Deepsky Observer’s Companion

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2002 December

1 Deepsky observing for the beginner

Some thoughts on taking up astronomy as a hobby.

1.1 Just starting out in astronomy?

The following thoughts and suggestions on astronomy as a hobby have been adapted from an article by Alan McRobert (1994) in *Sky & Telescope*.

1. Ransack your public library. "Astronomy is a learning hobby ... self-education is something you do yourself, with books, using the library."

2. Learn the sky with the naked eye. "Astronomy is an outdoor nature hobby. Go into the night and learn the starry names and patterns overhead."

3. Don't rush to buy a telescope. "To put a telescope to rewarding use, you first need to know the sky as seen with the naked eye, be able to find things among the stars with sky charts, know something of what a telescope will and will not do, and know enough about the objects you're seeking to recognize and appreciate them."

4. Start with binoculars. Ease of use, cost and performance make binoculars the ideal 'first telescope'.

5. Get serious about map and guidebooks. "A sailor of the seas needs top-notch charts, and so does a sailor of the stars. Fine maps bring the fascination of hunting out faint secrets in hidden sky realms. Many reference books describe what's to be hunted and the nature of the objects you find. Moreover, the skills you'll develop using maps and reference books with binoculars are exactly the skills you'll need to put a telescope to good use."

6. Find other amateurs. "Self-education is fine as far as it goes, but there's nothing like sharing an interest with others."

7. When it's time for a telescope, plunge in deep. Don't skimp on quality. "The telescope you want has two essentials. One is a solid, steady, smoothly working mount. The other is high-quality optics ... You may also want large aperture (size), but don't forget portability and convenience."

8. Lose your ego. "Astronomy teaches patience and humility - and you'd better be prepared to learn them ... The universe will not bend to your wishes; you must take it on its own terms. ... Most objects within reach of any telescope, no matter how large or small it is, are barely within reach. Most of the time you'll be hunting for things that appear very dim, small, or both. If flashy visuals are what you're after, go watch TV."

9. Relax and have fun. "Part of losing your ego is not getting upset at your telescope because it's less than perfect. Perfection doesn't exist, no matter what you paid. Don't be compulsive about cleaning lenses and mirrors or the organization of your observing notebook ... Amateur astronomy should be calming and fun. If you find yourself getting wound up over your eyepiece's aberrations or Pluto's invisibility, take a deep breath and remember that you're doing this because you enjoy it. Take it as fast or as slow, as intense or as easy, as is right for you."

"Two things fill the mind with ever new and increasing admiration and awe, the oftener and the more steadily we reflect on them: the starry heavens above and the moral law within."
– Immanuel Kant, The Critique of Practical Reason

"Astronomy is a typical monastic activity: it provides food for meditation and strengthens spirituality."
— Paul Couteau

Further reading:

Byrd D (1993) "Exploring the South Polar Sky" Journey with us to the Southern Hemisphere where you'll meet the biggest and best galaxies, the brightest custers and nebulae, and starfields galore] *Astronomy*, September, 68.

Eicher D J (1993) "Deep-sky Summer: The Milky Way" [Step right up and meet some of the most glorious sights in the summer sky] *Astronomy*, August, 70.

Ling A (1994) "Taking the Deep-Sky Plunge" [Are you ready to dive into the depths of space? Here's how to do it the easy way] *Astronomy*, March 58.

Ling A (1993) Cool Sharp Nights. *Astronomy*, October, 70. [Deepsky observing with a small refractor]

Skiff B A (1993) "M Is For Messier" [Naming deep-sky objects] *Sky & Telescope*, April, 38.

1.2 Introduction to deepsky observing

Two hundred years ago astronomers were mainly preoccupied with the globe on which they lived and the solar system of which it was a member. Consequently, only nineteen objects outside the solar system were known. Today, hundreds of thousands of objects have been discovered that lie beyond our solar system and are known collectively as deepsky objects. This appellation covers clusters of stars, nebulae and the galaxies. These distant worlds are the objects of study for the deepsky observer.

For the beginner, observing the deep sky requires time, patience and a willingness to learn. A small telescope will reveal hundreds of objects to the skilled observer, and many thousands are within reach of a modest telescope.

Through practice and experience, anyone can master the art of deep-sky observing. There are a wealth of deep-sky objects awaiting your scrutiny.

Observational astronomy is to a great extent an aesthetic pursuit. Enjoy the view as you explore the night sky, but in doing so, do yourself one favour: don't rush. As you move from one target to the next, pause a while. Don't just look at the universe – *see the universe*. Hopefully this guide will point you in the right direction as you start your journey of discovery.

"The pleasures of amateur astronomy are deeply personal. The feeling of being alone in the universe on a starlit night, cruising on wings of polished glass, flitting in seconds from a point millions of kilometers away to one millions of parsecs distant ... is euphoric."
– James Mullaney

"The amateur astronomer has access at all times to the original objects of his study; the masterpieces of the heavens belong to him as much as to the great observatories of the world. And there is no privilege like that of being allowed to stand in the presence of the original."

– Robert Burnham Jr.

1.3 Observing equipment

Some form of optical aid, either binoculars or a telescope, is needed if you want to observe the deep sky. Both types of instruments have pros and cons: binoculars are very portable, easy to use, offer wide-field views and are comparatively inexpensive. Telescopes, although more cumbersome, have greater light-gathering power, allowing fainter objects to be seen.

1.3.1 Binoculars

"Start with binoculars. Ease of use, cost and performance make binoculars the ideal 'first telescope'."

– Alan MacRobert

It is a misconception that a large telescope under dark pristine skies is needed to observe the deep sky. Nothing is further from the truth — a pair of binoculars can keep you happily occupied for years. Binocular vision, i.e. using both eyes, has several advantages over monocular vision: faint objects are slightly more easily seen, fine detail is more quickly - if not better - seen, and it is less tiring on the eye. Compared to a telescope, the binocular offers a wider field of view. Beginners are strongly advised to spend a few months exploring the sky with binoculars, getting to know the constellations and generally scouting the terrain before graduating to the telescope.

In selecting a pair of binoculars for astronomical work, one of the most important factors is the magnifying power of the glasses. Low-power glasses are ideal for wide-field views of the Milky Way, but higher-power glasses are preferred for the Moon, Sun and planets. Bear in mind that as magnification power increases, so does the binoculars' weight. A pair of 7x glasses can be hand-held comfortably for an extended period, but 10x binoculars will need some kind of support during viewing.

The second binocular specification refers to its aperture, i.e. the diameter of the binocular lens. This can range from 30mm to 80mm or

Table 1. Popular binocular configurations, from *Touring the Universe Through Binoculars* by Phil Harrington

Size	Advantages	Disadvantages
7x35	Easily hand-held; excellent wide-field views of Milky Way & deep-sky objects.	Smaller exit-pupil restricts dark sky effectiveness.
7x50	Easily hand-held; light-gathering ability sufficient for hundreds of objects; best choice.	Larger aperture may cause sky-glow problems in urban and sub-urban areas.
10x50	Good choice for urban and suburban users who want a little higher magnification.	May require a tripod.
10x70	Excellent for star clusters, nebulae and galaxies.	Heavy; tripod usually needed.
11x80	Excellent for faint objects.	Tripod needed; heavy.

more. The larger the aperture, the more light the instrument can collect. Incoming light is focused by the main lens and the image then magnified by the eyepiece. The final image is presented to your eye as a round disk of light known as the exit pupil. The diameter of the exit pupil can be found by dividing the aperture by the magnification; a 7x35 glass has an exit pupil 5mm (35mm ÷ 7 = 5mm) across, a pair of 11x80's has an exit pupil with a diameter of 7.3mm. The human eye has an opening, or pupil size, of about 2.5mm in bright daylight and about 7mm in total darkness.

When you use a pair of binoculars for astronomy, the size of the exit pupil must match your own pupil size. If the exit pupil is larger, then all the light that is collected is not being passed into your eye and goes wasted. If the exit pupil is smaller than your eye's pupil, then you are wasting some of the eye's light-gathering capability.

In choosing the combination of magnification and aperture, you should consider the conditions at your observing site. If you observe under dark rural skies, your pupils will fully dilate to around 7mm, and the binoculars should match this; suitable examples include 7x50, 10x70 and 11x80 glasses. If your site suffers from light pollution, your pupils will dilate to only 5- or 6-mm, in which case 7x35 or 10x50 glasses would be better suited. Table 1 (previous page) compares some popular binocular configurations.

1.3.2 Telescopes

"Most objects within reach of any telescope, no matter how large or small it is, are barely within reach. . . . If flashy visuals are what you're after, go watch TV." — Alan MacRobert

Telescopes are available in two basic types; mirror (reflector) or lens (refractor) designs. The size of a telescope is specified by the diameter of its largest optics (primary mirror or objective), traditionally expressed in inches.

Amateur reflectors typically have mirrors of 4- to 12-inches (10 to 30cm) in diameter. A popular line of telescopes in the United States sports a 17.5-inch (44cm) mirror, and even 25-inch (63cm) mirrors are available commercially. Refractors, on the other hand, typically have 2- to 5-inch (5 to 13cm) lenses. The main reason for the popularity of the reflector is its cost: a 6-inch refractor could sell for $4,000 while a 6-inch reflector can be as inexpensive as $500! Other considerations, such as size and transportability, also favour the reflector.

Bigger is better in deep-sky observing. The larger the objective (primary mirror or lens), the more light can be collected. But a large telescope used in the city can never show the faint objects that can be seen with a smaller telescope used under dark skies. And a large telescope that is too cumbersome to use will remain in the garage or loft, collecting dust and not starlight. Buy what you can afford, but make sure it gets used. (It is, of course, entirely possible to grind your own mirror and assemble the telescope yourself. But that's another story.)

Telescopes can be mounted in two basic ways. The simplest mount is known as the alt-azimuth configuration. The telescope moves around two axes, up-down and left-right, with the whole mounting standing level with the ground. Binoculars mounted on a photographic tripod is an example of an alt-azimuth mounting. Nearly all professional telescopes are mounted in an equatorial configuration. The scope still moves around two axes, but the whole mounting is now tilted upwards, pointing to the celestial pole of the sky. Mounted in this fashion, it now swings east-west and north-south. If a motor is attached to the mount, the telescope can be made to turn slowly towards the east at the same rate that the stars move westward. In this manner, a star remains in view, with the telescope tracking it continually.

This type of mounting has the advantage that its axes can be calibrated in right ascension and declination, the co-ordinate system used to describe an objects position in the night sky. If the mounting is accurately set up, you can find an object by merely turning the telescope until the setting circles point to the co-ordinates of the object. On the down side, aligning the telescope properly with the celestial pole can be tricky, and this type of mount is also more expensive than the alt-azimuth configuration. For the deep-sky observer, setting circles are useful but not essential.

The important issue when considering a mounting is its stability. A stable mount does not leave the telescope wobbling after you bump it. It is most unpleasant if the image bounces around each time you touch the telescope to adjust the focus.

1.3.3 Star atlases

"Fine maps bring the fascination of hunting out faint secrets in hidden sky realms."
– Alan MacRobert

All navigators , no matter how experienced, rely on maps to guide them. As captain of your telescope, you will need a good star atlas to find your way about the night sky. It is one of the most important observing aids for the astronomer.

Many introductory astronomy books contain starmaps for the beginner, some good, some not so good. An excellent set of charts can be found in the *Atlas of the Night Sky*, published in 1984 by Crescent Books. These charts, drawn by master cartographer Wil Tirion, show stars as faint as 6th magnitude, which is the faintest you can see with the naked eye from a good suburban site. Many deep-sky objects are plotted, and variable stars brighter than 6th magnitude at maximum are shown. Notable objects are listed beside each pair of charts. These charts are exceptional because the whole night sky is shown on only 5 A3-sized pages. They are excellent for use with binoculars, and their handy size make them easy to transport and use. For the beginner, these charts are arguably the best available, since they accurately summarize the night sky into clear, understandable sections.

The more experienced telescopic observer will need charts that show fainter stars and more deep-sky objects. The *Uranometria 2000.0* atlas, published in 1987 by Willmann-Bell, is an excellent star atlases. A two-volume set, it contains 473 computer-generated charts, showing 330 000 stars down to magnitude 9.5. The complete Revised New General Catalogue (RNGC) and an additional 10 300 deep-sky objects are shown. Each volume has a two-page hemisphere starmap which indexes the charts in that volume, making it easy to find the chart you need. The index maps are also very useful to help you orient yourself when you start your observing session.

The current 'Rolls Royce' of printed star atlases is the *Millenium Star Atlas*. Even though it is significantly larger (and more bulky) than the *Uranometria*, it shows much fainter stars (down to 11th visual magnitude) and covers the sky in 1 548 charts!

1.3.4 Miscellaneous equipment

"If the hours we spend under the stars are precious, an observing log helps us remember them. Relying on memory alone just isn't good enough; as years pass, details fade away until events might as well not have happened."
– David H. Levy

Deepsky observing is done in the dark. Well, almost. You will need some light to read the star charts, make notes and find your mug of hot coffee. A normal torch, useful during a power cut, is unusable at the telescope. Astronomers traditionally use a dim red flashlight because red light has less effect on night vision. Simply place sufficient layers of dark red cellophane (used for gift wrapping) in front of the torch, thereby cutting down and filtering the light. You can also paint the bulb with red nail polish for a more permanent arrangement.

Because of the notorious nature of human memory, you will need some way of recording your observations. At the telescope, a pencil and writing pad on a clipboard works well, as does a Dictaphone or tape recorder. I find using a small Dictaphone easier than writing descriptions by hand, partially because my handwriting is illegible but mainly because it is more convenient and allows greater freedom of expression. For sketching, a dark pencil, eraser and clipboard are useful, as well as sheets of paper with predrawn circles representing the field of view. Whichever record keeping method you choose, you should note the date and time of the observation, where the observation was made and with which instrument, the magnification used, and the condition of the sky. Record the sky conditions (seeing and transparency) and also include comments on clouds, haze or the presence of moonlight. Many observers design a standard observing form, which can be filled in at the telescope. This ensures you don't forget some important detail. After the observing session, your rough observing notes should be edited and transferred to a standard record keeping system, which will map your progress as a deep-sky observer.

Remember to dress appropriately for your observing session. Jeans and a T-shirt might be fine for warm summer nights, but cold winter nights demand a wiser choice. Jeans won't keep your legs warm enough - wear a pair of long-johns underneath. Two tracksuit pants - instead of the jeans - also work well. A sensible jacket, with several pockets, can be worn over a jersey and shirt to keep the upper part of your body warm. Wear two pairs of woolly socks and make sure your shoes or boots provide insulation, so that your feet don't leak heat to the ground. Most important of all, protect your extremities. Your nose, ears and fingers will loose heat more quickly. A balaclava and scarf will serve admirably, and a pair of warm, non-bulky mittens will keep your fingers agile and comfortable.

Observers often overlook the fact that they will be spending a considerable amount of time sitting at the eyepiece. Make sure your chair is comfortable and supports you in the right places. Bear in mind that the eyepiece will not be at a constant height throughout the night; some form of adjustable chair may be needed. When observing with my binoculars, I use a plastic milk crate (either on end or on its side) and various cushions for fine adjustment. Be careful not to strain your back or neck when observing — you grow tired much sooner and your overall performance is adversely affected.

Don't forget to pack in some snacks. Something hot to drink after you have just found that elusive galaxy adds to the reward. A sandwich, or some chocolate adds a little extra boost during your vigil at the eyepiece.

1.4 Planning your observing

1.4.1 Planning an observing programme

Searching for deep-sky objects is a great way to hone your observational skills. It is a good idea to do some homework before you go out to observe. Find out when the moon rises and sets, and work out how much time you will have to observe without the moon interfering. Draw up a list of objects to view. When selecting an object, make sure it will be high enough above the horizon so that the murky atmosphere doesn't interfere.

If you are going to draw up your own lists, begin by looking for some of the brighter "showpiece" objects, and then slowly graduate to more difficult targets as your observational skills develop. Apart from choosing your own objects, you can work according to an established observing project.

The Deep-sky Observing Section currently offers three observing projects. The first project is for the beginner, and calls for the observation of 31 bright objects. These objects originally appeared in an 18th century catalogue drawn up by **Lacaille** (see page 32 and Appendix 1). The second project concentrates on the objects in the catalogue drawn up by the late **Jack Bennett** (see page 39 and Appendix 4), comet hunter and dedicated amateur astronomer. Bennett's catalogue contains 152 objects which appear comet-like in smaller telescopes. Some of these objects can be quite challenging in small telescopes and binoculars.

