STARGAZERS' HANDBOOK

To infinity and beyond

Astronomy Club
IIT Kanpur

Acknowledgement

Astronomy has always been a fascinating field of study. However, beginners often feel left out when they don't get to grasp the basics of star observations and such. This manual is our humble attempt to bridge the gap between the novice and the expert.

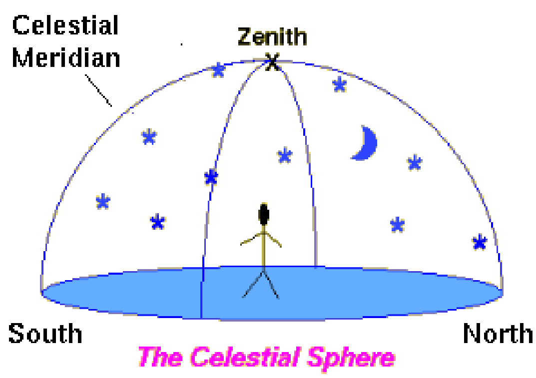
We would like to thank the entire astronomy club team, without whom we might never have been inspired enough to come up with the idea. We express our gratitude towards Nidhi Pashine, Akshat Singhal, Udhbhav Singh, Harsh Shah and Tej Pratap, who made this possible. We acknowledge the helping hand lent to us by Pulkit Agrawal, who has always been there when we needed him. Special mention for Karthik Vijayakumar and Ronak Shah, who made us dream beyond the horizon. Most of all, our heartfelt thanks go to all the readers who will be reading this. It is you who add meaning to our efforts, and if this book manages to create even a little bit of interest in you, we would consider our job well done.

Regards,
Anshul Modi & Jishnu Bhattacharya,
Coordinators,
Astronomy Club

Contents

Basic Astronomy

Celestial Sphere: If we look above at the skies, we find that all the stars are fixed on a sphere of infinite radius concentric to the earth and keeps repeating their pattern on this sphere .This fictitious sphere is called the *celestial sphere* .It is also useful in discussing objects in the sky by imagining them to be attached to a sphere surrounding the earth . The celestial sphere rotates about the fixed earth from east to west every sidereal day .At any one time we see no more than half of this sphere, but we will refer loosely to the imaginary half-sphere over our heads as just the celestial sphere.
The point on the celestial sphere that is directly over our heads at a given time is termed the *zenith*. The imaginary circle passing through the North and South points on our horizon and through the zenith is termed the *celestial meridian*.



Celestial Equator: The projection of the Earth's equator onto the celestial sphere is called the celestial equator.

Celestial Poles: The projections of the Earth's north and south geographic poles on celestial sphere become the north and south celestial poles, respectively.

Ecliptic Plane: The plane of the Earth's orbit around the Sun. In other words, Plane from which Sun passes on the celestial throughout a year sphere with respect to earth. The ecliptic plane is used as the primary reference plane when describing the position of bodies in the solar system. Most objects in the solar system orbit in roughly this plane and in the same direction around the Sun as the Earth

Latitude: Latitude, gives the location of a place on Earth (or other planetary body) north or south of the equator. Lines of Latitude are the imaginary horizontal lines shown running east-to-west (or west to east) on maps that run either north or south of the equator. Technically, latitude is an angular measurement in degrees (marked with °) ranging from 0° at the equator (low latitude) to 90° at the poles (90° N or +90° for the North Pole and 90° S or −90° for the South Pole)..

Longitude: The lines of longitude (meridian) that passes through the Royal Observatory, Greenwich, in England, establishes the meaning of zero degrees of longitude, or the prime meridian. Any other longitude is identified by the east-west angle, referenced to the center of the Earth as vertex, between the intersections with the equator of the meridian through the location in question and the prime meridian.

Lines of longitude appear vertical with varying curvature in this projection while lines of latitude appear horizontal as shown in above figure.

Celestial Coordinates:

Horizontal system:

The horizontal coordinate system is a celestial coordinate system that uses the observer's local horizon as the fundamental plane. This conveniently divides the sky into the upper hemisphere that you can see, and the lower hemisphere that you cannot (because the Earth is in the way). The pole of the upper hemisphere is called the zenith. The pole of the lower hemisphere is called the nadir.

The horizontal coordinates are:

- Altitude (Alt), sometimes referred to as elevation, that is the angle between the object and the observer's local horizon.
- Azimuth (Az), that is the angle of the object around the horizon, usually measured from the north point towards the east. In former times, it was common to refer to azimuth from the south, as it was then zero at the same time the hour angle of a star was zero.

The horizontal coordinate system is sometimes also called the az/el[1] or Alt/Az coordinate system.

The Horizontal Coordinate System is fixed to the Earth, not the Stars. Therefore, the Altitude and Azimuth of an object changes with time, as the object appears to drift across the sky. In addition, because the Horizontal system is defined by your local horizon, the same object viewed from different locations on Earth at the same time will have different values of Altitude and Azimuth.

Equatorial system:

This is the preferred coordinate system to pinpoint objects on the celestial sphere. Unlike the horizontal coordinate system, equatorial coordinates are independent of the observer's location and the time of the observation. This means that only one set of coordinates is required for each object, and that these same coordinates can be used by observers in different locations and at different times.
The equatorial coordinate system is basically the projection of the latitude and longitude coordinate system we use here on Earth, onto the celestial sphere. By direct analogy, lines of latitude become lines of declination (Dec; measured in degrees, arcminutes and arcseconds) and indicate how far north or south of the celestial equator (defined by projecting the Earth's equator onto the celestial sphere) the object lies. Lines of longitude have their equivalent in lines of right ascension (RA), but whereas longitude is measured in degrees, minutes and seconds east the Greenwich meridian, RA is measured in hours, minutes and seconds east from where the celestial equator intersects the ecliptic (thevernal equinox).

Hour Angle: In astronomy, the hour angle is one of the coordinates used in the equatorial coordinate system for describing the position of a point on the celestial sphere. The hour angle of a point is the angle between the half plane determined by the Earth's axis and the zenith (half of the meridian plane) and the half plane determined by the Earth's axis and the given point. The angle is taken with minus sign if the point is eastward of the meridian plane and with the plus sign if the point is westward of the meridian plane.The hour angle is usually expressed in time units, with 24 hours corresponding to 360 degrees.

Apparent and absolute Magnitude:

The apparent magnitude (*m*) of a celestial body is a measure of its brightness as seen by an observer on Earth, normalized to the value it would have in the absence of the atmosphere. The brighter the object appears, the lower the value of its magnitude.

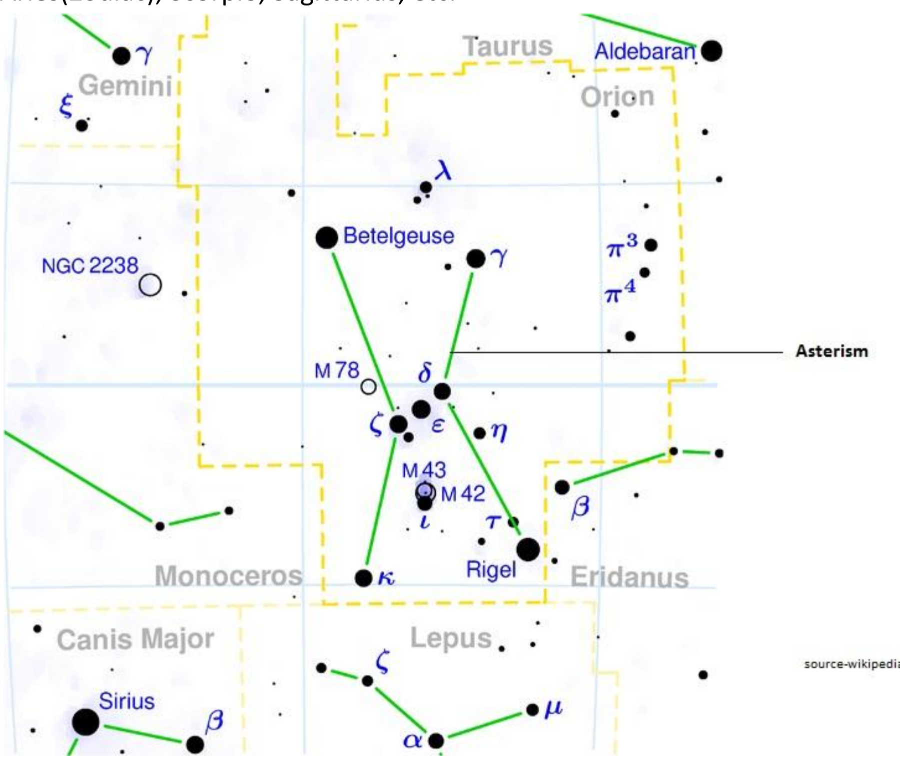
The absolute magnitude equals the apparent magnitude of an object if it were at a standard luminosity distance (10 parsecs, or 1 AU, depending on object type) away from the observer, in the absence of astronomical extinction. It allows the true brightness of objects to be compared without regard to distance.

What to See

Naked eye

Constellation

A constellation is a group of celestial bodies, usually stars, which appear to form a particular pattern in the sky. Not all the stars of a constellation are visible. The visible stars make a pattern called Asterism which is used to identify a constellation. There are in total 88 constellations. Constellations are easier way to divide the sky (celestial sphere model).The brightest star is termed as ‘α’, the one next to it is ‘β’ and so on. The constellations in which the sun lies along the whole year are designated as ‘*Zodiacs*’. eg- Ursa Major, Aries(Zodiac), Scorpio, Sagittarius, etc.



Planets

A planet is a body that orbits the Sun, is large enough for its own gravity to make it round, and has "cleared its neighbourhood" of smaller objects. Under this new definition, Pluto, along with the other trans-Neptunian objects, does not qualify as a planet. No need for examples.

Double Star

A double star is a pair of stars that appear close to each other in the sky as seen from Earth when viewed through an optical telescope. This can happen either because the pair forms a *binary star*, i.e. a binary system of stars in mutual orbit, gravitationally bound to each other, or because it is an *optical double*, a chance alignment of two stars in the sky that lie at different distances.

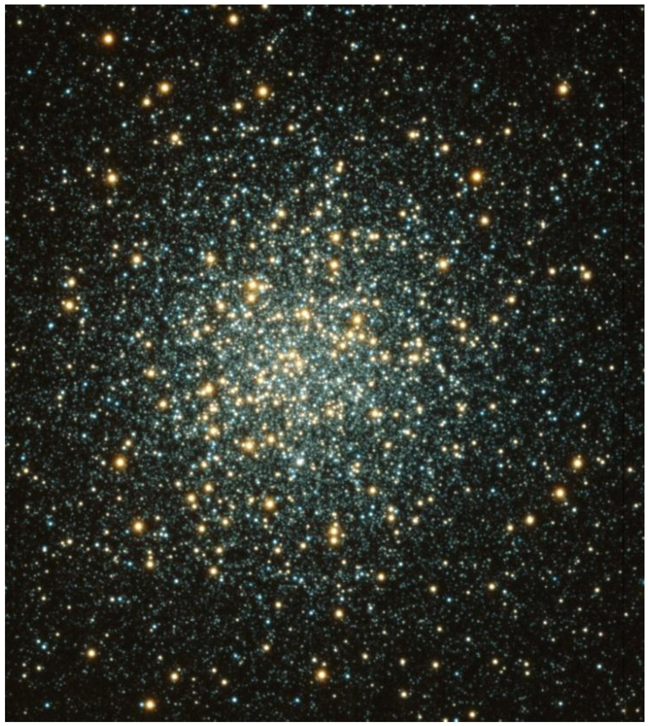
Through the Eyepiece

Open Cluster

An open cluster is group of stars seen near to each other when viewed through a telescope. They are loosely bounded to each other by mutual gravitation. The number of stars in an open cluster may be in thousands but only the prominenet ones are visible in the telescope.

Globular cluster

It is also a collection of thousands of stars but denser than the open cluster. Its name derived from the Latin word-*globulus* meaning a small sphere.The stars are tightly bound to each other by gravity which gives them a spherical shape and a relatively higher dendity at the centre.



Nebula

A nebula is collection of various gases mainly hydrogen and helium. It's the birthplace of stars. A hazy patch is seen when viewd from a small optical telescope. There also exist nebulae that seem as large as planets when viewed through an optical telescope and so are called *planetary nebulae.*

Galaxies

A galaxy is a collection of heavenly objects, dust, gases,etc. All the masses orbit around the centre of mass of the galaxy. Galaxies have been categerized on the basis of their shapes:- elliptical, spiral and irregular.

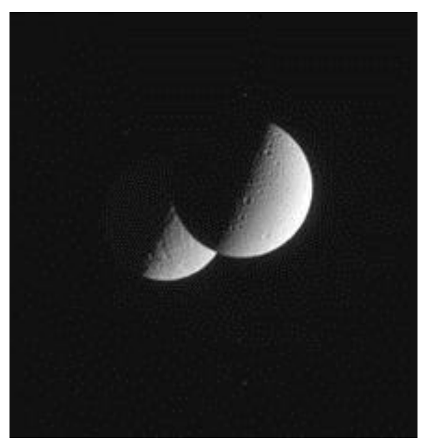
M31, la galaxie d'Andromède

Meteor Shower

It is an event in which many meteors radiate from a point in the night sky. On certain nights at a fixed time each year, the rate of meteors is more than normal. The rate tends to increase from midnight untill dawn. Some famous showers are Perseids (12^{th} Aug), Leonids (17^{th} Nov), etc.

Occultation

An occultation is an event in which a part of the viewed object is concealed behind another object. Occultation includes *transits* and *ecllipse. Transit* implies that a part of the farther object is hidden behind a nearer and smaller object. For example venus and jupiter will occult on 22/11/2065.



Comet

A comet is similar to planet but its orbit and composition are such that, when close to star, apart of it vaporizes rendering its luminus and possibly visible.

Tricks of Trade

Dark Adaptation

The eye has an "iris" (an aperture regulator) that controls how much light falls into the eye through the "pupil" (the aperture). The moment you see a bright light, the iris immediately contracts the pupil to allow less light. For observing faint celestial objects, the iris must open the pupil as wide as possible. Thus, one needs to be in dark surroundings for a while for this to happen. Moreover, the absorptive pigments ("Rhodopsin") in the eye are also designed to avoid excess exposure. The moment we look at a bright light, this pigment bleaches (i.e. becomes reflective rather than absorptive) and reduces the sensitivity to light. However, it takes about 30 minutes for the pigment to regenerate. Thus, one must ideally observe from a dark location with no surrounding lights, and allow the eye to adapt to the darkness for about half an hour to become more sensitive to dim light.

To read star atlases, amateur astronomers usually use dim red lights as they do not affect the dark adaptation as much.

It is very bad etiquette to shine a torchlight in the dark during a star party or an observing session, because it will spoil dark adaptation in no time.

Averted Vision

Light-sensitive cells in the eye are not distributed uniformly throughout the retina (which is the light-sensitive "screen" of the eye). The eye is constructed such that looking straight at an object makes light fall onto a region called the "fovea centralis", which has a large number of cone cells. The large density of cone cells helps the eye see more detail while looking straight at an object. Now, cone cells are sensitive to color, but not to dim light. Thus, the eye is "optimized" for viewing details in bright objects. But for faint objects, the cone cells are not responsive. It is the rod cells that are sensitive to dim light. The region in the retina which has a lot of rod cells, is not centered on the visual axis, but is off center. Thus, one can sense dim light better by not looking straight at the object, but looking away from it!

The technique of averted vision is based on this concept. In summary, it is "stare away from the object to see it better". People who predominantly use the right-eye, must look towards the right of the actual position of the object, but be aware of the actual position of the object. People who use the left-eye, must look towards the left of the actual position of the object, but be aware of the actual position of the object. This will greatly enhance what you can see. Practice using averted vision is what differentiates a first-time observer from a seasoned observer. Mastery over averted vision is important to be able to pick out faint detail in objects.

In the eyepiece of a telescope, averted vision is easy to use. If you use your right eye, stare to the right edge of the eyepiece (assuming the object is in the center of the field) and if you use your left eye, stare to the left edge. But be aware of the center of the field of view.

Averted vision can greatly improve views of objects. It can make globular clusters easier to resolve, show spiral structure in spiral galaxies etc.

Star Hopping [Refer to page no. 18 for detailed examples]

Star hopping is a technique to locate faint objects which are not visible to the naked eye. It uses bright stars as a guide to locate fainter objects. A known star is first tracked in the finder scope, and then the scope is moved so as to follow a known pattern of stars in the sky till the object is reached. Once the target object is reached, higher magnifications can be used for observation.

Using Optical Instruments

Observing with a pair of binoculars

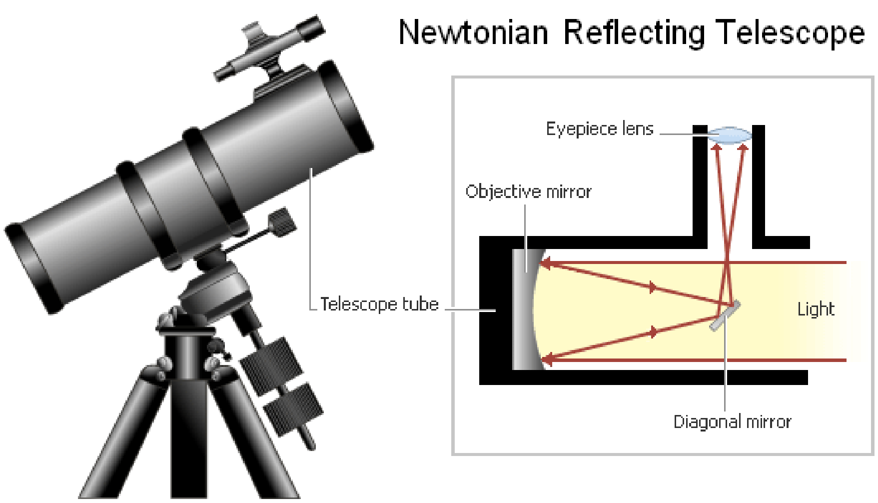
Astronomical Binoculars come in many different models for eg. 7X35, 10X50 or even much larger. A 10X50 model means that the aperture of each of the front lens is 50mm and it has a magnification of 10.

Due to their low magnification, binoculars are not as good as a telescope for observing bright objects like planets but they give an awesome view of objects such as star clusters, nebulas and even a few bright galaxies.

One can start binocular observation with separating bright double stars like Alcor and Mizar in Ursa Major or Alberio in Cygnus and then move on to fainter objects like great nebula in Orion, the Beehive cluster, globular cluster in Hercules or even the Andromeda galaxy.

Getting started with telescopes

Basic structure of a telescope



A telescope consists of various parts - telescope tube, mount, finder scope, eyepiece, stand, etc. The telescope tube consists of the primary and secondary mirrors or lenses (depending on the type of the telescope). It is connected to the stand by a mount which determines the movement of the tube. There are counter-weights attached to the mount to make sure the telescope is balanced.

There is a smaller scope called the finderscope attached to the main telescope. It is aligned to the main scope such that both of them point in the same direction. The purpose of this finderscope is to provide a greater field of view in order to easily trace the object to be observed.

The magnification of a telescope depends on the focal lengths of the optical components. It is simply the ratio of focal length of the objective to the focal length of the eyepiece.

Starting observation with a telescope

As a beginner, it's best to start with the moon or a bright planet. There are obvious reasons for this. First of all, it's easy to locate through the telescope in the night sky and secondly, it's a beautiful object to look at.

Choosing a site for observation

When you begin your observation, choose a location where the maximum possible region of the sky is visible. Also make sure that there is minimum glare of streetlamps or other sources of light. Then make sure that the tripod is stable on the ground and will not fall down.

Aligning your finderscope

To align the finderscope with the main telescope, first locate a bright object such as a street lamp situated far away . Then make sure that this object is in the center of the eyepiece. When this is done, lock the adjustments and then check the position of the object in the finderscope. Generally there are three adjusting screws on the finderscope. Tighten or loosen them as required such that the object moves to the center of the finder's field. At last, make sure that the object is still in the field of view in the main telescope.

Keep a check on magnification

While first locating the object, take care to start with low magnification. After locating the object, move to a higher magnification. Also, it may be tempting to use very high magnifications but the resolving power of a telescope depends on its aperture and the maximum useful magnification limit is around 50 times the aperture in inches.

How to See

Constellations

Constellations are groups of stars that form pictures in the sky. Constellations are always visible at the same time of year.To most people, a constellation is a group of stars which appear to form a picture in the sky, assuming one uses some poetic license. To astronomers, however, a constellation is a specific region of the sky, with astronomers breaking the visible sky up into 88 different constellations. Whether you are a layperson or an astronomer, constellations are a way of viewing the night sky and breaking the information in the sky up into usable chunks, rather than trying to take in the sky as a whole.

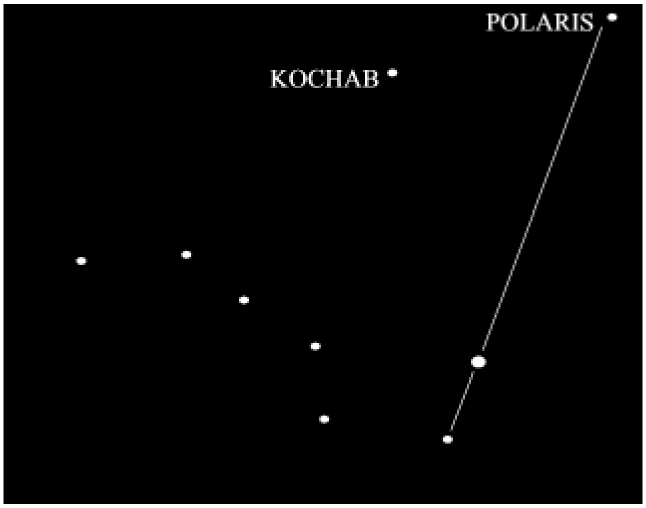
A star-pattern that is not officially classed as a constellation is referred to as an asterism. One famous example is the asterism known as the Big Dipper, a term unused by the International Astronomical Union (IAU) as the stars are considered part of the larger constellation of Ursa Major.

Although the cluster of stars in a constellation might look very close to each other from Earth, they are actually separated by considerable distances, and there are numerous stars between them which are too faint or too distant to see. In many cases, the light from distant stars simply has not reached us yet, because those stars are too new. Conversely, some of the stars which are familiar to us from their place in asterisms may not exist any more, but it may take millions of years for us to find out, since the light from the star is traveling across such an incredible distance. Even though all stars are moving through space, they are so far away that they seem to stay in the same place, so the pictures we see always stay the same. You don't need any binoculars or telescope to see the constellations. Most are large pictures in the sky and are best seen without any optical aid.

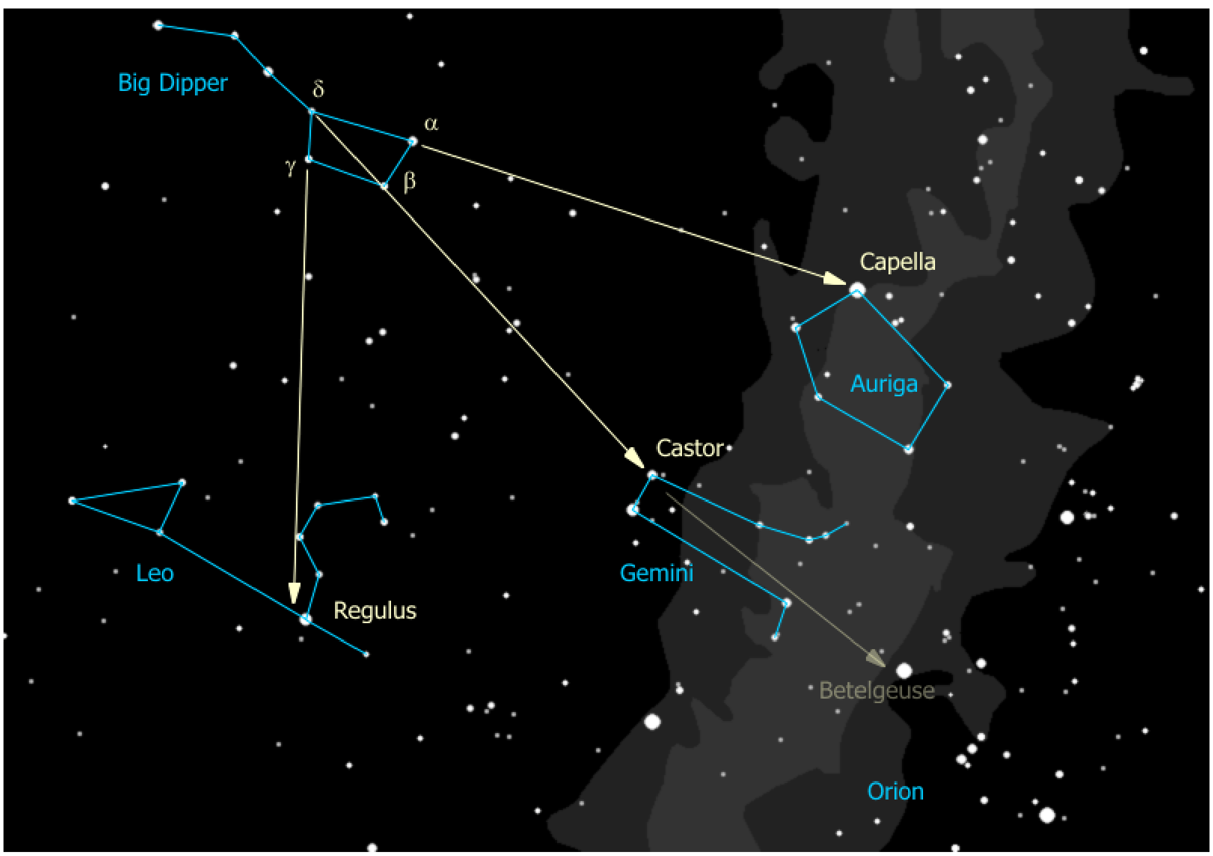
Learning the constellations is very important part of successful star gazing.Before using a telescope to view the night sky you should first try to become familiar with all the major constellations. Knowing the constellations allows one to see the hidden tapestry behind the stars. It becomes much easier to locate the planets, the nebulas, messiers and star clusters. This is especially helpful if you want to use a telescope.

