1.INTRODUCTION

Knowing what to look at in the sky, and being familiar with the instruments required for observation would be useless if the observer does not know how to find celestial objects.

The human eye can see without optical aid objects to magnitude 6. This would limit the observer to the 6,000 stars brighter than magnitude 6, the planets except Neptune and Pluto, the Moon and some deep sky objects, like M31, M8, M13, the Double Cluster in Perseus, and another few deep sky objects.

The observer can point the telescope to these objects, but the vast majority of deep sky objects cannot be found with the naked eye and, therefore, the observer must be able to point his/her scope to the right spot in the sky.

2. THE CONSTELLATIONS

The constellations are portions of the sky containing stars and deep sky objects. They were named by assigning them the names of mythological subjects, and the constellations were sometimes identified, with a huge imagination, with the shapes of the subjects they were named after. The astronomers have divided the sky into 88 constellations.

The first approach to finding a celestial object is to know the constellation were the object is located. However this approach would be equivalent to find a person saying the country where the person is located. To complicate matters, the constellations differ enormously in size. On one hand there are tiny constellations like Saggita, covering just a few square degrees of the sky, and there are large constellations like Ursa Major covering hundreds of square degrees of sky.

Knowing how to locate the constellations however is a must for amateur astronomers, and all amateur astronomers should put enough time and effort in learning the location and boundaries of all the constellations visible from their observing places.

3. ASTRONOMICAL COORDINATES

An object could be located easily if we know its coordinates, the scope is fitted with setting circles, and it is properly aligned. There are two types of coordinate systems, alt-azimuth, and equatorial.

3.1. Alt-azimuth coordinates.

The alt-azimuth coordinates measure two angles: the altitude and the azimuth. The altitude is the angle measured in degrees from the horizon to the object. The altitude varies from 0 to 90 degrees. Objects located in the horizon have an altitude of 0 degrees, and objects in the zenith have an altitude of 90 degrees. The azimuth is measured westward (clockwise) in degrees from the North to the object. The East's azimuth is 90 degrees, the South 180 degrees, the West 270 degrees and the North 0 degrees.

Alt-azimuth coordinates are not constant. They vary depending on the hour and the latitude of the observer. Astronomical charts do not show alt-azimuth coordinates for this reason.

To determine the alt-azimuth coordinates of an object at a specific time would require the observer to recalculate the coordinates for the time of the observation.

3.1. Equatorial Coordinates.

The equatorial coordinates of an object measure two angles: its declination and right ascension. In a way, the right ascension and declination are equivalent to longitude and latitude on Earth.

There are two terms that need to be explained before continuing. The longitude on Earth is the angle measured from the Greenwich meridian to a particular meridian. When speaking of celestial coordinates, the meridians are called hour circles. The hour circle of a celestial object is the circle that passes by the celestial poles and the object. In Figure 1, the hour circle of object S would be the circle PSS"P'. The Greenwich meridian is an arbitrary point on Earth chosen as the 0 degree longitude. In the sky the equivalent to this point is called the vernal equinox, and its location is not arbitrary. The vernal equinox is the point where the celestial equator intersects the ecliptic. In Figure 1, the vernal equinox is the point V on the celestial equator.

The declination is the equivalent to latitude and measures the angle in degrees from the celestial equator to the object along the object's hour circle. Objects North of the equator have positive declination and objects South of de equator have negative declination. The declination varies from 0 to 90 (or –90) degrees. In Figure 1, the declination of object S is the arc S"S.

The right ascension is the angular distance measured eastward (counter clockwise) from the vernal equinox to the hour circle of the object along the celestial equator. The right ascension is the equivalent to longitude. In Figure 1, the right ascension of object S would be the arc VS". The right ascension is