The third project is dedicated to the work of **Sir John Herschel**, who was the first person to systematically survey the whole night sky with the aim of drawing up a comprehensive catalogue of deep-sky objects. Between 1834 and 1838 he stayed at the Cape of Good Hope to work on the southern portion of his catalogue, which formed the basis of the NGC (New General Catalogue) which is still in use today. The Herschel project involves the study of 400 of these objects.

Herschel's work at the Cape is discussed on pages 34–35 and in Appendix 3.

1.4.2 Preparing for an observing session

1. Dress appropriately.

Comfort is everything in backyard astronomy. If you're not warm enough, standing out there under a star-filled sky in no fun at all. Common sense, folks. I prefer to bring along several layers of clothing (e.g. warm longjons, sweatsuit pants, jeans) and wear as needed.

2. Snack food.

Food is an essential part of any observing kit. My favourite is filter coffee and rusks. A good sandwich is most welcome after a few hour's observing. And sweets like winegums last a l o n g time, although the eternal mastication they induce can unsteady your view at the eyepiece!

3. Bug repellant.

Mossies. Bane of the deepsky observer. Nothing is more ominous than the high-pitched whine of these blood-sucking pests. Bug spray or lotion neatly solves the problem, although I regularly carry a tube of skin lotion, just in case one of them get a bite in first.

4. Torches.

Besides your trusty red torch for observing, make sure you have enough batteries just in case. Since your observing light should be extremely faint, pack in a normal (unfiltered) torch that you can use to pack up with, or check if you've left anything behind. And don't forget the batteries.

5. Observing notebook.

Don't forget your notebook. Even if you use a dictaphone, one often needs to make notes. And of course you should be sketching. . .

6. Accessory table. You'll need somewhere to put all the stuff you've packed in. I carry all my maps, books, notebooks and "stuff" in several milk-crates, each measuring 29 x 35 x 53cm. These stack securely one on the other, making a handy table. Sometimes, an extra chair is also handy as a make-shift table.

7. Comfortable chair

It's likely that you'll be sitting for a long while behind your eyepiece. Make sure the chair you pack in is comfortable and sturdy. Some deck chairs simply don't work well with tripod-mounted binoculars, since their wide, splayed legs often get in the way. I enjoy moving around while observing at the telescope's eyepiece, so I rarely sit down while observing. But the periods of standing are regulary interrupted by moments of sitting down, making notes, planning, and just enjoying the night sky.

8. Protect starmaps from dew

The best way to protect your staratlas from dew is to keep it indoors. I make photocopies of each map I use at the eyepiece. I like scribbling notes in the margin of the maps, and refuse to do so on the original book. The loose-leaf photocopied A4 pages fit well in plastic sleeves. For complex regions requiring several maps, I suggest you use the 20-page plastic sleeve files, which will hold 40 maps back-to-back. Also, a stack of maps, held in place on a clipboard, is well protected if a plastic sheet tops off the pile.

9. Zap the dew on your optics

Having your eyepieces dew up can unexpectedly end your observing session. A blast of hot air for a few seconds will defog the dampest eyepieces, mirrors or lenses. Commercially available 'dew zappers' are basically modified electric hair dryers.

Further reading:

Barclay, J. (1994) "Under the Southern Sky" Astronomy, October, 72.

Cain, L. (1986) "Observer's Page: Visual astronomy rediscovered." Sky & Telescope, 72(6, December), 662

Dodd, L. (1994) "Under the Southern Sky: Part 2" Astronomy, December, 78.

Eicher, D. (1985) "Stars of the Circumpolar South" [double-page map] Astronomy, March, 34.

Eicher, D. J. (1989) "Don't Forget the Bug Spray" [Be prepared for anything under the stars with these ten essential items. Don't leave home without them!] Astronomy, August, 67.

Forrest, S. (1989) "Forum: Tricks of an Observer's Trade" Astronomy, August, 98.

Harrington, P. (1994) "Running a Celestial Marathon" [One night, 110 deep-sky wonders. Observe them all and you've comleted the grueling Messier Marathon] Astronomy, March, 61.

Houston, Walter Scott (1980) "Observing the deep sky." Sky & Telescope, 60(6, December), 476.

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MacRobert, A. M. (1987) "Backyard Astronomy: The art of planetary observing - II." Sky & Telescope 74(6, December), 603.

Nagler, A. (1991) "Choosing Your Telescope's Magnification" Sky & Telescope, May, 553.

Polakis, T. (1995) "Deep-sky on Four a Day" [Is there life after observing the Messier objects? Try the Herschel 400 in 100 nights like I did from Arizona] Astronomy, June, 65.

Rabalais, M. (1986) "How to Conquer the Messier Objects" Astronomy, December, 88

Spevak, J. (1993) "Night of the Deep-Sky Observer" [Follow a lone sky watcher through a night of viewing springtime clusters, nebulae, and galaxies] Astronomy, March, 62.

1.5 Observing techniques

When you arrive at your observing site with your equipment and a list of objects to observe, you should ready the telescope for the night's work. Set up your telescope or binoculars using your red torch; this will allow your eye to start adjusting to the dark. Both refractors and reflectors should be allowed to reach thermal equilibrium with the surrounding air, and reflectors should be collimated properly. Take the time to identify the constellations you will be observing in and look for useful asterisms or star patterns to help you find your way. You are ready to start the search for your first object.

1.5.1 Star-hopping

"One tends to 'discover' a lot of interesting things while star-hopping"

One of the most basic, and valuable, observing skills is star-hopping, which is simply the following of a trail of stars from a place you know (eg. a bright star) to a place you don't know (eg. the galaxy you are hunting for).

You can plan your star-hop at the eyepiece, but it is recommended that you plan your first star-hop in advance, while you are drawing up your evening's observing list.

Find the deep-sky object in question, say a galaxy, on the starchart. Search around it for a bright star or asterism that you will be able to locate in the sky with ease. Now look for a trail of stars which will lead you from the star to the galaxy.

It is rather like playing connect-the-dots. Sometimes you might have to go a roundabout way to get to your target, or you may choose a different bright star to start from.

Bear in mind that once you have found the galaxy, you can use it as the beginning of a star-hop to the next object.

Clark (1990) feels strongly about this basic technique, as do I: "Star hopping should be learned by all amateur astronomers. It is the method of starting at a known naked-eye star and using a chart to move carefully from star to star until the desired object is reached."

Garfinkle (1995) notes: "Getting there is half the fun, they say. This is certainly true when travelling between the stars in search of star clusters, nebulae, galaxies and such. Using a technique called star-hopping, you step your way across the heavens until you arrive at your ultimate destination. Its easy, its fun, and its a great way to learn the landscape of the night sky. Star hopping is like crossing a wide stream on stepping stones. To get from point A to point B, you step, or hop, from star to star using a finder scope's (or eyepiece's) field of view as a guide. Your hops often lead to a wonderful object while taking you past a multitude of interesting sights along the way.

MacRobert (1988) offers the following star-hopping tips:

1. "Double- and triple-check directions in the eyepiece. Always think in terms of celestial north, south, east and west, never up, down, left or right. If you have an equatorial mount, polar align it at least roughly. Now the mounts motions follow the four cardinal directions. Turn the finder's eyepiece to make its cross-hairs line up with these directions too."

One of the first accomplished star-hoppers: Sir James South claimed that William Herschel was able, from a cold start, to find any object in the sky in under five minutes with the 20-foot telescope.

2. "Remember that a map is not exactly like the sky." The magnitude-symbols used to show the stars do not accurately reflect the way we perceive stellar brightness, so don't be caught by brightness discrepancies when using a starchart.

3. "Pay particular attention to star's positions. Look for patterns of at least three stars that fix the point you're after: little triangle, rectangles, kite shapes, and so forth. Triangles are the most basic units of star-hops. Pay close attention to their shapes."

4. "Know your scale." Figure out how big your finder's field of view is on the chart, and also for the eyepieces you use to star-hop with.

Veteran **Steve Coe** described his technique to the IAAC mailing list as follows:

"I have a method of star-hopping that I use for faint or difficult to find objects. It involves the fact that I have four aids that allow me to easily and confidently move to fairly exact location in the sky. Those four things are: Telrad, University 11X80 finder with an Amici prism, *Bright Star Atlas* and *Uranometria 2000* star atlas. I get the general idea of where I want to go in the sky with the Telrad and *Bright Star Atlas*. Using these together I can with certainty point the scope at a "jump off star", generally naked eye, to star from. The *Bright Star Atlas* lets me answer the question "OK, which one of you guys is Sigma" or whatever. Now that I am on the starting location I am ready to move up to a deeper magnitude."

"I turn to the page in *Uranometria* that has the bright star on it, and hopefully it also has the deep sky object I seek. Then I note an asterism that is directy north, south, east or west of the object I am looking to find. This works because I have a Bigfoot Mount, which is essentially a German Equatorial. Then once I am directly even with the object in a cardinal direction, I move the scope to the oject, moving in only one direction at a time. I have found two helpful things: the large finder shows all the stars marked on Uranometria and the Amici Prism will show the sky in the same orientation as the charts."

"I used to spend a lot of time looking for a faint object, not certain if I just wasn't seeing it, or am I in the wrong location. This method allows me to be quite certain that I am at the location marked on the chart. Now I can move to the right spot and if the object isn't there, it isn't there and I can move on."

Lew Gramer, IAAC listowner, wrote:

"By the way, it may be worth mentioning something else about star-hopping: the hopping techniques you use probably will depend on your sky conditions! For instance, under extremely bright skies (or with a smaller scope), I find that "aiming" the scope with a Telrad (i.e., a "gun-sight" pointer), then doing wide-field eyepiece sweeps usually picks up any star pattern I'm trying to hop to, But under darker skies (and/or larger apertures), having a finder as well as the Telrad and Panoptic eyepiece can be very handy!"

"In the end, I guess I use a combination of finder, Telrad, and eyepiece hopping techniques with my dobsonian - and a completely different set of techniques (involving distinct north-south and east-west motions) when I'm using an equatorial mount!"

1.5.2 Directions in the sky

To plan your star hop, you will need to know how far each hop can be. This depends on the size of your field of view (the amount of sky you can see at one time).

For binoculars, the diameter of the field remains constant, but each eyepiece used on a telescope has a different field diameter.

Select your lowest-power eyepiece, which will have the widest field of view. Turn the telescope onto a bright star and centre the star in the field of view. If your telescope has a drive, turn it off. Now watch the star as it drifts across your field of view.

The star will move towards the western (preceding) edge of your field and new stars will appear at the eastern (following) edge. North and south lie at right angles to the west-east line, south being the direction you have to move the telescope to find the south pole. Thus, directions in the sky have east and west switched around; if north is to the top, then east will be to your left.

Using these cardinal directions is really only useful to indicate angles which are multiples of 45°.

To specify directions more accurately, the position angle (PA) is used. A PA of 0° is North and 90° is East. Northeast would be PA = 45° while PA = 260° points a little south of west.

To help you get to grips with position angles, you might like to try and estimate the PA for some easy double stars. The following short list names six (out of many) double stars that can be split with binoculars. The magnitudes of the two components are given, along with their separation in arc seconds. The PA is measured from the brighter star, so it tells you where to look for the fainter star of each pair. Not only is it fun to estimate the PA of a double in the sky and look it up to see how close you came, it is also good practice for keeping your directions straight.

Star	Magnitudes	Sep ″	PA °
alpha Cru	1.1, 5.1	90	202
alpha Leo	1.4, 7.6	177	307
gamma Lep	3.6, 6.2	96	350
delta Ori	2.2, 6.8	53	0
sigma Tau	4.7, 5.1	430	14
nu Sco	4.0, 6.3	41	337

Once you can identify north-south and east-west in the sky, you will be able to read a star chart. Star atlases are calibrated according to the equatorial co-ordinate system which measures distances north and south of the celestial equator in degrees (declination), and west to east in hours (right ascension).

The north celestial pole lies at +90° and the south celestial pole at –90° .

Right ascension is measured west to east, going from 0h to 12h to 23h and back again to 0h. Right ascension thus increases to the east and declination increases to the north.

1.5.3 Measuring the field of view

The simplest method of measuring the field of view relies on the use of a star chart.

Knowing north and east in the sky, you can easily turn your star chart so that the image in the eyepiece corresponds to the chart. Look for two stars that just fit in your field of view, and locate these stars on the star chart. You can now measure this distance on the map and compare it with the scale on the margin of the map to convert your linear measurement to degrees or arc minutes.

Remember that 1 degree (°) = 60 arc minutes (60′) = 3600 arc seconds (3600″). Binoculars typically have fields larger than 4degrees , and telescopes normally give a view smaller than 2degrees.

It is essential to be able to judge angular distances in the sky. The following table lists some angular estimates:

Solar / lunar diameter:	½°
Width of index nail at arms length:	1°
Orion’s Belt:	3°
Short arm of Crux:	4½°
Long arm of Crux:	6°
Width of clenched fist at arm’s length:	10°
Long arm of Diamond Cross:	10°
Span of open hand at arms length:	20°

Everyday objects can also serve as angular gauges. To determine the apparent angular size of anything in degrees, divide its linear width by its distance from your eye, then multiply by 57. For example, a 30cm ruler held one metre from your eye measures 30 ÷ 100 x 57 = 17°.

A more accurate method to determine the diameter of your field of view involves measuring the time it takes for a star to drift across your field along the east-west line.

This method is only useful for telescopes, since a star will take ages to cross the large field offered by binoculars. Choose any bright star, preferably far from the south pole – a star in Orion’s belt would be a good choice.

Centre the star in your field of view, turn off the drive, and place the star just outside the eastern edge of the field. As the star drifts into view, start your stop-watch. When the star disappears at the western edge, stop the watch and note down the elapsed time. Repeat this measurement several times and take the average.

If this average time, T, is measured in minutes, then: field of view in arc minutes = 15 x T x cosine(D), where D is the declination of the star (taken from a star catalogue, or estimated from a starmap).

For example, suppose you measure several transits of Canopus and calculate the average time to be 3.5 minutes. Canopus’ declination is roughly –52.7°. The field of view is then 15 x 3.5 x cos(–52.7) = 15 x 3.5 x 0.6 = 31.5 arc minutes. Thus the field of view is roughly half a degree across.

Make a note of the size of each eyepiece in your logbook, since a given eyepiece used on a specific telescope has a fixed field of view.

1.5.4 Keeping observing notes: a logbook

"The palest ink is clearer than the best memory."
– Chinese proverb

"Anyone who observes the sky should keep a logbook," is the emphatic opinion of Roger Clark. David Levy (1989) writes: "If the hours we spend under the stars are precious, an observing log helps us remember them. Relying on memory alone just isn't good enough; as years pass, details fade away until events might as well not have happened ... So many people have told me that they would like to start an observing log but haven't gotten around to it. Yet it's easy and fun to do, and our observations will mean so much more when they're recorded accurately."

"The format of your log is not important; the content is. So any system that works is fine. Some observers prefer to draw in their logs, while others would rather compute. Some keep a diary. And some prefer the discipline of forms. Although forms make sure that you remember what to put down, I find them confining. Blank paper lets you record the unexpected. ... The free-form approach leaves unlimited room for variable star estimates, planetary drawing, times for photographic exposures and notes from other observers."

"If you observe certain types of objects systematically, you might consider keeping separate observing logs ... Why not take rough notes in the field and then transfer the data to files on your home computer?"

Clark points out that even the most casual celestial sight-seeing becomes more meaningful is a few notes are jotted down in a permanent record. Thorpe (1988) says that "keeping a notebook makes a more satisfied observer. It will remind you of all the things you've seen, the way you felt while observing, and the frustration and successes you've had with the hobby. And, most importantly, it will prompt you to observe more carefully and to see more when you observe.

"A notebook is your private record of the universe. Although at first you may have to adjust to updating it, the notebook will eventually contain unique records of your journey through the universe. Astronomy offers great personal satisfaction. It would be a shame if all those wonderful memories of your involvement with astronomy simply faded away with time."

Clark laments the fact that he did not always keep good notes; reading through his recollections, I am much reminded of my own early attempts at note-taking: "Back then I also made many drawing a half inch to two inches wide, but rarely included field stars. Thus there is no way to tell the scale of a drawng or the size of what was seen. Is that fuzzy patch the full extent of a galaxy including the spiral arms, or only the bright central region?"

Further reading:

Eicher, D. J. (1989) "Don't Forget the Bug Spray" [Be prepared for anything under the stars with these ten essential items. Don't leave home without them!] Astronomy, August, 67.

Levy, D. H. (1989) Star Trails, Sky & Telescope, 77(6, June), 659.

Thorpe, A. M. (1988) "Should You Keep an Astronomical Notebook?" Astronomy, January, 50.

Zentz, G. L. (1992) "A Personal and Permanent Journey through the Universe" [Time spent beneath the stars with a journal will richly reward astronomical memories] Astronomy, February, 80.