Perhaps the most well known figure in the night sky is the Big Dipper. It is a part of the constellation Ursa Major. This is the third largest constealltion in the sky and is visible for a major portion of the year on account of its favourable position in the sky. It is also useful as a guiding tool for finding other constellations.

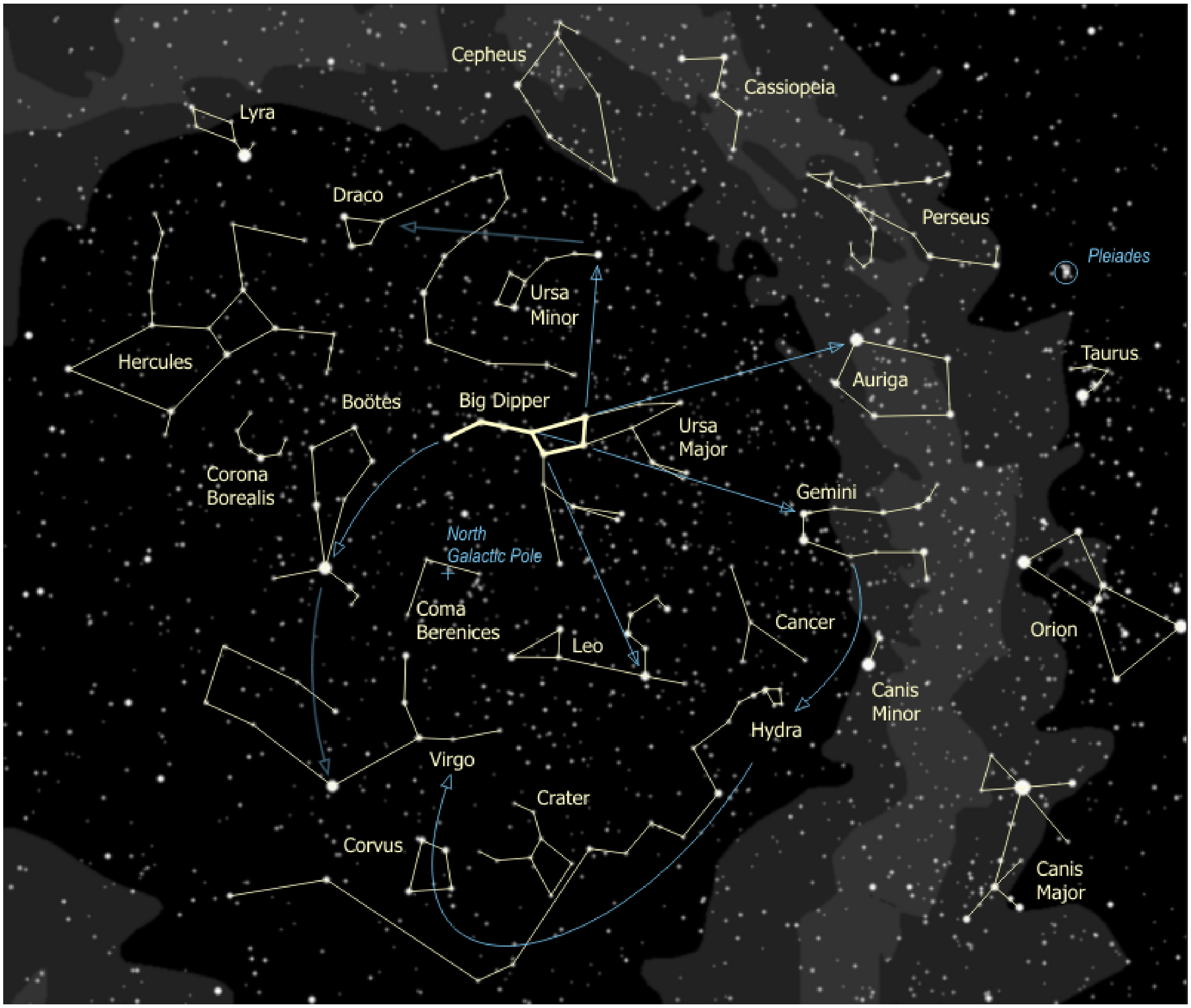
Extending the straight line joining α and β Ursa Major we find the pole star Polaris which is part of the Ursa Minor or Little Bear. Extending the stars on the tail in an arc we come to Arcturus of Bootes the Herdsman. Extending this arc in a straight line we reach the star Spica of Virgo The Virgin. Virgo is a constellation of the Zodiac and is the second largest in the sky.



The Dipper also points to other important stars. You can follow the two stars across the top of the cup and they lead you to the northernmost bright star Capella, in the constellation Auriga. If, instead of going up from the front of the cup, you go down from the back of the cup, you end up at the star Regulus in the constellation Leo. And if you go across the cup, from the back top to the bottom front, you end up at Castor in Gemini. You can continue that line on until you get to Betelgeuse in Orion, the brilliant red star to the west.



We start off with Bootes. Arcturus is the third brightest star in the sky. Next to Bootes is the crown shaped constellation, Corona Borealis or the Northern Crown. The brightest star is called Alphecca. Going on to Spica, we arrive at our first constellation of the Zodiac, Virgo the Virgin. Being large but faint, this constellation can be hard to spot. The region in between the 'Y' shape has a cluster of faint galaxies, visible only through a large telescope.

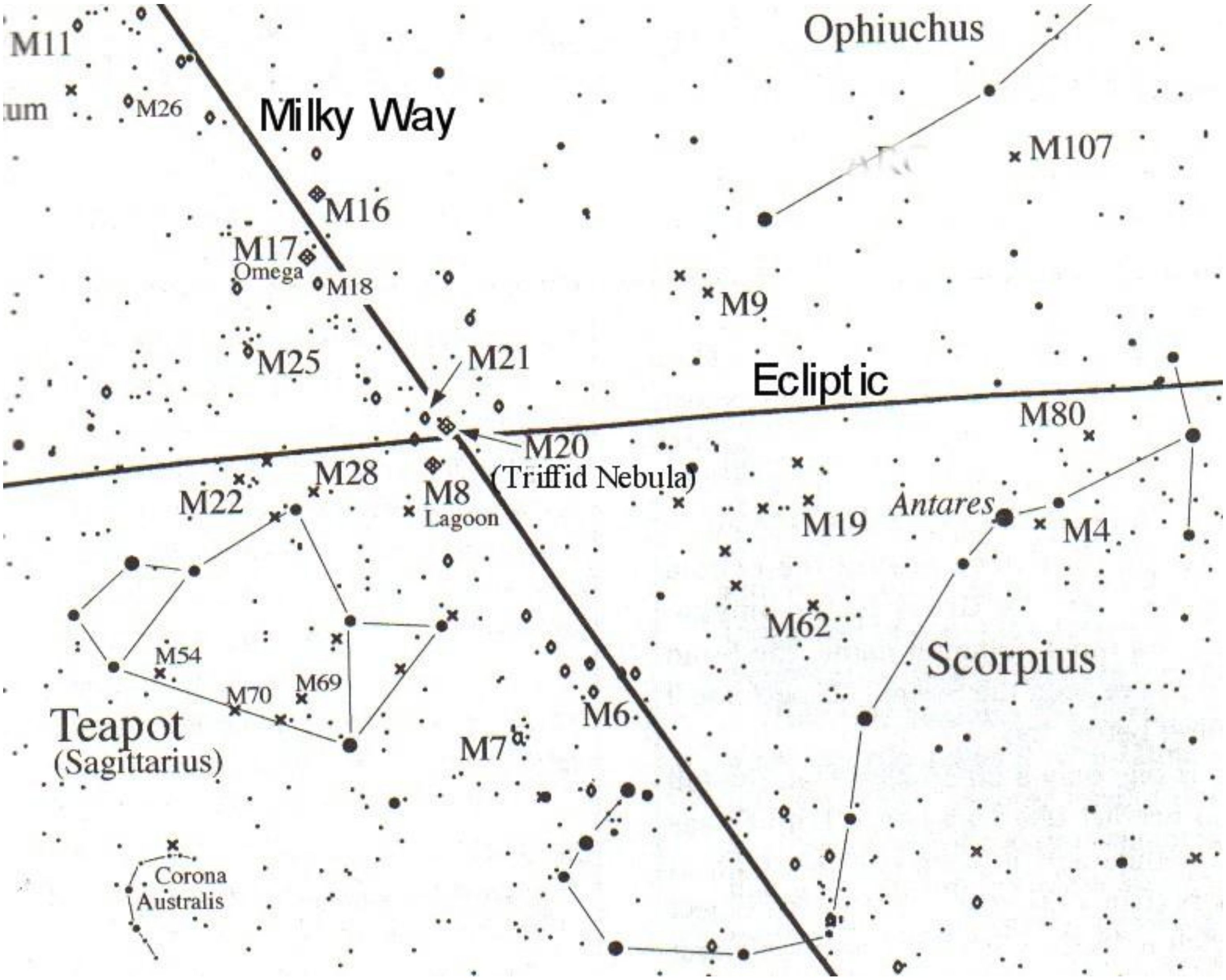


Next to Virgo we see Leo the Lion. It is one of the few constellations which resembles its namesake. The inverted ‘?’ shape marks the head of the lion with the lowermost star of the head being Regulus, the brightest star of the constellation. Beyond Leo is Cancer the Crab. this is a small constellation but has a famous cluster of stars, the Beehive cluster, which is visible with a moderately sized telescope. Past Cancer is Gemini, the Twin sisters. The two parallel lines mark the bodies of the sisters.

Below Gemini, you will find the famous constellation of Orion, the hunter. Betelgeuse can be found from the Bid Dipper. The three stars in a line in the mid region form the belt of Orion, and a line of stars vertical to them forms the sword. This is where the Orion Nebula can be found which is a prominent seat of new star formation. To the South West of Orion you will see a bright star. This is the star Sirius which is the brightest in the sky. It is in the constellation Canis Major, the hunting dog. Extending the line joining Betelgeuse and λ Orionis, we come to Aldebaran in Taurus, the Bull. The 'V' shaped figure forms the head of the bull with Aldebaran as its eye. In this constellation you will find the open cluster Pleides, which is visible even through the naked eye. Above Orion is Auriga the Charioteer, which has a pentagonal shape. It has many galaxies in it which can be visible through a moderately sized telescope.

Moving to another region of the sky, we move back to Bootes. Here, extending the line joining Arcturus and Alphecca, you will reach a star that is a part of a quadrilateral called the keystone of Hercules. This constellation is visible through Spring and Summer and contains the globular cluster of stars M13. Follow this line to go to Vega of Lyra the harp. Here the famous Ring Nebula is located. Moving on, you will come to Deneb of Cygnus. Below Cygnus, you will be able to see a kite shaped figure. This is Aquila whose brightest star Altair, along with Deneb and Vega from a figure called the Summer Triangle.

Between the stars Spica and Altair you will find the constellation of Ophiucus the Serpent Bearer. This is a large but faint constellation and can be a handful to spot in less than good skies. This is also termed as the thirteenth sign of the Zodiac as the sun spends almost a month in this constellation. Ahead of this is the easily identifiable Scorpio. It is hard to see the full Scorpio from northern skies or wehere the horizon visibility is obstructed.The brightest star Antares is a red giant. The constellation of Libra above Scorpio used to be the pincers of the Scorpion but were later divided into a separate constellation. To the left of Scorpion is Sagittarius. This constellation resembles a teapot and is identified by that shape in the sky. It is very interesting to the curious astronomer as a lot of interesting objects lie in it.



The constellations of Sagittarius and Scorpio lie on the centre on the Milky Way in the sky. The Milky Way is the projection of the disk of our galaxy on our sky. It is a remarkable sight in dark skies where it is easily identifiable as a milky patch across the sky.

This concludes our outline of the major constellations in the sky. There are some other constellations which will be visible at various periods of time throughout the year, but we will explain them as they come along.

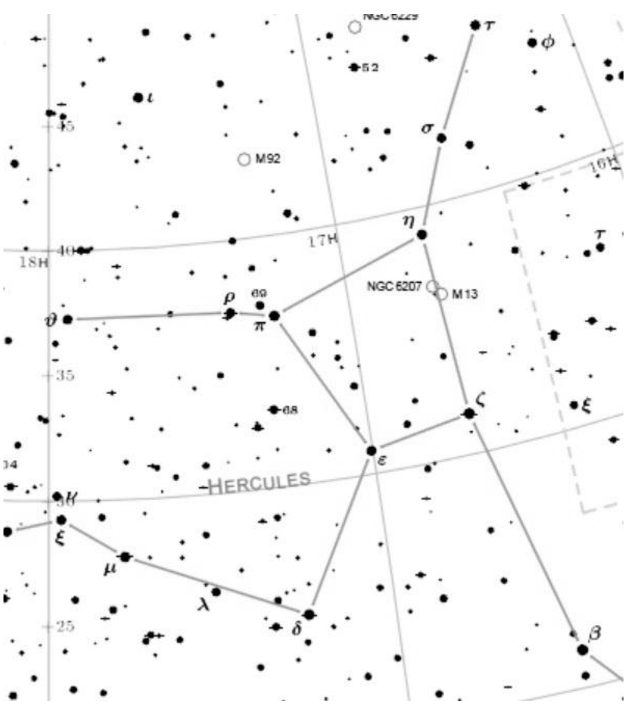
Star Hops

Star hopping is a useful technique to find deep-sky objects in particular. Most deep-sky objects are invisible to the unaided eye, and some are invisible even through the finder scope of a telescope. Finding deep-sky objects requires you to point precisely at the location of the object without even being able to see the object.

Star hopping helps here. The idea is to look for familiar patterns of stars and move from one pattern to another, to finally zero in on the object's location. One usually starts by pointing the telescope / binocular at a bright star / a pattern of stars that is visible to the naked eye. One then locates patterns that are visible only in the telescope / binocular one after the other, to zero in on an object.

A star-hop needs to be planned meticulously using a software / star chart, and must be executed by continuously comparing what is seen in the eyepiece with the star chart / software and use that as an aid to move towards the object.

Of course, the software's view could be magnified differently, and rotated at an angle in comparison to the view in the eyepiece. You should be able to mentally match the two by using star patterns, despite them being oriented differently and zoomed in differently. Using very distinct patterns of stars greatly helps here.



Examples

M 13

M 13 is a globular cluster of stars located in the constellation of Hercules. As shown in the chart. It's located on the line joining the η and ζ stars of Hercules. In order to locate M 13, one would point to a location in the sky on the line joining these two stars around one-third the distance between them and closer to the η star.

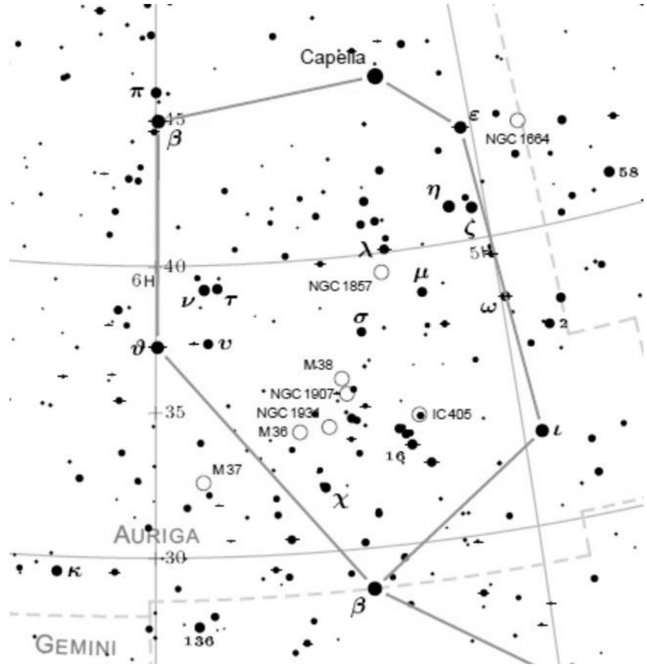
Messiers in Auriga

Another example is the constellation Auriga. It contains open star clusters M36, M37 and M38 in Auriga. In order to track M38, locate the stars ι and θ Aurigae and sweep your finderscope to a location midway between these two stars.

For locating M36, first point the scope towards χ star of Auriga and then move along the line joining β and χ to reach M36.

Once you have located M36, move your telescope in the southeast direction till you reach M37. It is the fairly bright and can be located in the finderscope.

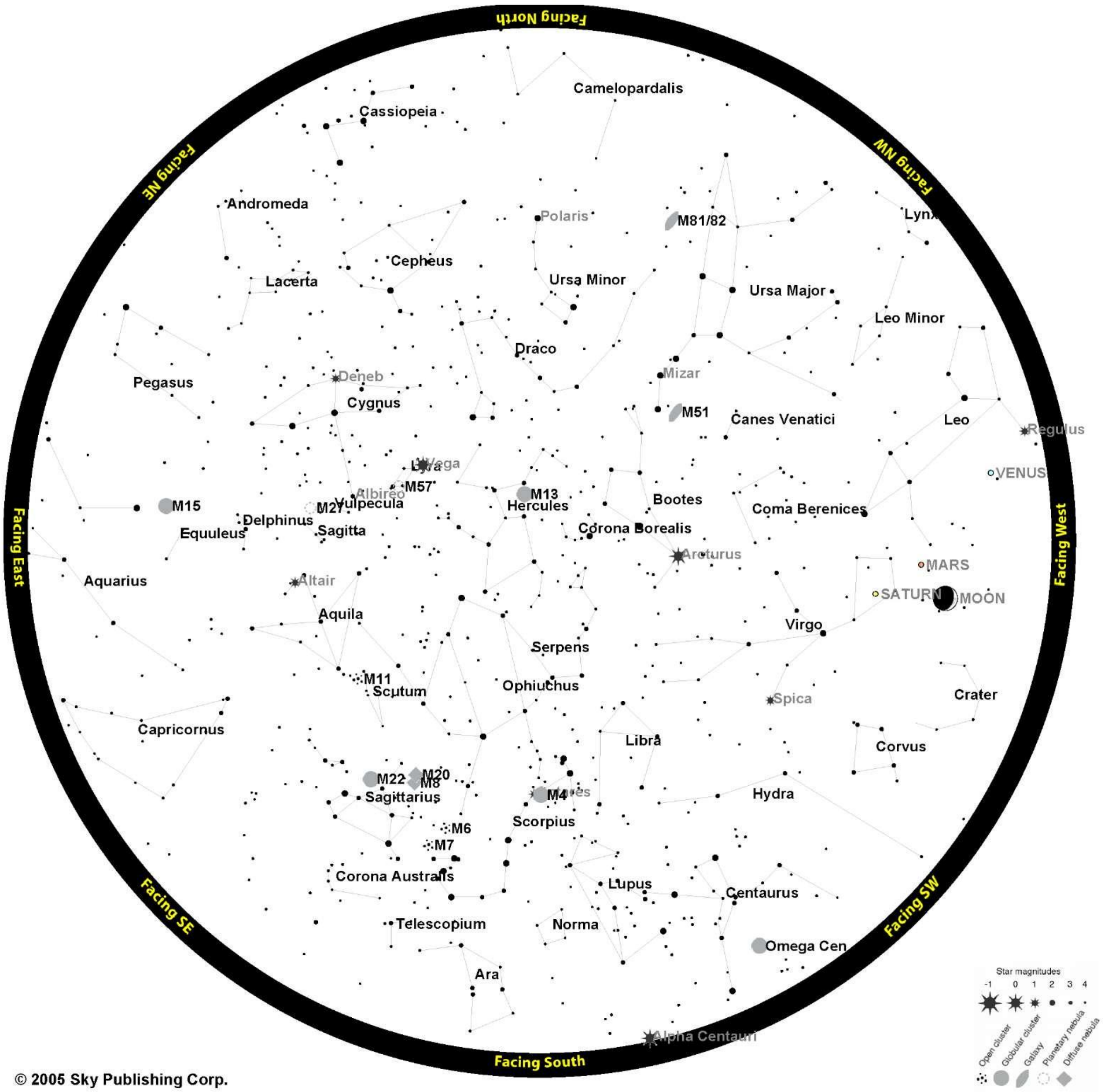
These were some simple star hops for locating a few bright messiers. For more examples of star hops, refer to the Messier Guide Charts section.



How to Use This Chart

Go outside within an hour of the time listed below. Hold the chart out in front of you, and turn it so that the curved edge (the horizon) marked with the direction you're facing is on the bottom, with the lettering right-side up. The stars above this horizon on the chart now match the stars in front of you. The center of the chart is straight overhead (the zenith). So a star shown halfway from the edge to the center can be found in the sky halfway from horizontal to straight up.

Kanpur, IN Jul. 15, 2010, 09:00 pm



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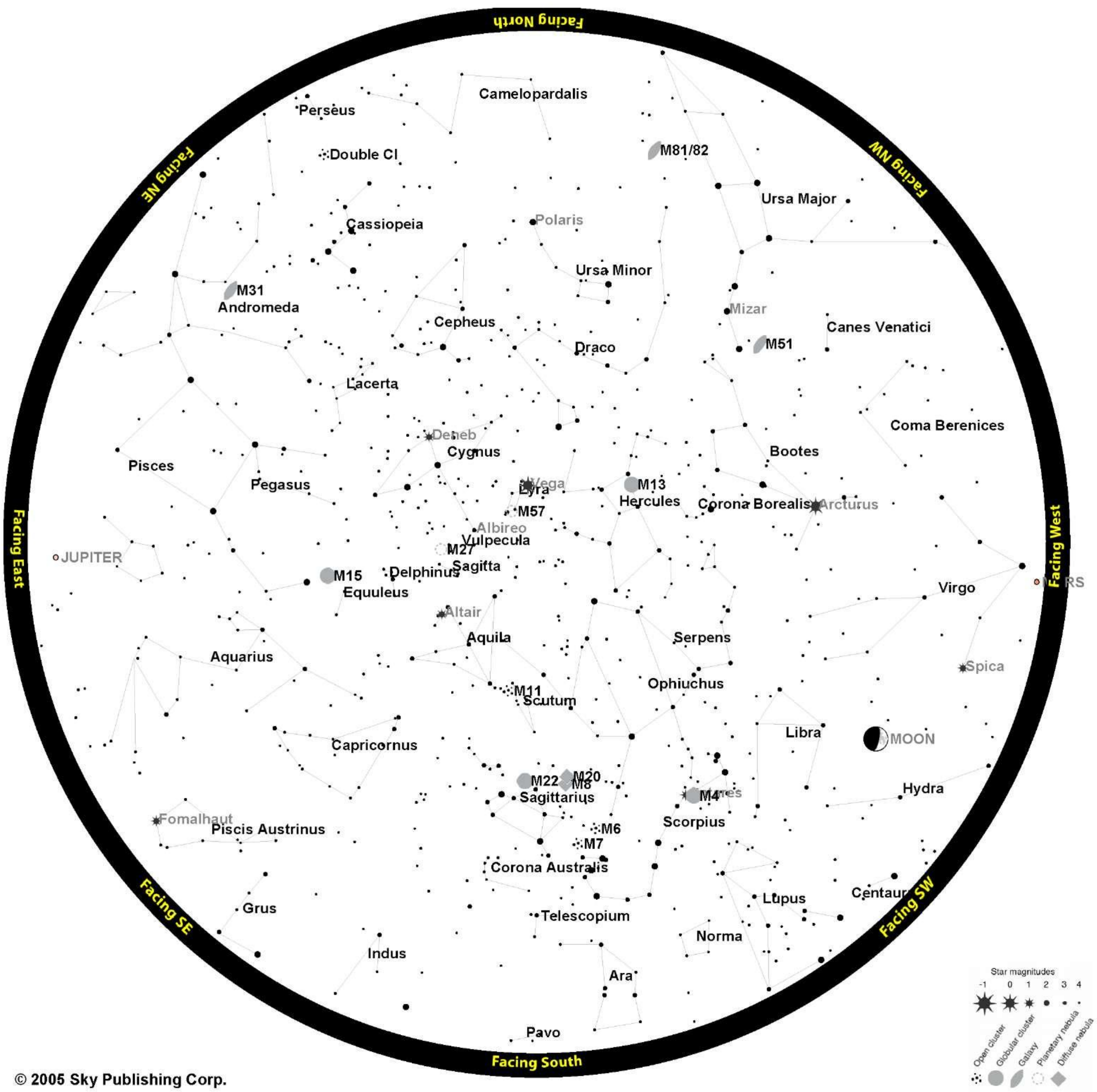