measured in hours, minutes and seconds and it varies from 0 to 24 hrs. There is no East or West right ascension.
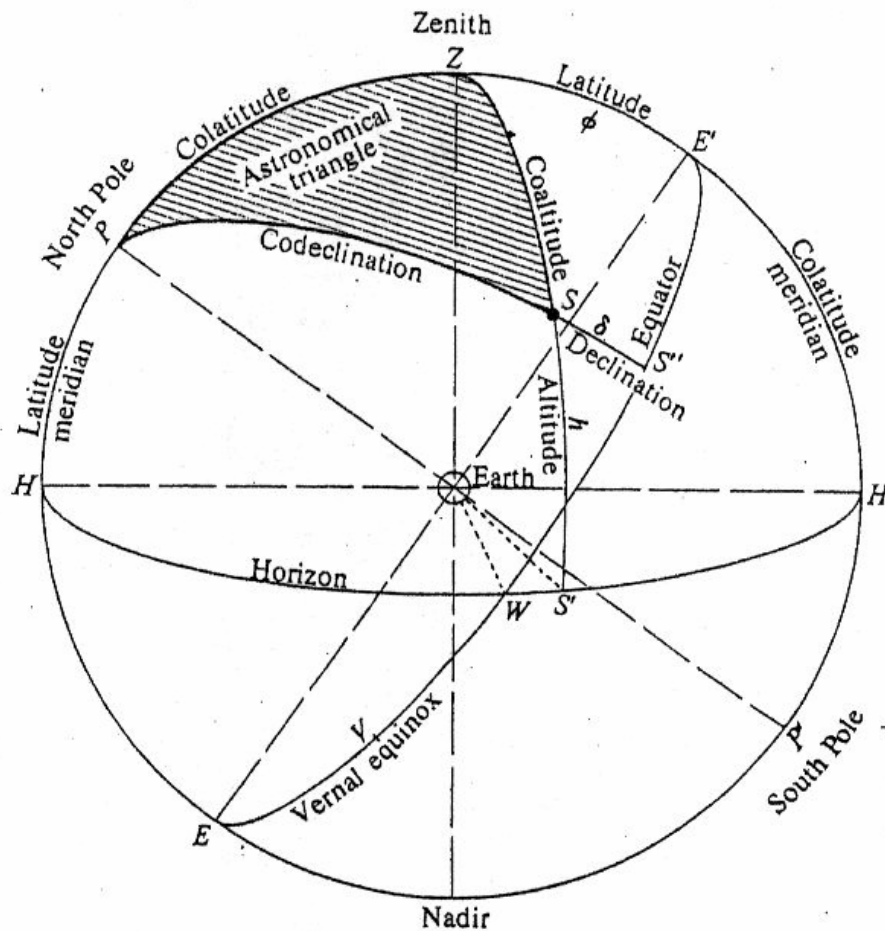

Figure 1. Celestial Sphere

Equatorial coordinates are constant, except for the small changes due to precession and proper motion. The equatorial coordinates of celestial objects are revised each 50 years and the revision is called epoch. The celestial coordinates found in current catalogues are for the year 2000, and are referred as epoch 2000 or J 2000 (the J for Julian year).

The great advantage of equatorial coordinates is that they are practically constant, and, therefore, all star charts come with a right ascension/declination grid, in the same way that most Earth maps come with the latitude/longitude grid. This allows pinpointing the object very easily in the chart, and its corresponding position in the sky.