Eighteenth-century observers were the first to systematically use abbreviations when describing the appearance of deep-sky objects. You, too, can benefit from using these arcane ciphers when you take notes of the objects you observe.

1.5.5 Keeping observing notes: recording descriptions

Sooner or later, the novice deepsky observer comes across an apparently non-sensical string of characters, like: vB. cL. mE. mbM. r, used to describe an object.

These abbreviations were popularised by Sir William Herschel, and first described by him in his paper "Catalogue of One Thousand new Nebulae and Clusters of Stars" published in 1786. He wrote: ". . . and that I might describe all these objects in as small a compass as could well be done, I have used single letters to express whole words. . ."

Over the years these abbreviations were refined and added to; they were used by John Herschel, and Dreyer used them when he published the "New General Catalogue" or NGC. Some years later, a German astronomer published an enhanced list of abbreviations, reproduced below in Appendix 5.

Modern observers, too, can benefit from such abbreviations. It makes note-taking at the eyepiece a cinch, reducing the writing time and increasing accuracy. In my case, my normal handwriting approximates graphological schizophrenia, and trying to decipher notes from last week is agonising. Using a combination of abbreviations and normal text makes for concise descriptions and goes a long way in solving the legibility problem. Some folk maintain that abbreviations restrict your thinking and that your descriptions then all turn out more or less the same; this simply isn't true, in the same way that taking dictation doesn't reduce the vocabulary of the speaker.

Some examples of my note-taking for open clusters:

(1) "Cl D = 1/6 K18. Cl is constrn by 3 * W & 2 E"

(2) "S: 2 9m * (no col) rough NS with neb. Co Cl L&S *, F*s to W of 2 B *; best seen avv"

(3) "1 * 9m on edge eRi glow vF-eF *s. Of these, the Ber * are in S groups iR scatt abt."

The translation of these is quite straight-forward:

(1) "Diameter of cluster is one-sixth of the field of view of the 18mm eyepiece. The cluster is constrained by three stars to the west and two to the east."

(2) "The first impression, in the sweeping eyepiece [lowest power]: the cluster shows as two 9th magnitude stars (of no distinct colour), arranged roughly north-south, within a nebulous haze. Closer examination shows a coarse cluster of large and small [i.e. bright and faint] stars, with the fainter stars to the west of the two brighter ones; cluster needs averted vision to show well."

(3) "A 9th mag star on the edge of an extremely rich glow of very faint to extremely faint stars. Of these, the brighter ones are gathered in small groups irregularly scattered about."

The abbreviated version is 73% shorter, and consequently much quicker to write down. Use the time saved in this way to sketch the object.

Which brings us back to William again. He wrote: "By going into the light so often as was necessary to write down my observations, the eye could never return soon enough to that full dilation of the iris which is absolutely required for delicate observations. The difficulty also of keeping a proper memorandum of the parts of the heavens which had been examined ... intermixed with many short and long stops while I was writing ...." lead him to modify the design of his telescope and his observing methods.

The changes were successful: "Soon after I removed also the only then remaining obstacle to seeing well, by having recourse to an assistant, whose care it was to write down, and at the same time loudly to repeat after me, every thing I required to be written down. In this manner all the descriptions of nebulae and other observations were recorded; by which I obtained the singular advantage that the descriptions were actually writing and repeating to me while I had the object before my eye, and could at pleasure correct them, whenever they disagreed with the picture before me without looking from it."

Few of us have the luxury of a night assistant, willing to takes notes for us. But technology can step in and offer a willing surrogate - the dictaphone or portable tape recorder. For obvious reasons, mine is christened Caroline.

Often, however, the fluidity of ideas is best expressed by a free-form diagram, making a combination of note-taking and electronic recording necessary. A final note: Don't forget to add details about yourself, your telescope, etc. to your descriptions. Herschel wrote: "It should be observed that all estimations of brightness and size must be referred to the instrument with which the nebulae and clusters of stars were seen; the clearness and transparency of the atmosphere, the degree of attention, and many more particular circumstances, should also be taken into consideration."

An **observing checklist** is currently being developed; e-mail me for more details.

1.6 The art of visual observing

"Keep observing. You will get better with practice. Your brain learns to see more as you do more observing."
– Eric Greene

When you have successfully star-hopped to your target, don't expect to see right away everything it has to offer. The first look always shows less than comes out with continued inspection. The great observer Sir William Herschel wrote:

> "You must not expect to see at sight . . . seeing is in some respects an art which must be learned. Many a night have I been practicing to see, and it would be strange if one did not acquire a certain dexterity by such constant practice."

Acquiring such "dextrous vision" is one of the most valuable skills a deepsky observer learns. Deepsky observing has its own techniques, most of which are aimed at helping your eye see in near-total darkness. When viewing the Moon or planets, the telescope's main purpose is to magnify distant detail. Deepsky objects, on the other hand, depend on a telescope's light-collecting ability. They are not too small to be seen without optical aid, they are too dim.

1.6.1 The eye and dark adaptation

To maximise your sensitivity to dim light you should allow sufficient time for your eyes to get used to the dark. You must also allow for continued dark adaptation during the observing period. During the first minute, the eye's sensitivity increases ten fold. In 20 minutes it increases 6000 fold and forty minutes of dark adaptation increases sensitivity 25,000 times!

This means that a faint object which was overlooked in an early part of your observing run may be readily seen later, so don't expect to see faint objects at their best until at least a half hour into an observing session.

Note that light adaptation is much faster that dark adaptation, so even a brief exposure to light will destroy your night vision. It is also best to consistently avoid all light for as long as possible before observing.

Prolonged exposure to bright sunlight reduces your ability to dark adapt for a couple of days; wear dark glasses at the beach. In the long run, ultraviolet light ages both the eye lens and retina, reducing sensitivity. So if you wear eyeglasses outdoors, ask your optometrist for UV-filtering lenses.

Night vision is also impaired by alcohol, low oxygen and low blood sugar. So don't observe while drinking, smoking or fasting. In fact, nicotine retards dark adaptation to such an extent that even a single cigarette smoked half an hour before your eyes start dark adapting will slow down this process.

> *"As stargazers we should practice what Lee Cains calls 'the serene art of visual observing.' We must learn to see with the mind as well as the eye. This means really examining and contemplating the varied scenes before us in the eyepiece. All deep-sky objects deserve at least 15 minutes of your time. Glancing at an object once it's found and then rushing to another and another is like reading only the Cliff's Notes of the world's great novels."* – James Mullaney

1.6.2 Sky brightness

Light pollution is the most serious hazard the deepsky observer faces. Deepsky objects are extended sources of light, and their visibility is influenced by the contrast between the object and the background sky. Light pollution increases the brightness of the night sky and thus decreases the contrast between object and sky. A dark sky is even more important than a large telescope: a small instrument in the country will show faint clusters and galaxies better than a very large telescope in a city. If you have to live with light pollution, take pleasure in what can be seen. The degree of light pollution is sometimes rated by determining the faintest star visible with the naked eye.

With no light pollution, the limiting magnitude is usually assumed to be 6.5, though some people with exceptional vision can see fainter. Under such conditions, the sky is packed with stars, the Milky Way is a mass of swirling, jumbled detail and any clouds appear blacker than the sky itself.

At a limiting magnitude of 5.5, clouds are brighter than the sky because they are lit from below. The Milky Way is still easily visible but far less detailed.

At limiting magnitude 4.5, the Milky Way is barely detectable as a faint, nearly featureless band.

City dwellers typically face a limit of 3.5. The Milky Way is completely invisible, and Epsilon Crucis, the fifth brightest star of Crux, lying just inside the cross, is invisible. Two of the four stars that make up the rectangle of Musca (south of Crux) are also gone.

At magnitude 2.5, stars are very few and far between. Only three stars of Crux can be seen, and the whole of Musca disappears.

The good news is that you can see through light pollution. A pair of binoculars in the heart of Johannesburg show fainter stars than can be seen with the naked eye from Sutherland.

A dark spot in the backyard of a suburban home is a convenient site. You’ll find that if you observe late at night, the sky is slightly darker since more lights get turned out. Any nearby light, say a bothersome street light, can be shielded off by some sort of screen around the telescope. In pays to minimise the light from the bright sky that gets into your telescope. Extend the front of the tube with a long dewcap made from stiff blackened cardboard. On a reflector, place a ring of black paper around the main mirror, so that light from the ground doesn’t come in around the mirror’s edge. Stray light can be blocked off at the eyepiece by pulling a black T-shirt over the eyepiece-end of the telescope and then inserting your head in the neck of the garment. This “observing capsule” can be worn around the neck as a scarf when not at the eyepiece. Using the T-shirt in this fashion warms it slightly, which helps to prevent dewing of the eyepiece during use.

Another basic strategy to combat light pollution is to penetrate it with high powers. For more details, see the section on magnification below.

1.6.3 Seeing and transparency

"Most of all, practice. There's no other way to master deep-sky observing. And don't quit on any object, no matter how vague it may look, until you've given it a good, long, thorough scrutiny."
– Alan MacRobert

As mentioned above, there is more to a deep-sky object than meets the eye at the first glance. This is to some extent caused by the atmosphere and also by the nature of human perception.

The quality of the telescopic image, as far as this depends upon the condition of the atmosphere, is known as *astronomical seeing*.

When you view an object at high powers under average seeing conditions, the image shimmers and boils. The degree of disturbance can be estimated using the Antoniadi scale.

The severity of this shimmering changes from night to night and sometimes from minute to minute. When the seeing is poor, a small telescope will show twinkling stars which jump about playfully, but with a large aperture telescope, the lateral motions will be averaged out resulting in a steady blob.

When a deep blue, breezy afternoon turns to a dark and clear night, we have a night of high *transparency*. The dark sky and high contrast afford ideal conditions for viewing faint stars and extended objects such as galaxies and nebulae.

High transparency and good seeing usually avoid one another. The hazy summer doldrums often produce the best seeing and are excellent for revealing double stars and planetary details.

1.6.4 Prolonged observing

The nature of human perception plays a significant role in deepsky observing. In our day-to-day experience of the world we are used to seeing things easily. If something can't quite be made out, our natural reaction is to move closer. But this is impossible in astronomy. Instead, we have to get everything we can out of very distant views. This means learning new visual skills that involve active, concentrated effort.

As you watch an object quiver and churn in the eyepiece, unsuspected detail will flicker into view during brief moments of stability, only to fade out for a while before being glimpsed again. The image of a difficult object builds up rather slowly. First one detail is notice and fixed, and you think there's nothing more to be seen. But after a few minutes another detail becomes evident, then another. The skilled observer learns to remember these good moments and ignore the rest, building up a gradual, integrated picture of the object.

Related to this is the fact that the eye, like a camera, can build up an image over time – according to skilled observer Roger N Clarke. It has been found experimentally that a faint image will build up towards visibility for as long as six seconds. This may seem counter- intuitive, but bear in mind that most of your visual experiences have been in bright light; under these conditions the eye's "exposure time" is only about 1/10th of a second. Furthermore, fixating on an object in daylight tends to make it less visible. In fact, if the eye is held completely stationary, it becomes completely unable to see anything! In the dark, however, things are different.

To make use of the eye's extended viewing capacity, you will need to keep the image at the same spot on your retina; this helps explain why bodily comfort is so essential for viewing faint objects. Fatigue and muscle strain increase random eye movement. This does not, however, mean you have to stare at the object. It is the physically non-tense but mentally alert approach that succeeds on faint objects. If you use your right eye to observe, don't close your left eye tightly. This places unnecessary strain upon the eye. Keep it open and wear a eye-patch or cover your eye with a cupped hand.

1.6.5 Averted vision

While keeping the image on the same spot on the retina helps the image to build up, looking directly at it will probably cause it to disappear!

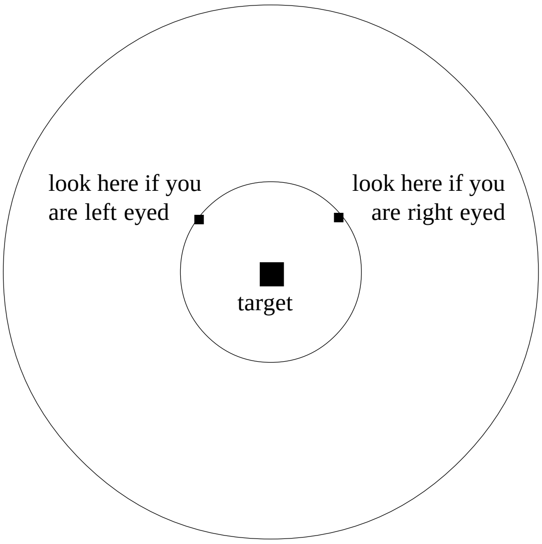
This is so because the light then falls on the fovea centralis, a region packed with bright-light receptors (cone cells) but fairly poor in dim-light receptors (rod cells). The rods are concentrated around the edges of the retina.

By looking slightly away from a faint object, its light falls onto the edge of the retina where it is picked up by the sensitive rod cells. This very important technique is known as *averted vision*.

Your eye is most sensitive to a faint object when its image lies 8 to 16° from the centre of your vision in the direction of your nose. Almost as good a position is 6 to 12° above your centre of view.

Never place the object to the right of centre in your right eye, or left in your left eye – the image is likely to fall on the retina's blind spot and vanish altogether.

Incidentally, averted vision is not the way to look for colour in deepsky objects. The rod cells do not respond to colour, whereas the cone cells do. You should thus look directly at the object when examining it for colour.



1.6.6 Sketching

An excellent way to train yourself to see better is to make sketches. These don't have to be works of art; the idea is to record details more conveniently than through words. An open cluster requires no artistic talent whatsoever. To give you some indoor practice, try making sketch copies of photos of open clusters. You may want to enlarge the photo with a photocopier and then sketching it from a distance.

When you sketch at the telescope, remember to note down the date and time, instrument details, sky condition and the size of the field of view. Also indicate on the sketch where north and east are. It is strongly recommended that you sketch as much as possible. While you are making the sketch, you are continually examining the object, paying close attention to certain smaller details. This close scrutiny often results in the discovery of hitherto unseen features. A sketch also serves as an excellent record of the object you are studying. Detailed objects require lengthy descriptions that may become confusing when read later. We all know the saying that a picture is worth a thousand words.

A deepsky drawing conveys precisely what the mind sees, and is an expression of the observer's experience. A sketch is the result of the eye's amazing range of sensitivity, and the mind's powerful ability to integrate and interpret. It depicts what is seen through the eyepiece — something that photos and CCDs can never do.

Why sketch?

A drawing of a deep-sky object makes a personal record of what was seen by the observer, and so is satisfying as an end in itself. However, drawing also forces the observer to look for more detail and, in time, this will develop a trained eye that will be useful in all types of observing. (Macdonald, 1993). Tom Polakis says: "Drawing what you see through a telescope is a good way to document subtle details. By comparing renditions made on different nights, you can look for changes due to sky conditions or your growing ability as an observer."

"As with most endeavours, skill and hard work produce quality results ... Good drawings do not require special artistic talent or experience, but they do demand close attention, much time at the telescope, much time redrawing . . . and honesty in not recording details remembered from photographs but not positively seen."
– Roger N Clark

Roger Clark writes: "It's often said that a picture is worth a thousand words. Composing a thousand words takes much time and though and still may leave the reader with the wrong mental image. So when it comes to accurate recording of scientific data, there's often no substitute for a picture.

In past centuries a scientist was necessarily a draftsman. Nowadays scientists in almost all fields rely on photography to record images, and the pencil and sketchpad no longer rank as essential scientific tools. Visual astronomy, however, remains an exception." Michael Sweetman of Tucson, Arizona, wrote in Astronomy's Letters column: "I've been drawing objects since I began observing, and I draw every time I go to the telescope. I approach my drawings as scientific illustrations. When you're preparing for a drawing, proper eyepiece and magnification selection are important . . . Too little power and the delineation of details can't be made out, too much power, and contrast and form in extended objects like nebulae are lost. A realistic drawing also requires proper paper selection and drawing technique, refined from hours of experience at the telescope and practice away from the telescope. . . . As with most endeavours, skill and hard work produce quality results."

Equipment

If good observations are to be made, it is essential that the observer is comfortable and relaxed. An observing chair of some sort should be used at the eyepiece. A clipboard is handy for holding the rest of your drawing equipment, including your red observing light — I use a red mini-reading-lamp, with the bulb replaced by two super-bright LED's, to throw an even light over the sketching area.