SKY & TELESCOPE

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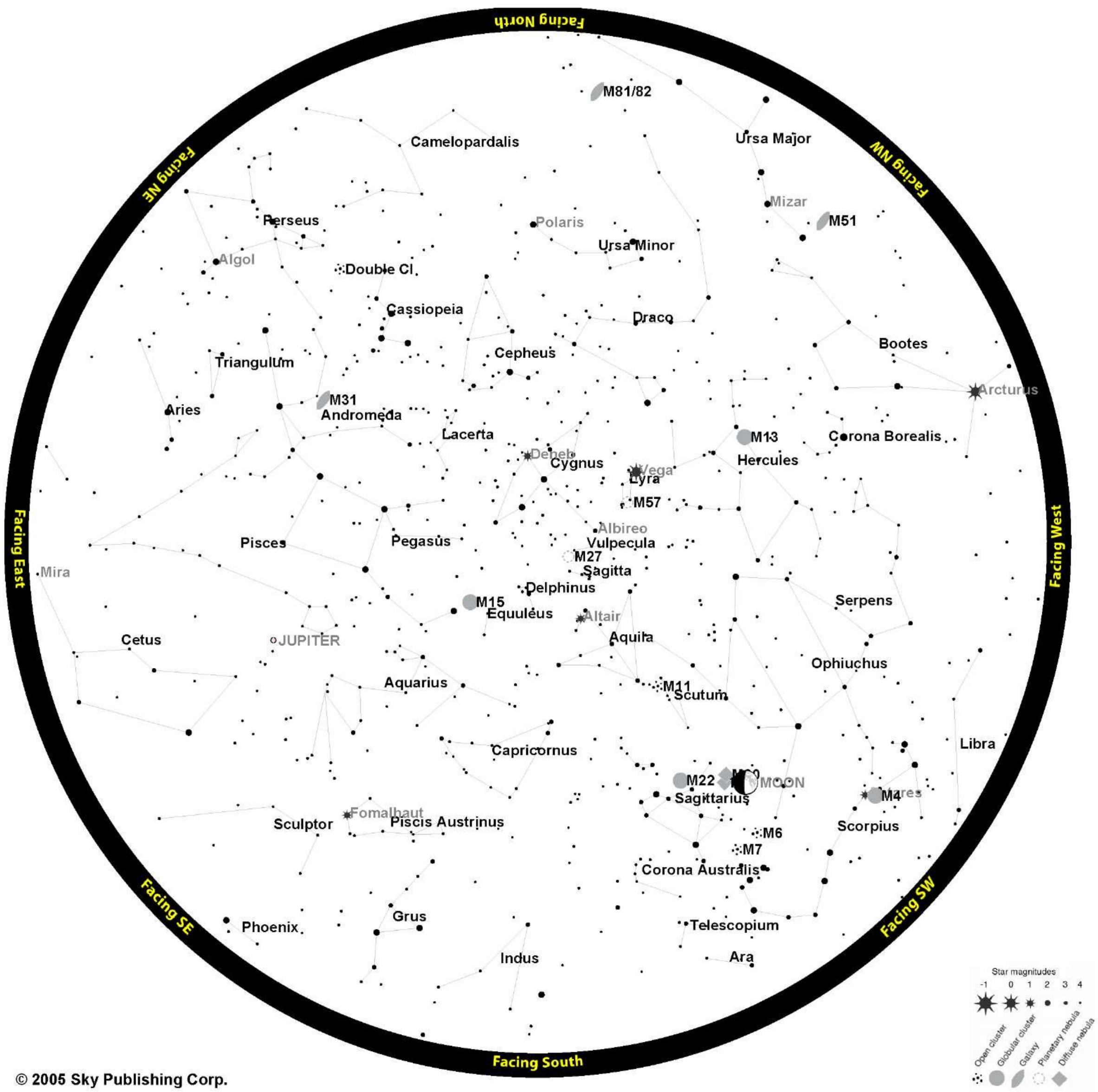
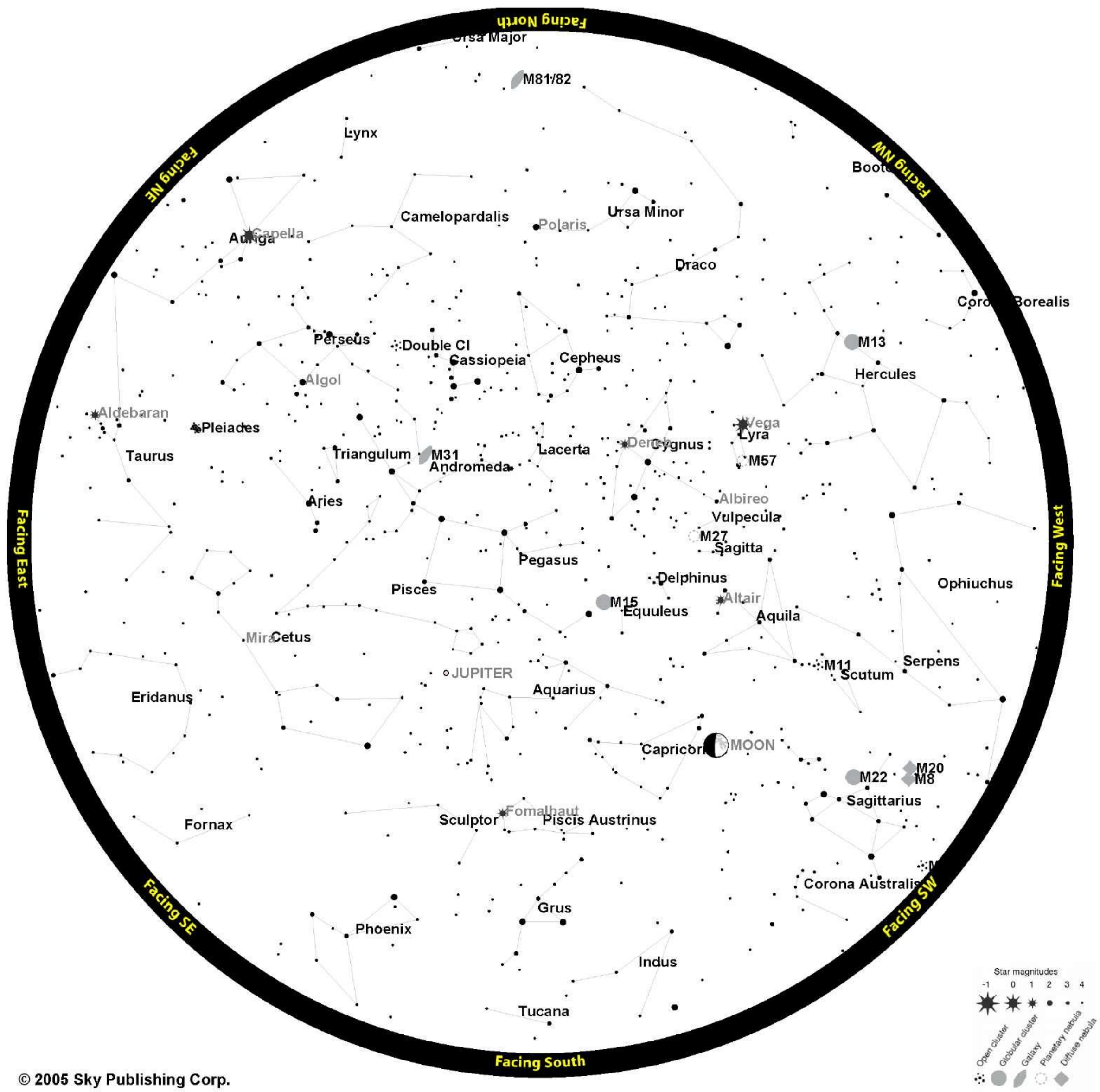


How to Use This Chart

Go outside within an hour of the time listed below. Hold the chart out in front of you, and turn it so that the curved edge (the horizon) marked with the direction you're facing is on the bottom, with the lettering right-side up. The stars above this horizon on the chart now match the stars in front of you. The center of the chart is straight overhead (the zenith). So a star shown halfway from the edge to the center can be found in the sky halfway from horizontal to straight up.

Kanpur, IN   Oct. 15, 2010, 09:00 pm



How to Use This Chart

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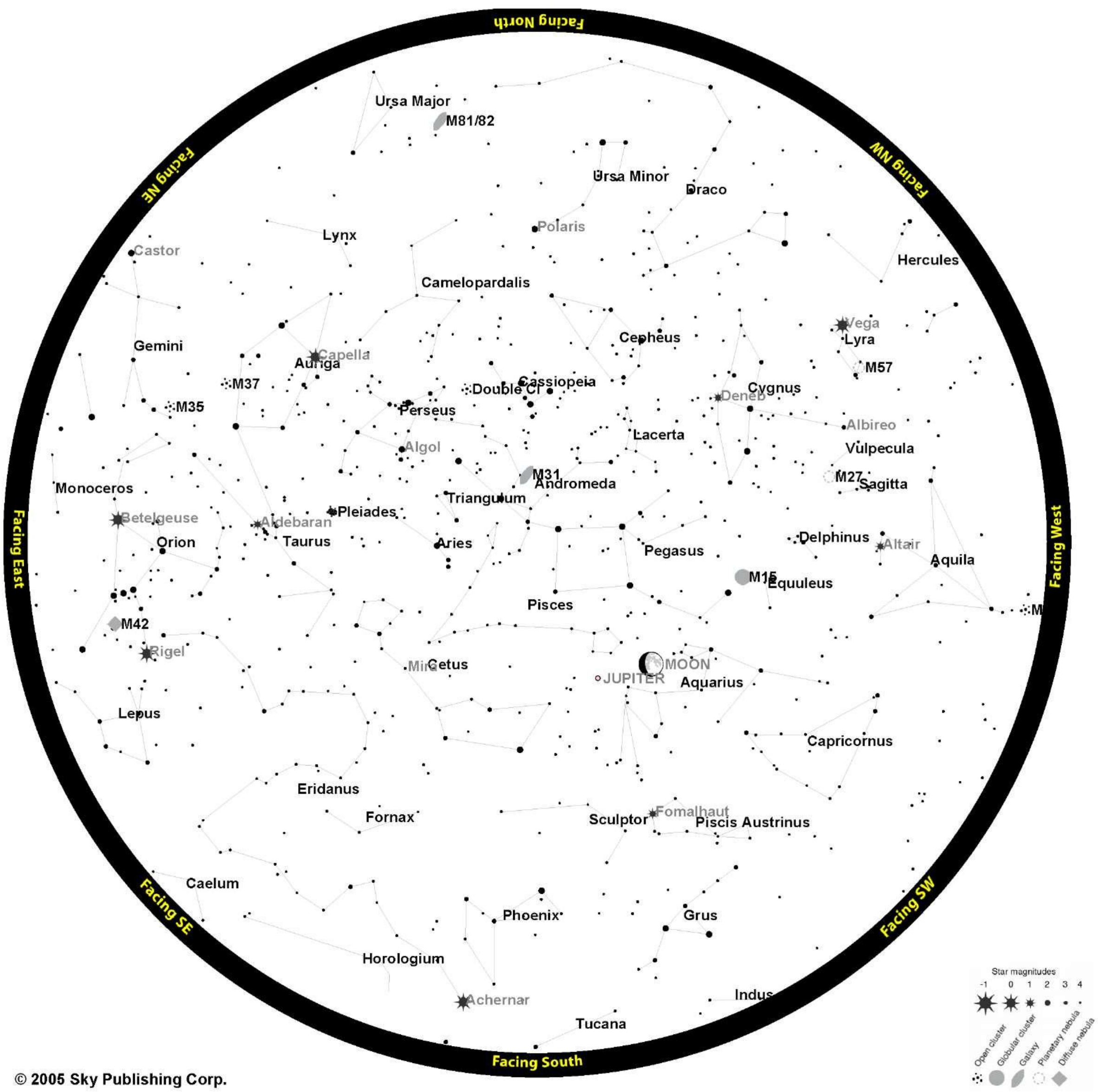
Kanpur, IN Nov. 15, 2010, 09:00 pm



How to Use This Chart

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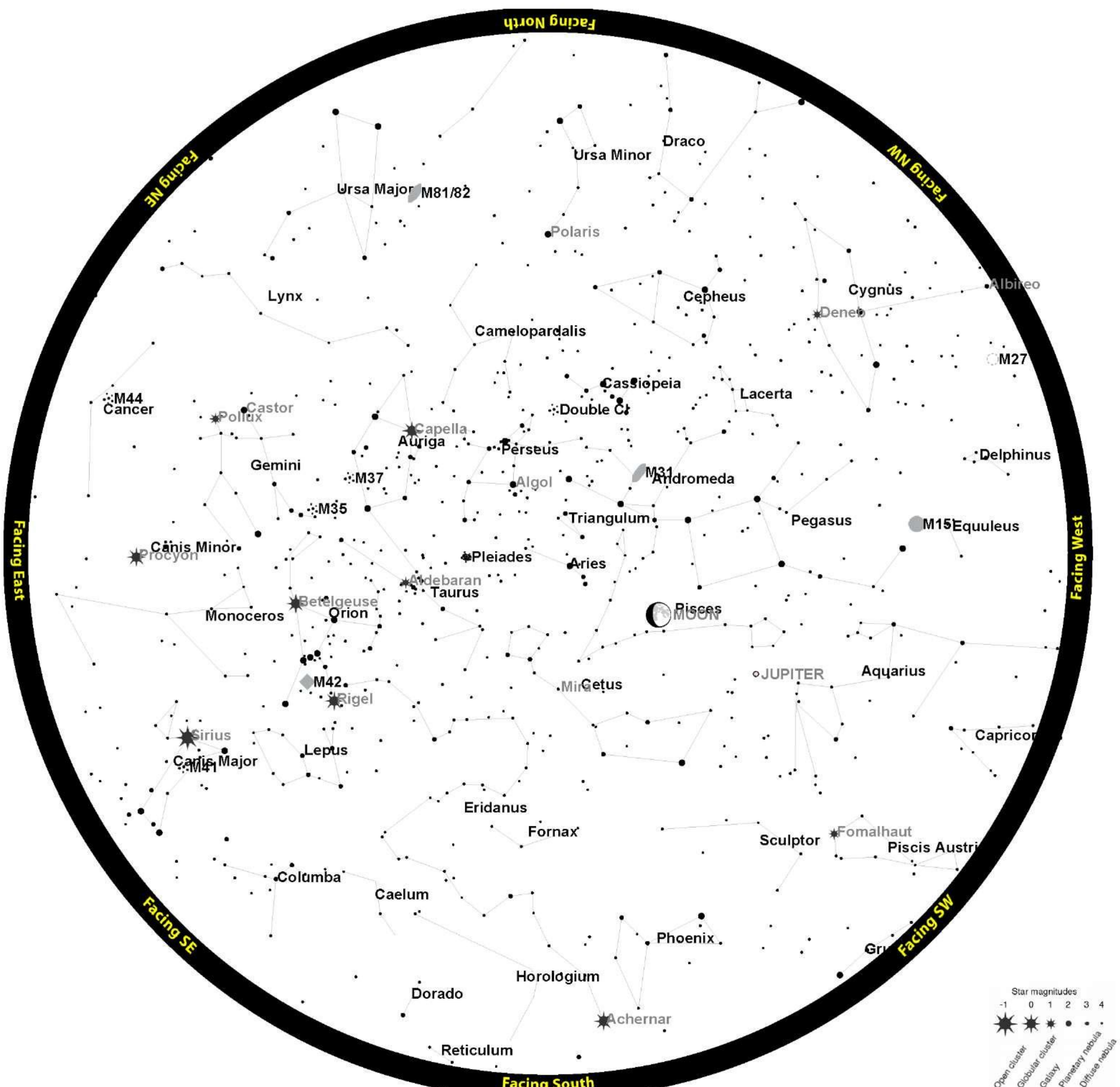
Kanpur, IN   Dec. 15, 2010, 09:00 pm



How to Use This Chart

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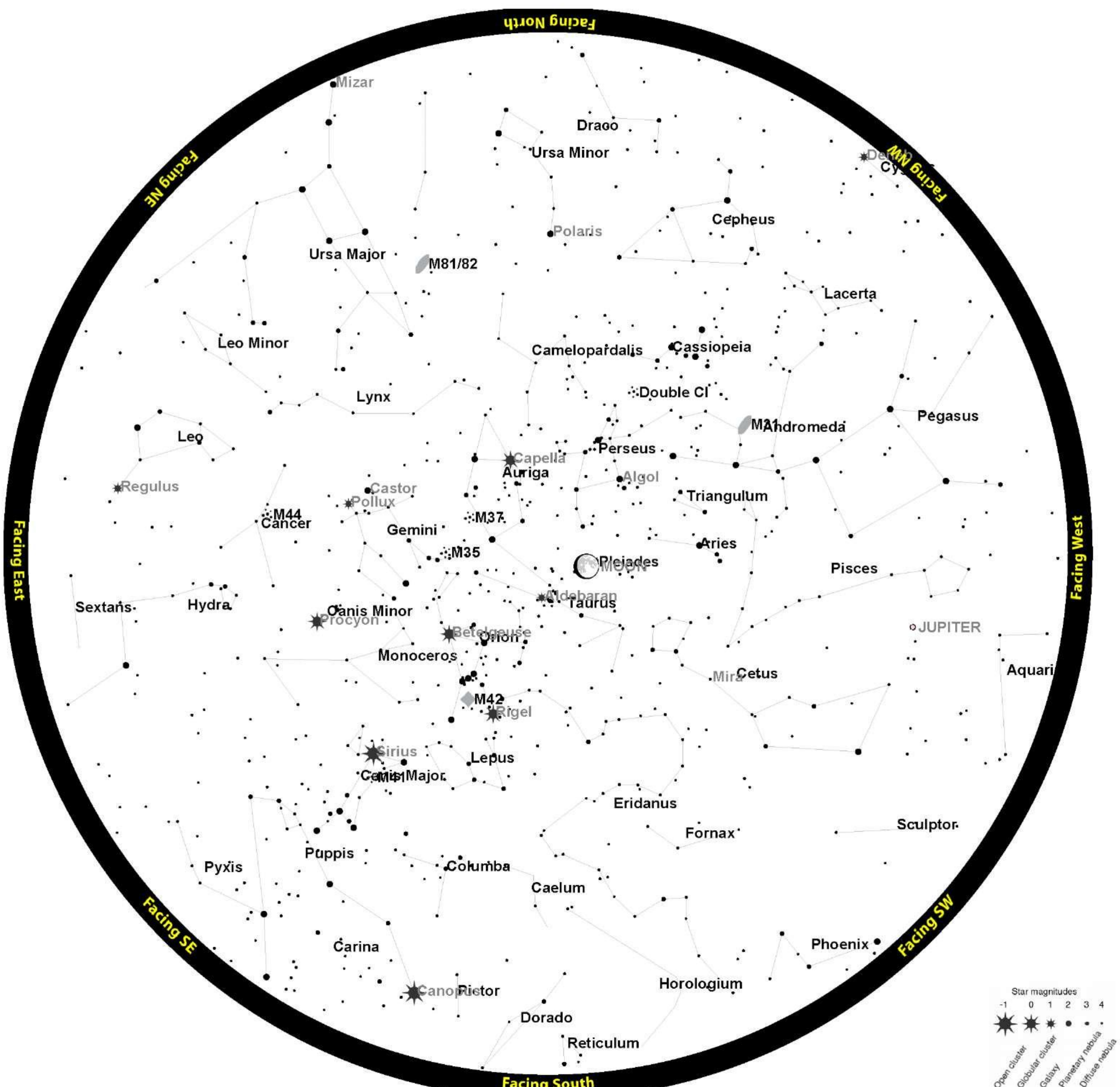
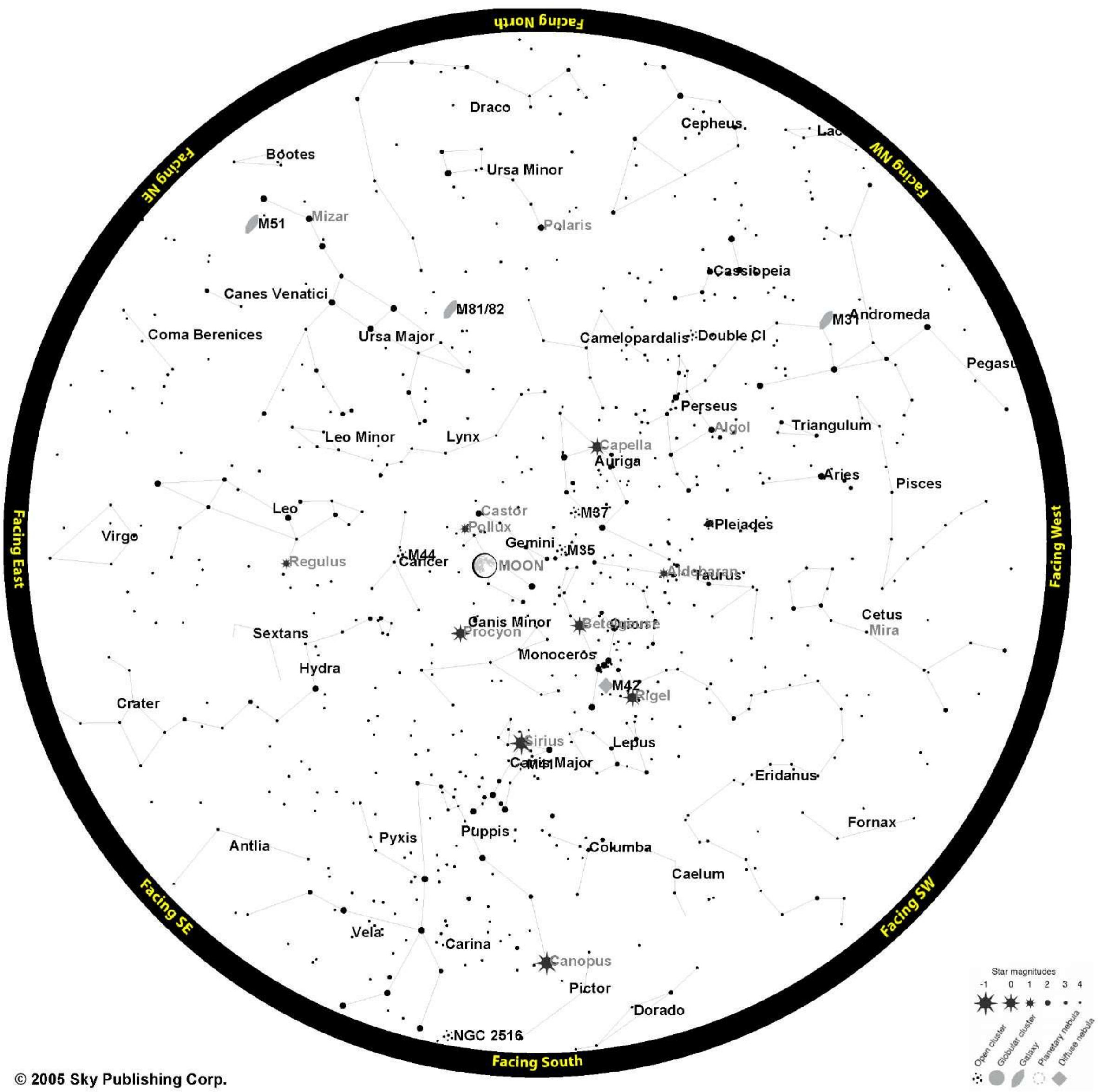
Kanpur, IN   Jan. 15, 2011, 09:00 pm



How to Use This Chart

Go outside within an hour of the time listed below. Hold the chart out in front of you, and turn it so that the curved edge (the horizon) marked with the direction you're facing is on the bottom, with the lettering right-side up. The stars above this horizon on the chart now match the stars in front of you. The center of the chart is straight overhead (the zenith). So a star shown halfway from the edge to the center can be found in the sky halfway from horizontal to straight up.

