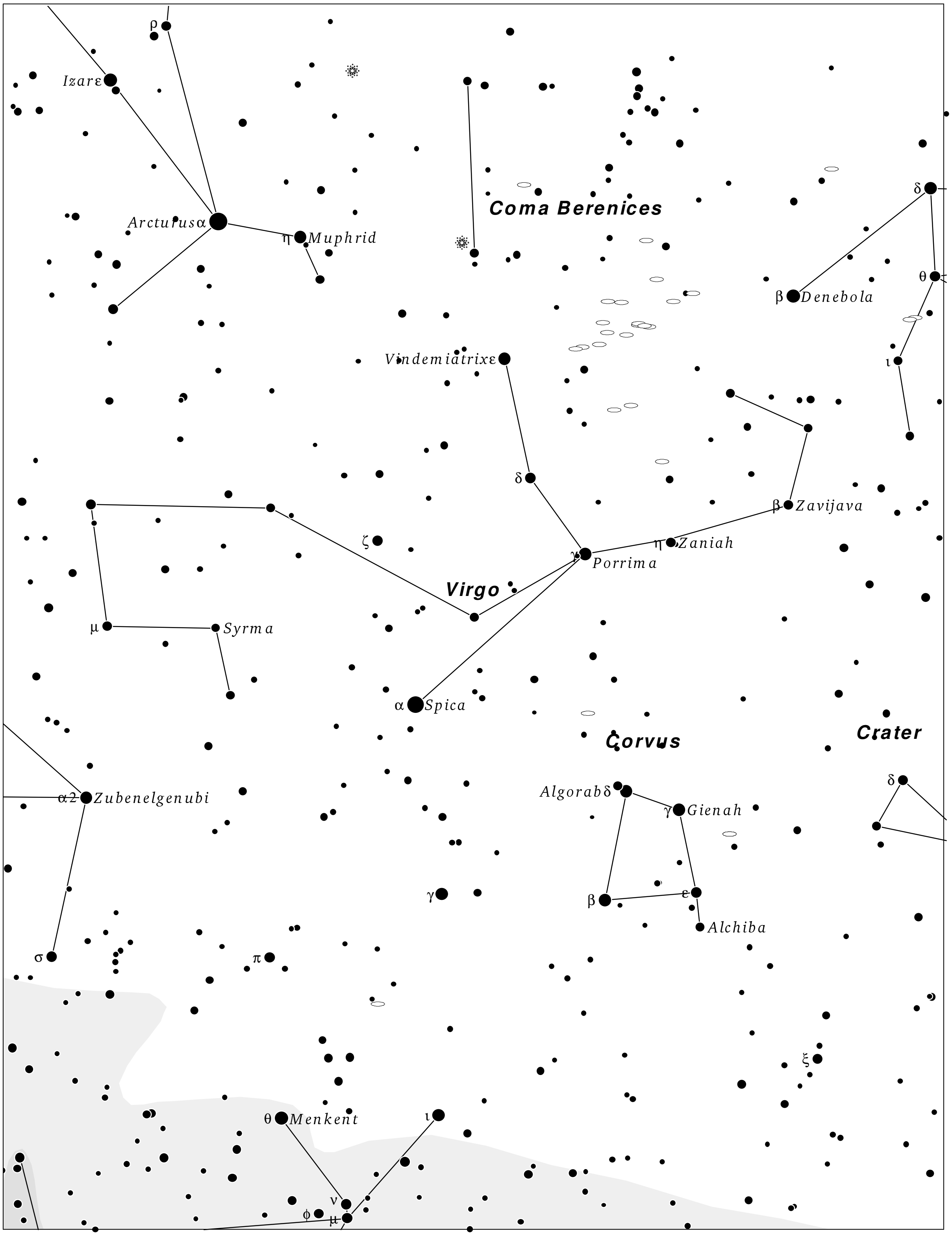
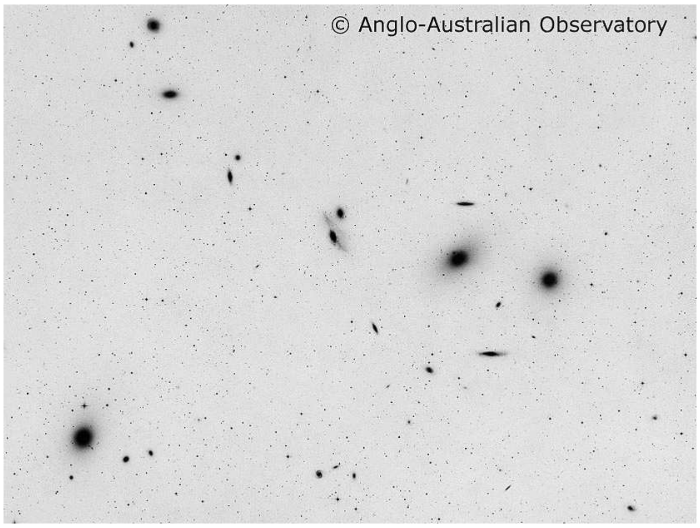
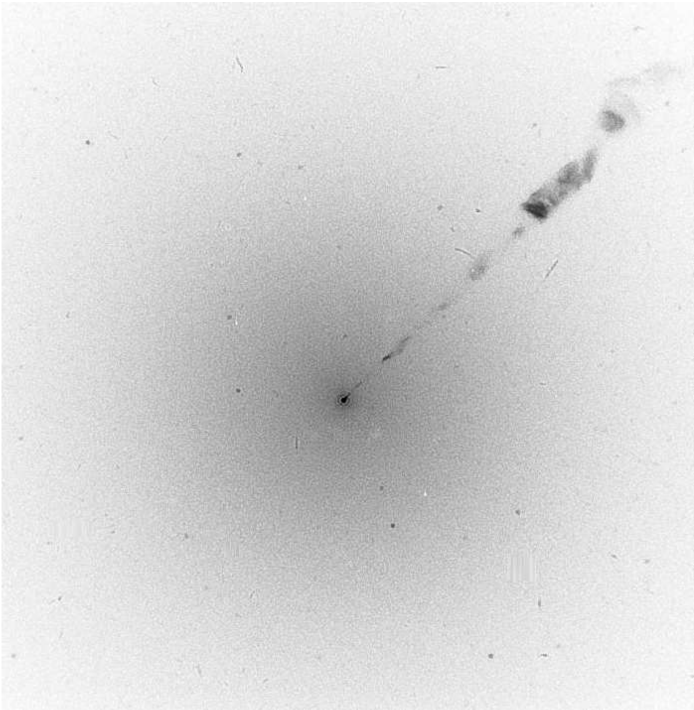


Figure 32: **Galaxies in the Central Region of the Virgo Cluster**



This is a ground-based picture of the central regions of the Virgo Cluster. A number of bright galaxies can be seen in this image (including M87 in the lower left hand corner). On the original image, several dozen cluster members can be seen.

Figure 33: **The Core of the Giant Elliptical Galaxy M87**



At the very center of M87 sits a *super-massive* black hole. This object appears to have a mass that is several million times that of the sun! Around this black hole is a disk of very hot gas that is spiraling into the black hole. The energy generated by this process results in a high velocity stream of material (a "jet") being ejected along the polar axis of the gas disk. This collimated jet can be seen emerging from the nucleus of the galaxy in this *HST* image of M87. The jet extends for about 5,000 light years, becoming much broader as it gets further from the black hole.