The drawing paper should be illuminated by a dim red light, since a white light will destroy too much of the observer's night vision which is so essential for visual deep-sky observing. Macdonald (1993) suggests using an A5-sized hardcover sketch book, the paper of which should be high-quality cartridge paper. I use 80g bond laser-printer paper, cut in half into an A5 size. Before the page is divided, a checklist and circle is laserprinted. The circle on the sketch pad represents your field of view in the eyepiece. Macdonald suggests a 50mm diameter circle; Mitchell 75-100mm; I prefer 60mm.

You'll need a pen to plot stars. Mitchell (1995) is of the opinion that "a pencil works better than a pen because a pen cannot convey gradations of brightness." While a normal ball-point or fountain pen certainly won't work, a fine-point felt-tip pen (we call them koki-pens) is perfect. They make exquisitely small dots with their tiny fibre tips. For brighter stars, slightly more pressure on the pen produces a larger blob. For really bright stars, either use a thicker tipped pen, or colour in a little circle. Of course, bright stars remain point sources, so don't draw them as large disks; rather as bloated spots.

A soft-leaded pencil or charcoal stick (sold at art supply shops) and an eraser is also on your shopping list. Only one type of pencil is used at the eyepiece, says Macdonald; different grades of pencil may be used to enhance the drawings indoors later on. He writes that the "ideal sketching pencil is the Ebony pencil (#6325) made by Eberhard Faber. It is coarse and soft enough to let you use just about any sketching technique you want."

Finally, you'll need a "smudge stick" or cottonwool earbuds to smudge portions of the drawing. This creates the impression of haziness and testifies to the fact that there are few straight edges and neat boundaries to deep-sky objects.

Drawing techniques

Before you put pencil to paper, study the object intently. Try different eyepieces to see the most detail; use various filters to enhance contrast. Use averted vision to pick out the fainter detail, letting the overall impression build up in your mind. David Coleman (1994), commenting on sketching Mars, notes “I began each drawing session by not drawing the planet! It was important for me to spend a quiet 15 or 20 minutes carefully observing. It takes practice and patience to train your eye to pick up faint detail, so try not to rush right into drawing.”

Every time I sketch, I’m impressed by how much detail I would have missed had I just looked at the object for a short while and noted a description. Fainter stars and subtle detail is revealed through extended observing. Studying the object with intense concentration and averted vision, says Mitchell, reveals more and more detail.

“Any drawing takes considerable time, first at the telescope, then indoors . . . A very simple subject with only a couple of field stars, such as a faint, featureless galaxy, may take only 10 minutes at the telescope. Most subjects take over 30 minutes, and complicated ones like the Orion nebula (M42), several hours.”
– Roger N Clark

When you do start sketching, draw only what you see.

The **first step** in sketching is to plot the positions of the brightest stars in the field of view. These stars serve as markers that keep the drawing’s proportion correct. Start by plotting a prominent star in accurate relation to the field of view circle. Now plot a second one at the appropriate distance, and angle. Work from the outside, inwards. Examine the field, and pay close attention to other stars that make distinctive triangles with the two already drawn. Select a star that makes a recognisable shape, and add it in. Continue in this was by making triangles, or extended lines, or even rectangles, with new stars. In this way, a framework is erected within which fainter stars may be filled in.

Drawing in the bright skeleton of stars should be done quickly. Spend more time imprinting the image in the mind than staring at your sketchpad. “While dividing attention between the eyepiece and sketchpad, preserve as much night vision as possible by keeping your red light subdued. Limit exposure to light by spending most of your time studying the object, and then draw bits of remembered detail in short bursts.” Once you’ve selected a spot to position a star, see if there are other triangles in which it is also involved, that can confirm its position.

If your initial framework is not accurate, rather start again. If, as you get on, you plot a star in the wrong place, make sure you correct it. Because I use a pen to plot stars, it’s not a simple matter of erasing. Instead, I place the tip of the pen on the offending star, and draw a short (<1mm) tick away from it. When the drawing is retouched indoors, there stars are removed. A note in the margin can also draw attention to any alterations as needed.

Continue plotting the fainter stars, in relation to the brighter ones, until you’ve added all the stars you can see.

With the stars in place, **sketch the major details of the object**, capturing the general shape. Mitchell says: “This later serves as a template when it comes tome to fill in any subtle detail in the object’s shape.” I advise that you do this very lightly; often, as you continue observing the object, this overall impression changes, especially on complex objects. This again emphasises that prolonged observing shows detail not seen in the initial scrutiny.

With the basics recorded, **refine the sketch by adding details**: the glittering of stars resolved in globulars, dark dust lanes in galaxies, and so on. Each type of object has a slightly different approach.

Open clusters are my favourite sketching target. Accurate placement of stars is vital, as is the faithful rendering of their brightnesses. Slowly build up the image, working from the outside inwards, using triangles and lines to position the stars. If there are an overwhelming number of stars, slightly defocus the eyepiece, which hides the fainter clutter. Then refocus to fill in the fainter members.

Open clusters, by the way, respond well to moonlight. While the brightened night sky drowns out fainter deepsky objects, star clusters can be seen reasonably well. Take advantage of a clear but moonlit light to prepare sketches of open clusters. Fainter stellar members can be added in on a dark night.

Globular clusters can be a real challenge, especially for larger telescopes. Start by drawing the core dark, and the outer regions in successively fainter layers of pencil — say two or three separate layers. This should give a zoned or tree-ring appearance to the sketch, but this is eliminated by careful smudging, either with a smudge stick or an earbud. This creates a realistic nebulous effect, if you make sure the edges fade naturally with on discernible edge. Be careful that you don’t inadvertently increase the size of the object with too much smudging; rather start out slightly smaller and build up the correct size with repeated pencilling and smudging.

The shading should as accurately as possible reflect the brightness profile of the object; does it brighten suddenly or gradually; is the brightening slight or marked?

To round off the drawing, add stars that are involved in, or very close to, the cluster. The resolved stars should be added in from the cluster edge, working inwards. Of course, in the case of a well resolved, rich globular cluster (say Omega Centauri in a 15-inch) it's not a good idea to accurately plot every star; simply create the general impression. Mitchell cautions, however, that you shouldn't "get carried away and resort to madly peppering the cluster with stars at random."

Galaxies are drawn in much the same way as globular clusters, starting with the darker central area (e.g. an elongated bar), working outward. Successive smudging defines the outer reaches of the galaxy, while an eraser is used to indicate obscuring dust lanes.

"Most of all, practice. There's no other way to master deep-sky observing. And don't quit on any object, no matter how vague it may look, until you've given it a good, long, thorough scrutiny."

Planetary nebulae need a different approach. Many planetaries have well-defined disks that don't need smudging. Whether its small and bright, or large and faint. first sketch in the outline of the disk. Then fill in the centre so that the nebula becomes a smooth disk. Some planetaries, however, are diffuse, and their disks need to be slightly smudged.

Diffuse nebulae are probably the most difficult. They are often so faint that smudged pencil creates too strong an image. Macdonald suggests you rub your forefinger or cotton bud with the pencil until it is coated with a fine layer of lead. I prefer to rub the pencil a number of times on a scrap part of the paper. When it is well-coated with lead, I then load a cotton bud by drawing it over this "lead palette". Use this coated cotton bud to draw the shape of the nebula. Brighter portions may be enhanced by smudging with the finger.

Dark nebulae can be captured with the same approach, although some of them have well-defined borders and are thus more like planetary nebulae. Since some of these nebulae are extremely large, a rich-field telescope, or large binoculars, show them better. Such a wide field, however, often includes a great number of brighter stars, needing a longer time to sketch accurately. I prefer preparing the star-field beforehand, by printing out on an A4 sheet an unlabelled starmap, down to say 8th magnitude. At the eyepiece, the dark nebulae are then filled in on this framework; the idea, after all, is to sketch the nebula, not the background stars.

Finishing the drawing

As you study the field, notice at which edge of the eyepiece the stars appear to move out. Indicate this position on your sketch - this is west. East is on the opposite side, of course. To indicate north, turn the sketch so that east is pointing upward. If you are using a Newtonian, which has two mirrors, north is to the right. If you have a one-mirror system, like a refractor with a star-diagonal, north is to the left. Don't forget to also record the date (and time), instrument and eyepieces used, and the observing conditions which may influence the quality of the drawing. Also see the section on using an *Observing Checklist* for details.

Preparing the final version

Your field sketches are not supposed to be finished works of art, but rather rough drafts. For complex objects, you'll probably have made several drawings. When you've completed an evenings sketching, return indoors to prepare a better rendition of your work, under normal lighting conditions. Combine the rough sketches into a composite version and make any corrections that you noted.

When you next observe, take your sketch out to the telescope for a moment of truth. Compare it to the view in the eyepiece, looking for and noting any inaccuracies. In this way, you can ensure maximum fidelity in your final sketch. Your final sketch should readily show the casual viewer what the skilled observer was able to discern only with time and effort at the eyepiece.

Reproducing and displaying sketches

McDonald suggests redrawing your sketches if they are to be displayed or sent to other observers or observing sections. He redraws the sketch, enlarging it by representing the field of view with a 100mm circle. "This time," he notes, "different grades of pencil are used to highlight different features. For example, a 4B (very soft) pencil is used for the cores of galaxies or very bright planetary nebulae, and an HB for faint nebulosity. It should be remembered, however, that the relevant positions and brightnesses of the stars and nebulae must be the same as in the original drawing. Otherwise, the drawing will lose its accuracy." I much prefer to do the reproduction digitally, by scanning in the final drawing into a computer graphics file. Open clusters can be scanned in and retouched with minimum effort. Nebulous objects require a certain amount of knowledge of graphics editing software to deal with properly. This creates a permanent record with all the benefits of a digital document. If it is necessary to make a hand-drawn copy, photocopy your original, perhaps enlarging it as necessary. Nebulae, which almost always reproduce badly, can now be touched up as discussed above.

1.6.7 Choice of magnification

When choosing the "best" magnification for an object, you must bear in mind that the eye has very poor resolution in dim light. In bright light, the eye can resolve detail finer than 1 arc minute, but can't make out features smaller than 20 arc minutes when the illumination is about as dim as the dark-sky background in a telescope. This means that details in a very faint object can be seen only if they are magnified sufficiently.

While a low-power eyepiece concentrates a faint extended object's light and increases its apparent surface brightness (the illumination of a given area on the retina), it does not enlarge it sufficiently for clear resolution.

Unlike a star, an extended source such as a galaxy or nebula will grow dimmer as the magnification is increased. Such an object's surface brightness is proportional to the area of the exit pupil. Thus, an object viewed with an exit pupil 1mm in diameter has only 2 percent of the surface brightness is has with a 7mm exit pupil.

As magnification is increased, the sky background grows dimmer at the same rate that the object does, so the contrast remains the same. But with higher magnifications, delicate structure is larger and hence more visible.

Faint stars are best seen at high magnification since the star's image remains constant while the background grows dimmer, improving contrast.

What all this means is that it is wise to try a wide range of powers on any object. You may be surprised by how much more you'll see with one than another.

"The secret of success is constancy to purpose."
– Disraeli

1.6.8 Practice makes perfect

Practice is the only sure-fire way to improve your skills as a deepsky observer. Don't give up on an object, no matter how vague it may look. Have another go. Consider this passage from *The Amateur Astronomer's Handbook* by James Muirden:

> "No opportunity should be lost to train the eye to work with the telescope; to observe the same object with different powers so as to see the effect of magnification; to try to see faint stars; and to draw planetary markings. In the beginning, to be sure, this may all seem to be wasted effort; the observing book will fill up with valueless sketches and brief notes of failure. But this apparently empty labour is absolutely essential; for, as the weeks pass, a steady change will be taking place. Objects considered difficult or impossible to see will now be discerned at first glance, and fainter specters will have taken their place. Indeed, these former features will now be so glaringly obvious that the observer may suppose that some radical improvement has occurred in the observing conditions. But the credit belongs entirely to the eye.."

1.7 Astronomy and vision

The following pages contain the collected writing of several experienced observers, giving their opinions about the finer points of visual observing.

Topics discussed include dark adaptation, averted vision, magnification, contrast and observing at the limit. Extensive use is made of the works of K P Bowen, R N Clark, L Cain, A MacRobert and S J O'Meara.

Bowen (1984) summarizes the route taken by light as it encounters a human eye: "The light first encounters the cornea, a transparent window of living tissue that is the main image-forming element of the eye. It finally reaches the retina, where two types of light-sensitive elements – rods and cones – detect it."

"The cones distinguish colour, and function best in a bright environment. Rods, on the other hand, cannot discriminate colour, but are better as motion detectors and operate best in low-light conditions. The cones are most sensitive to green light at about 5600 angstroms, while the rods respond best to blue-green light at about 5100 angstroms. The retina can detect and function over an incredible brightness range of 10^{14} times, a marvel indeed."

1.7.1 Dark adaptation

In low-light conditions, the eye takes a while to adapt. MacRobert (1985) advises: "Give your eyes at least half a hour to thoroughly adapt. Complete dark adaptation is critical for seeing faint deep-sky detail. Most observers never reach proper dark adaptation, because they use torches that are too bright. Studies have shown that even red light when sufficiently bright impairs night vision. Make your own "observing capsule" by draping a dark cloth over your head. I prefer to wear a black T-shirt upside-down, which I can pull over my head as needed. It doubles as a neck-warmer, too. This dark shield cuts off interfering lights and reflections from the telescope tube (which in my case is glossy white aluminium). One observer raises the issue of 'hood humidity' - while the warm radiation from your face slows the process of dew formation on the eyepiece, the humidity from your eye and breath speeds it up. "Since the hood traps the moisture from your face, you may need to buy or rig up a little heater for your eyepiece to prevent dew from forming on the lens. A simpler solution is to step away periodically to let the pocket of humid air disperse." An eye-piece heater is probably a better solution.

Another way to maintain dark adaptation is to observe with one eye, while reading starcharts and taking notes with the other. I found the eyepatches supplied by hospitals to be woefully inadequate, being tiny, discrete things. Instead, I cut a large (12cm x 9cm) piece of soft black leather into an oval shape and attached a length of pants-elastic. While at the eyepiece, this flops over my left eye, which can then be kept open and relaxed while taking in no distracting image. In less than a moment, I flop the patch over my right eye and use the left for 'normal' viewing.

1.7.2 Averted vision

The cones are concentrated in the central retina and are the only light-sensitive elements in the fovea centralis, which is an area of our vision about 1.5° in diameter where we have our highest resolving ability.

Outside this area, the rods rapidly gain predominance and reach maximum concentrations in a narrow oval ring located about 19° horizontally and 15° vertically from the fovea. This off-axis concentration of rods is the reason why 'averted vision' (looking slightly away from the point of interest) produces such a dramatic improvement in our ability to see faint objects. The dimmest astronomical sources the eye can detect, whether stars or nebulae, are seen only with averted vision. Practice aiming your eye in one direction while paying attention to something a little off to the side. As MacRobert (1985) points out, "This is what deep-sky observing entails almost all the time."

This is a bit tricky at first, because we must bypass our eye's built-in natural instinct to place whatever we're looking at directly on the fovea. Look at a part of the field away from the spot where the desired object is, yet be aware of that location without gazing at is. With practice the technique becomes second nature.

Clarke points out that, on the periphery, the eye is about 40 times (4 magnitudes) more sensitive than the fovea. Peripheral vision, Clarke notes, is best when the ojbect appears 8 to 16 degrees off-axis in the direction toward the nose. The areas up, down and toward the ear are not quite as sensitive. The blind spot lies 13-18 degrees towards the ear; placing the object here will cause it to vanish altogether.

1.7.3 Troxler phenomenon

The eye tends to 'ignore' an image if its position on the retina remains stationary for any length of time. This is known as the Troxler phenomenon, and the eye usually changes its fixation without our realising it about 10 times a second to avoid it. During intense observation, however, a person can fixate on an object long enough to cause the image to fade somewhat. Conscious sweeping of the field or taking a break from the eyepiece for a few seconds will help prevent this fade-out.

1.7.4 The role of magnification

A faint extended object (e.g. a galaxy, a bright spot within a galaxy or nebula) should be viewed with enough magnification so it appears several degrees across to the sky. To be detected, it must be surrounded by a darker or lighter background, so the eye can distinguish contrast. Various magnifications should be tried to bring details into the range of best detection. At each magnification, considerable time must be spent examining for detail. Higher magnification should be tried until the object is totally lost from view. The eye should be dark adapted for at least 30 minutes so the photochemical visual purple is at full abundance. Bright stars and extraneous lights will tend to destroy dark adaptation." (Clarke 1990:18)

One piece of conventional wisdom is that low magnification should be used for deepsky observing, so that light from a faint object is concentrated on a small area of the eye's retina. Clarke argues: "This would be true if the retina worked passively, like photographic film. But it doesn't. The visual system has a great deal of active computing power and combined the signals from many receptors to detect a faint extended object.