Kanpur, IN   Feb. 15, 2011, 09:00 pm



How to Use This Chart

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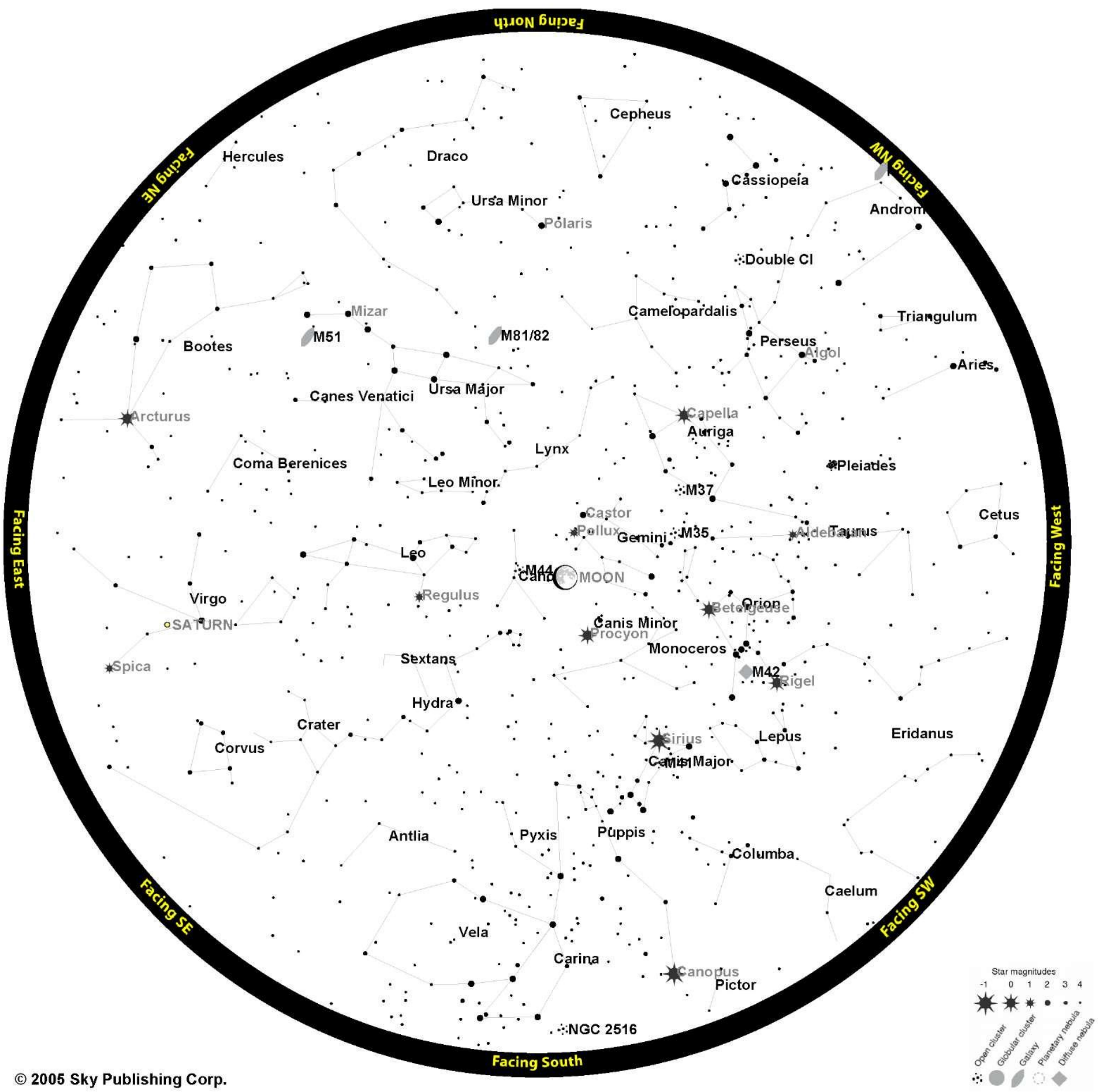
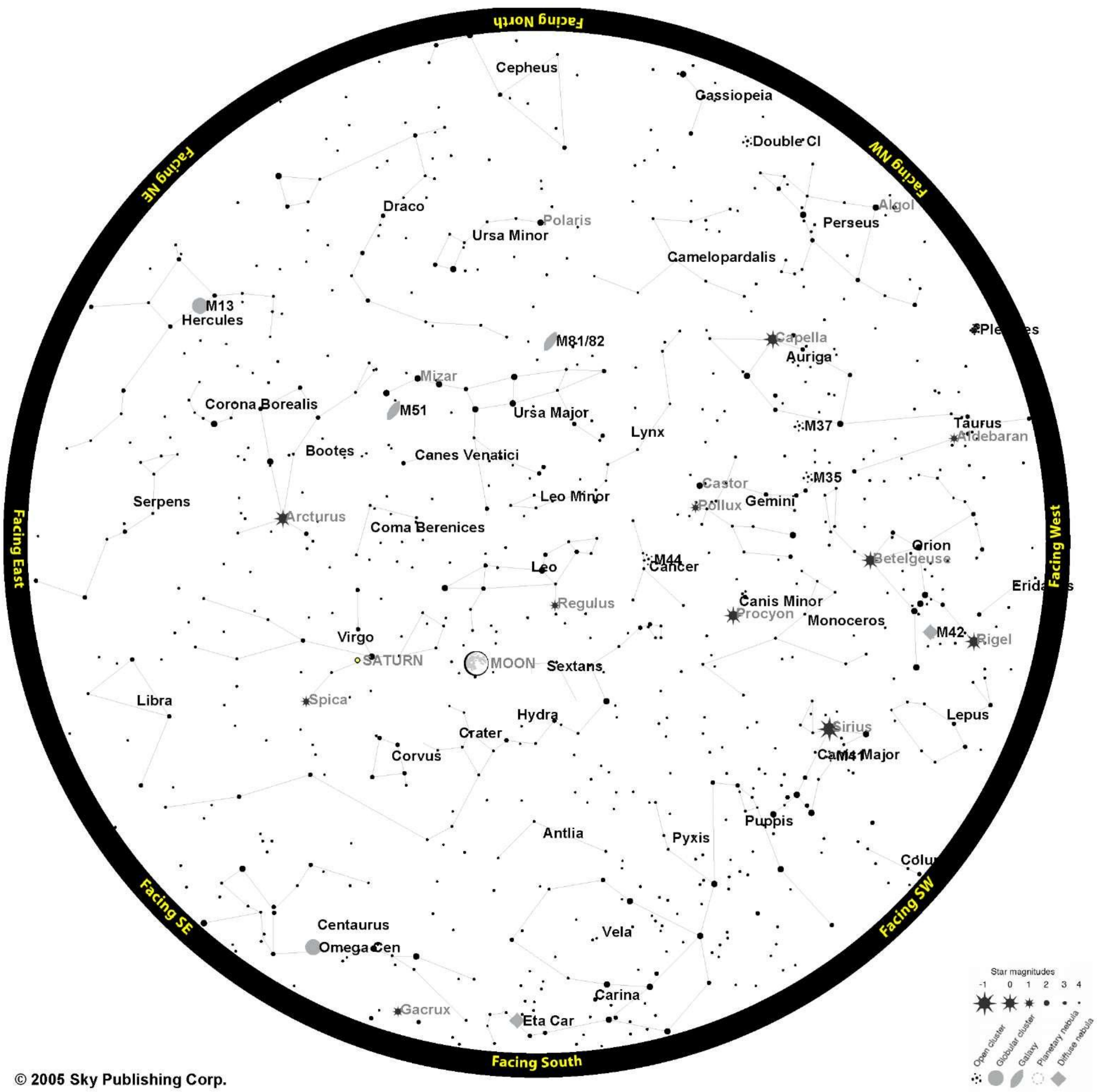
Kanpur, IN   Mar. 15, 2011, 09:00 pm



How to Use This Chart

Go outside within an hour of the time listed below. Hold the chart out in front of you, and turn it so that the curved edge (the horizon) marked with the direction you're facing is on the bottom, with the lettering right-side up. The stars above this horizon on the chart now match the stars in front of you. The center of the chart is straight overhead (the zenith). So a star shown halfway from the edge to the center can be found in the sky halfway from horizontal to straight up.

Kanpur, IN   Apr. 15, 2011, 09:00 pm



How to Use This Chart

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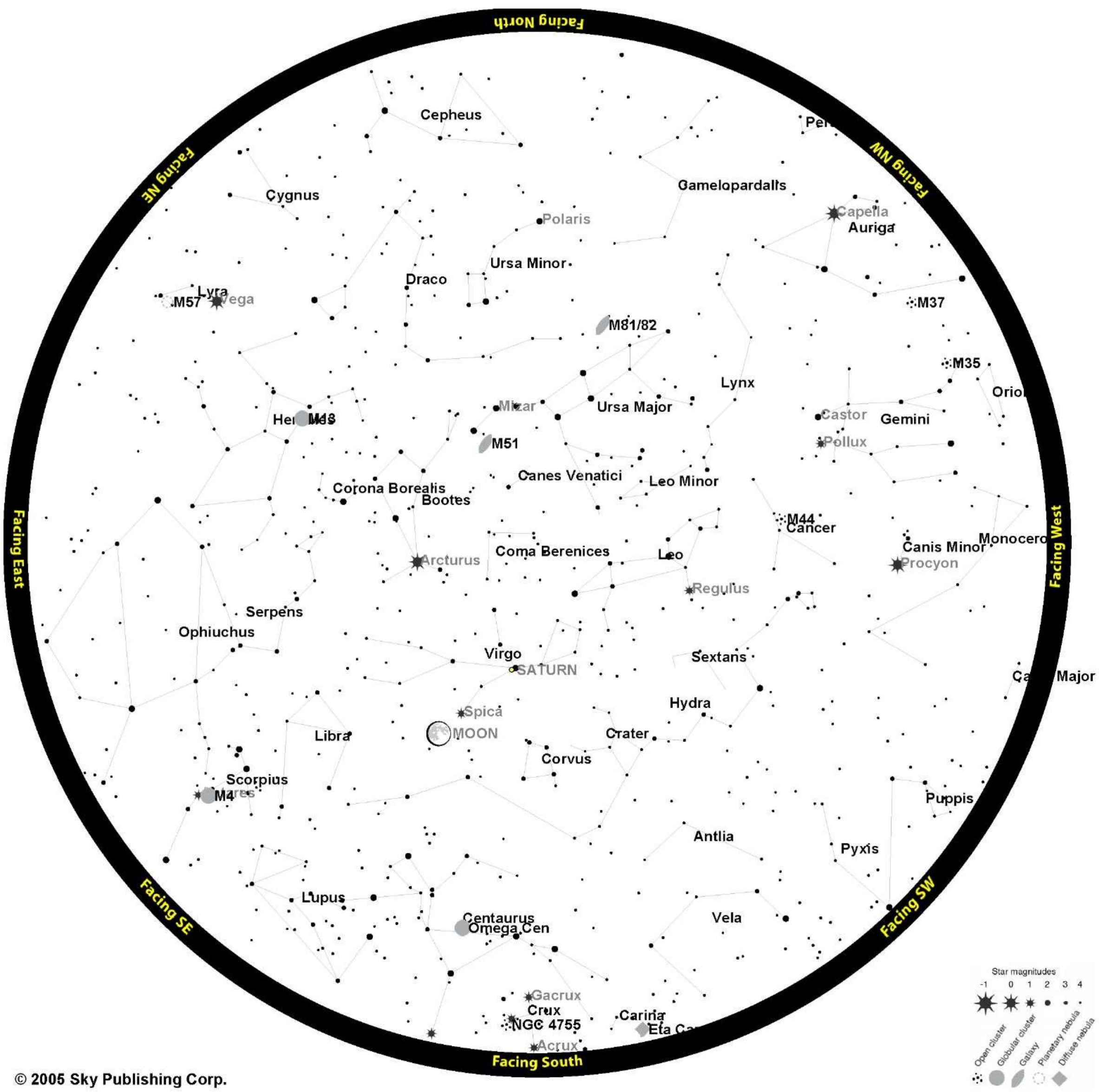
Kanpur, IN May 15, 2011, 09:00 pm



The Guide Charts: How to use them

In the Guide Charts that follow, the following symbols are used for various objects:
● Stars, ◌ Open clusters, ⦿ Globular clusters, ○ Diffuse nebulae, ʘ Planetary nebulae, **o** Galaxies, □ Other objects

For the convenience of the user, in all Charts except Chart 10B, north points to the top of the page. For easy recognition, the outlines of the well known constellations have been marked in. The lines of constant right ascension (R.A.), in hours, and declination (Dec.) in degrees have been dotted in; these will help to estimate the actual angular distances between objects, a help *since the field of view of the telescope is known. Remember that / hour in R.A. is equal to 15" of arc.*

The following steps are suggested in the use of the Charts:

a. For the time of the year and the time of the night at which observations are to be made (say 10pm-12am) note the constellations that are visible and preferably overhead. Turn to the Chart near the end of the book showing the distribution of Messier objects in the sky and note which objects will be suitable for observation. Choose a few of them for viewing.

b. For each of the objects chosen, turn to Table 2 and note down what type of object it is, its magnitude, its size and the expected difficulty in locating it. Remember that the magnitude and size are approximate and the notion of difficulty is really somewhat subjective; for diffuse objects the integrated magnitude can be misleading and the actual size seen may be much smaller depending on the quality of the telescope. Table 2 also indicates the Guide Charts to be used.

c. During the daytime itself, prior to observation, carefully examine the appropriate Guide Chart. For the object under consideration note its position with respect to nearby stars and estimate angular distances if they are small. Read the text and hints opposite the Guide Chart and make a plan of how to locate the object.

d. At night, prior to observations, if might help to take this book out opened to the appropriate Chart, hold it overhead with north and east aligned with their true directions, and note, using a dimmed torch, exactly where in the sky the object is to be found. Mote the locating stars and nearby groupings.

e. Finally, after having let your eye adjust to the dark, use your gunsight to locate the object; look through the eyepiece and slowly make small sweeps of the area until the object is located. *Knowledge of the field of* view *of your eyepiece can help you greatly in estimating distances.* If you have difficulty in locating what should be an easy object it might help to start afresh with the gunsight.

GUIDE CHART 1

OBJECTS M31, M32, M33, M74, M76, M110

GENERAL COMMENTS: For evening viewing suitable months are October through December however M33, M74, M76 and M110 are best seen late at night (after 11pm) in October

LOCATING & OBSERVING HINTS:

M31 (E) The Andromeda Galaxy: Can be seen by the naked eye as a Faint, hazy patch 1^{c}W and a little N of ν Andromadae. Best seen, with low powers : very bright but no features, such as spiral arms, will be visible.

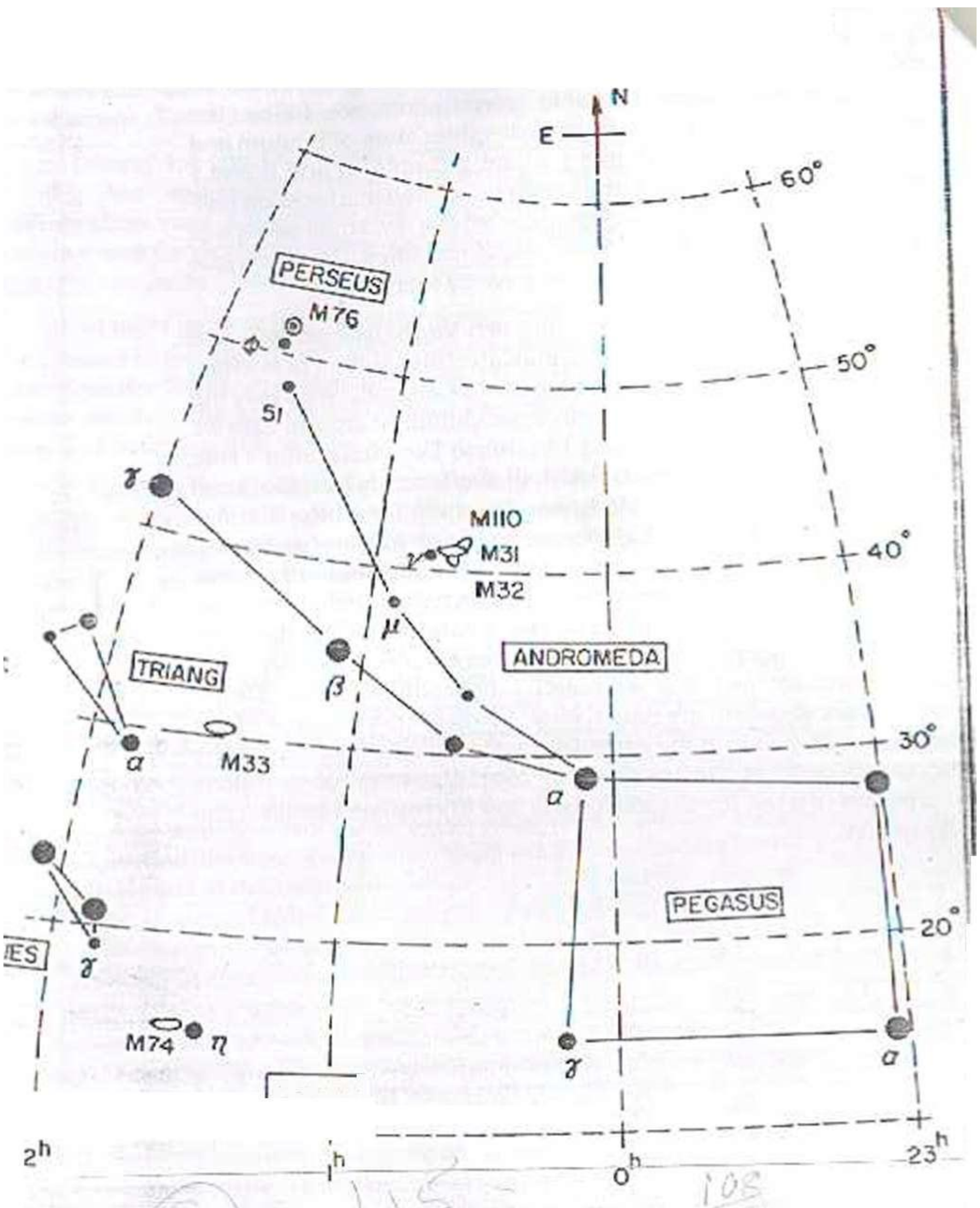
M32(A): About *25'* S of the centre of M31: seen as a small *hazy* bell about 2' -3' in diameter. Best to locate M31 centre it and move the field about ½ º S to see M32.

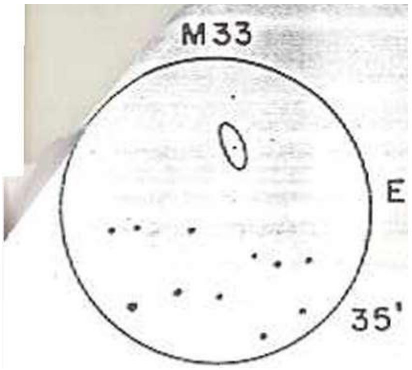
M110(D): About ½° W and ½° N of M31 , faint and elongated. Locate by centering M31 and moving NW 40-45'.

M33(X): Still, clear, dark nights are essential for this giant, spiral galaxy. To find M33, locate α ***Trianguli and*** β ***Andromedae.*** The galaxy is just south of the line joining them, a little more than 1/3rd of the way from α ***Trianguli.*** Low powers are best; in fact, it is said that this object is easier in a good pair of binoculars (say. a 7X50) than in a 20 cm telescope.

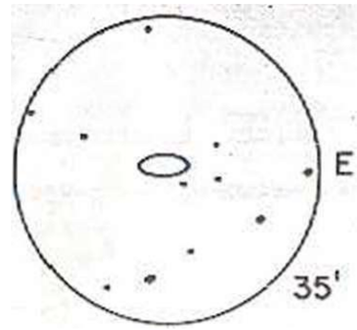
M74(X): Another faint, elusive, difficult galaxy. Starting from the ***Great Square of Pegasus,*** find η piscium, which lies on the extended line joining α and γ ***Pegasi;*** M74 lies of the way up and just S of the line joining η ***Piscium*** to γ ***Arietis.*** In the same field 5' to the east are a pair of 10th mag stars lying N-S about 3' apart. Dark adaptation and averted vision may be essential.

M76(D): Although this planetary nebula is one of the faintest objects in Messier's catalogue, it is not so difficult to find. Locate 51 ***Andromedae*** on the northern limb of Andromeda; 4th mag. ϕ ***Persei*** is just N of this star. M76 is less than 1°N and a little W of ϕ Persei. This pretty object is a miniature ***M27.***





Field Near M33



Field Near M74

GUIDE CHART 2

OBJECTS: M52, M103, h & χ *Persei*

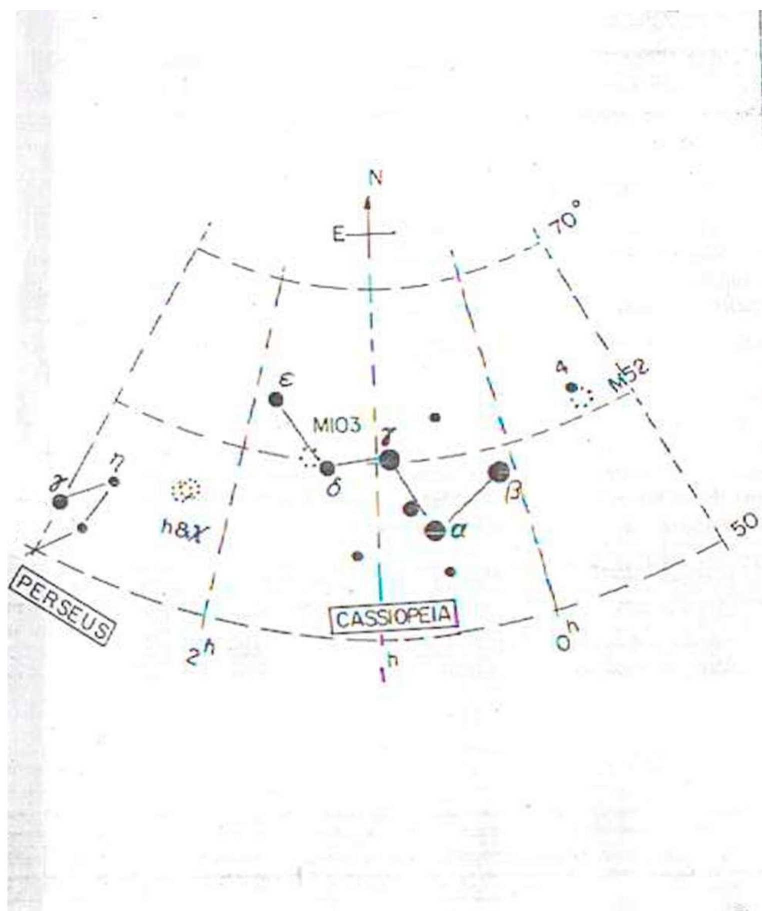
GENERAL COMMENTS: While these four northerly open clusters can be seen from October to January, the best months are October and November, when they will be close to the meridian around 11pm - 12am.

LOCATING & OBSERVING HINTS:

M52(A): Lies 1 °S and a little W of 5th mag. A Cassiopeiae, which is a little N of the extended α–β *Cassiopeiae* line. A small cluster, with an orangish star of about 8th mag. and an arrowhead shape.

Ml03(A): Locate by moving 1° E and ½°S of 6 *Cassiopeiae.* A loose, poor cluster which can be confused with a number of equally impressive objects In the vicinity. The outer stars form an isosceles triangle, one side of which contains a red star at its middle: the bright star Σ *131* at the apex is a double star.

h & χ Persei (E): This beautiful double duster is also known as the *Sword-Handle in Perseus,* visible to the naked eye. It is possible lo manoeuvre the centres of the clusters into the same field. Locate 4th mag. η Persei (see Chart 3 also); the double cluster lies 1/3rd of the way up and a little S of the line joining η Persei to δ *Cassiopeiae.*



GUIDE CHART 3

OBJECTS: M34, M45, M77

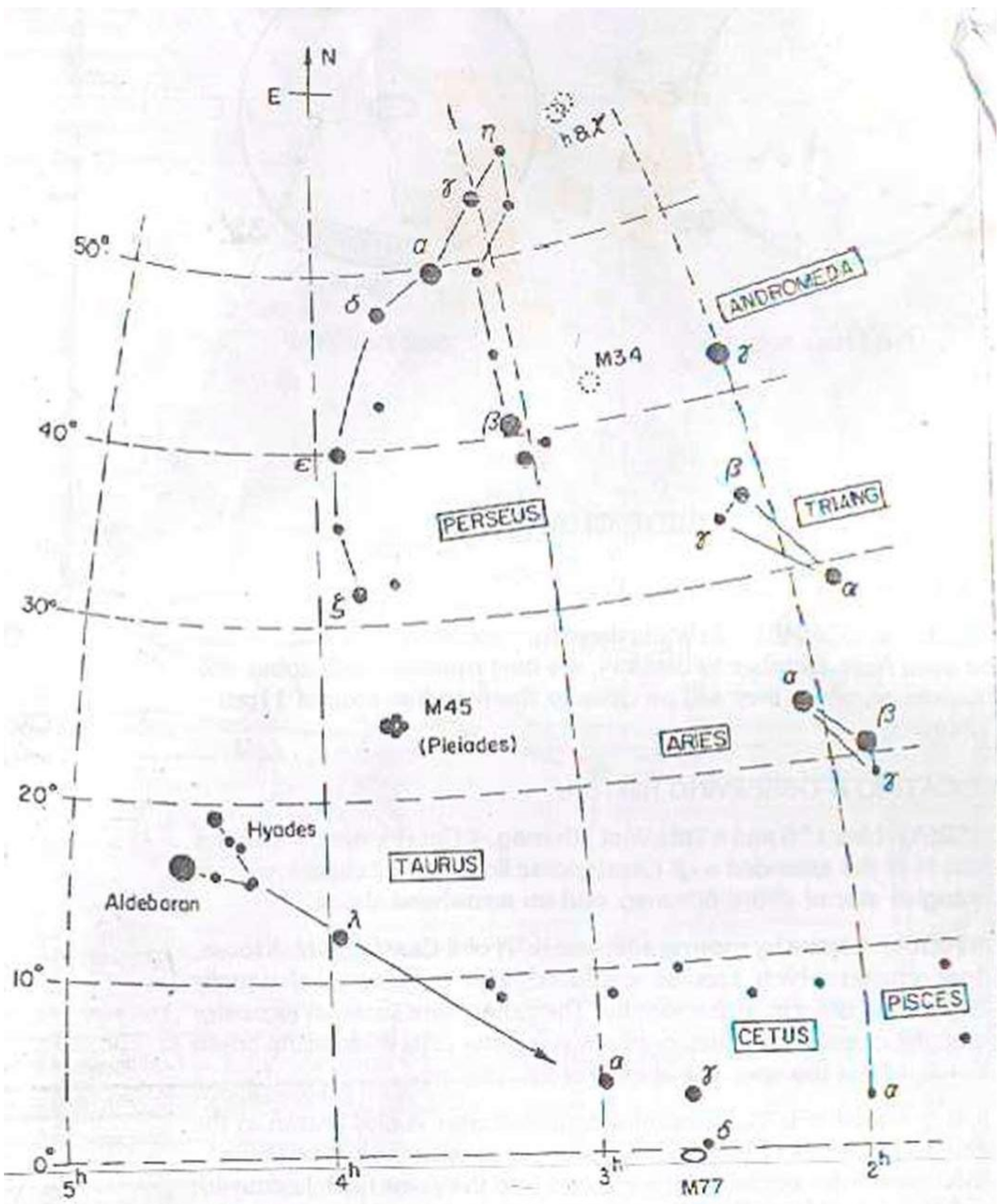
GENERAL COMMENTS: The *Pleiades* can be observed through February, but October to December would be best for M34 and especially M77. The three objects are somewhat widely spaced in the sky.