Figure 2 is a computer-generated chart of the Saggittarius area, showing some Messier and NGC objects and the right ascension/declination grid.
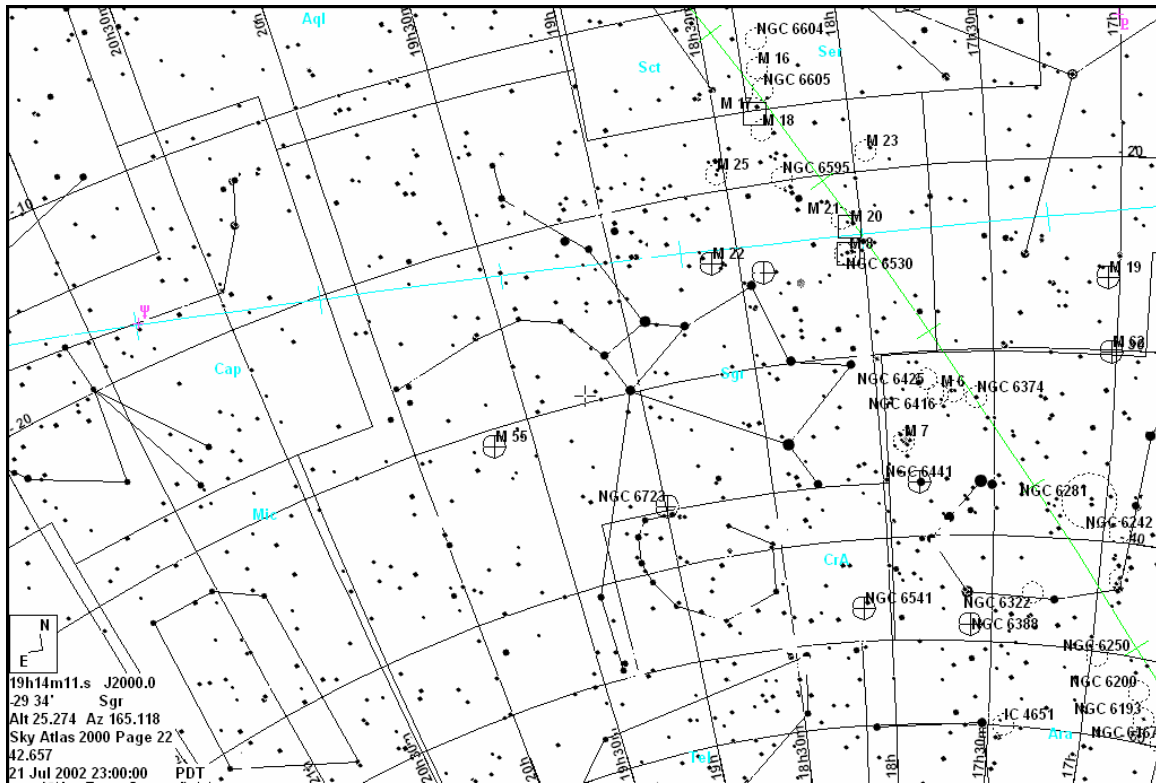

Figure 2. Sky Chart

We have learned how to locate objects in charts and we will speak later on these notes how to go from the charts to the actual sky. However in order to locate objects in the charts the observer needs to determine what objects he/she will be observing and that is the purpose of the next sections of these notes.

4. CATALOGUES

The catalogues of celestial objects are nothing more than listings of objects. The data included in the catalogue includes the designation and catalogue number, right ascension and declination for an epoch, and most of the times the magnitude. The listing may include some other information such as spectral class, type of object, range of brightness for variable stars and so forth.

4.1. Stars

The Bayer designation is the most common for stars. Bayer assigned greek letters to the brightest stars of a constellation. Alpha was the brightest, beta the second brightest and so forth. However Bayer run out of greek letters to cover all

the visible stars of a constellation, and Flaamsted suggested to assign numbers to the rest of the stars not designated by the Bayer system.

Stars that are too faint to be designated by either the Bayer or Flaamsted designations are designated by other catalogues such as the SAO, Hipparchos, GSC, PPM, Tycho, etc…catalogues.

4.2. Deep Sky Objects

Deep sky objects are catalogued in three main catalogues: Messier, NGC and IC catalogues.

4.21. Messier Catalogue

The Messier catalogue consists of a list of 110 objects prepared by the French astronomer Messier in the 18th century. Messier was a comet hunter and in his search for comets he came across a number of "fuzzy" comet-like objects. When he realized that those objects were not comets, he prepared a list of them to help other astronomers to avoid confusion if they came across the same objects. The Messier catalogue is very often the first observing goal of beginners. The catalogue includes star clusters, nebulas and galaxies, and they are all within reach of a 90 mm scope.

4.2.2. NGC Catalogue

NGC stands for New General Catalogue. Its purpose was to catalogue nebulas, clusters and galaxies. The catalogue includes almost 7,900 deep sky objects.

4.2.3. IC Catalogue

IC stands for Index Catalogue and its purpose was to supplement the NGC catalogue. It adds another 5,000 deep sky objects.

4.3.3. Other Catalogues

There are several other catalogues to choose from. The Caldwell and Herschel catalogues list deep sky objects in the hundreds. There are catalogues for galaxies alone such as the PGC (Principal Galaxy Catalogue), the UGC (Upsala General Catalogue), the MPG (Morphological Catalogue of Galaxies) and some others. The PGC alone lists over 100,000 galaxies.

Then there is the Hikson catalogue, for groups of galaxies, The Aarp catalogue for galaxies, the Terzan Globulars, the PK catalogue for planetary nebulas, etc…

Many objects are listed in several catalogues at the same time. M31 for instance is listed in the Messier, NGC, PGC, UGC and MPG.