Increasing the magnification spreads the light over more receptors, and the brain's processing power can then bring into view fainter objects having lower contrast. When you switch from a low to a high power, you could gain a magnitude or more in faint stars. This works because high power reduces the surface brightness of the entire field by spreading out the light. Doing this dims the sky background without affecting the total amount of light arriving from small, discrete objects. Stars appear so tiny that their surface brightness hardly looks changed at high power. But even an already dim, diffuse galaxy won't be rendered any less visible when its surface brightness is lowered (at least within limits), because the galaxy's contrast with the sky remains the same. You're actually likely to see it better, because your eye perceives low-contrast objects better when they are large. The neural network in your retina is smart enough to gather and correlate the galaxy's light from a wide area. Deepsky vision is quite different in this regard from the behaviour of 'dumb' photographic film, which responds to surface brightness only."

Clarke also notes: "It is normally accepted that the highest power [usefully employed on a telescope] is about 50 to 60 times the objective in inches. This limit is correct only for bright objects ... for fainter objects the eye has less resolution and needs to see things larger, so higher powers are called for. At the limit of the eye's detection ability, the highest useful magnification is on the order of 330 per inch of objective!

High magnification demands a lot from your telescope. If the mounting is unstable, or the slow-motions not smooth, then each vibration or bump will cause the image to dance about wildly. Further, the field of view becomes narrower as you magnify, making objects a bit more difficult to keep track of. The effects of an unstable atmosphere are exaggerated at high magnification. Clark notes that "magnification also reduces the surface brightness of everything in view. It must not reduce an object's surface brightness below the eye's detection limit, of course, or the object will disappear.

So while higher magnification does decrease surface brightness, MacRobert notes, the total number of photos of light entering the eye remains the same. It doesn't really matter that these photons are spread out over a wider area; the retinal image-processing system will cope with them. At least within certain limits. A trade-off is needed to reach the optimum power for low-light perception: enough angular size but not too drastic a reduction in surface brightness.

Mel Bartels on his "Visual Astronomy" page concludes that there are a number of ways to make an object detectable. Regarding magnification, he says: "Use sufficient magnification to make the background invisible and the object about one degree in apparent size. Most amateurs today use too low of power because their scopes don't track, and because 'that's what everyone else does'. John Dobson was the first large aperture observer to point out the advantages of high magnifications. Al Nagler, and Brian Skiff, among others, have recommended high magnifications. By increasing magnification, you are decreasing sky background brightness, and making the object larger in apparent size, both crucial to detectability. For small extended objects, you may exceed the old double star observers' rule of 50x per inch of aperture."

Nils Olof Carlin summarises: "To detect a faint object, you can increase magnification till the sky is so dark that you have difficulty seeing the field stop, or till the object has an apparent size of 1 degree, whichever comes first."

The retina has very poor resolution in dim light (which is why you can see a newspaper at night but not read it). Details in a very faint object can be seen only if they are magnified sufficiently. To get the most out of observing, use different magnifications, including very high, and take time to closely examine the object. And don't forget to make a sketch.

1.7.5 The role of contrast

Lee Cain (1986) writes that the "most important factor in observing deep-sky objects is contrast. The eye is capable of seeing extremely faint objects as long as there is sufficient contrast with the background." "Cleanliness influences contrast. Dirty optical surfaces are perhaps the biggest enemy of contrast in telescopes. Dirt near the telescope's focal plane is most detrimental, because here the light is concentrated and light-scattering dust is more nearly in focus to the eye. Eyepieces, diagonals, and secondary mirrors should be kept as clean as possible."

"The inside of a telescope should be blackened and well baffled to kep stray light form entering the eyepiece. But the amount of stray light in even a poorly baffled telescope is less than what enters the eye from around the outside of the eyepiece. ... I suggest using a rubber eyecup or draping a black cloth over your head while observing."

1.7.6 Deliberate image motion

Since the low-level light receptors, rods, are good at picking up motion, some observers lightly tap the telescope tube, causing the image to move about. In this way they notice detail in an object that they otherwise wouldn't pick up. How much to rock? With a 40arcmin field of view, I use up to 10 arcmin swings (amplitude). In my experience, the image should not move too rapidly, or it simply becomes a blur — you don't want to generate your own seeing! Also, this techniques seems more effective when used with a telescope than when applied with binoculars.

Factors that affect visual acuity: age, smoking, alcohol, altitude, blood-sugar level, diet, and pre-exposure to bright sunlight.

1.7.7 Observing at the limit

Schaefer (1989) notes: "Only three parameters have a big effect on the limitng magnitude: aperture, magnification, and the naked-eye limiting magnitude at zenith. A telescope of larger aperture obviously collects more light. Higher magnification spreads the background sky brightness over a larger angle, so a telescopic viewer sees a fainter skyglow and hence can pick out fainter stars. The zenith magnitude is an indicator of sky brightness: the fainter you can see without the telescope, the fainter you can see with it."

An important concept is the probabilistic nature of observing at the limit. Schaefer comments that "the actual limit depends on the observer's confidence. If you're absolutely sure that a star of magnitude 14.0 is always visible, you may still get occasional definite glimpses of a 15.0 star. Faint-star visibility is a probabilistic affair." Clark (1994) expands on this: "Observers looking at extremely faint stars note that the star will blink into view occassionally; it is only seen for brief moments. "By increasing the 'integration time' - the time spent trying to make a detection - a few blinks detected at the same location can build up to the positive identification of stars or faint objects normally considered beyond reach ... The longer you look, the fainter you should see. Laboratory research on the eye's response to faint light shows that detection limits can be likened to a probability curve ... there is no single limiting magnitude for a given telescope aperture."

"The best observers achieve results at the 2 percent level, yet they are actually detecting the target star perhaps only 1 percent of the time. The reason is simple: its difficult to hold your eye steady enough to allow the most sensitive part of your retina to collect photons from a tiny part of the total image. This while you might spend 100 seconds trying to detect a faint star, it is challenging to hold your eye steady in the correct position for even 50 seconds. Even the best observers can't do it all the time, and they have practiced the technique long and hard."

Some 5 to 10 minutes are needed to detect faint objects at the 5% probability level. “To push the detection level to the 2 percent threshold requires much longer observation time. You also need to be far away from city lights and have keen averted vision and intense concentration. If you cannot escape all city lights, there are tricks that will help you achieve the faintest possible observation. High on my list is total isolation from extraneous light. Cover your head with a black cloth if you must. Or use higher magnifications, which help reduce the sky background and the interference of bright stars in the field ... Another aid is to tap the telescope tube lightly when trying to confirm a sighting of a faint star, since our eyes are very sensitive to motion. Some observers breathe more deeply or frequently than normal, in the hope that doing so will deliver more oxygen to the eye’s receptors.”

“But there is more to observing than simply detecting faint stars. The probabilty principles can apply to contrast in extended objects. You may detect a low-contrast feature on a planet by simply observing it long enough for it to ‘flash’ into view. Planetary observers usually credit seeing changes as being responsible for all fine, low-contrast detail they see. Some of these ‘moments of good seeing’ might well be the eye and brain combination hitting those low probability levels! ... Again, to reach the lowest levels, you must have excellent skies ... You must be far from cities and work on very clear nights.”

1.7.8 Colour vision

Clark (1990) writes that “the human eye is a remarkable detector of colour under bright daytime conditions. But the colour receptors, the cones, do not function at all in the low light levels of night, so no colour is seen.”

Shaefer (1993) points out that “the human eye can detect colours form sources brighter than 1500nL. The reason is that photopic vision (i.e. day vision which uses the retinal cones; as opposed to scotopic vision, or night vision, which uses rods) has three types of photopigments, each with a different spectral sensitivity. So the eye simultaneously measures the brightnesses of an image over three different wavebands, much like taking CCD images through three different filters or taking a colour photograph with three different chemical dyes. The situation is also analogous to photometry in the Johnson UBV system, where three intensities are measured.

To detect colour in deep-sky objects, do not use averted vision – look directly at the object.

1.7.9 Are two eyes better than one?

Bowen (1985) reports: “When low-contrast targets are viewed, there is a 40% improvement in resolution with binocular as compared to monocular vision. Binocular vision also gives an improvement in contrast sensitivity on the order of 40%. Also, there is a lower light threshold; there is a 25–40% gain in the ability to see faint objects.”

The atmosphere which blankets us greatly influences our view of the universe. Weather conditions, too, play an important role in the quality of observing. Not to forget the growing problem of light pollution. Some of these complex topics are discussed here.

1.8 The atmosphere, weather, and seeing

"Under a clear sky," writes Schaefer (1993), "the twinkling of stars creates an atmosphere of liveliness." MacRobert (1995) says that "viewed at high power from the bottom of our ocean of air, a star is a living thing. It jumps, quivers, and ripples tirelessly, or swells into a ball of steady fuzz." Schaefer continues: "This rapid change in a star's apparent brightness is termed *scintillation*. Even though stars subtend infinitesimal solid angles, they appear in a telescope as a finite disk with fuzzy edges. This image blurring is called *seeing*. When a star is viewed through a small telescope, the light appears to move around like a will-o'-the-wisp dancing around a fairy. This effect is called *image movement*."

"All three phenomena are closely related manifestations of turbulence in the atmosphere. The correct idea was first advanced by Robert Hooke in 1665 when he suggested the existence of "small, moving regions of atmosphere having different refracting powers which act like lenses." The refractive index of the air varies slightly from point-to-point due to small changes in temperature and density caused by turbulent motions of the winds and heating from the ground. So the path of a beam of light passing through the atmosphere will be bent and kinked from the random scatterings imposed by the weak refractive prisms of air. An observer on the ground will be able to see light from a point source by looking in many directions at once. This spreading of the light into a 'seeing disk' is caused by many small angle scatterings, and hence has a two-dimensional Gaussian distribution. As the wind blows the eddies across the line of sight, the number and centroid of paths will shift randomly resulting in scintillation and image movement."

"The best introductory article on this topic is Young (1971) while Mikesell, Hoag and Hall (1951) provide a good discussion of the observational properties of scintillation. A review paper by Coulman (1985) gives a detailed technical discussion along with an extensive bibliography."

Slow and fast seeing

MacRobert (1995) notes that "Telescope users recognize two types of seeing: 'slow' and 'fast'. Slow seeing makes stars and planets wiggle and wobble; fast seeing turns them into hazy balls that hardly move. You can look right through slow seeing to see sharp details as they dance around, because the eye does a wonderful job of following a moving object. But fast seeing outraces the eye's response time."

Twinkling

"An old piece of amateur folklore is that you can judge the seeing with the naked eye by checking how much stars twinkle. This often really does work. Most of the turbulence responsible for twinkling originates fairly near the ground, as does much poor seeing. But high-altitude fast seeing escapes this test. If the star is scintillating faster than your eye's time resolution (about 0.1 second), it will appear to shine steadily even if a telescope shows it as a hazy fuzzball."

Transparency

Transparency describes the clarity of the atmosphere. As the transparency worsens, faint stars begin to disappear. Extended objects such as nebulae suffer most from poor transparency, lunar and planetary detail from poor seeing, star clusters equally from both effects.

How to identify sources of seeing

MacRobert (1995) "Tube currents of warm and cool air in a telescope are real performace killers. Reflectors are notorious for their tube currents. Any open-ended tube should be ventilated as well as possible. Suspending a fan behind a relfector's mirror has bgecome a popualr way to speed cooling and blow out mixed-temperature air. It's easy to check whether tube currents trouble your images. Turn a bright star far out of focus until its a big, uniform disk of light. Tube currents will show as thin lines of light and shadow slowly looping and curling across the disk."

On the other hand, if the out-of-focus star disk swarms with wrinkles that scoot across the view, entering one edge and leaving the other, then there is local seeing near the telescope.

To combat local seeing:

- allow telescope cool-down before observing
- avoid tube currents – flows of warm and cool air in a telescope tube
- keep body heat and breath out of the light path
- telescope surroundings should be “thermally friendly’ – grass is better than pavements; the flatter and more uniform the greenery the better; the higher off the ground, the better.

Weather indicators

The following bits of advice were gleaned from various authors; I really don’t have a good understanding of the weather and its role in astronomy – any help would be welcome.

1. Watch the colour of the daytime sky, especially near the horizon. The bluer the sky, the darker the night will probably be. The white haze in a blue sky consists of microscopic water droplets that have condensed on tiny solid particles, primarily sulphate dust from distant factories and power plants. These particles are the precursors of acid rain. They do just as good a job of scattering artificial light at night. A deep blue sky in the afternoon should mean a transparent sky after dark.

2. If low humidity is predicted by the weatherman, that’s a good sign.

3. A windy cold front sweeping through a city can clear out local air pollution, leaving the night marvelously dark. The windiest city and suburban nights are often the darkest. A passing rainstorm or blizzard can also leave an unusually dark night in its wake.

4. Poor seeing does seem more likely shortly before or after a change in the weather, in partial cloudiness, in wind, and in unseasonable cold. Any weather pattern that brings shearing air masses into your sky is bad news.

5. After a cold front passes - often with a heavy rain or snowstorm - the sky usually becomes very dark and crystal clear but, unfortunately, very turbulent. These clear nights, when stars twinkle vigorously and the temperature plummets, may be great for deep-sky observing but are usually worthless for the planets.

There is a separate resource for determining the naked-eye limiting magnitude – contact me if you would like this information.

Impact of light pollution

A typical suburban sky today is about 5 to 10 times brighter at the zenith than the natural sky. In city centers the zenith may be 25 or 50 times brighter than the natural background.

Where there’s no light pollution the limiting magnitude is usually assumed to be 6.5, though some people can see fainter. Under such conditions, the sky is packed with stars, the Milky Way is a mass of swirling, jumbled detail and any clouds appear blacker than the sky itself. At a limiting magnitude of 5.5, clouds are brighter than the sky because they are lit from below. The Milky Way is still easily visible but far less detailed. At limiting magnitude 4.5, the Milky Way is barely detectable as a faint, nearly featureless band. At a limit of 3.5 the Milky Way is completely invisible.

David W. Knisely recently posted an item to sci.astro.amateur (Subject: Measuring sky ‘darkness’, Date: Thu, 22 Jan 1998 19:52:21), in which he suggests the following guidelines for naked-eye limiting magnitudes and overhead light-pollution ratings:

Light pollution Severe: Only mag. 3.0 and brighter (or worse) are visible.

Light pollution Moderate: mag. 3.1 to 4.5 visible.

Light pollution Mild: mag. 4.6 to 5.5 visible.

Light pollution Dark Sky: mag. 5.6 to 6.5 visible (occasional light domes).

Light pollution Pristine: mag. 6.6 and fainter visible (little or no light pollution).

1.9 Selecting an Observing Site

When selecting an observing site, various criteria should be considered. I've collected the points of view of a few authors, summarising the properties they think are important.

My feeling is that convenience and comfort should be carefully considered. The quicker and easier you can observe, the more often you'll do it. Also, as MacRobert notes, "your surroundings colour your experience of the universe." I've spent hours observing alone in a nature reserve, with only the sound of small animals and the nearby stream to compliment the celestial views — a different level of enjoyment compared to my backyard, with its easy access to the CD player and coffee machine.

Hunter (1989) considers:

1. transparency
2. favourable weather
3. height above sea lelvel
4. seeing
5. amount of sky visible from the site
6. cost of using the site
7. cost of transport to the site
8. set-up time

MacRobert (1991) presents his "list of six things that matter." They are:

1. lights nearby
2. light pollution in the sky itself
3. how much sky is visible
4. convenience
5. privacy/safety
6. the location's overall aesthetics.

From Sidgewick (reference incomplete):

1. remoteness from road and rail traffic
2. remoteness from any urban area, especially in the direction of the prevailing wind, and in inhabited buildings in the immediate vicinity,
3. absence of all artificial lights not controllable from the site
4. clear view of the whole stellar hemisphere
5. protection from the wind
6. surroundings planted with low vegetation, or at least grassed

Site selection and dew:

To help eliminate dew, you can choose a site less prone to dewing. As it gets later in the evening, the air cools, gets heavier and sinks into low-lying areas. The moisture-laden air thus settles into valleys and low depressions, and dew is likely to form; to avoid this, select a site situated on the side of a gentle hill.

MacRobert's (1995) suggestions: Geography is critical. Smooth, laminar airflow is the ideal sought by observatory siting committees worldwide. The best sites on Earth are mountaintops facing into prevailing winds that have crossed thousands of miles of flat, cool ocean. You don't want to be downwind of a mountain; the airstream breaks up into turbulent swirls after crossing the peak. Nor do you want to be downwind of varied terrain that absorbs solar heat differently from one spot to the next. Flat, uniform plains or gently rolling hills extending far upwind can be almost as good as an ocean for providing laminar airflow. You may learn to predict which wind direction brings you the smoothest air.