LOCATING & OBSERVING HINTS:

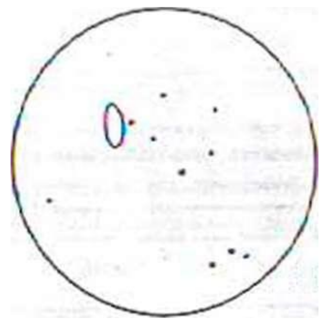
M34(E): This easy open cluster lies a little more than 1/3rd of the way from *Algol* (β *Persel)* to γ *Andromedae* and a little N of the ine joining them. It is bright, more then 30' dia. with many stars distributed in pairs; just visible to the naked eye under good conditions

M45(E): *The Pleiades:* The most well known open cluster, also known as the *Seven Sisters. Seven Virgins* etc. Shining at 1.5 mag. It is easily visible to the naked eye. The whole cluster contains several hundred members and is surrounded by nebulosity, especially around the star *Merope.* M45 contains many beautiful strings of stars (like pearl necklaces); it is best seen with as wide a field (low power) as possible; while the nebulosity is easily photographed, it is not that easy to see and is apparently best seen at low powers

M77(A): This *Seyfert galaxy* appears almost star-likc in a small telescope. The V of the Hyades cluster points to the triangle formed by α, γ and δ *Ceti*. M77 lies about 1 ° to the E and to the S of δ *Ceti.* Close to its east is a 10th



mag. star which can be used to confirm the nebulous appearance of the galaxy.



Field Near M77

GUIDE CHART 6

OBJECTS: M41, M44, M46, M47, M48, M50, M67, M93

GENERAL COMMENTS: All the 8 objects in this Chart are open (i.e., galactic) clusters. Although open clusters are often bright and easy to see, identification is sometimes troublesome if the cluster is in a rich star field, say, in a part of the Milky Way. The best months for the objects in this Chart are January through March.

LOCATING & OBSERVING HINTS:

M41 (E): A beautiful, bright open cluster, a little to the W and 2/3rd of the way up from δ *Canis Majoris* to *Sirlus.*

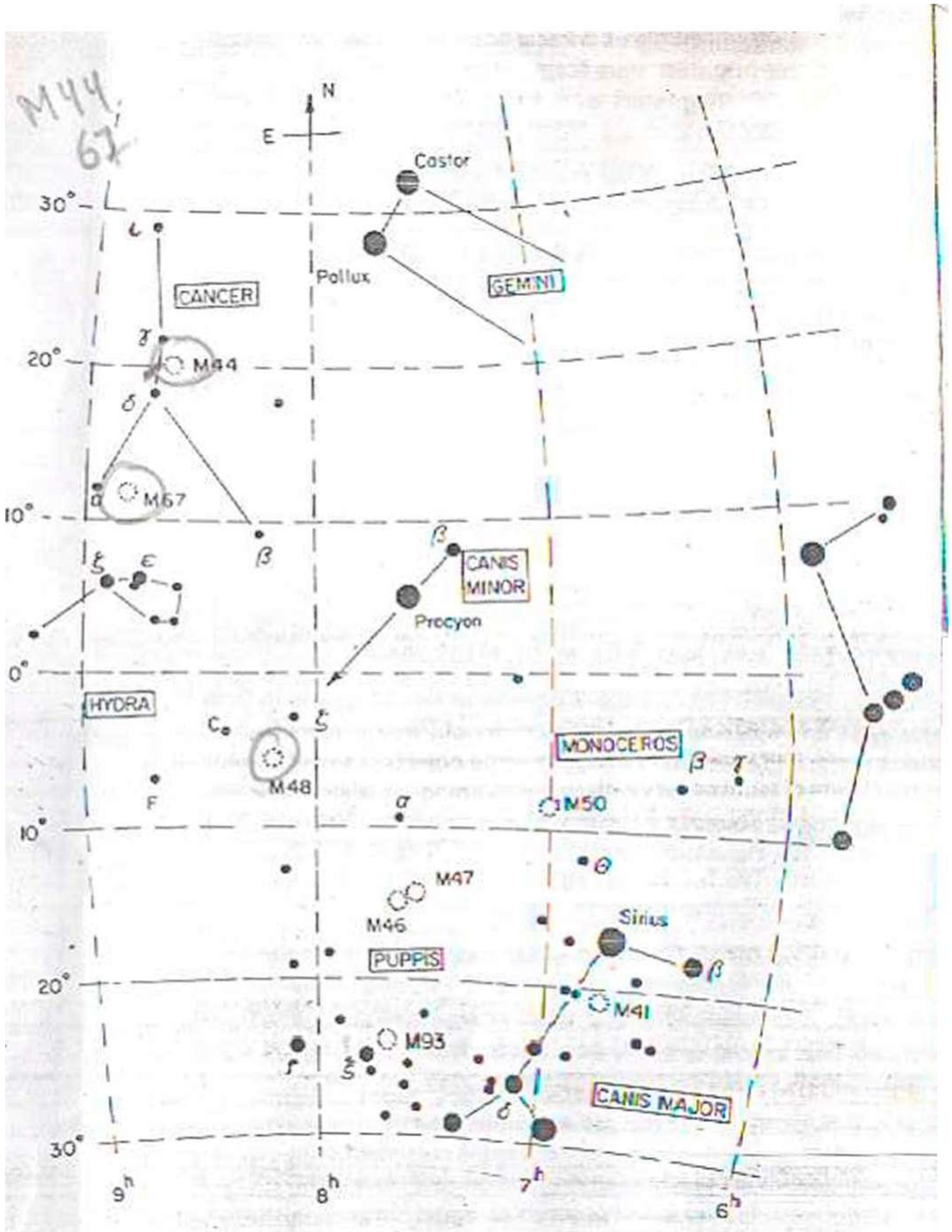
M44(E): *Praesepe* or the *Beehive Cluster:* This brilliant, lovely cluster, which is visible to the naked eye is too large for the field of a normal telescope to be seen in its entirety; best at low powers. To find M44 locate the λ formed by the principal stars of Cancer; *Praesepe* lies between γ and δ and a little to the *W.*

M46(A): A gem of faint stars that needs a dark sky to be fully appreciated; contains a planetary nebula, *NGC2438,* about 10' NE of centre, but this requires, high power, good aperture and excellent conditions to be seen. Locate 4th mag. α *Monocerolis* which lies almost half way between ξ *Puppis and Procyoir,* M46 lies a little W and 2/3rd of the way up from ξ *Puppls* to α *Monoeerotis.*

M47(A): Lies a little more than 1 °NW of M46: contains a number of very bright stars including a double, Σ *1121* (separation 8"), near the centre.

M48(A): Use β *Canis Minoris* and *Procyon* to locate the 4th mag. stars ζ *Monocerolis* and *C Hydrac.* this fine cluster forms a right triangle with these two stars as shown.

GUIDE CHART 6



M50(A): Although this cluster lies in the rich Monoceros portion of the Milky Way, it is distinguishable as it has a boundary of slightly darker sky around it: the brightest stars form a heart shaped figure. First locate the three 4th mag. stars α ß and γ *Monocerotis;* M50 lies almost half-way between α and ß *MonoczroUs*.

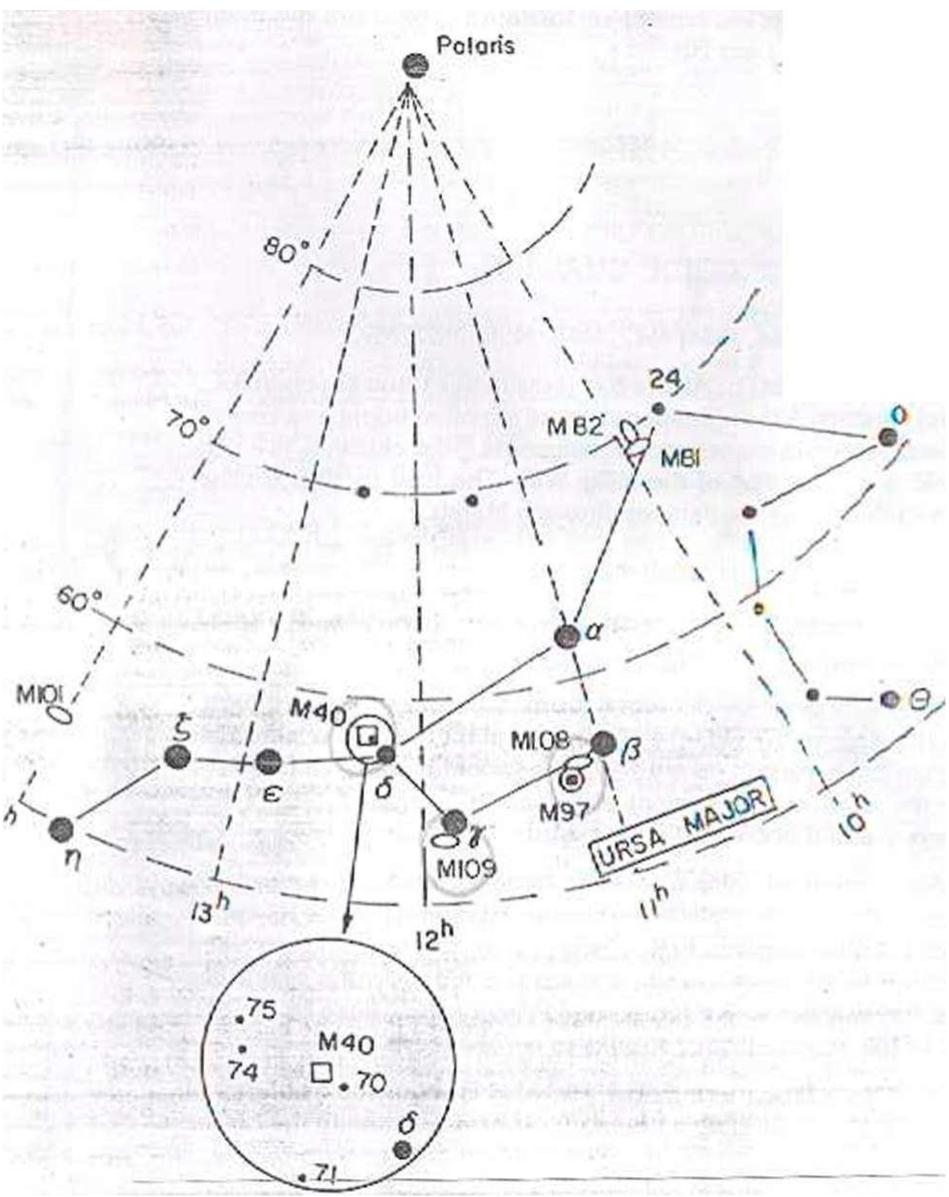
M67(A): Once the λ shape of the principal stars of Cancer has been located, M67 car be found 2°W of α *Cancri.*

M93(A): The central portion of this cluster is compact and triangular in shape with many coloured stars. A little difficult to locate as it is in a rich portion of the Puppis Milky Way. Locate ξ *Puppis;* M93 lies about 1.5°NWof ξ.

GUIDE CHART 7

OBJECTS: M40, M81, M82, M97, M101, M108, M109

GENERAL COMMENTS: All the 7 objects in this Chart are in Ursa Major. M81 and M82 being the northern most Messier objects. As a consequence It is essential, especially for the last four objects in the list, that viewing be done when the objects are close to the meridian, late at night or very early In the morning, i.e., between



11pm and 3am. Best months are February-May.

LOCATING & OBSERVING HINTS:

M40(A): This pair of almost identical 9th mag.stars *(Winneke 4,*9.0 and 9.3 mag. 49" separation) is less than 2°NE of δ *Ursae Majoris.* First locate 5th mag. *70 Ursae Majoris* by moving 1^c along the extended line joining γ to δ; now move another ½ ^{c} In the same direction; M40 should be close to the centre of the field.

M81 (A) & M82(A): These two galaxies which can be manoeuvred into the same low power field are quite different in appearance: M81 is a large oval while M82, the irregular, is narrow and elongated. This pair of beautiful objects is among the brighter of the Messier galaxies. To locate: join γ to α and proceed an equal distance farther, then move NE about 2°.

M97(X): *The Owl Nebula:* The best sky conditions are necessary to *locate* this planetary. From *Ursae Majoris* move a quarter of the way *,to* γ, then move 1 °S and carefully scan the region using averted vision: if you see a 6th mag. star, M97 is about Vz° ENE. The planetary appears as an almost circular, faint patch. Bears repeated hunting and viewing.

MlO1(X): The position of this galaxy is easily located; it forms an almost equilateral triangle with ζ and η *Ursae Majoris.* It lies about 10'E of ar 8th mag. star and 25'S of a curve of fainter stars. Best conditions, dark adaptation and averted vision are essential.

M108(X): Lies about 2° from β *Ursae Majoris* just S of the β- γ line. This difficult, elongated galaxy appears as a pretty sliver when seen.

M109(X}: Another spiral that requires good conditions, dark adaptation, averted vision etc. Just about 40'SE of γ *Ursae Majoris.*

GUIDE CHART 8

OBJECTS: M3. M51. M53. M63, M64, M85, MQ4, Ml00. M106

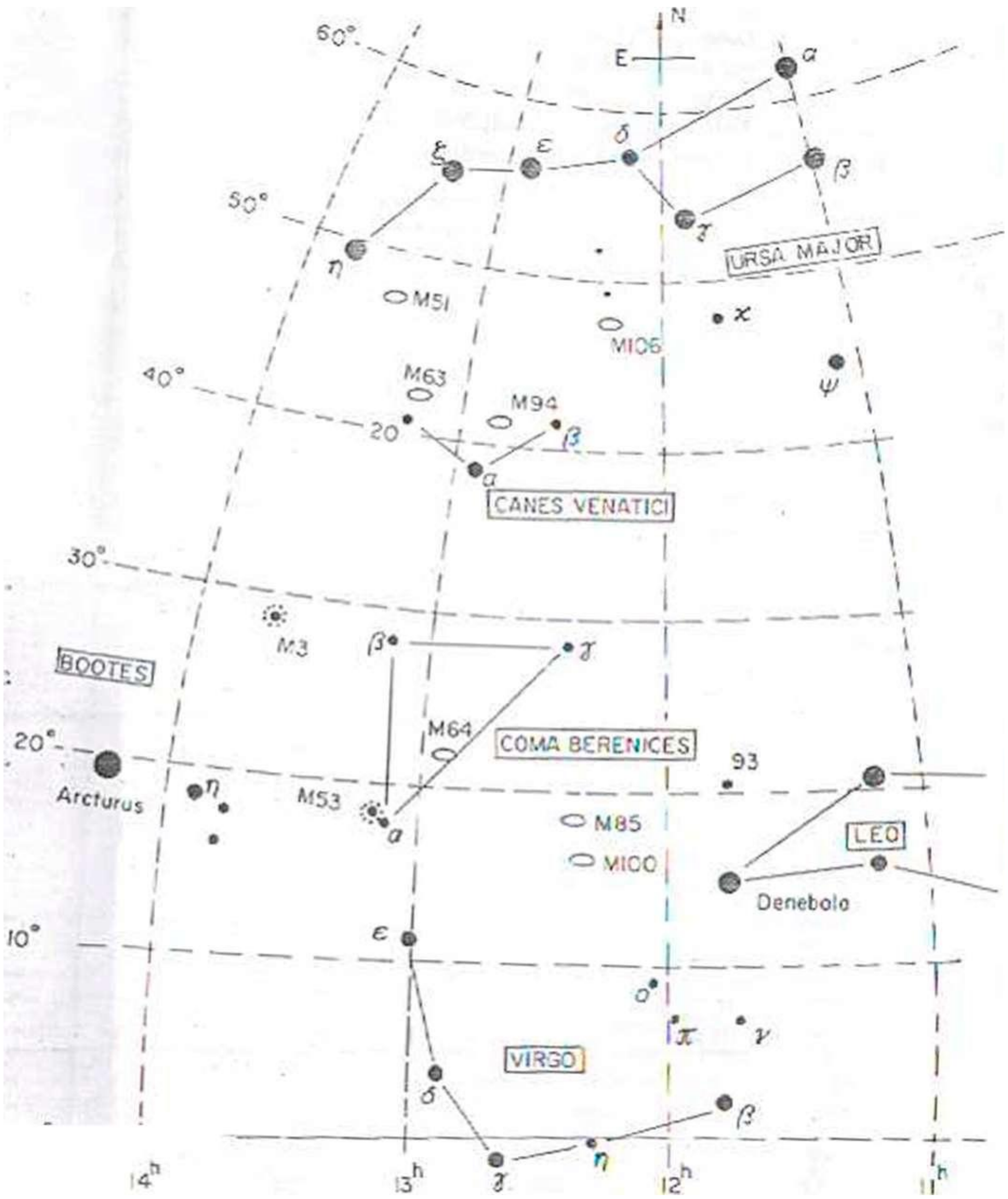
GENERAL COMMENTS: The objects include two fine globulars and some of the more unusual and brighter Messier galaxies. In order to locate these objects, first locate the triangles made up of α, β and *20 Canum. Yenaticorum* and *α,* β *and* γ *Comae.* Tor late evening - early morning viewing March to May would be best.

LOCATING & OBSERVING HINTS:

M3(A): This bright globular cluster lies a little less than half way from *Arcturus* to 3rd mag. *a Canum Venaticorum.* Note that γ and β *Comae* also point to it.

M51(A): The *Whirlpool Galaxy:* Although M51 is quite bright compared to the fainter Messier galaxies it can be elusive; good sky conditions are essential for satisfactory observation. In a 15 cm scope the fair.ter companion galaxy to the N should be visible; together they make a superb sight justifying the name given to the object. To find M51 move ¾ of-the -way from η-*Ursae Majoris to* β *Canum Venacizorum* and then a little S.

M53(E): This small, pretty globular lies almost exactly 1°NE of a Camae



M63(D): This faint spiral requires good conditions and averted vision, it lies about 1 ½ °N and a little W of *20 Cenum Venaticorum.*

M64(A): *The Black-Eye Galaxy*: A comparatively bright and large spiral compared to the other galaxies in the Coma Virgo region. Even though the 'black-eye' is not that easily visible in small telescopes, the use of averted vision does help to see some detail. M54 is about l/3rd of the way up from *α to γ Comae* and a little to the E.

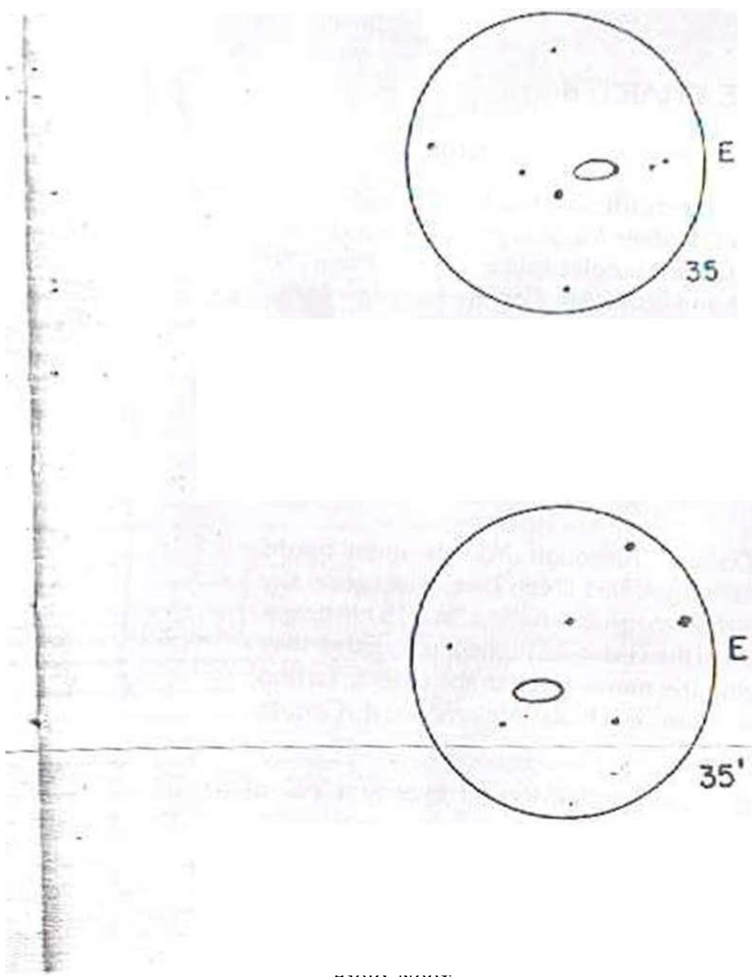
M85(A): Like M84 this is an SO spiral, i.e. in appearance almost an elliptical; appears as a bright oval in a small telescope. Nearby, 6' to its E, is a'fainter galaxy *NGC4394,* which may also be seen. Locate 4th mag. *93 Leonis*; M85 is almost halfway between this star and *α Comae* and a little to the S.

M94(A): One of the brighter Messier galaxies, M94 forms an isosceles triangle with *α* and β *Canum Venaticorum.* As the nucleus is bright, the galaxy is not difficult to pick up

M100(D): This spiral appears as a circular patch, almost like a faint globular. Location: almost exactly half-way between ε *Virginisand* 4th mag. *93 Leonis.*

M106(A): Elongated sprial. half-way between β *Canum Venaticorum* and γ *Ursae Majoris.*

N



Field Near M100

GUIDE CHART 9

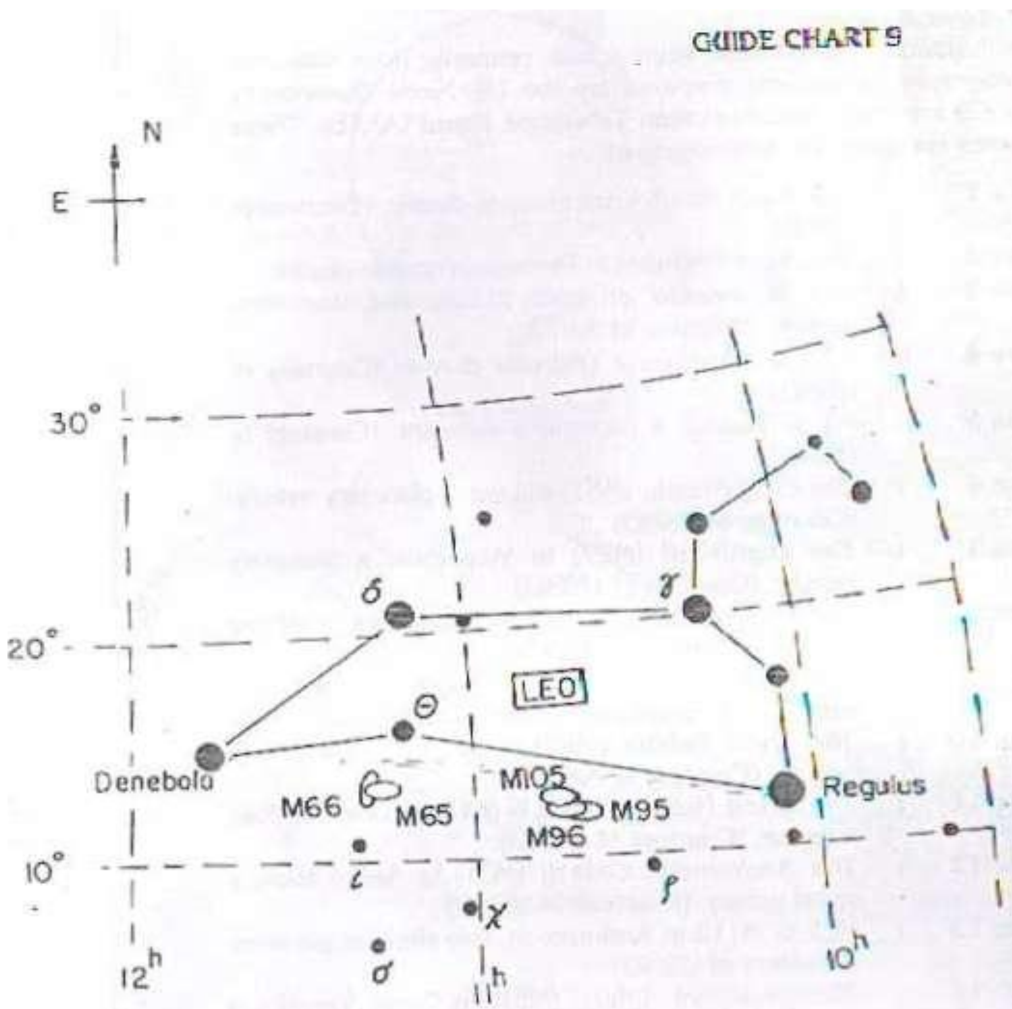
OBJECTS: M65. M66. M95, M96, M103.

GENERAL COMMENTS: These are all spiral galaxies in Leo. All the usual care required for viewing faint objects should be exercised. For late evening viewing the best months are January through March.

LOCATING & OBSERVING HINTS:

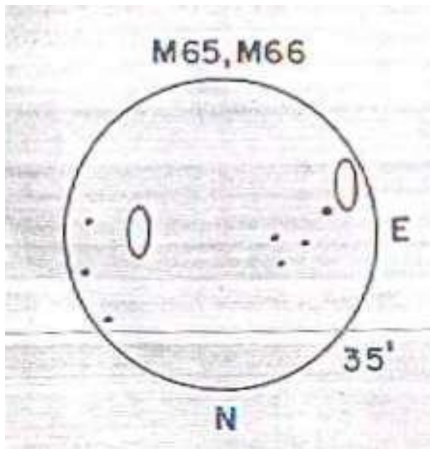
M65(A) & M66(A): Both these spirals are faint and elongated, M65 being the fainter of the two: their major axes lie in an approximately NS direction. Locate τ Leonis; this pair lies about half-way between τ and θ *Leonis.* As the distance between them is only about 30' they can be maneuvered into the same field

M95(D) & M96(A): The two galaxies are about 50' apart. M95 being E and just a little S of M96. M95, much the fainter of the two, appears as a glowing patch with a faint, star like nucleus: M96 is brighter and has a better defined centre. Locate 4th mag. *P Leonis:*M96 lies a little more than 1 /3rd of the way



from *P* to *ϑ* and M35 is a little to to the E. Its best to find M96. then hunt for M95, return to M96 and confirm by locating M105 to the N.