5. CELESTIAL CHARTS

Once we have chosen what to look at in the sky and learned its coordinates from any of the catalogues, we have to locate the object in a celestial chart. Charts are nothing more than a representation of the night sky.

There are several types of charts available. Perhaps the simplest of them is the planisphere. The planisphere is like a dial in which the time and the date of the observation can be selected to show how the sky looks at that time. The planisphere does not have a lot of detail; showing stars to magnitude 3 or 4, and very few deep sky objects. However, the planisphere is an invaluable tool because it shows a wide patch of sky and the positions of several constellations relative to each other. A planisphere should be part of an amateur astronomer gear.

Celestial charts are maps of the sky drawn to different levels of detail. They can include stars from magnitude 5 to magnitude11. They have advantages and disadvantages. Magnitude 5 or 6 charts show a bigger portion of the sky than more detailed charts and make navigating the sky easier. Magnitude 9 and 11 charts show much more detail than magnitude 5 charts, however the field shown on each page is much smaller and they never show a full constellation in one page, making it more difficult to navigate the sky.

There are several good charts available. The best Known are the Sky Atlas 2000, that charts about 80,000 stars and deep sky objects to magnitude 8 in 27 charts; Uranometria 2000, that charts approximately 350,000 objects to magnitude 9.5 in two volumes, and the Millennium Star Atlas that charts over 1,000,000 objects to magnitude 11 in three volumes of large size charts. Our recommendation for beginners is the Sky Atlas 2000.

In the recent years, with the advent of fast computers, planetarium programs have become very popular. These programs compile millions of objects to magnitude 15 or fainter. The great advantage of these programs is that the user can generate charts for years either in the past or the future, filter the type of objects to be seen, adjust the scale to a size that can be printed and take them along to the field. In addition these programs allow plotting the position of the planets, which cannot be shown in other charts, and plot the position of newly discovered comets by entering into the program the comet orbital elements provided in the Internet by the Minor Planet Center. Figure 2 is a computer-generated chart.

6. GETTING THERE

We have learned to select celestial objects in any of the catalogues available and to locate them in celestial charts. It is now time to find in the sky the objects we have located in the charts.

We must point out that the comparison of the constellation size as it appears in a chart compared as it appears in the sky is astounding. When we look at a chart we imply that when we look at the sky the constellation will be small, and that is not the case. Sometimes we are looking at the right spot in the sky and fail to recognize the constellation simply because we think it is much smaller than what it is in reality, and we are not looking at a wide enough portion of the sky.

6.1. Star Hopping

Star hopping consists in locating an object "hopping" from stars easy to recognize, and by following patterns and shapes in the sky. Almost everybody knows how to locate Polaris, the North Star, by following an imaginary line passing by beta Ursa Majoris (Merak) and alpha Ursa Majoris (Dubhe). Extending this line five times the distance between Merak and Dubhe (called for this reason the Pointers) we find Polaris. It is possible to hop in this way to many objects, even if they are not visible with the naked eye.
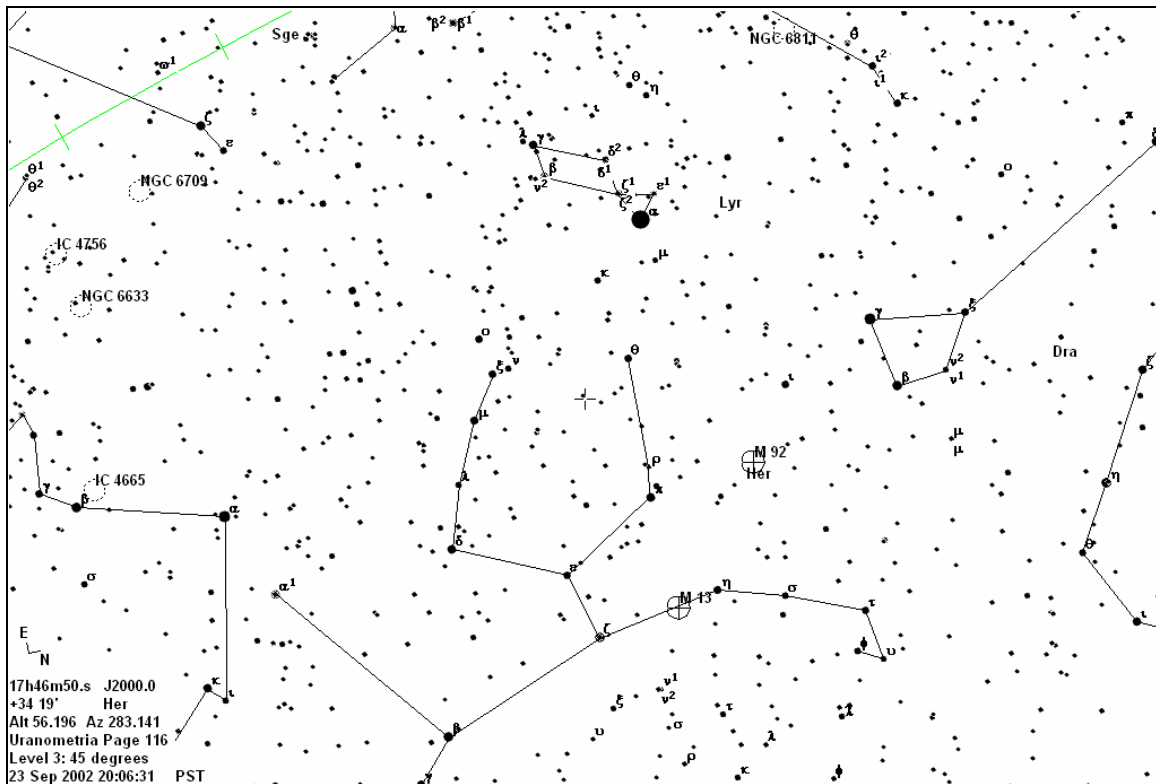