Messier's list isn't the only one, you know. Nor the oldest, for that matter. Messier published the first version of his catalogue in 1771; twenty years before him, another Frenchman, Nicholas-Louis de la Caille, was observing the southern sky from Cape Town and compiled the first southern list of non-stellar objects.

2 Deepsky catalogues

2.1 Lacaille

One of the earliest catalogues of deepsky objects is the one prepared in the 1750's by Abbe Nicholas Louis de la Caille (1713–1762), who has the distinct honour of being the first person to systematically observe the whole sky. During his stay at the Cape of Good Hope, Lacaille drew up a short list of the most remarkable objects he had come across.

Lacaille was at the Cape primarily to compile a star catalogue. During his short visit (1751–1752) he accurately recorded positions and magnitudes of no less than 10 000 stars. He also published a list of 42 southern nebulae, which he divided into three types: 'Nebulosities not accompanied by stars', 'Nebulosities due to clusters', and 'Stars accompanied by nebulosity. In his report to the French Academy of Sciences, Lacaille wrote:

> "The so-called nebulous stars offer to the eyes of the observers a spectacle so varied that their exact and detailed description can occupy astronomers for a long time and give rise to a great number of curious reflections on the part of philosophers. As singular as those nebulae are which can be seen from Europe, those which lie in the vicinity of the south pole concede to them nothing, either in number of appearance. I am sketching out this description and list to serve as a guide for those with the equipment and leisure to study them with larger telescopes. I would have greatly desired to present something more detailed and instructive in this article, but with ordinary refractors of 15 to 18 inches [in length] such as I had at the Cape of Good Hope, I had neither adequate nor convenient enough instruments for this kind of research. Those who do take the trouble to see what has occupied me during my foreign sojourn will see well enough that I did not have time to make that sort of observation."
>
> "I have found a great number of the three types of nebulosities in the southern part of the sky, but I do not flatter myself to think that I have noticed them all, especially those of the first and third types, because they can only be perceived after twilight and in the absence of the moon. However, I do hope that the list is passably complete in regard to the most remarkable of the three types." *(Quoted from Gingerich)*

Evans (1990) notes: "Considering that this list is based on the data from [the star catalogue], that is, almost always one shot of the passing sky in a very small telescope, certainly very inferior to modern binoculars, it is as good as might be expected. One can also reflect that Lacaille seems to have been the first person ever to observe systematically the whole sky, an honor which the present author once ascribed to Sir John Herschel, who used much the same technique with a telescope of some ten times larger diameter from a site some 6 miles south of Lacaille's. He, of course, did very much better and is the principal source of the southern data in the NGC."

Lacaille also studied the Magellanic Clouds:

> "As a result of examining several times with a telescope . . . those parts of the Milky Way where the whiteness is most remarkable and comparing them with the two clouds common called the Magellanic Clouds, which the Dutch and Danes call the Cape Clouds, I saw that the white parts of the sky were similar in nature, or that the clouds are detached parts of the Milky Way, which itself is often made of separated bits. It is not certain that the whiteness of these parts is caused, according to received wisdom, by clusters of faint stars more closely packed than in other parts of the sky, whether of the Milky Way or of the Clouds, I never saw with the ... telescope anything but a whiteness of the sky and no more stars than elsewhere where the sky is dark. I think I may speculate that the nebulosities of the first kind are nothing more than bits of the Milky Way spread round the sky, and that those of the third kind are stars, which by accident are in front of luminous patches." (Quoted from Evans)

His record of the Coalsack, the prominent dark nebula in Crux, is one of the first on record:

> "One can add among the phenomena which strike the eye of anyone looking at the southern sky, a space of about 3 degrees in every direction which seems intensely black in the eastern part of the Southern Cross. This is caused by the contrast with the brightness of the Milky Way which surrounds this space on all sides."

Lacaille's catalogue is presented in Appendix 1 (page 40) with an English translation and co-ordinates precessed to J2000.0.

The first "proper" southern deepsky catalogue was drawn up by a former factory hand who had taught himself astronomy – James Dunlop (1795-1848). Dunlop arrived in New South Wales, Australia, in 1821 and observed the southern skies with a 9-inch speculum mirror. He drew up a list of about 600 deepsky objects, for which he was awarded the Gold Medal of the Royal Astronomical Society.

2.2 James Dunlop

One of the earliest cataloguers of the southern sky was James Dunlop, who spent several years observing the sky from Paramatta ('Place of Eels'), New South Wales, Australia. In his 1827 article, presented to the Royal Society by Sir John Herschel, Dunlop writes:

> "The following nebulae and clusters of stars in the southern hemisphere were observed by me at my house in Paramatta, situated about 6″ of a degree south and about 1s.78 of time east of the Brisbane Observatory. The observations were made in the open air, with an excellent 9-feet reflecting telescope, the clear aperture of the large mirror being nine inches. This telescope was occasionally fitted up as a meridian telescope ...
>
> "... the eye end of the telescope was raised or lowered by a cord over a pulley attached to a strong wooden post let into the ground about two feet: with this apparatus I have observed a sweep of eight or ten degrees in breadth with very little deviation ... and the tremor was very little even with a considerable magnifying power.
>
> "I made drawings or representations of a great number of the nebulae and clusters at the time of observation ... and also very correct drawings of the Nebulae major and minor, together with a representation of the milky nebulosity surrounding the star Eta Robur Caroli. ...
>
> "The reductions and arrangement have been principally made since my return to Europe; and I trust this catalogue of the nebulae will be found an acceptable addition to that knowledge which the Brisbane observatory has been the means of putting the world in possession of, respecting that important and hitherto but little known portion of the heavens."

For various reasons, a great many entries in Dunlop's catalogue are suspect. Some are badly described and are difficult to verify, while others simply do not exist.

John Herschel (see next section) was the first astronomer to try and locate Dunlop's objects; in some cases he was able to identify the objects Dunlop described.

I have compiled a list of Dunlop objects as observed by Herschel; these are listed in the table in Appendix 2 on page 41. Included in that list is one identification made by Magda Streicher, a member of the Deepsky Section.

I would be glad to assist anyone who would like to take on this task of properly cross-identifying Dunlop's objects – please contact me.

Further reading:

Cozens G & White G L (2001) James Dunlop: Messier of the southern sky. *Sky & Telescope*, June, 112–116.

Cozens G (1987) James Dunlop – Pioneer of the Southern Skies. *Universe* , February, 6–7.

2.3 John Herschel

Shortly after Dunlop's work appeared, the renowned observer John Frederick William Herschel arrived in Cape Town to continue his survey of the northern skies. In 1847 his lengthy "Cape Results" was published, containing the first thorough deepsky catalogue of southern objects.

"I resolved to attempt the completion of a survey of the whole surface of the heavens, and for this purpose to transport into the other hemisphere the same instrument which had been employed in this, so as to give a unity to the results of both portions of the survey and to render them comparable with each other."

"On January 15, 1834 there arrived at the Cape a young English scientist and philosopher who for sheer drive, intellectual capacity and versatility has had few equals in the long history of callers at Table Bay.

"John Frederick William Herschel, Bart., K.H. was born at Slough, near Windsor, on the 7th March, 1792 and died at Collingwood, Kent on the 11th May, 1871, in his eightieth year. He is buried in Westminster Abbey not far from Newton. John was the only child of Sir Frederick William Herschel and, like his father, was one of the greatest astronomers of all ages."

"In 1820, assisted by his father, he completed a mirror of 18 inches diameter and 20 feet focal length [f/13] which became the heart of the telescope with which much of his later observing was done."

"...there was an air of dilettantism about Herschel. His mind ranged over a vast number of subjects ... but when it came to physical hard work his enthusiasm would often flag ... Professor Pritchard in his biographical notice in the Encyclopaedia Britannica wrote 'Herschel had become an astronomer from a sense of duty, just as his father had become one by fascination and fixed resolve: hence it was by filial loyalty to his father's memory that he was now impelled to undertake the completion of that work which at Slough had been so grandly commended. William Herschel had explored the northern heavens; John Herschel determined to explore the heavens of the south, as well as re-explore the north.' "

Evans continues: "We need now to envisage Herschel some time in 1832: He is one of the most celebrated scientists in Europe, a knight, honored by numerous scientific bodies, happily married, acquainted with all the most distinguished scientists of Europe, a polyglot, with German, French, Italian, Latin and Greek at his command. He has made a name for himself in mathematics, astronomy, chemistry and several other fields. Now he thinks of observing the southern sky just as he has done the northern, and he seeks for a place to carry out his ambition. The choice is very limited . . . South America, South Africa, and Australia." For obvious reasons he chose South Africa; it offered, amongst others, "an astronomical tradition and an active observatory, a healthy climate, and a convenient longitude."

"To achieve this object, he and his family set sail from England late in 1833 aboard the East Indiaman, the 'Mountstuart Elphinstone'. After a voyage of two months they came ashore, Herschel himself, his wife, the four children Caroline, Emilia Mary, William James, and Isabella. Then there was the mechanic, John Stone, who had in his charge the 20-foot reflector of 18 inches aperture (with classical pedantry the mirrors provided for it were often referred to as 'sesquipedalian') and an equatorially mounted refractor of 5 inches diameter and 7 feet focus [f/17]."

For the next four years, Herschel swept the southern skies, producing a detailed catalogue of non-stellar objects, published in 1847 as *Results of Astronomical Observations made during the years 1834, 5, 6, 7, 8, at the Cape of Good Hope; Being the completion of a telescopic survey of the whole surface of the visible heavens, commenced in 1825*.

This southern catalogue gives positions and descriptions for 1708 objects, of which 98 also appear in his northern catalogue. Of these objects, Herschel notes:

"206 have also been identified, with more or less certainty . . . with objects observed by Mr Dunlop, and described in his Catalogue of

An Occupation for an Independent Gentleman: Astronomy in the life of John Herschel

"Sir John Frederick William Herschel occupies a pivotal position in the history of British astronomy. He formed the living link between two styles or traditions of science by being the last major specimen of one breed, and the inspiration and intellectual role model for the generation to follow. For John Herschel was perhaps the last significant figure to devote himself wholly and full-time to fundamental research in astronomy and its related sciences on the strength of a private fortune. And while the stature that he enjoyed did much to stimulate the concept of the 'professional' astronomer in Britain, so many of these men of the rising generation who admired his thorough-going dedication to science were themselves more obviously professional in the respect that they earned their livings through academic science. One sees in him, therefore, an eclectic blend of attitudes towards what science was, how it should be pursued, and how it should be paid for."

(Chapman 1993)

"As Nelson swept the seas you sweep the skies, leaving little for those who may come after you."

Letter from Thomas Maclear to John Herschel, Royal Observatory, April 5, 1834

Nebulae. The rest of the 629 objects, comprised in that catalogue, have escaped my observation; and as I am not conscious of any such negligence in the act of sweeping as could give rise to so large a defalcation, but, on the contrary, by entering them on my working lists . . . took the usual precautions to ensure their rediscovery; and as I am, moreover, of opinion that my examination of the southern circumpolar region will be found, on the whole, to have been an effective one, I cannot help concluding that, at least in the majority of those cases, a want of sufficient light or defining power in the instrument used by Mr Dunlop, has been the cause of his setting down objects as nebulae where none really exist. That this is the case, is many instances, I have convinced myself by careful and persevering search over and around the places indicated in his catalogue."

"The principal object kept in view during the progress of my southern sweeps was the discovery of new nebulae. The detection and measurement of double stars was regarded as of subordinate interest, and allowed to interfere as little as possible with the former enquiry. To have executed a regular review of the southern heavens with the twenty-feet reflector for the purpose of detecting close double stars would have required at least two additional years."

When London viewed the southern skies: The reception of Sir John Herschel's Cape Results.

"One sometimes wonders whether John Herschel felt haunted by the nebulae: as objects which he had inherited from his father and about which he could never really make up his mind. ... he hoped that after sufficient investigation with large telescopes their nature might be revealed just 'as the double stars have yielded to this style of questioning.' Yet that promise was never fulfilled in his lifetime, and in the introductory pages of his definitive 'Catalogue of Nebulae and Clusters of Stars' one senses the presence of a problem long since recognised yet not yet solved."

(Ruskin 1997)

Notes from Herschel's Cape diaries

John Herschel's diaries during his 19th century stay at the Cape give a fascinating insight into the life of this active observer. During his visit, he worked closely with Thomas Maclear, HM Astronomer at the Royal Observatory at the Cape of Good Hope.

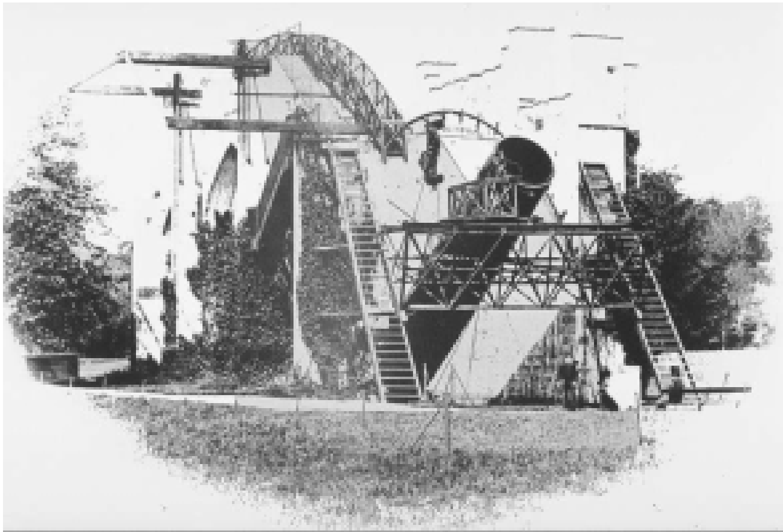
I have gone through three works directly related to this period: Herschel's own "Results of Cape Observations", and the diary extracts published by Warner & Warner (1984) and Evans et al (1969).

From these I have collected some lists of interesting or otherwise remarkable objects, presented in Appendix 3 (page 42). On several occassions, Herschel noted regions very rich in faint stars – these 'Milky Way Clusters', together with their corresponding NGC numbers, are given in Table 1. Interesting descriptions and challenging objects are given in the other two tables. There is also a reproduction of the first deepsky sketch he made at the Cape.

Johann Dreyer's 1888 update of John Herschel's 'General Catalogue' has become the most widely-used deepsky catalogue of all times, listing 8,000 objects of all types excepting dark nebulae.

2.4 Dreyer

Dreyer was born in Denmark, but emigrated to Ireland in 1874 to work at Lord Rosse's great observatory in Parsonstown. Though an amateur, the third Earl of Rosse had built successively larger speculum mirror reflecting telescopes through the late 1830's and early 1840's. The series culminated in a massive 72-inch telescope, the largest in the world from the date of its completion in 1845 until its dismantling just before the first World War. Rosse, his son (the fourth earl), and his observers (Dreyer was one of these) spent years examining and measuring the known nebulae in the northern sky with the famous "Leviathan of Parsonstown," and discovered many more fainter nebulae themselves.



The Leviathan of Parsonstown

During the observations, it became clear to Dreyer that it was time to update Sir John Herschel's so-called GC (General Catalogue) of nebulae and star clusters, published in 1864. Just a decade later, there were simply too many new nebulae being discovered and too many different lists to consult for previous discoveries. Preparing observing lists or simply finding if a nebula had been previously found by another observer had become a time-consuming chore. Thus, Dreyer published a supplement to the GC of about 1000 new objects in 1878, and — having suggested yet another supplement in 1886 — was instead asked by the Royal Astronomical Society to assemble a "new general catalogue" of non-stellar objects. Dreyer, who had in the meanwhile been appointed Director of Armagh Observatory in Northern Ireland in 1882, then added the latest 1500 objects to the previous lists, combined them all in Right Ascension (for 1860) order, and the "New General Catalogue of Nebulae and Star Clusters" appeared as Volume 49, Number 1 of the Memoirs of the RAS in 1888.

Assembling the NGC, Dreyer had to contend with conflicting claims of position and description for what he often suspected to be the same nebula. Some of these he could check himself; most — because of the overwhelming numbers of objects — he simply had to accept as published. Fortunately, he was an excellent transcriber — very few of the errors in the NGC can be traced to carelessness on his part (his most common error, or that of his uncredited assistants, was to apply precession with the wrong sign to declinations). Most of the problems in the NGC are with the original positions and descriptions, coming as they did from many different observers using telescopes ranging in size from 2 inches to 72 inches, and relying on auxiliary instrumentation that ranged from nonexistent to state of the art.