Ml05(A): This small elliptical lies almost half-way between *P* and *ϑ Leonis* and a little lo the W; or can be found by moving a little more than 1 /3rd of the way from *Regulus* to *Denebola* and then a little S. In the same field can be seen another elliptical *NGC3384*, about 8' to the E; a third galaxy, *NGC3389,* also lies n this field to the S. making a right angle with the other two, but it is much fainter. Confirm by locating M96 which lies about 1^{o} SS



Field Near M65 & M66

GUIDE CHARTS 10A & 10B

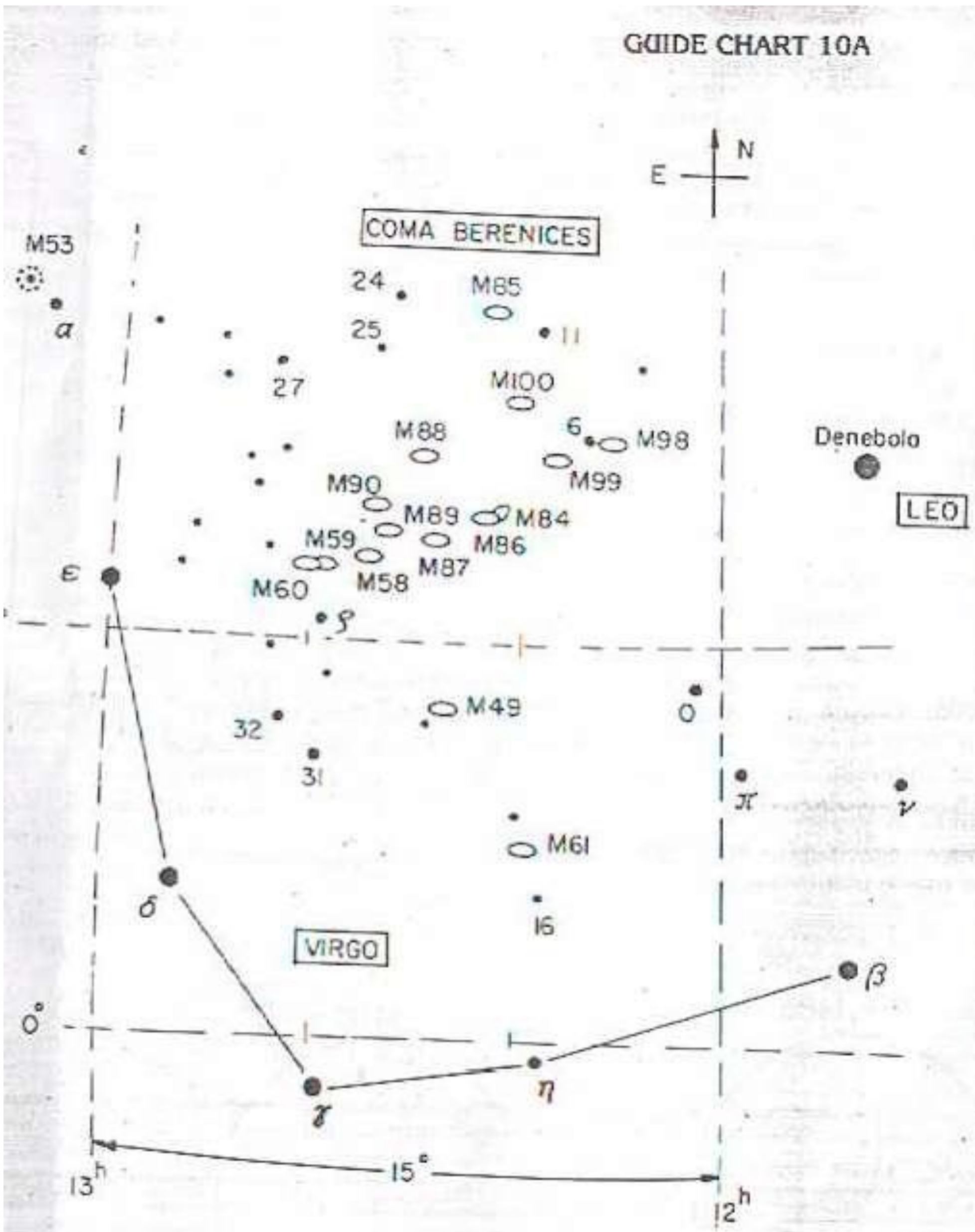
OBJECTS: M49. M58, M59, M60, *M*61, M84, M86, M8, M88, M89, M90, M93. M99

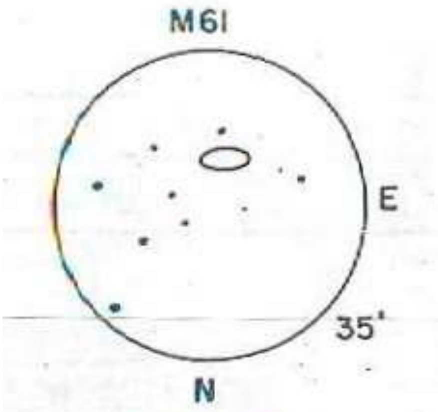
GENERAL COMMENTS: These Charts deal primarily with the Messier galaxies in the Coma-Virgo region. Most of these galaxies are visually small and faint; they require full darkness adaptation, averted vision and clear dark skies for best results. One must also be warned that the whole region teems with faint galaxies and so care and checking are required to make sure that the object seen is indeed what is sought to be seen. The Virgo-Coma galaxies are an excellent exercise for training in observational skills. It is suggested that M49 and M61 be tackled individually. For the rest: (a) make a trip starting with M60. M59 and going carefully through M58. M87, M86 and M84. (b) go back to M58 and find M89, M90 and M88 in that order, and (c) finally tackle M98 and 99 separately. Repeat, to be certain that you know the region well. For early morning and late evening viewing, the best months are February through April.

LOCATING & OBSERVlNG HINTS:

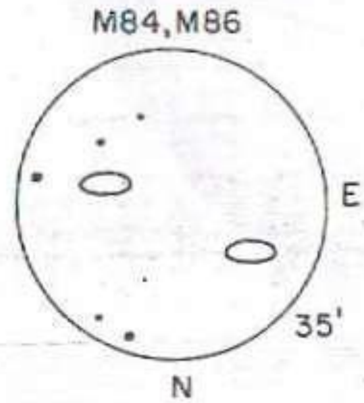
M49(A): A comparatively bright elliptical that looks a bit like a globular cluster. Just slightly N of the *δ Virginis* - *Denebola* line and a little less than half way from *δ*.

M61(D): A diffuse, pale spiral for which averted vision is essential. Locate the triangle formed by 4th mag o, *tt* and *v Virginis.* M61 is almost exactly half way between *δ* and *v Virginis.*

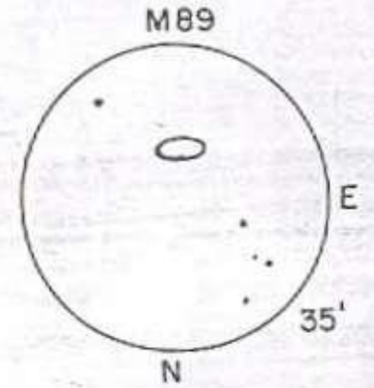




Field Near M61



Field Near M84 & M86



Field Near M89

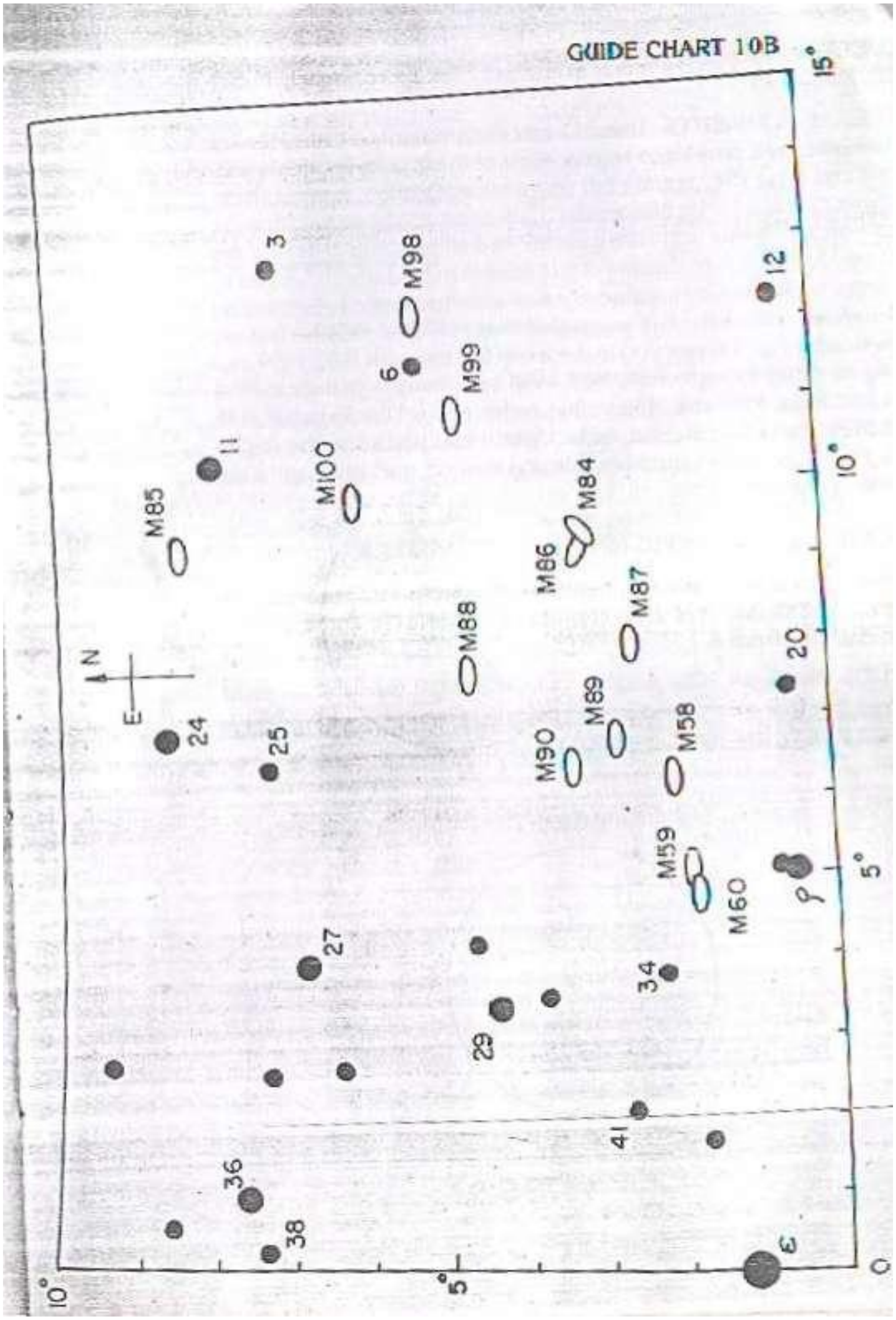
M60(A) & M59(A): These two ellipticals area little less than 30' apart. M60. the brighter of the two has a round outline and a bright nucleus. In the same field if the instrument is adequate, can be seen two fainter galaxies: *NGC4647.* a 11.5 mag. spiral very close to M60, and a 12th mag. elliptical *NGC4638.* which lies equidistant from M59 and M60 and 20' S of the line joining them. To locate: using averted vision, if necessary. locate 5th mag. ρ Virginis and move 1.5o N and a little E to find M60.

M58(A): This spiral is the brightest of the Messier galaxies in the Virgo group: looks somewhat like nearby M60. Located by moving 1° W of M59 and a little N.

M87(A): One of the most famous galaxies; a giant elliptical with an optical jet issuing from it. it is an intense radio source. One of the brightest in this group, it lies a little more than 1.5^{o} WNW of M58.

M86{A) & M84(.A): Like M85, M84 is an SO spiral and hence appears almost like its nearby neighbour M86. an elliptical. This pair, which are about 20' apart can be found by moving about 1.5^{o} WNW of M87;they appear almost round and brighten towards the centre. About 25' ENE of M86 can be seen a pair of 10th mag. galaxies, *NGC4438* and *NGC4435* more difficult is *NGC4388* which lies about 30' SE of M84. Thus under good conditions, one can see 5 galaxies is this 1^{o} field with a 15 cm telescope!

M89(A): Move about 50' NW from M58 to locate this elliptical: small and round in appearance.


GUIDE CHART 10B
N
E
M85
M100
M98
M99
M84
M86
M87
M88
M89
M90
M58
M59
M60
3
6
11
12
20
24
25
27
29
34
36
38
41
ρ
ε
0
5°
10°
15°

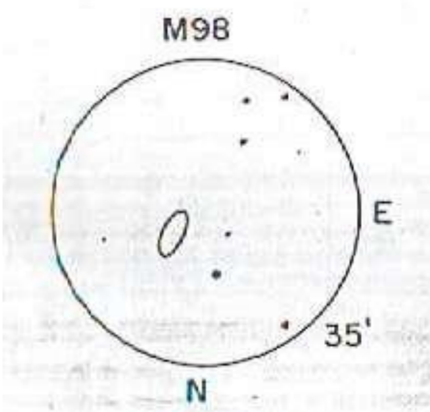
M90(A): Can be located by moving about 40' N of M89 and a little E. The spiral's major axis dearly lies approximately N-S.

M88{A): The flattened, disc shape can be made out clearly. The principal axis of the galaxy lies along the NW-SE direction and a single star and a pair of stars lie at the two ends of this axis. Locate by moving a little more than 1½ °NW of M90.

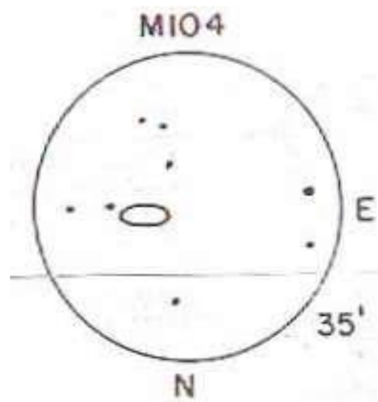
M93(D): This faint, almost edge-on spiral lies 30' to the W of 5th mag. σ Comae: appears pale and elongated.

M99(D): Lies about 45' SE of σ Cornae; this spiral is face-on and easier than M98.

M63(D): This faint spiral requires good conditions and averted vision, it lies about 1 ½ °N and a little W of *20 Cenum Venaticorum.*



Field Near M98



Field Near M104

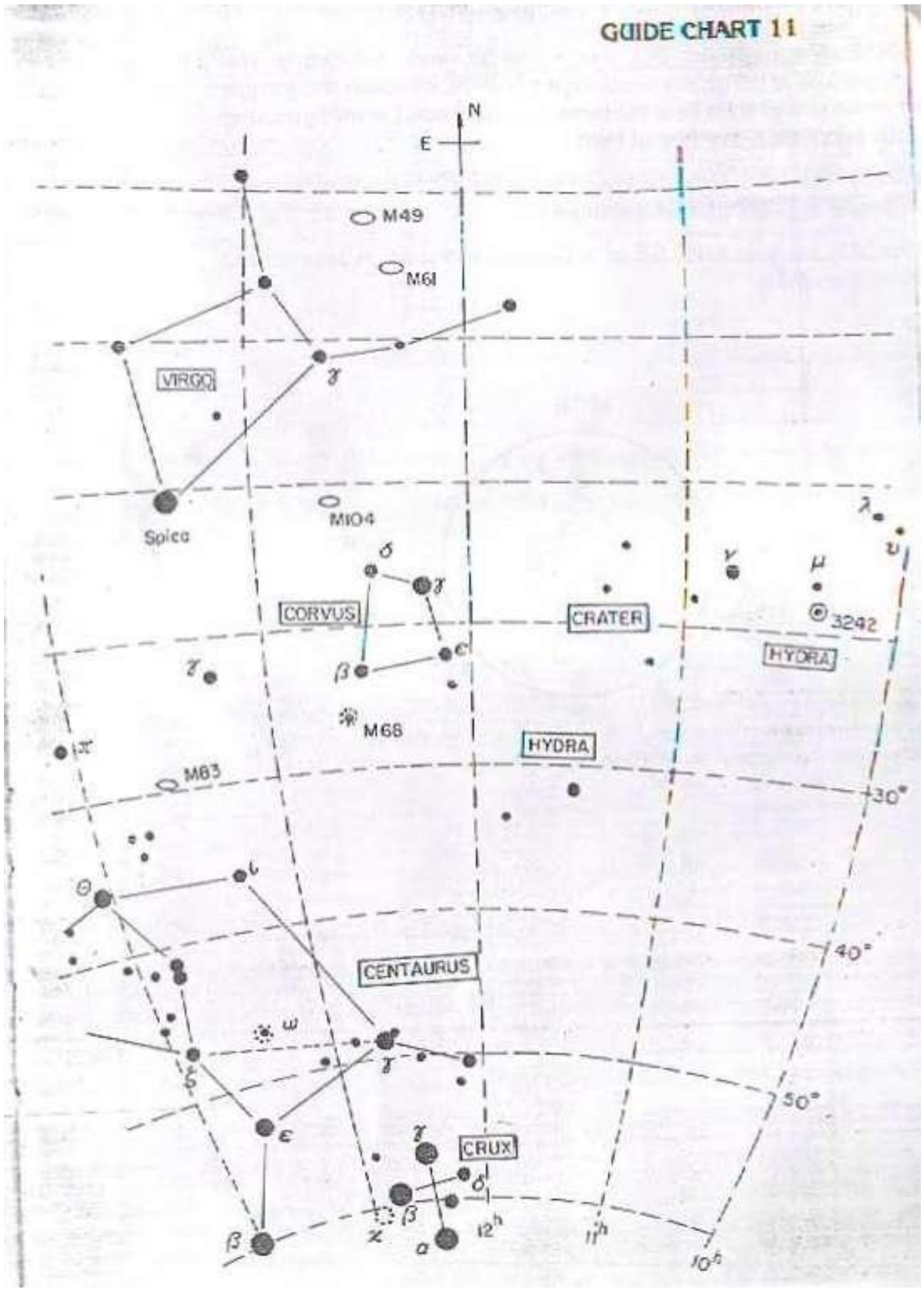
M64(A): *The Black-Eye Galaxy*: A comparatively bright and large spiral compared to the other galaxies in the Coma Virgo region. Even though the 'black-eye' is not that easily visible in small telescopes, the use of averted vision does help to see some detail. M54 is about l/3rd of the way up from *a to γ Comae* and a little to the E.

M85(A): Like M84 this is an SO spiral, i.e. in appearance almost an elliptical; appears as a bright oval in a small telescope. Nearby, 6' to its E, is a'fainter galaxy *NGC4394,* which may also be seen. Locate 4th mag. *93 Leonis*; M85 is almost halfway between this star and *a Comae* and a little to the S.

M94(A): One of the brighter Messier galaxies, M94 forms an isosceles triangle with *a* and β *Canum Venaticorum.* As the nucleus is bright, the galaxy is not difficult to pick up

M1OO(D): This spiral appears as a circular patch, almost like a faint globular. Location: almost exactly half-way between ε *Virginisand* 4th mag. *93 Leonis.*

M106(A): Elongated sprial. half-way between β *Canum Venaticorum* and γ *Ursae Majoris*



GUIDE CHART 12

OBJECTS: M5, $M9_t$ MIO. M12, M13, M14, M92, M107

GENERAL COMMENTS: This Chart contains 8 globular clusters in the Serpens - Ophiuchus - Hercules part of the sky. Some of these can be resolved with a 15 cm or 20 cm telescope but high magnification. will be: required. April and May are likely to be the best months for viewing.

LOCATING & OBSERVING HINTS:

M5 E): Bright, pretty globular; easy to resolve. Locate 4th mag. *109* and *110 Virginis;* which lie between Arcturusand β *Librae;* M5 lies to the E of *110* in line with *109* and almost equidistant.

M9 (A): Small globular. Locate 4th mag ξ *Ophiuchi;* this globular lies a little to the E of the midpoint of the ξ-η line.

M10(A): Bright: outer portions can be resolved in a 15 cm. Move 1/3rd of the way from ζ to α *Ophiuchi* and a little E to find M10.

M12(A): Bright;easy to resolve. Can be found by moving 1/3rd of the way from δ to γ *Ophiuchi* and a little S.

M13[E): A very famous globular, it can be made out with the naked eye on clear, dark rights. Can be partially resolved even with a 10 cm scope. A little less than half way from η to ζ *Herculis.*

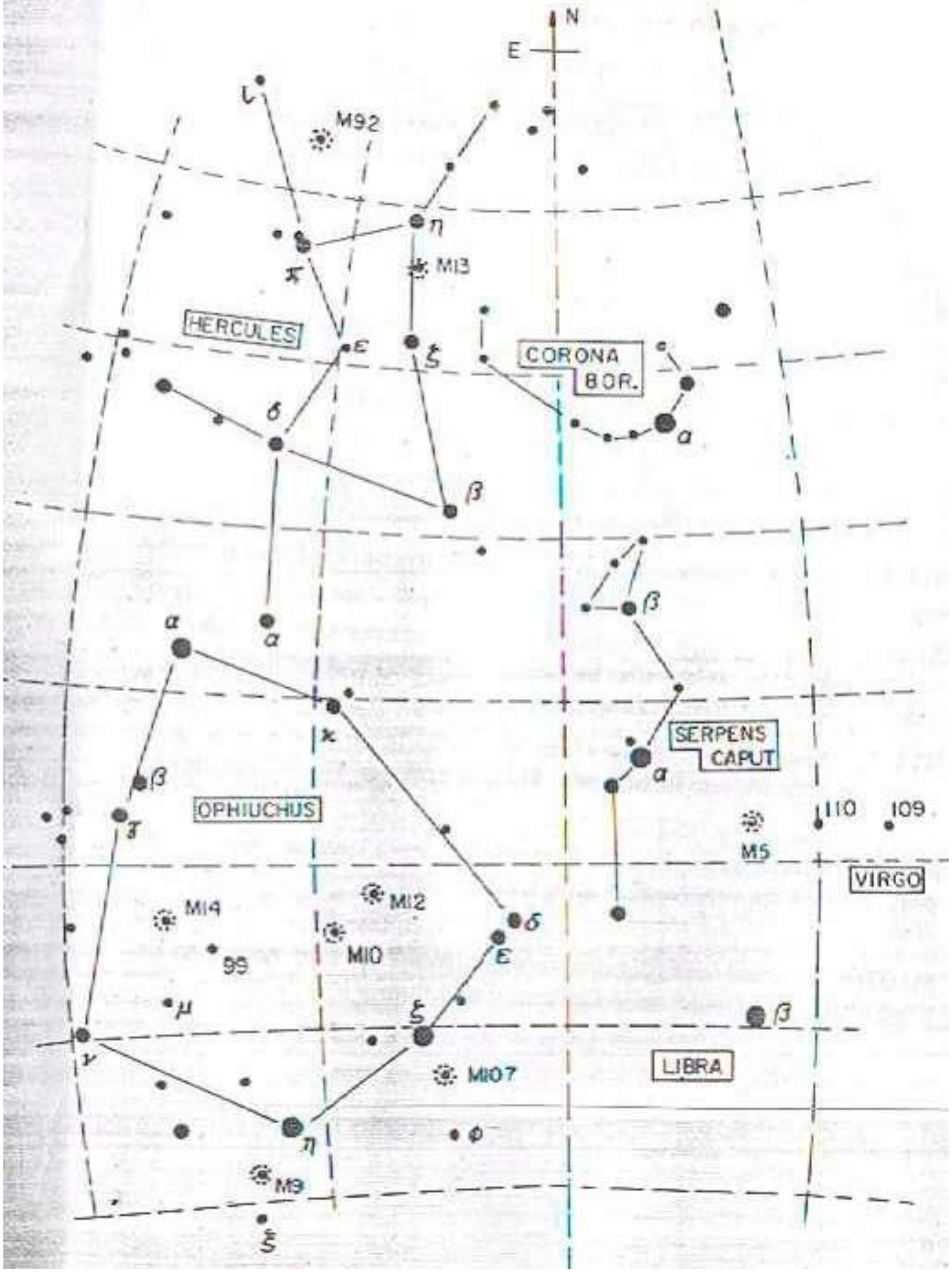
M14(A): Move 1/3rd of the way from γ to η *Ophiuchi* and slightly SE to locate this object. Round and faint, it appears like an elliptical galaxy.

M92(E): Almost as bright as its near neighbour M13 in Hercules; outer portions can be resolved. A little further than half-way from η to t *Herculis.*

M1071 (A): A small faint globular, found by moving a littie more than a third of the *way* from ζ to φ

Ophiuchi and then a little W.