Figure 3. Star Hopping

Figure 3 is a computer-generated chart showing the location of two globular clusters in Hercules, M13 and M92. The chart also shows other nearby

constellations, Lyra (the little rectangle center-top) and the head of Draco (the little diamond on the right of M92) to help in locating he objects. M13 is very easy to locate because it is about a third of the distance between zeta and nu Hercules. These two stars are part of an easy to find asterism called the Key Stone in Hercules. M92 could be found using some of the stars of the Key Stone and the head of Draco.

Other objects are not so easy to find, because they may be located in areas of the sky devoid of bright stars, and the hops are longer than in populated areas of the sky, however practically any object can be located this way by an experienced observer.

6.2. Setting Circles

Another way to find celestial objects is by using setting circles, either mechanical or digital. Setting circles were discussed before in these notes. It must be reiterated that mechanical setting circles must be of good quality to be effective. In addition, whether we use mechanical or digital setting circles, the scope must be accurately aligned for the circles to be precise, especially in long scope slews.

It must be noted that star hopping and using setting circles are not exclusive approaches. We believe that amateur astronomers should have enough knowledge of the constellations to hop from star to star.

7. OBSERVING PLANS

Observers should plan their observations in advance. A well planned observation night will result in fewer swings of the telescope and better efficiency in the observing. At a minimum the observer should plan the observations for each session, and it is still better to arrange some kind of long term goals

7.1. Planning an Observation Session

Equipped with a planisphere or still better a computerized planetarium program, the observer starts by looking how the sky will look the night of the planned observation. The observer can use time intervals of 1 hour, or ½ hour, or whatever interval he/she considers adequate. By knowing what constellations are going to be up in the sky, it is simple to choose the objects to look at during the observation session in each constellation, and write down their celestial coordinates, type of object, magnitude and angular size. The objects selected are located in the corresponding sky chart and if the observer is planning to use a computerized scope, the coordinates can be programmed in the scope computer for the night.

Figure 4 shows an example of a "Grand Tour" schedule for computer-guided telescopes. In this particular case the coordinates (right ascension and

declination) of each object are already stored in the computer's memory. For "star hopping" the schedule would include columns for the coordinates.