At one extreme were the careful observations of the astrometrists working at professional observatories. These observers were actively involved not only in nebular astronomy — indeed, with one or two exceptions, the nebulae consumed very little of their time and attention — but in setting up the fundamental coordinate reference system which we still use today in a form little different than it was a century ago. These observations, made with precision optical micrometers, tie the positions of the nebulae into the fundamental system with random errors on the order of a few

Further reading:

Gingerich O (1988) J L E Dreyer and his NGC. Sky & Telescope, December, 621.

Sinnott R W (1988) NGC 2000.0, The Complete New General Catalogue and Index Catalogue of Nebulae and Star Clusters by J. L. E. Dreyer. Sky Publishing Corporation and Cambridge University Press.

Dreyer, continued

tenths of an arc-second. Only in the past two decades have better positions for a significant number of galaxies been determined from plates taken with astrographic telescopes.

On the other hand, there were many amateur and semiprofessional astronomers actively making discoveries. Some of these observers were well-equipped with large, solidly-mounted telescopes fitted out with modern instrumentation. Some, like Isaac Roberts, were even at the forefront of astronomical photography. Others were neither as fortunate in their observing gear, nor as careful in their observing habits. Many scanned the skies with nothing more than an eyepiece and setting circles at their disposal. Yet, they published their discoveries along side those from the professional observatories. Dreyer had to handle them all.

Thus, the NGC is a compendium of the good and the not so good. Through long experience and comparison of lists of positions from various observers, Dreyer had a good idea whose observations were trustworthy, and whose were not. He also realized the importance of not letting this information be lost (as well as simply giving credit where it's due!), so he listed the discoverers of each nebula and star cluster, and gave fairly complete references to the discovery publications.

In 1895 and 1908, he published supplements to the NGC which he called the Index Catalogues. Nearly all of the bright, large, nearby non-stellar celestial objects have entries in one of these three catalogues. Thus, the catalogue numbers — preceded by the catalogue acronyms, NGC and IC — are still frequently used by astronomers to refer to these objects.

(written by Harold G. Corwin, Jr., Ph.D., from the NGC/IC Project web pages)

NGC trivia: Which constellation has the most NGC objects? And the least?

Constellation	Number of NGC	Constellation	Number of NGC	Constellation	Number of NGC	Constellation	Number of NGC
Vir	678	Sgr	85	Aql, Cas	41		
UMa	411	Tri	82	Car, Phe	40	Pyx	13
Cet	404	Ari	81	CMa	39	Sct	12
Leo	392	Ser	75	PsA, UMi	38	Hyi, Mic,	
Eri	325	Men	74	Cep, CrB	37	Ret	11
						Vol	9
Peg	319	For	69	Vel	36	Aps, Cru	8
Psc	305	Cyg, Gem	67	Crv	35		
Dra	299	Ori	66	Lyr	34	CrA, Mus,	
Com	298	Sex	64	Lep	33	Sge, TrA	6
Dor	297	LMi	62	Tel	28	Cir, Oct	5
						Cha, Equ	4
Boo	262	Scl, Tuc	61	Cap	27		
Hya	228	Mon	59	Hor, Lac	26		
CVn, Her	214	Lib	57	Aur	24		
And	154	Pup	56	Del	22		
Aqr	142	Sco	50	Pic, Vul	20		
Cen	138	Ant, Gru, Pav	49	Lup	18		
Cnc	114	Tau	47	CMi, Col	17		
Lyn	98	Cam	45	Ara	16		
Per	95	Ind	44	Cae	15		
Crt	87	Oph	43	Nor	14		

The **NGC/IC Project** is an attempt to correctly identify all of the original NGC and IC objects, starting with the original discoverer's notes and working forward in time to encompass the work of contemporary astronomers, both professional and amateur, such that the identity of each of the NGC and IC objects is known with as much certainty as we can reasonably bring to it from the existing historical record.

[http://www.ngcic.com]

At the turn of the century, a handful of objects were added to the Index Catalogues by three observers at the then Royal Observatory, Cape of Good Hope (1883-1902).

2.5 Royal Observatory, Cape of Good Hope

Several deepsky objects were discovered at the Royal Observatory, Cape of Good Hope, around the turn of the 20th century. **R T A Innes** and **J Lunt** both recorded 7 new IC objects, while **W H Finlay** discovered three. Most of the discoveries were made with the 6- and 7-inch refractors, although the 18- and 24-inch telescopes were also used.

Object	Discoverer	Description
IC 1954[2]	Innes	10.5 mag., round, 2' diameter, near CPD –52° 414 (7" Merz refractor)
IC 2035[2]	Innes	9.8 mag, round, 10" diameter, near CPD –45° 403 (7" Merz)
IC 2042[3*]	Innes	CPD –47° 418. Nebulous star, (8.8 vis), 1' in diameter. [1897 Feb 5, 7" Merz]
IC 2056[2]	Innes	9.8 mag, round, 1' in diameter, brighter in the middle" (7" Merz)
IC 2141[2*]	Innes	9.7 mag, round, 10" in diameter, brighter in the middle" (7" Merz)
IC 2621[1]	Lunt	New (1900) 10h56m28.2s, –64°42.7' A stellar nebula found visually with the 24-inch o.g. (objective grating) prism. Mag 10-11. Immediately N.p. CPD –64°1588. Spectrum on plate 159 (12/6/ 1901), chart on plate 164 (14/6/ 1901).
IC 2949[3]	Finlay	[No description] (6 or 7-inch refractors, 1884 July 27]
IC 4291[1]	Innes	New (1875) 13h 28.6m, –61° 25'. A small round nebula about 1' in diameter, brighter towards the centre.
IC 4400[2*]	Innes	Faint, small, elongated (7" Merz)
IC 4406[1]	Innes	Cordoba DM –43°,9005. (1875) 14h14m30.8s, –43°34.2s. As seen with the 7-inch on 14/8/1901, this is a fine planetary nebula, 10 mag., about 20'' in diameter. Examined on the same night with the 18-inch telescope, it appears dumb-bell shaped. Mr J. Lunt, with the 24-inch o.g. prism found the spectrum to be that of a gaseous nebula. This nebula also appears on several Carte du Ciel plates. Plate 3689, with 1 hour exposure, shows two very elongated spindle-shaped nebulae of the same length, parallel to each other and in contact at their points of greatest condensation or brightness. Angle of elongation = 80°. The different appearances shown by the different instruments is instructive. This nebula was also found at Arequipa. See Harvard Circular No. 60, received here 22/ 8/1901.
IC 4407[3*]	Finlay	[No description; used 6 or 7-inch refractors, 1883 September 20]
IC 4490[3*]	Innes	Cor D M -35° 9764 14h36m 45s, -35° 34.7m. "elliptical neb. surrounding two stars as if they were the foci of an eclipse, mags. 9.5 and 10. The Cor. DM mag. of the chief stars is 9.7. In a high- power field with Lac. 6076. (February 1897, 7")
IC 4606[3]	Finlay	Follows a faint star 4.5 secs, and is 0.5 S (1887 September 8)
IC 4662[1]	Innes	New (1875) 17h 34.8m, -64° 37'. A faint oval nebula 1' in diameter. N.p. eta Pavonis. Found with the 7-inch.
IC 4670[1]	Lunt	New (1900) 17h 49m 6.6s, -21° 47.0' A stellar nebula found visually with the 24-inch o.g. prism. Mag 12-13. Immediately S.f. CPD -21°6502. The nebula is 2.5s pr. a slightly brighter star of the same declination. Photographed on plates 178 and 182 (24/6/1901 and 8/7/1901)
IC 4865[3*]	Innes	A faint nebula joined to, but N.p. a 9.5 mag. star. There is perhaps a stellar nucleus (11 November 1897, 7" Merz)
IC 5079[3]	Innes	Equal to a 9.7 mag star, elongated 15"; perhaps a small group of stars or a ring nebula." (26 November 1897, 7" Metz refractor)
IC 5170, IC 5171, IC 5181, IC 5201, IC 5224[1]	Lunt	Five new nebulae were picked up with the 18-inch telescope during a search for Brorsen's Comet in 1900 ... These are near the nebulae h 3924, h 3931 and h 3932.
IC 5267[3]	Finlay	[No description] (6 or 7-inch refractors, 1886 December 26]

Entries marked with an asterisk are flagged as non-existent in the RNGC. Superscript numbers indicate the discovery announcement: [1] *Monthly Notices of the Royal Astronomical Society*, Vol 62, April 1902, p 468. "Notes on Nebulae observed at the Royal Observatory, Cape of Good Hope." (communicated by Sir David Gill, KCB, FRS, HM Astronomer). [2] *MNRAS*, Vol 59, March 1899, p 339. "Nebulae observed at the Royal Observatory, Cape of Good Hope, in 1898." (communicated by David Gill, CB, FRS, &c, HM Astronomer). [3] *MNRAS*, Vol 58, March 1898, p 329. "Nebulae observed at the Royal Observatory, Cape of Good Hope." (communicated by Dr David Gill, CB, &c, HM Astronomer).

With the era of visual telescopic discoveries of deepsky objects largely behind us, observing catalogues are nevertheless still drawn up. In the 1970s South African comet hunter Jack Bennett, published two lists of comet-like deepsky objects, "shades of Messier" as he demurely put it.

2.6 Jack Bennett

For two decades, starting in the late 1960's, the southern sky was patrolled by a dedicated South African comet-hunter named Jack Bennett. He observed from his urban backyard with a 5-inch low-power refractor. Not only did he discover two comets, he also picked up a 9th magnitude supernova in NGC 5236 (M83), becoming the first person ever to visually discover a supernova since the invention of the telescope.

Jack Bennett at the eyepiece of the 12-inch Pretoria Centre telescope. It is housed in the Jack Bennett Oservatory which is on the grounds of the Christian Brothers College. On the reverse side of the original photo, in Bennett's own handwriting, is the caption: "Pretoria Centre telescope, 1977, with antiquated observer".

Bennett was born on April 6th, 1914 and passed away on May 30th, 1990. A long-standing member of the Astronomical Society of Southern Africa (ASSA), he was elected President in 1969. The Society awarded him the prestigious Gill Medal for services to astronomy in 1970 and in 1986 he received an Honorary Degree of Master of Science from the University of Witwatersrand. In 1989, at the recommendation of Rob McNaught of Siding Springs Observatory, the asteroid VD 4093 was named after him.

Bennett was a skilled observer and in the spirit of Charles Messier drew up two lists of southern objects that appeared comet-like in his telescope. His first list (Bennett, 1969) was published four months before he discovered his first comet. The supplementary list (Bennett, 1974) was followed three months later by his second discovery.

In his 1969 Presidential Address to the ASSA Bennett said: "As an aid to the recognition of comet-like objects in the Southern sky, and to help observers to eliminate them in comet searches, I have over the past five years compiled a list of 130 such objects visible south of the celestial equator. Nearly a hundred of these have been encountered under varying conditions in comet sweeps using a 5-inch short-focus refractor with a magnification of 21 diameters. The rest have been added, and duly observed with the same telescope, after consulting various sources, notably E. J. Hartung's first-rate book 'Astronomical Objects for Southern Telescopes' which includes details of the appearance in telescopes of various apertures of all but 16 of the 130 objects." Bennett's 1974 article "Some objects of interest in the southern sky" introduced 22 new comet-like objects "which had been observed (many of them repeatedly) in comet sweeps" since his first list was published. These two lists have been combined to form the Bennett Catalogue (Appendix 4, page 43). Bennett's list reads like the "Who's Who of the Deepsky". Among the 152 objects are the Tarantula, Omega Centauri, 47 Tucanae, Sombrero and the Silver Coin. Twenty-six of Messier's objects are listed. Bennett noted that including such bright objects may be unnecessary, but added: "it is surprising how easily even these can be mistaken for comets when seen at low altitudes and poor conditions."

Almost half the objects in Bennett's list are globular clusters, which makes sense since these bear a striking resemblance to comets. The constellation richest in Bennett objects is Sagittarius, followed by Ophiuchus. Bennett wrote that "the constellations Scorpio, Ophiuchus and Sagittarius . . contain a bewildering variety of comet-like objects. These are mostly globular clusters and all except the largest defy attempts to distinguish them from tailless comets. This relatively small area of sky contains about a third of all the comet-like objects visible with small telescopes south of the equator."

Dorado also contains many Bennett's – five galaxies and six clusters and nebulae. The latter lie within the Large Magellanic Cloud which, according to Bennett, "should normally be avoided like the plague by anyone looking for comets. There are, however, a few objects on the outskirts of the Clouds which are regularly encountered in comet sweeps, and these have been included in the list, if only as a warning to the observer of the perils that lie ahead of him!"

Appendix 1: Lacaille's deepsky catalogue

"**List of nebulae of the first class**. Or nebulosities not accompanied by any star visible in a telescope of two feet. ... It is possible that each of these nebulae may really be a faint comet; time did not allow me to decide, by searching the sky, to see if they remained always in the same place."

No.	RA h	m	(J2000.0) s	Dec °	′	″	Description
1–1	0	33	43	–72	4	20	It resembles the nucleus of a fairly bright small comet.
1–2	5	38	8	–69	10	6	It resembles the preceding, but it is fainter.
1–3	7	50	55	–38	35	44	Large nebulosity of 15' to 20' in diameter.
1–4	12	59	4	–70	49	24	It resembles a small comet, faint.
1–5	13	26	37	–47	29	35	Nebula in Centaurus; it appears to the naked eye like a third magnitude star seen through a thin mist, and in the telescope, like a large, ill-defined comet.
1–6	13	37	1	–29	52	59	Small, formless nebulosity.
1–7	13	46	9	–62	56	49	Small, confused spot.
1–8	16	25	17	–40	41	55	It resembles a fairly large comet without a tail.
1–9	16	23	36	–26	33	39	It resembles a small nucleus of a faint comet.
1–10	16	55	29	–39	30	49	Faint patch, oval and elongated.
1–11	18	30	2	–33	32	8	It resembles a small nucleus of a faint comet.
1–12	18	36	27	–23	57	17	It resembles the preceding.
1–13	19	27	15	–71	34	55	It resembles the preceding.
1–14	19	40	10	–30	59	10	It resembles the faint nucleus of a large comets.

"**List of nebulous stars in clusters.**"

No.	RA h	m	(J2000.0) s	Dec °	′	″	Description
2–1	4	2	53	–44	26	38	A compressed heap of about 12 faint stars of 8th magnitude.
2–2	7	26	12	–34	7	20	Heap of 8 stars of 6th–7th magnitude, which forms, to the naked eye, a nebulosity in the sky.
2–3	7	58	59	–60	49	28	Group of 10 to 12 stars, much compressed.
2–4	8	11	9	–37	12	4	Two neighboring groups of confused stars are seen by the eye but in the telescope they are faint, distinct stars, very numerous and close.
2–5	8	38	49	–53	5	3	Small heap of stars.
2–6	8	46	41	–42	15	5	Heap of seven or eight stars, slightly compressed.
2–7	10	21	23	–51	42	50	Heap of four or five stars, very small and compressed.
2–8	10	35	51	–58	12	11	Small heap of four faint stars forming a lozenge.
2–9	10	42	57	–64	23	26	The star Theta Navis, of the third magnitude or less, surrounded by a large number of stars of sixth, seventh and eighth magnitude, which make it resemble the Pleiades.
2–10	11	6	27	–58	39	12	Prodigious cluster of faint stars, very compressed, filling up in the shape of semi-circle of 20′ to 25′ in diameter.
2–11	11	22	55	–58	19	36	Seven or eight faint stars compressed in a straight line.
2–12	12	53	28	–60	22	12	Five or six faint stars between two of sixth magnitude.
2–13	16	54	9	–41	52	34	Heap of seven or eight faint compressed stars.
2–14	17	53	41	–34	48	9	Group of 15 or 20 stars, very close together, in the figure of a square.

"**List of stars accompanied by nebulosity**. ... I have not observed a single star above 6th magnitude which was surrounded or accompanied by nebulosity."

No.	RA h	m	(J2000.0) s	Dec °	′	″	Description
3–1	5	3	18	–49	28	58	Faint star surrounded by a nebulosity
3–2	8	10	49	–49	13	32	Five faint stars, in the shape of a T, surrounded by nebulosity.
3–3	8	42	21	–48	4	52	Star of 6th magnitude, connected to another more southern one by a nebulous trail.
3–4	9	27	48	–56	59	5	Faint star surrounded by nebulosity.
3–5	10	43	51	–60	6	22	Two faint stars surrounded by nebulosity.
3–6	10	44	11	–59	29	39	Large group of a great number of faint stars, a little compressed, and occupying the space of a semi-circle of 15′ to 20′ diameter; with a slight nebulosity spreading in that space.
3–7	11	36	1	–61	36	56	Three faint stars close together, enveloped in nebulosity.
3–8	14	34	56	–56	36	13	Two faint stars in a nebulosity.
3–9	15	22	21	–59	12	17	The same [as above]
3–10	16	3	27	–60	33	30	Three faint stars in a straight line, surrounded by nebulosity.
3–11	17	40	41	–53	45	40	Faint star enveloped in a nebulosity.
3–12	17	40	6	–32	15	43	Unusual cluster of faint stars, disposed in three parallel bands, forming a lozenge of 20′ to 25′ diameter and filled with nebulosity.
3–13	18	3	52	–24	24	20	Three stars enclosed in a trailing nebulosity parallel to the Equator.
3–14	21	31	27	–56	55	25	Two faint stars surrounded by nebulosity.