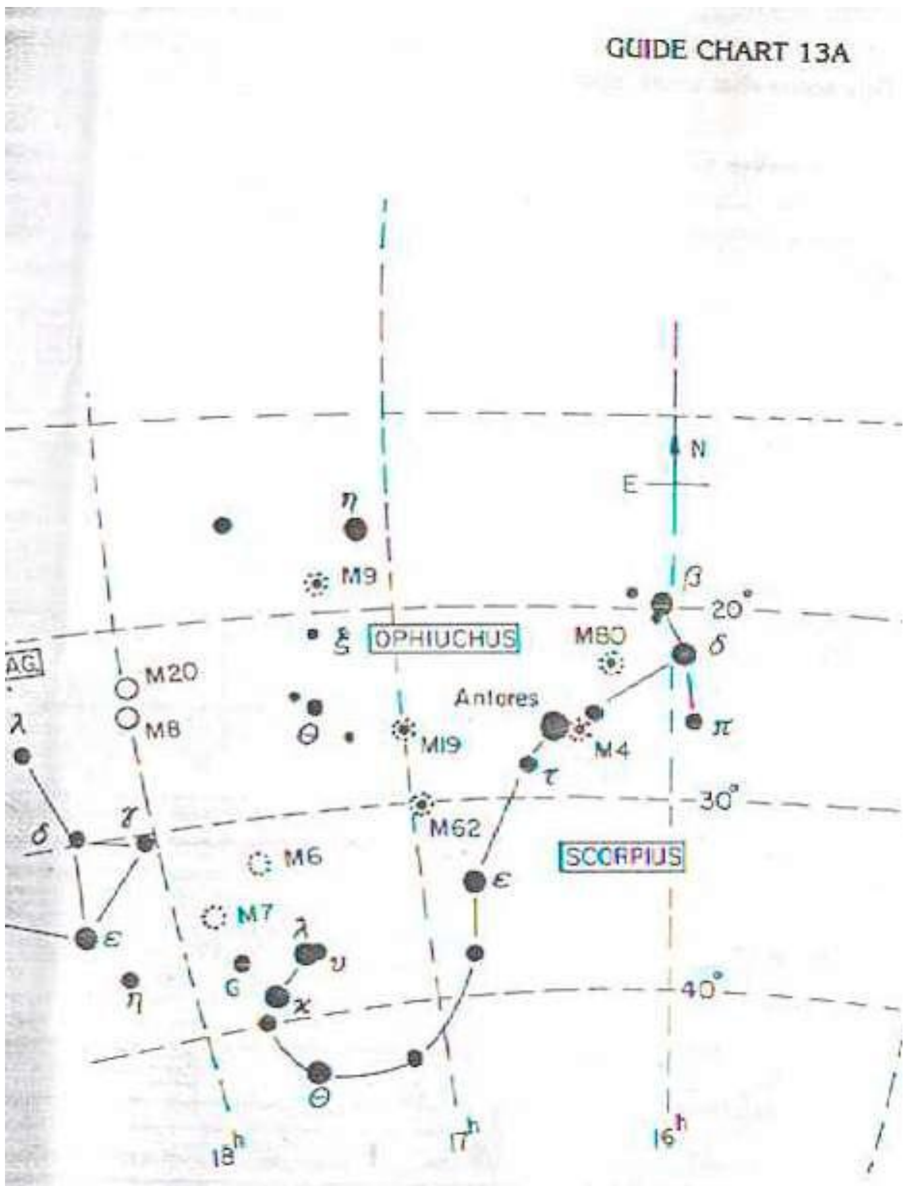
GUIDE CHART 12



GUIDE CHARTS 13A & 13B

OBJECTS: M4, M6, M7, M8. M19. M20, M21, M22, M28 M54 M55 M62, M69, M70, M80 '

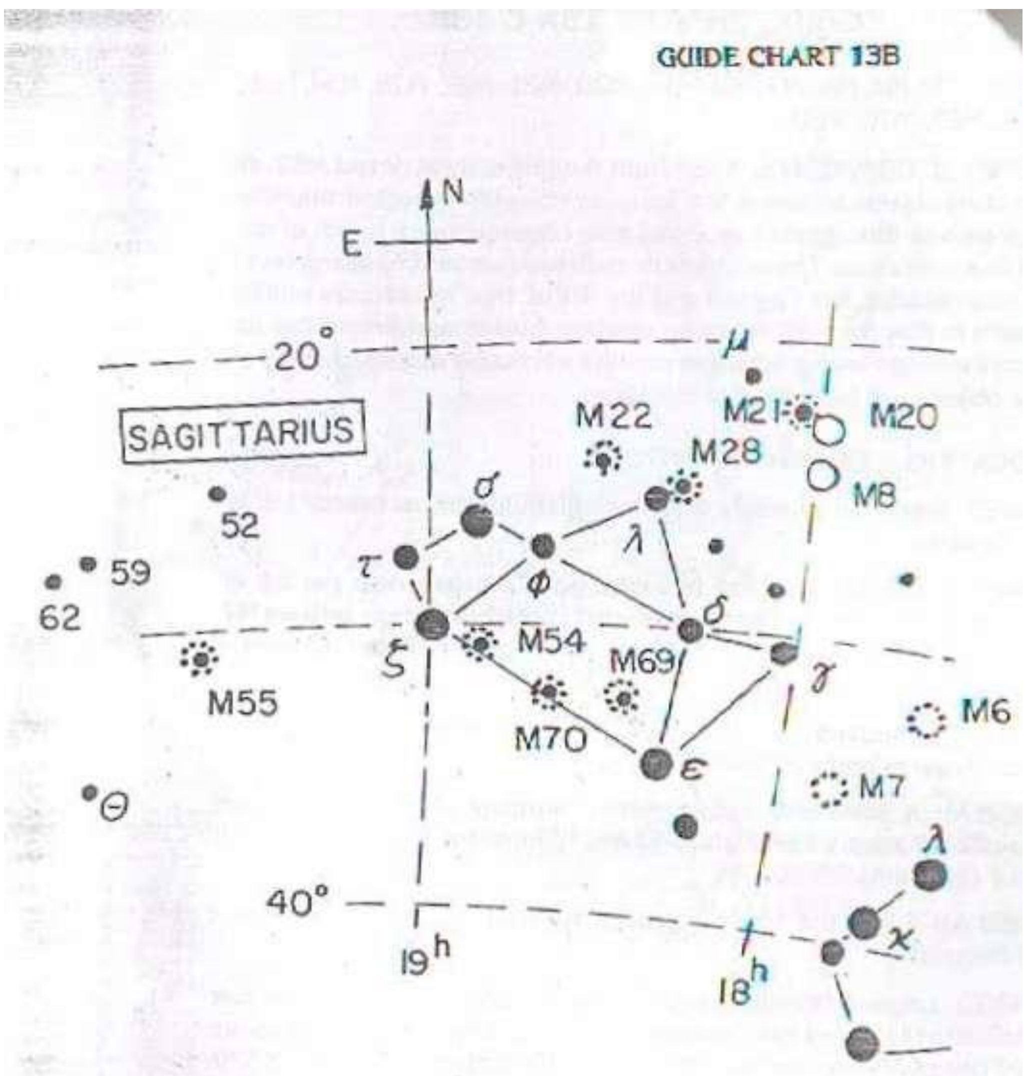
GENERAL COMMENTS: Apart from the globulars M19 and M62 all the other objects belong to the Scorpius - Sagittarius region; the Milky Way passes through this area and as a consequence it is rich in star fields and clusters. These Charts contain two outstandinq examples of diffuse nebulae, the *Lagoon* and the *Trifid.* Best months are middle March to May morning viewing; August and September for early evening viewing but these months will not be very satisfactory as the objects will be setting at this lime.



LOCATING & OBSERVING HINTS:

M4(E): Bright, large, easily resolvable globular almost exactly 1 ½ ° W of *Antares.*

M6(E) & M7(E): A pair of beautiful open clusters near the tail of Scorpius. M6 appears like a butterfly with outspread wings; brilliant M7 is visible to the naked eye. M7 is almost exactly half-way between κ *Scorpii* and γ *Sagittaril;* M6 is 3 ° NW of M7.
M19(A): Compact, but pretty globular; forms an equilateral trianqle with *Antares* and ε *Scorpii.*
M62(A): A somewhat unsymmetric. compact comet-like globular. Locate 4th mag. § *Ophiuchi,* M62 lies 1/3rd of the way from ε *Scorpii to* § *Ophiuchi.*
M80(A): Small but bright globular, half-way between *Antares* and β *IScorpii.*
M8(E): *Lagoon Nebula:* Beautiful. bright, diffuse nebula that is just viable to the naked eye; however, a clear, dark sky is required to see its full beauty Associated with M8 is the brilliant open cluster *NGC6530*. To locate : M8 is on the σ-λ Sagittarii line with M8 and σ equidistant from λ
M20(A): *Trifid nebula:* This famous emission-reflection nebula is best located by moving about 1 ¼ ° N of M8 and a little W. Not an easy object in small telescope, the dark lanes require a large aperture for resolution; dark skies and averted vision are a must.



M21 (A): This somewhat small. Sparse cluster is just about *1*° NE of M20

M22 (E): Is a smaller version of u *Centauri:* big. Bright easily resolvable globular. Locate *by* moving along the τ- σ *Sagittarii* line beyond o; the distance from M*22* to o is a little less than twice the distance from τ to σ

M28 (E): Globular 1⁰ NW of λ *Sagittarii.*

M54 (E): Small. Bright globular about 1/5th of the way from to ζ *Sagittarii* and a little N.

M55 (A): Open, somewhat irregular globular. Move from ζ along the δ -ζ *Sagittarii* line, about the distace between them, then a little S to find M55.

M69(A) & M70 (A): Two small. Comparatively faint globular; the centre of M70 appears more condensed and a tall of small stars appears attached to it. M70 lies about half-way between ζ and ε *Sagittarii,* M69 is about 1/4th of the way from ε to φ *Sagittarii.*

GUIDE CHART 14

OBJECTS: M11, M16. M17. M18. M23 M24. M25. M26

GENERAL COMMENTS: These objects are in Serpens, Scutum and Sagittarius For the objects in this Chart one mint be familiar with the 3rd mag. stars ξ *Sagittarii* and ξ Serpentisand the 4th mag. stars α, β, γ and δ *Scuti.* μ *Sagittarii* and σ Serpentis and the 5th mag. star η *Seuti.* For early morning viewing the best months would be April, May and for early evening viewing. September.

LOCATING & OBSERVING HINTS

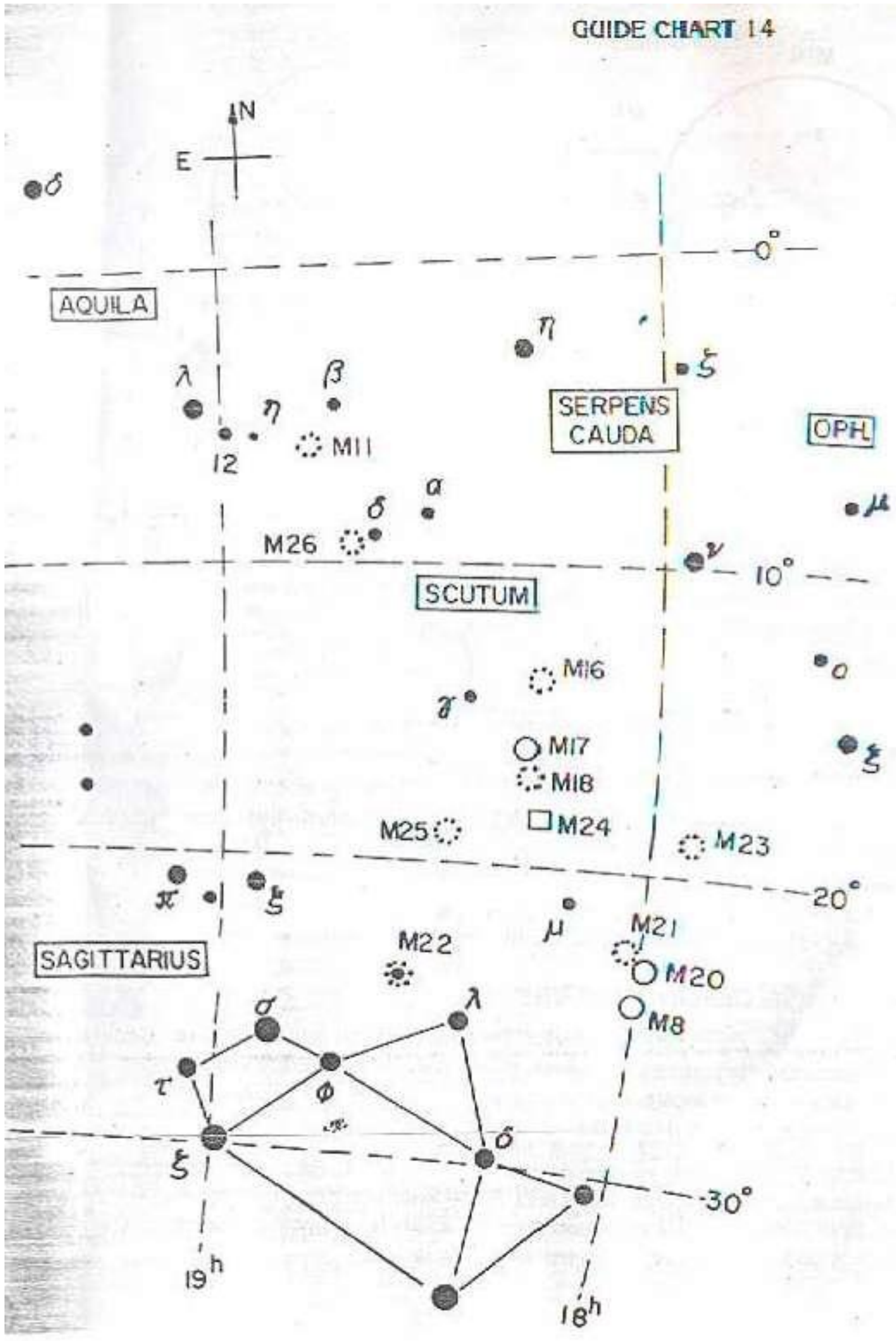
M11(A); *Wild Duck:* A superb fan shaped cluster, with a compact dense centre and an outer periphery of stars in the shape of a flight of wild ducks. There is a bright star at the apex of the fan and two more to the SE. First locate the Scutum area by following the line *Altair*-δ- λ *Aquilae to 12 Aquilae (see* Chart 15) to its W is 5th mag. η *Scuti.* Ml1 is about 2° W and a little S of η*;* or find the midpoint between λ *Aquilae* and α *Scuti* and move a little NW.

Ml6(A): A galactic cluster and associated diffuse nebula in Serpens: the cluster is easy to locate but the nebulosity is not that easy to see. Clear, dark skies and averted vision are essential for seeing the nebulosity. To locate: move l/3rd of the way from γ *Scuti* to ν *Ophiuchi* and then a little S.

M17(A): *Omega* or *Horse Shoe Nebula:* Best approached from M16 by moving about *2½ ° S* and a little E: or move 1 ° N and a little E of Ml 8. which lies half way between ξ *Sagittarii and* σ *Serpentis.* This is a real beauty, the brightest portion of which looks like the number 2; quite unmistakable and worthy of careful study.

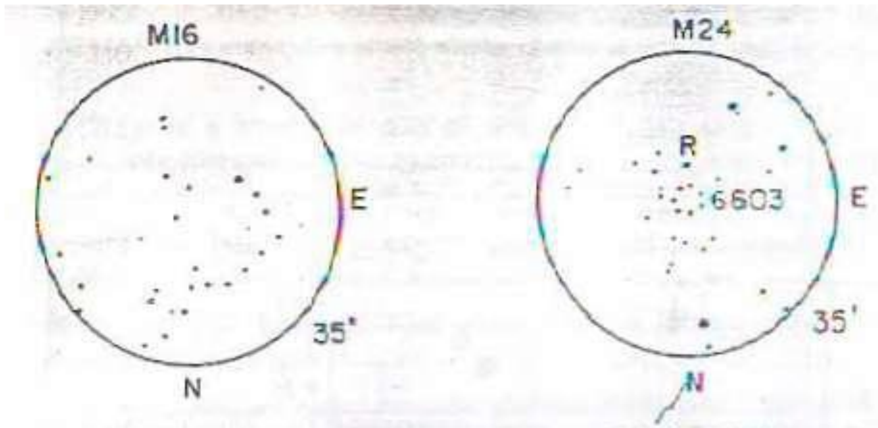
Ml8(A): A rather poor, undistinguished open cluster with one or two bright stars; the fainter ones form an S. Located half-way between ξ *Sagittarii* and σ *Serpentis.*

M23(A): This pretty open duster lies a little less than midday from *ξ Sagittarii* to ξ *Serpentis.*



M24(A): Is a detached patch of Milky Way about 1° X 1 ½ ° in size halfway between ξ *Sagittarii* and ξ *Serpentis.* Near the NE boundary of M24 is a genuine cluster *NGC6603 (*about 4' in diameter),It lies N of a reddish star.

M25(A): A very fine cluster with many bright coloured stars A little more than half-way from A *Sagittarii* to γ *Scuti* and slightly to the E.



Field Near M16 Field Near M24

M26(A): A small, comparatively faint open cluster; near the centre. 4 bright stars form a kite shape and immediately to the N and S are patches of faint stars. M26 is about 1" ESE of δ *Scuti* (4½ mag.)

GUIDE CHART 15

OBJECTS: M27, M23. M39. M56. M57. M71

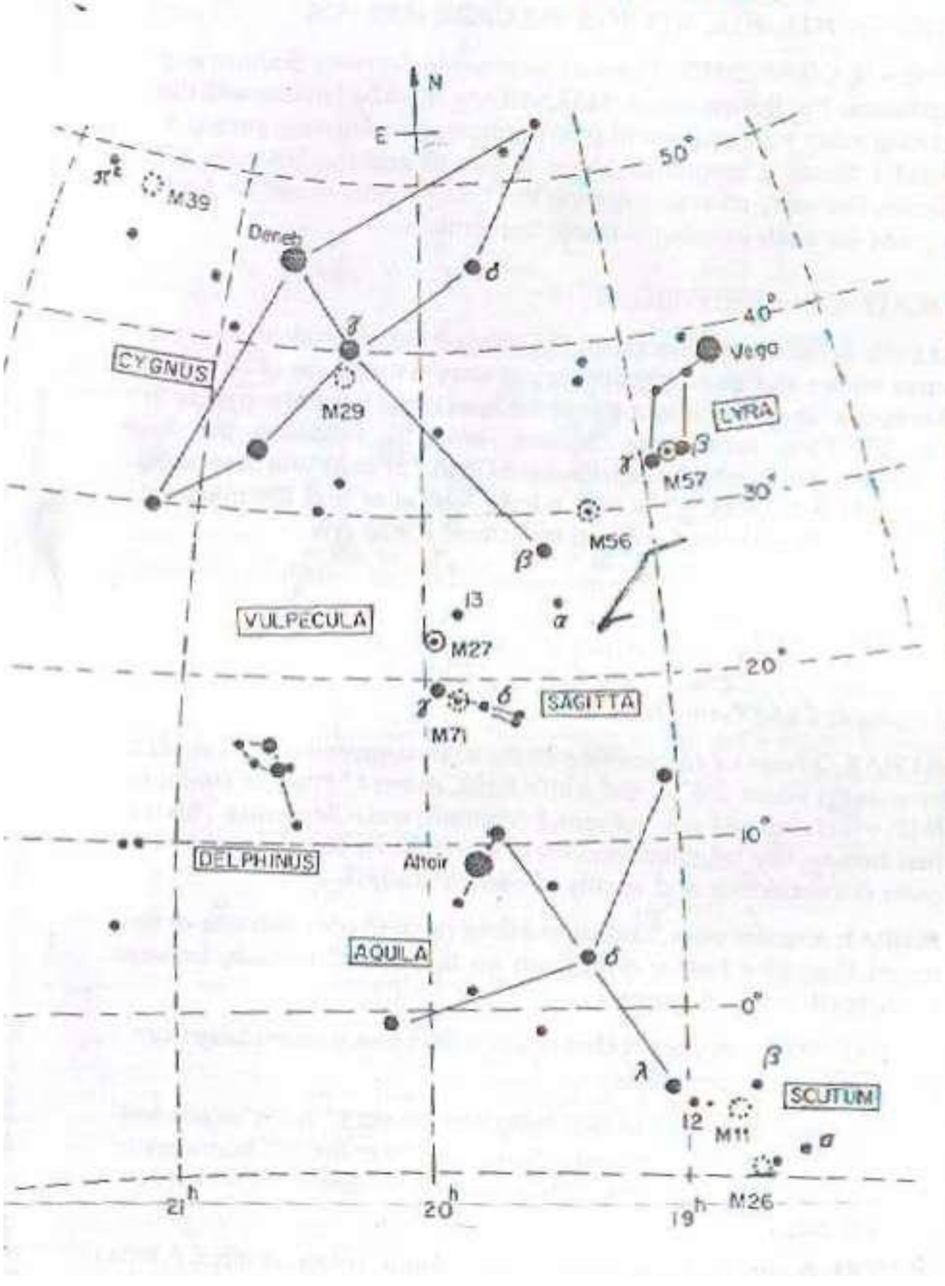
GENERAL COMMENTS: Except for M39 all the objects lie within the *Summer Triangle.* Included among these are two celebrated planetary nebulae: the *Dumb-bell* and the *Ring.* Best months would be August and September for early evening viewing; clear nights in July would be even better for late night viewing f: the weather permits.

LOCATING & OBSERVING HINTS:

M27(A): *The DumbBell Nebula:* This is a grand object whose appearance fully justifies the name given to it. The planetary is quite bright and easy to locate. M27 Is on the γ *Lyme - β Cygni* line, as far from *β* as γ is from *β;* it is also 3° N of γ *Sagitcae.*

M29(A): A poor open cluster consisting of very-few-stars.The four- brightest stars form a rectangle and three others form a triangle just N of the rectangle. The surrounding star field is far more impressive M29 is almost *2* ° S of γ *Cygni* and a little E.

GUIDE CHART 15



M39 (A): Bright open cluster with three stars at the corners of an equilateral triangle and most of the rest falling inside the triangle. Locate 4th mag rr² *Cygni; M39* is 1/4th of the way from this star to

Deneb.

M56 (A): Small globular, a little less than half-way from *β Cygni* to γ *Lyrae.*

M57 (A): *Ring Nebula:* Though of 9th mag. this small, pretty planetary is clear and distinct: the ring can be made out as the centre is quite dark. Easily located a little more than half-way from γ to *β Lyrae.*

M71 (A): Somewhat faint, irregular shaped globular cluster. Locate Sagitta in the Summer *Triangle*: M7I lies between γ and δ *Sagittac.*

GUIDE CHART 16

03JECTS: M2 M15. M30. M72, M73, M75

GENERAL COMMENTS: For early evening viewing, the best months are August and September; clear rights in July would be best for late evening viewing.

LOCATING & OBSERVING HINTS:

M2(A): Bright globular cluster about 1/3rd of the way from *β Aquarii* to ε *Ptgasl* and a little to the W.

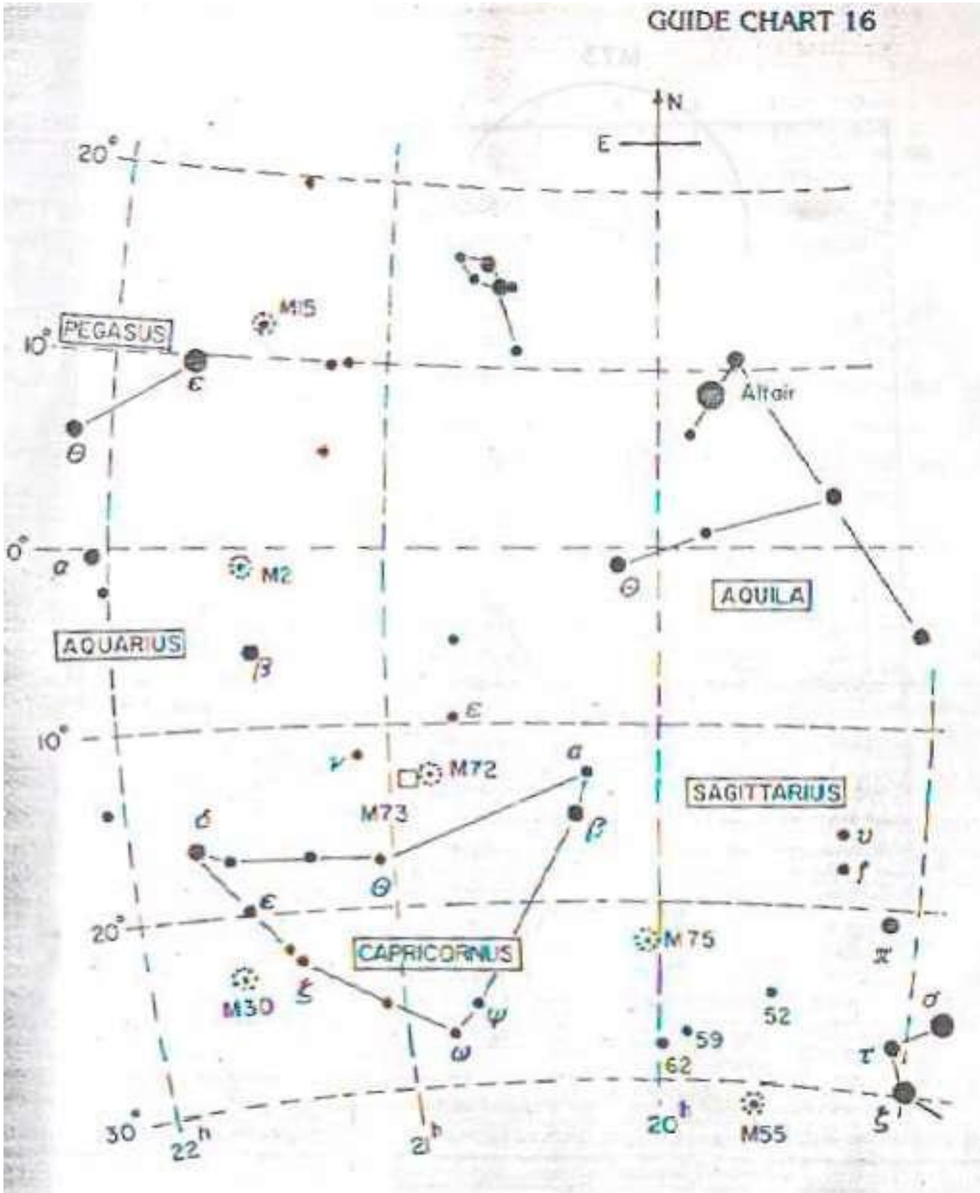
M15(A): Very faint globular cluster. Continue the line *θ* to ε *Pegasi* beyond ε by an amount equal to one half the distance between *θ* and ε to find Λ\ 15.