GRAND TOUR SCHEDULE
ORION, LEPUS, ERIDANUS AND CETUS

The alignment stars for the tour are Dubhe, Sirius and Betelgeuse

The tour starts on Orion and goes through Lepus, Eridanus and Cetus

Calibration stars for the tour are Rigel, Zaurak and Menkar

Number	Object	Description	Constellation	Mag.
1	NGC2141	Galactic Cluster	Orion	9.4
2	NGC2186	Galactic Cluster	Orion	8.7
3	NGC2122	Galactic Cluster	Orion	9.1
4	M78	Diffuse nebula	Orion	8.0
5	M42	Diffuse nebula	Orion	N/A
6	M43	Diffuse nebula	Orion	9.0
7	Rigel	Alignment Star	Orion	0.3
8	NGC1964	Galaxy	Lepus	11.5
9	M79	Globular Cluster	Lepus	8.4
10	NGC1637	Galaxy	Eridanus	11.5
11	NGC1600	Galaxy	Eridanus	11.9
12	NGC1535	Planetary Nebula	Eridanus	9.6
13	Zaurak	Alignment Star	Eridanus	2.3
14	NGC1084	Galaxy	Eridanus	10.7
15	NGC1052	Galaxy	Cetus	10.5
16	Menkar	Alignment Star	Cetus	2.6
17	NGC1087	Galaxy	Cetus	10.9
18	M77	Galaxy	Cetus	8.9
19	NGC1055	Galaxy	Cetus	10.6
20	NGC0936	Galaxy	Cetus	10.1

Recalibration Stars

	RA			Declination		
	Hours	Minutes	Seconds	Degrees	Minutes	Seconds
Rigel	5	14	32	-8	12	6
Zaurak	3	58	2	-13	30	31
Menkar	3	2	17	4	5	23

Figure 4. Observation Schedule

We would recommend that observation plans for a night are scheduled to keep the scope in a certain area of the sky, specially for computer-guided scopes, to

avoid long slews from an end of the sky to the other. This could result in long time waiting periods while the scope slews.

The schedule in Figure 4 was planned for the scope to move up and down in declination along right ascension lines. In this way the scope slewing was kept to a minimum, basically waiting for the objects to drift into the scope field of view,

RA			dec						
Hr.	min.	sec	o	'	"				
21	30	0	12	10	0	M	15	Gc_Peg	6.4
22	0	42	17	44	17	N 7177		Gx_Peg	11.2
22	37	24	23	47	52	N 7332		Gx_Peg	11.1
20	7	52	31	21	35	N 7217		Gx_Peg	10.1
22	37	5	34	25	10	N 7331		Gx_Peg	9.5
22	35	58	33	57	29	Quintet		Gg_Peg	14.0
23	1	0	30	8	39	N 7457		Gx_Peg	11.2
23	1	7	16	23	24	N 7454		Gx_Peg	11.8
23	0	4	15	58	57	N 7448		Gx_Peg	11.7
23	4	57	12	19	18	N 7479		Gx_Peg	10.9
23	20	15	8	12	23	N 7619		Gx_Peg	11.1
23	20	42	8	13	2	N 7626		Gx_Peg	11.1
23	44	16	10	46	4	N 7742		Gx_Peg	11.6
23	44	22	9	56	4	N 7743		Gx_Peg	11.5
0	3	15	16	8	45	N 7814		Gx_Peg	10.6
0	3	59	20	45	0	N 7817		Gx_Peg	11.8

Figure 5. Grand Tour Data File

Figure 5 is a partial print out of a Grand Tour data file as entered in the computer. The first column on the left is the right ascension hours. Note how the right ascension changes very slowly while the declination degrees (4th column from the left) swipes up and down along right ascension lines. The last columns on the right indicate the name and type of object (i.e. N7177, **G**ala**x**y), the constellation (Pegasus) and the magnitude (11.2). These last columns appear in the computer display to allow the observer identify what he/she is looking at.

7.2. Long Term Observing Plans

Most amateur astronomers start the hobby choosing the Messier Catalogue as their first long term plan. Although all the 110 Messier objects can be seen in one night during the month of March, it normally takes a beginner between 6 months and one year to complete it. Once the Messier catalogue is complete, there are many other things to see. The NGC and IC catalogues total almost 13,000 objects, then there is the Herschel 400 list and the Caldwell catalogue. Some observers decide to go through all the deep sky objects of a particular Uranometria page, others decide to observe the 100 Hickson galaxy groups, while others make their long term plan to observe the PK catalogue of planetary

nebulas or the faint globular clusters of the Palomar and Terzan lists.. The choices are many.

Long term planning is an excellent complement to field observing as well. To establish his/her plan, the observer will have to research astronomical resources. There are many guides to observing in the bookstores or public libraries. Books like "The Messier Album", "Turn Left at Orion", "Observing the Constellations" or "Peterson's Field Guide to the Stars and Planets" are excellent sources.

All amateur astronomers should have a copy of "Burnham's Celestial Handbook". This handbook consists of three volumes of information for the 88 constellations. The handbook is out of print, but can be found in second hand bookstores. The handbook was written at a time when emphasis was put on observing binary and variable stars and it contains extensive data listings for these types of objects, but it also contains very extensive information about deep sky objects in each constellation. The coordinates of the objects in this book are epoch 1950, but they can be used perfectly for the epoch 2000, unless the observer is performing very precise astrometry work.

8. OBSERVATION RECORDING

It is a good practice to record permanently in some way what we see in our observations. An observation log should contain the object designation and common name, if it has one, the place, date and time of the observation, the seeing conditions and transparency, the equipment and magnification used, and our comments and description of what we observe.

The log can be either written on paper or recorded in a tape recorder. We recommend using a tape recorder, because writing in the dark when it is cold outside is not very convenient. A portable tape recorder can be used and the comments can be logged into the computer later at home.

As a matter of fact, we should record subsequent observations of any object seen in the past. By comparing notes we can measure how our observing perception and technique has progressed with experience.

9. OBSERVING AND OTHER CONSIDERATIONS

Observing skills improve with practice. With time we learn to look at and see features that we missed the first time we looked at an object. The first time I saw M33, the Pinwheel Galaxy in Triangulum, I was not very impressed because all I could see was just a glow in the sky, a little brighter towards the center. I remember somebody mentioning that there was a lot of detail. I just couldn't see it. One year later when I looked at M33 again I was surprised. I was able to make out spiral structure, and I was able to make out the knotty HII regions of star formation. With practice we learn how to look for dust lanes, spiral structure and

HII regions in galaxies; we learn how to search for the central star in a planetary nebula or red giants and binary stars in open clusters.

A technique used by observers is averted vision. Averted vision is used to see faint objects. When using averted vision we do not look straight at the object, instead we concentrate on looking at an object nearby. The cones (or rods. I'm not sure which) on the sides of our eyes are more sensitive to faint light and thus let us see things that are not visible looking at them straight. A classical example is the planetary nebula NGC6826. This object is called the Blinking Planetary for that reason. It can be seen with averted vision but it disappears when looking at it straight.

There are other techniques learn with practice. For example in the search for very faint objects like dwarf galaxies and Terzan clusters, it helps to sake the scope a little, because the vibration may make the object more apparent.

Another thing to consider is observing in cold weather. Standing still at the scope eyepiece does not make us sweat. Observing is hindered if one does not have a minimum of comfort. The key point is not to get cold, meaning that it is better to bundle up prior to getting cold. Once we are cold it is difficult to warm up by adding extra clothing. Hot drinks as hot chocolate and coffee are of great help.

Then there is the issue of having some light to look at charts, to move around, to change eyepieces and insert filters, to hold the focuser knob or to find the computer keys. In the process to adapting to darkness, the human eye secretes a chemical over a period of time. That chemical goes away the moment a light hits the eye. It takes another 15 to 20 minutes to get the eye adapted to darkness again. Red light does not affect the eye as much as white light does, therefore any light source use by the observer should have a red lens or use a red LED.

More and more, the observer's equipment is becoming more sophisticated. Computers and computer-controlled drives are common. Digital imaging (CCD) is becoming more and more popular. Dew formation is fought with low voltage heated resistors around the scope tube. Sometimes hair driers are used for the same purpose. All the mentioned systems require electric power. Sometimes, like in Anza, there is 110 V supply available but more often electric power is not available.

Power can be supplied by 12 V DC batteries and converted to 110 V AC by power inverters. There are packages available in the market that fulfill this need. They are self-contained batteries with a built-in charger and a built-in inverter. These packages are very convenient except that they do not hold a lot of current to last a full night of scope guiding, driving and imaging.

A longer lasting approach is to buy the elements separately. A deep-cycle marine battery may hold as much as 120 Amp/Hr. This should be enough to run a

computer, the motor drives and the imaging equipment for a full night. The draw back is that they require a separate charger and DC/AC inverter, but ampere by ampere they are cheaper than the self-contained packages.