M30(A): A smaller globular. M30 almost forms an equilateral triangle with ε and *ζ Capricorni, 5½* mag. *41 Capricorni* lies about 1/2 ° E of the globular.

M72 (A): The faintest of the Messier globulars. First find *ε Aquarii. M72* is a little beyond half-way from *θ Capricorni* to ε *Aquarii.*

M73 (A): Is just an asterism, i.e. a group of stars. Best located by moving 1 ½° E and a little S of M72; three faint but distinct stars form a triangle with a much fainter star to their W (see the relevant figure).

M75(A): *A* small globular with a bright centre. In order to locate this object first note 4th rnag. ρ and υ Sagittarii: M75 lies half-way between υ *Sagittarii* and ω *Capricorni.*


GUIDE CHART 16
N
E
PEGASUS
M15
Altair
AQUILA
AQUARIUS
M2
M72
M73
SAGITTARIUS
CAPRICORNUS
M75
M30
52
59
62
M55
20°
10°
0°
10°
20°
30°
22h
21h
20h

Astrophotography

The Astrophotography Learning Curve

Getting Started in Astronomy

- Read some introductory material about getting started in astronomy as a hobby.
- Buy some good basic general introductory astronomy books.
- Join a local astronomy club.
- Start looking through a lot of other people's telescopes at star parties and other observing outings.
- Subscribe to some astronomy magazine or go to a library and read such magazines.
- Learn the important stars and constellations of the night-time sky.
- Learn about right ascension and declination and setting circles.

Beginner Astrophotography

- Buy some introductory astrophotography books.
- Research the current DSLR Cameras that are good for astrophotography.
- Buy a camera that is good for astrophotography and learn how to use it.
- Learn how to correctly focus your camera.
- Start taking star-trail photos and other fixed camera on tripod shots.

Intermediate Astrophotography

- Learn about polar alignment.
- Learn how to make a simple or advanced barn door camera mount.
- Begin shooting wide-angle shots with the barn door mount.
- Start seriously researching in-depth which telescope and mount to buy.
- Perfect your wide-angle barn-door technique.
- Decide which telescope and mount you want, and buy them.
- Learn how to use the new scope and mount.
- Master the art of drift polar alignment.
- Learn how to manually guide.
- Start shooting piggy-back photos with telephoto lenses on top of your new telescope.
- Perfect your piggy-back technique.

Advanced Astrophotography

- Start taking astrophotos at the prime focus of your scope and manually guide them with an off-axis guider.
- Master prime focus astrophotography and manual guiding techniques.
- Get an SBIG™ ST-4 autoguider or webcam to use as an autoguider.
- Learn how to use the ST-4 or web cam as an autoguider.

- Master the technique of prime-focus deep-sky astrophotography with an auto-guider.
- Relax and enjoy the beauty of the night sky while the auto-guider does all the work.
- Learn how to digitally enhance your astrophotos.
- Enjoy the satisfaction of your accomplishments and share the beauty of the universe with others.

We expect that you have gone through the first part of this learning curve. If not, you can still refer to the first few sections of this handbook and start your tour in the world of astrophotography. So we'll basically cover the beginner's and intermediate astrophotography. For further details you can meet any of the club members.

Beginner Astrophotography

There are basically four different kinds of digital cameras.

- Digital SLR Cameras (DSLR)
- Dedicated, Cooled Astronomical CCD Cameras (CCD)
- Digital Snapshot Cameras (DSC)
- Webcams

Digital Single Lens Reflex cameras - DSLRs have removable lenses with a wide variety of focal lengths from fisheyes to super telephotos. They offer complete creative control over aperture, shutter speeds and ISO. They have large digital sensors. Their lenses can be removed and replaced with an adapter that allows them to be hooked up directly to the telescope where the scope acts as the camera lens.

Astronomical CCD cameras - These cameras are specially cooled to reduce noise, and are specifically made for scientific and imaging purposes by manufacturers such as Santa Barbara Instrument Group, Starlight Express, Apogee Instruments and Finger Lakes Instruments. They are made to be used through a telescope, but adapters can be purchased that allow use with camera lenses for wide angle shots. Astronomical cameras require a computer to be used.

Digital Snapshot Cameras - DSC cameras have non-removable lenses and limited maximum exposure times. DSC cameras can be used for scenic astrophoto scenes, but do not work very well for longer exposures for deep-sky imaging.

Webcams - Webcams are usually inexpensive cameras with color CCD or CMOS chips that are made to stream video over the web. They have very small chips with tiny high-resolution pixels that shoot continuous digital video. They work very well for high-resolution planetary imaging, but not very well for deep-sky imaging.

If you already have a digital camera, that's the one you should get started with. Even if you don't have any kind of telescope or other astronomical equipment, you can still take pictures of the Moon, constellations, star trails, and wide-angle scenic twilight shots.

How to Pick A Camera

Before you buy anything, ask yourself these questions:

- What kind of pictures do you want to take?
- What is the best kind of camera to take them with?
- How much do you want to spend?
- How deep do you want to get into it?

Think seriously about these subjects before you decide which camera to buy. The best camera for you depends on the answers to these questions!

What Kind of Pictures Do You Want to Take?

There are different kinds of astrophotography and different cameras excel at different aspects of the hobby.

Scenic: Scenic astrophotography would include wide-angle shots such as the crescent Moon setting in the twilight or the Milky Way. Photographs of atmospheric phenomenon, such as the aurora would also be included. This category doesn't have strict definitions, but pretty much anything you can shoot on a fixed tripod with a relatively short exposure of about 30 seconds or less.

Planetary: Planetary photography encompasses the Sun, Moon, and planets of the solar system. Planetary photography requires high-resolution to pick out tiny details on planets such as Jupiter and Mars, as well as small craters on the Moon and details in sunspots. These objects are bright, so exposure is not the problem, but "seeing" or atmospheric steadiness is.

Deep Sky: Deep-sky astrophotography includes the real jewels of the night sky - star clusters, nebulae and galaxies. These objects require long-exposures and low-noise cameras.

What's the Best Camera to Take Them With?

- Scenics - DSC or DSLR
- Planetary - Webcam
- Deep-sky - CCD or DSLR

Recommended Cameras

- **Entry-Level**
    - Canon EOS 1000D (Digital Rebel XS)
    - Nikon D5000
- **Consumer / Prosumer**
    - Canon EOS 500D
    - Nikon D300S
- **Professional**
    - Canon EOS 5D Mark II
    - Nikon D3S

However, there is no minimum requirement to enter the field of astrophotography. You can start with your own digital cameras like sony cybershot, Nikon, Canon, etc. Or even webcams can give you good pictures. So, why sit out? Let's begin with the fun part.

SCENIC ASTROPHOTOGRAPHY :

You can get started taking simple astrophotos, such as of constellations, with almost any kind of digital camera. A tripod helps, but you don't really even need one of those.

First let's go over some quick facts and terms about digital cameras.

Shutter Speeds, Aperture, ISO

Except for the moon, the stuff we want to shoot in the night sky is pretty faint. That means we need to record as much light as we can. Cameras control the amount of light taken in a picture by two basic ways. There is a shutter that opens and lets light hit the digital sensor in the camera, and there is a variable-sized hole, called the aperture or diaphragm, in the camera lens. If we leave the shutter open longer, we record more light. If we use a larger hole, we let more light in. Nothing complicated here.

Shutter speeds run in fractions of a second, usually around 1/1,000th of a second at the shortest exposure to many seconds at the longest. Most DSLRs also have a setting called "bulb" that keeps the shutter open as long as you press the shutter button down.

Aperture settings run in a crazy series of numbers like f/2.8, f/4, f/5.6, and f/8. Confusingly, the smaller the number, the larger the hole in the diaphragm. So, f/4 is a bigger hole than f/8.

Most cameras also have a way to change their "sensitivity". This is kind of a trick setting though. You can't really change the sensitivity of the sensor in the camera, but you can adjust a setting called the ISO, which is sort of like a multiplier factor. ISOs may run from 100 to 400 in simple cameras, or up to 800, 1600 or 3200 in more expensive cameras. The higher the ISO number, the brighter the resulting image will be. Unfortunately, the noise, or grain, gets worse at the higher ISOs, but we won't worry about that for now.

To get started, you will have to figure out how to get your camera to use as long a shutter speed as possible, at as wide an aperture as possible, and at as high an ISO as possible. Unfortunately, you may have to read the manual to learn how to do this. Sorry. Your other option is to just dig around in the camera's menus looking for these settings, but sometimes they can be hard to find and not labeled very clearly.

Set the camera on manual exposure if it has that setting. Then set the lens to its widest opening, usually f/2.8. Set the ISO to the highest it will go, usually 400 for simple point and shoot cameras. If the camera doesn't have a manual exposure setting, set it to night mode.

Just put the camera on a tripod and aim it at a nice constellation and take the longest exposure at the widest aperture that you can, at the highest ISO that you can. Heck, you don't really even need a tripod. Just use a beanbag and place it on a solid object, like the hood of your car.

Use the camera's self timer to open the shutter, and try not to move the camera during the exposure.

Take a series of exposures, and double the exposure for each. Start at 1 second, then try 2 seconds, 4 seconds, 8 seconds, 15 seconds and 30 seconds.

Now you can examine the results on the back of the camera. Open them up and look at them at 100 percent magnification. You will probably find that they are fairly noisy, or what we used to call "grainy" in the days of film photography last millenium.

The longer exposures will naturally record the most stars, but after a while when they get too long, the stars will start to trail. Really long star trails can make interesting photos in themselves and we will cover this later. Look through your series of different exposures and pick the frame that is the longest without unacceptable trailing.

See how easy that was!

There are many kinds of astronomical objects that you can shoot with just a simple digital camera on a tripod, such as constellations, the Moon, twilight scenes, star trails, the brighter planets, and the Milky Way (if you have a dark observing location).

Planetary Images

This includes the images of planets like Jupiter, Saturn, Venus, Mars and Mercury along with our own Moon and sun.

Using a WebCam

What You need is a decent telescope (One in the club will be more than enough), A webcam (any of the modern day computer webcams will do) , a webcam adapter (present in the club) and an astrophoto processing software like Registax.

Attaching the webcam to the telescope: This can be done in two ways. Either by removing the original lens of the webcam and then putting it on the adapter; Or by keeping the webcam's lens and then putting it on the adapter. In latter case, the magnification is higher but it's pretty difficult to handle. So it's better if you start with the first method and then switch to second one over time.

. **Finding the Planet Through the Webcam** (webcam astrophotography method starts here)

The first step can be the trickiest part of it all! It is necessary to precisely center the planet in a relatively high power eyepiece. This must be done before switching to the webcam. Here are the steps involved:

1. Insert 2X Barlow lens. Webcam is not inserted yet.
2. Insert 32mm eyepiece for a low power, wide field of view. Adjust RA and DEC until the planet is as close to center as possible.
3. Carefully switch to the higher power eyepiece. I use a 10mm Plossl for this. This gives me about 400X magnification which is close to my highest "useful" magnification.
4. Center the planet and make sure it holds its position. A good polar alignment helps a lot here!
5. Very carefully, switch to the webcam (i.e.., remove the eyepiece and insert webcam).
6. Open the webcam software program. If the planet is not visible on the screen, it is usually due to 1 of 3 things: gain setting is too low, the planet is not centered (normally the case), or the telescope is WAY out of focus.

Once the planet is centered on the screen, then it is time to make some adjustments to the webcam. First, adjust the **shutter speed** and **gain**. To obtain the best quality, it's advisable to select a shutter speed of 1/25 seconds or 1/33 seconds (or even 1/100 seconds in the case of Mars).Gain should be set to a value below 50%. It is important to keep the gain as low as possible but still see the detail. Otherwise, the finer details will be over-exposed. See screenshot above for typical settings:

Another important setting is the **frame rate**. The frame rate is directly related to image quality. Normally, a frame rate of 5 fps (frames per second) or 10 fps works fine. Basically, 5 fps yields a higher resolution frame than 10 fps. However, by using 10 fps, one can obtain more frames (to stack) in a given time period. 5 fps works well when the seeing is very steady. Otherwise, one can use 10 fps.

7. Capturing the Video

Start by taking a 3-4 minute video (AVI) of the planets. This will yield hundreds of frames from which to stack (stacking process will be discussed later in the article). For example, if one takes a 3 minute video at 10 fps, he/she will end up with 1800 frames (3 minutes x 60 seconds x10 fps). To a certain extent, the more frames available for stacking, the better the detail possible. It is important to note that there is a point where the detail will become blurred due to planet rotation. This is especially the case with Jupiter and its 10 hour rotation period. Thus, one should limit one's videos to about a 4 minute maximum recording time. As explained later, not all of the 1800 frames can be used during the stacking process.

Once you have started the video, watch the planet to make sure that it does not drift off the screen. If it starts to get close to the edge, make a fine adjustment to RA or DEC on the motor drive hand controller. The better you polar align the scope to start with though, the less you have to worry about drifting!

8. Registax Processing

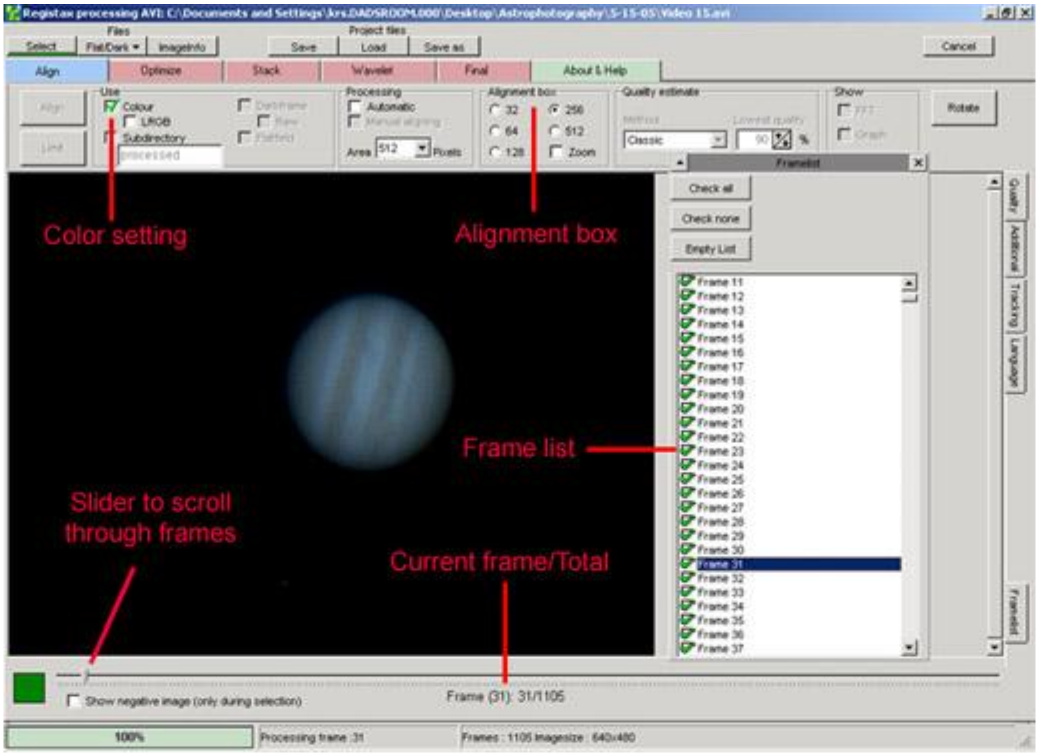
Next comes the fun part of processing the video. The program of choice for stacking frames is Registax. Since Registax 3 is the latest version of software as of this writing, let's use it as an example. However, the basic principles are the same with any version of Registax.

Registax can be downloaded at http://registax.astronomy.net. Thanks to Cor Berrevoets (creator of Registax), it is available as freeware. His program is WELL appreciated!

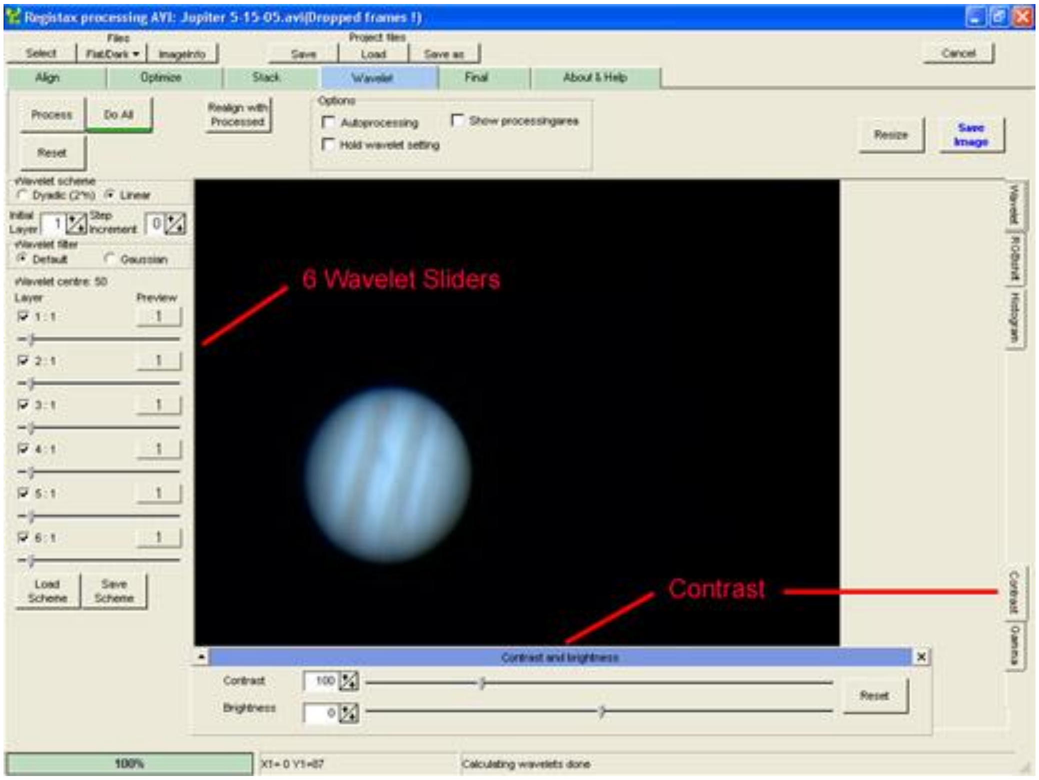
Here is the basic procedure for converting an AVI video into a single stacked imaged.

1. Change screen area to 1024 by 768 pixels. In Registax 3, the entire screen is not visible with 800 by 600 resolution.
2. Open Registax and click on the select button at the top left of screen. Choose the video taken with webcam.
3. Scan the individual frames in the avi to find the best looking one. Frames will vary in quality from each other mostly due to the fluctuations in the atmosphere. It is important to select a frame that provides the sharpest detail in the group since all others will be sorted according to

this frame. Frames can be previewed by using the slider bar or the framelist. See screenshot below. Click to open in separate window (for easy reference).



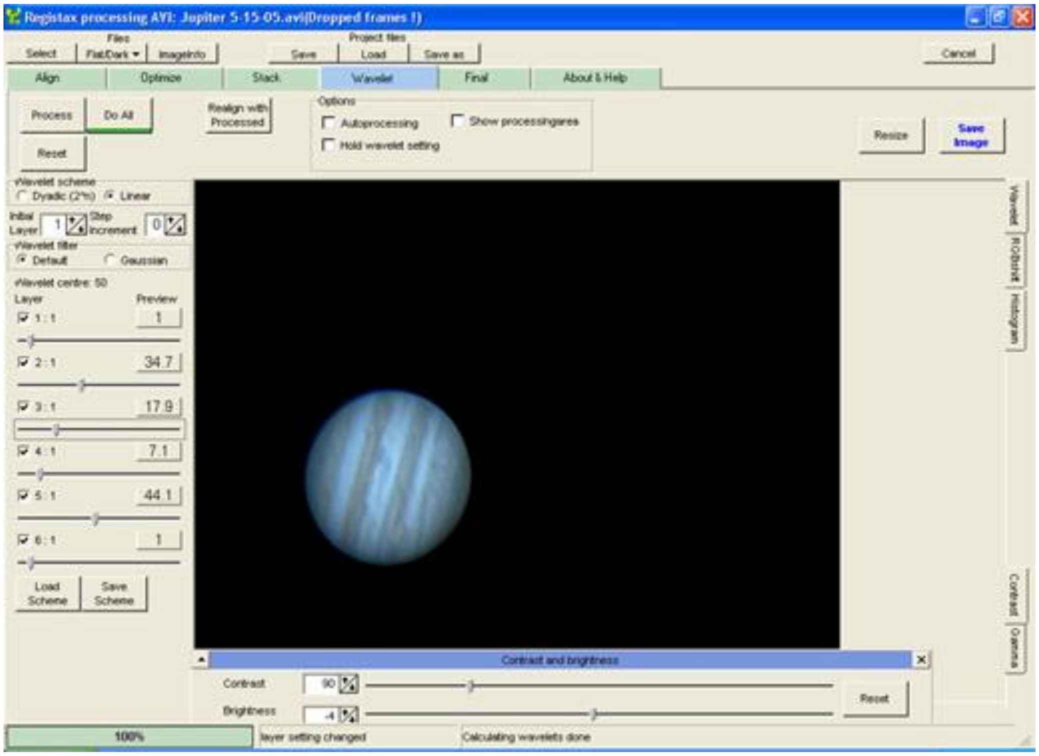
4. Once the best frame is found, then an alignment box must be drawn around the image or particular feature within the image. I usually draw a box around the entire image though. There are several sizes of alignment boxes to choose from. These include 32, 64, 128, and 256. I select a size that is just large enough to completely surround the image of the planet.
5. Be sure to check the box "Use Colour".
6. In the Quality Estimate section, select the Classic method and a Lowest Quality setting of 90%. This means that only those frames that are at least 90% as good as the reference frame will processed.
7. Click the Align button and the alignment process will begin.
8. At the end of the alignment process, note (at the bottom of screen) the stack size vs. the original number of frames. The lower quality frames (as compared to the reference frame) were screened out. Clicking the Limit button will eliminate the lower quality frames. Note the fewer number of frames for processing.



9. Now click on the Stack tab. Further refinement will be performed here. If the Stackgraph is not already displayed, click on the tab. Note the 2 sliders. The vertical slider is for difference cutoff. This is adjusted downward to eliminate those frames that are significantly different from the others. Here one should cut off any large spikes. The horizontal slider controls the quality of the frames. The graph slopes downward from left to right. The left side being the highest quality frames (again, as compared to the originally selected reference frame) and the right side being the least quality frames. Better frames are selected as the slider is moved to the left. As this adjustment is made, the number of frames shown at the bottom of the screen will change.
10. When the best frames are selected, it is time to stack them together. Registax combines all the selected frames (that were at least 90% as good as the reference frame plus the additional manual adjustments) into a final composite image. Its advisable to have a stack of at least 300 frames. The more frames that are stacked, the better the signal to noise ratio (more signal, less noise). Since each frame varies a bit in the amount of detail that was captured, the final stack will be a nice composite with lots of detail!
11. Now click the Wavelet tab. This is where the magic begins! Click the contrast tab and move the slider slightly to the left for both contrast and brightness. Note the wavelet sliders in the screenshot below.
12.

12. Now it is time to adjust the wavelet sliders to bring out the detail in the composite image. I normally only adjust the sliders for layers 2-5. A lot of trial and error takes place at this stage. As the sliders are moved to the right, detail is brought out of the image. A nice balance must be struck between under-processing and over-processing the photo. If the wavelets aren't adjusted enough, then not all of the available detail will be brought out in the image. Over adjusting

however will only make the photo grainy (noise). Here is a screenshot of the image above after some adjustment of the layers:



As you can see, the detail really stands out! Now it is time to polish up the image for final version.

13. Click on the Final tab. Click on the Save Image button or copy it to the clipboard. Note that final processing can be performed here. However, one can finish it up in a photo editing program (Adobe Photoshop normally).

9. Further Processing- Adobe Photoshop

Basically, the following tools in Photoshop are used to clean up the photo for the final version:

- Crop (to center image)
- Rotate canvas (for proper orientation)
- Levels (tonal range and color balance)
- Contrast
- Brightness
- Despeckle (cleans up some of the noise)
- Unsharp Mask (sharpens image but introduces noise!)
- Color Balance
- Hue & Saturation

Dark Sky Site Etiquettes

- No White Lights after Dark! Use dim red lights after sundown. Use only the minimum light necessary for safety. If you must use lights, please ask first, to avoid spoiling someone's night vision or astrophoto. Shield Shelter your light with your body, telescope, car or whatever to minimize glare.
- Before approaching a telescope ask if the owner is doing photography or imaging. If they are, be careful not to step in front of the field of view of the telescope or lens. Especially don't wave a light around in the vicinity.
- When using Green laser pointers please do so sparingly as they DO affect night vision.
- If using a computerised Star Chart PLEASE DO USE the Night Mode.
- Don't touch other people's equipment or lenses. If you do accidentally touch someone else's lens or eyepiece, perhaps smudging it in the process, don't try to clean it yourself. Apologize to the affected party and let them decide what to do.
- Sharing views is a benefit to finder and seeker, but please ask before you look through another's telescope. Better yet, wait until you are invited.
- Keep food and drink away from telescopes. If there are children present, keep a close eye on them.
- The last two people should sweep the area with their flashlights to see if anyone accidentally dropped something important. If you find anything left behind, contact the club President the next day and then bring the item with you to the next meeting to be re-united with its owner.