Positions precessed to J2000.0 from Lacaille (1755); translation of his description adapted from Jones (1969:215).

Appendix 2: James Dunlop's deepsky catalogue

Dunlop's original catalogue listed 629 objects; of these, Herschel was able to find only 142.

Recently (2001 February), Magda Streicher showed that Dunlop 410 is the same as Herschel's NGC 2547.

The remaining 486 Dunlop objects have never been verified since he first recorded them over 150 years ago.

Those objects that have been verified are shown in the table on the right. This presents a challenge to the careful deepsky observer: to discover that happened to the missing Dunlop objects.

Dunlop	NGC	Dunlop	NGC	Dunlop	NGC	Dunlop	NGC	Dunlop	NGC
1	7590	213	1974	337	1261	445	3201	562	1436
2	7599	215	2004	342	5662	454	6216	563	2546
18	104	218	2121	343	5999	456	6259	564	2818
23	330	220	2035	348	1515	457	6388	568	6400
25	346	225	6362	349	3960	466	1512	573	6723
62	362	235	1810	355	3330	469	5643	574	1380
68	6101	236	1818	356	5749	473	6541	578	2298
81	1795	240	2029	357	5925	479	625	591	1350
90	1943	241	2027	359	6031	480	1487	594	2090
98	2019	246	1831	360	6067	481	3680	600	1532
102	2058	262	6744	364	6208	482	5128	607	6652
106	2122	265	2808	366	6397	483	6192	609	2658
114	1743	272	4609	376	6584	487	1291	612	6416
129	1910	273	5281	386	3228	499	6231	613	6637
131	1928	282	5316	388	5286	507	55	614	6681
136	1966	289	3766	389	5927	508	1851	617	3621
142	2070	291	4103	397	2972	511	4709	619	6569
143	2069	292	4349	400	6167	514	6124	620	6809
160	2136	295	6752	406	7049	518	7410	623	5253
164	4833	297	3114	410	2547	520	6242	624	6715
167	1755	301	4755	411	4945	521	6268	626	2489
169	1770	302	5617	412	6134	522	6318	627	6266
175	1936	304	6025	413	6193	535	2477	628	5236
193	2159	309	3372	417	6352	536	6139		
194	2164	311	4852	425	6861	547	1317		
196	2156	313	5606	426	1433	548	1316		
201	2214	323	3532	431	5460	549	1808		
206	1313	326	6087	438	1493	552	5986		
210	1869	333	5715	440	5139	556	6281		
211	1955	334	6005	442	6204	557	6441		

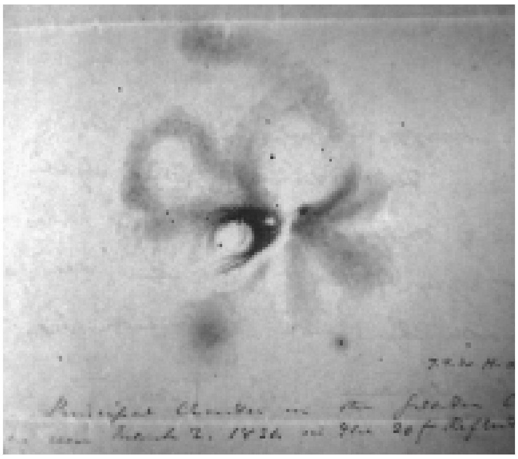
Appendix 3: Interesting stuff from John Herschel's Cape observations

Table 1. Milky Way patches

h	NGC	h	NGC	h	NGC	h	NGC
2837	1925	3117	2547	3496	5120	3684.5	—
2924	2061	3130	2609	3506	5155	3685	6360
2988	2132	3140	2669	3537	5299	3702.5	—
3042	2220	3142	2670	3625	6115	3704	6437
3070	2318	3301	3446	3643	6200	3709	6455
3080	2374	3342	3680	3660	6259	3716.5	—
3105	2483	3475	5045	3673	6322	3724	6529

Table 2. Interesting descriptions from the 'Cape Results'

h	NGC	Notes
2534	1325	like Halley's comet
2861	1963	shaped like a '3'
2878	1978	like the LMC by eye
3075	2359	like silhoutte of figurine
3083	2384	"dark interval"
3094	2439	red star
3099	2451	orange star
3111	2516	orange star
3171	2910	vacant middle
3188	2997	looks like Halley's comet
3232	3142	Halley's comet suspect
3239	3199	curved shape
3334	3603	red star
3407	4609	black space near α Crucis
3514	5189	"very strange"
3573	5662	yellow star
3582	5764	nebulous group of stars
3644	6204	rectangular cluster
–	6253	triangular open cluster
3707	6451	open cluster with dark band
3708	6453	Herschel thought it was M7
3716.5	–	between 3716/7, shaped like Cape of Good Hope



The first deepsky object John Herschel sketched during his stay at the Cape was NGC 2070, the Tarantula Nebula in the Large Magellanic Cloud. This sketch (right), made 1834 March 2, is preserved in the Cape Town Archives. See *MNASSA*, Centrepiece, August 2002 for details.

Table 3. Observing at the limit – challenging objects from the 'Cape Observations'

h	NGC	Herschel's comments
2310	28	requires attention
2311	31	requires attention
2405	482	a difficult object
2437	686	requires attention
2446	729	eeeF
2461	822	a difficult object
2519	1284	eeF, barely percept
2543	1352	very difficult
2605	1506	eeeF
2610	1516	eeeF
2879	1995	exceedingly difficult
3143	2714	difficult but certain
3210	3082	requires verification
3462	4950	barely perceptible.
3633	6164	violently suspected
3182	2953	suspected nebula

Appendix 4: The Jack Bennett Catalogue

Ben	Other	RA (J2000.0) h m s	Dec ° ′	Con
Ben 1	NGC 55	0 14 54	–39 11	Scl
Ben 2	NGC 104	0 24 06	–72 05	Tuc
Ben 3	NGC 247	0 47 06	–20 46	Cet
Ben 4	NGC 253	0 47 36	–25 17	Scl
Ben 5	NGC 288	0 52 48	–26 35	Scl
Ben 6	NGC 300	0 54 54	–37 41	Scl
Ben 7	NGC 362	1 03 12	–70 51	Tuc
Ben 8	NGC 613	1 34 18	–29 25	Scl
Ben 9	NGC 1068	2 42 42	–00 01	Cet
Ben 10	NGC 1097	2 46 18	–30 17	For
Ben 10a	NGC 1232	3 09 48	–20 35	Eri
Ben 11	NGC 1261	3 12 18	–55 13	Hor
Ben 12	NGC 1291	3 17 18	–41 08	Eri
Ben 13	NGC 1313	3 18 18	–66 30	Ret
Ben 14	NGC 1316	3 22 42	–37 12	For
Ben 14a	NGC 1350	3 31 06	–33 38	For
Ben 15	NGC 1360	3 33 18	–25 51	For
Ben 16	NGC 1365	3 33 36	–36 08	For
Ben 17	NGC 1380	3 36 30	–34 59	For
Ben 18	NGC 1387	3 37 00	–35 31	For
Ben 19	NGC 1399	3 38 30	–35 27	For
Ben 19a	NGC 1398	3 38 54	–26 20	For
Ben 20	NGC 1404	3 38 54	–35 35	Eri
Ben 21	NGC 1433	3 42 00	–47 13	Hor
Ben 21a	NGC 1512	4 03 54	–43 21	Hor
Ben 22	NGC 1535	4 14 12	–12 44	Eri
Ben 23	NGC 1549	4 15 42	–55 36	Dor
Ben 24	NGC 1553	4 16 12	–55 47	Dor
Ben 25	NGC 1566	4 20 00	–54 56	Dor
Ben 25a	NGC 1617	4 31 42	–54 36	Dor
Ben 26	NGC 1672	4 45 42	–59 15	Dor
Ben 27	NGC 1763	4 56 48	–66 24	Dor
Ben 28	NGC 1783	4 58 54	–66 00	Dor
Ben 29	NGC 1792	5 05 12	–37 59	Col
Ben 30	NGC 1818	5 04 12	–66 24	Dor
Ben 31	NGC 1808	5 07 42	–37 31	Col
Ben 32	NGC 1851	5 14 06	–40 03	Col
Ben 33	NGC 1866	5 13 30	–65 28	Dor
Ben 34	NGC 1904	5 24 30	–24 33	Lep
Ben 35	NGC 2070	5 38 36	–69 05	Dor
Ben 36	NGC 2214	6 12 48	–68 16	Dor
Ben 36a	NGC 2243	6 29 48	–31 17	CMa
Ben 37	NGC 2298	6 49 00	–36 00	Pup
Ben 37a	NGC 2467	7 52 36	–26 23	Pup
Ben 38	NGC 2489	7 56 12	–30 04	Pup
Ben 39	NGC 2506	8 12 00	–10 47	Mon
Ben 40	NGC 2627	8 37 18	–29 57	Pyx
Ben 40a	NGC 2671	8 46 12	–41 53	Vel
Ben 41	NGC 2808	9 12 00	–64 52	Car
Ben 41a	NGC 2972	9 40 18	–50 20	Vel
Ben 41b	NGC 2997	9 45 36	–31 11	Ant
Ben 42	NGC 3115	10 05 12	–07 43	Sex
Ben 43	NGC 3132	10 07 00	–40 26	Vel
Ben 44	NGC 3201	10 17 36	–46 25	Vel
Ben 45	NGC 3242	10 24 48	–18 38	Hya
Ben 46	NGC 3621	11 18 18	–32 49	Hya
Ben 47	Mel 105	11 19 39	–63 30	Car
Ben 48	NGC 3960	11 50 52	–55 41	Cen
Ben 49	NGC 3923	11 51 00	–28 48	Hya
Ben 50	NGC 4372	12 25 48	–72 40	Mus
Ben 51	NGC 4590	12 39 30	–26 45	Hya
Ben 52	NGC 4594	12 40 00	–11 37	Vir
Ben 53	NGC 4697	12 48 36	–05 48	Vir
Ben 54	NGC 4699	12 49 00	–08 40	Vir
Ben 55	NGC 4753	12 52 24	–01 12	Vir
Ben 56	NGC 4833	12 59 36	–70 53	Mus
Ben 57	NGC 4945	13 05 24	–49 28	Cen
Ben 58	NGC 4976	13 08 36	–49 30	Cen
Ben 59	NGC 5061	13 18 06	–26 50	Hya
Ben 59a	NGC 5068	13 18 54	–21 02	Vir
Ben 60	NGC 5128	13 25 30	–43 01	Cen
Ben 61	NGC 5139	13 26 48	–47 29	Cen
Ben 62	NGC 5189	13 33 30	–65 59	Mus
Ben 63	NGC 5236	13 37 00	–29 52	Hya
Ben 63a	NGC 5253	13 39 54	–31 39	Cen
Ben 64	NGC 5286	13 46 24	–51 22	Cen
Ben 65	NGC 5617	14 29 48	–60 43	Cen
Ben 66	NGC 5634	14 29 36	–05 59	Vir
Ben 67	NGC 5824	15 04 00	–33 04	Lup
Ben 68	NGC 5897	15 17 24	–21 01	Lib

Jack Bennett Catalogue, continued

Ben	Other	RA (J2000.0) h	m	s	Dec °	′	Con
Ben 69	NGC 5927	15	28	00	–50	40	Lup
Ben 70	NGC 5986	15	46	06	–37	47	Lup
Ben 71	NGC 5999	15	52	12	–56	28	Nor
Ben 72	NGC 6005	15	55	48	–57	26	Nor
Ben 72a	Tr 23	16	01	30	–53	32	Nor
Ben 73	NGC 6093	16	17	00	–22	59	Sco
Ben 74	NGC 6101	16	25	48	–72	12	Aps
Ben 75	NGC 6121	16	23	36	–26	32	Sco
Ben 76	NGC 6134	16	27	42	–49	09	Nor
Ben 77	NGC 6144	16	27	18	–26	02	Sco
Ben 78	NGC 6139	16	27	42	–38	51	Sco
Ben 79	NGC 6171	16	32	30	–13	03	Oph
Ben 79a	NGC 6167	16	34	24	–49	36	Nor
Ben 79b	NGC 6192	16	40	18	–43	22	Sco
Ben 80	NGC 6218	16	47	12	–01	57	Oph
Ben 81	NGC 6216	16	49	24	–44	44	Sco
Ben 82	NGC 6235	16	53	24	–22	11	Oph
Ben 83	NGC 6254	16	57	06	–04	06	Oph
Ben 84	NGC 6253	16	59	06	–52	43	Ara
Ben 85	NGC 6266	17	01	12	–30	07	Oph
Ben 86	NGC 6273	17	02	36	–26	16	Oph
Ben 87	NGC 6284	17	04	30	–24	46	Oph
Ben 88	NGC 6287	17	05	12	–22	42	Oph
Ben 89	NGC 6293	17	10	12	–26	35	Oph
Ben 90	NGC 6304	17	14	30	–29	28	Oph
Ben 91	NGC 6316	17	16	36	–28	08	Oph
Ben 91a	NGC 6318	17	17	48	–39	27	Sco
Ben 92	NGC 6333	17	19	12	–18	31	Oph
Ben 93	NGC 6356	17	23	36	–17	49	Oph
Ben 94	NGC 6352	17	25	30	–48	25	Ara
Ben 95	NGC 6362	17	31	54	–67	03	Ara
Ben 96	NGC 6388	17	36	18	–44	44	Sco
Ben 97	NGC 6402	17	37	36	–03	15	Oph
Ben 98	NGC 6397	17	40	42	–53	40	Ara
Ben 98a	NGC 6440	17	48	54	–20	22	Sgr
Ben 98b	NGC 6445	17	49	12	–20	01	Sgr
Ben 99	NGC 6441	17	50	12	–37	03	Sco
Ben 100	NGC 6496	17	59	00	–44	16	CrA
Ben 101	NGC 6522	18	03	36	–30	02	Sgr
Ben 102	NGC 6528	18	04	48	–30	03	Sgr
Ben 103	NGC 6544	18	07	18	–25	00	Sgr
Ben 104	NGC 6541	18	08	00	–43	42	CrA
Ben 105	NGC 6553	18	09	18	–25	54	Sgr
Ben 106	NGC 6569	18	13	36	–31	50	Sgr
Ben 107	NGC 6584	18	18	36	–52	13	Tel
Ben 107a	NGC 6603	18	18	24	–18	25	Sgr
Ben 108	NGC 6618	18	20	48	–16	11	Sgr
Ben 109	NGC 6624	18	23	42	–30	22	Sgr
Ben 110	NGC 6626	18	24	30	–24	52	Sgr
Ben 111	NGC 6638	18	30	54	–25	30	Sgr
Ben 112	NGC 6637	18	31	24	–32	21	Sgr
Ben 112a	NGC 6642	18	31	54	–23	29	Sgr
Ben 113	NGC 6652	18	35	48	–32	59	Sgr
Ben 114	NGC 6656	18	36	24	–23	54	Sgr
Ben 115	NGC 6681	18	43	12	–32	18	Sgr
Ben 116	NGC 6705	18	51	06	–06	16	Sct
Ben 117	NGC 6712	18	53	06	–08	42	Sct
Ben 118	NGC 6715	18	55	06	–30	29	Sgr
Ben 119	NGC 6723	18	59	36	–36	38	Sgr
Ben 120	NGC 6744	19	09	48	–63	51	Pav
Ben 121	NGC 6752	19	10	54	–59	59	Pav
Ben 122	NGC 6809	19	40	00	–30	58	Sgr
Ben 123	NGC 6818	19	44	00	–14	09	Sgr
Ben 124	NGC 6864	20	06	06	–21	55	Sgr
Ben 125	NGC 6981	20	53	30	–12	32	Aqr
Ben 126	NGC 7009	21	04	12	–11	22	Aqr
Ben 127	NGC 7089	21	33	30	–00	49	Aqr
Ben 128	NGC 7099	21	40	24	–23	11	Cap
Ben 129	NGC 7293	22	29	36	–20	48	Aqr
Ben 129a	NGC 7410	22	55	00	–39	40	Gru
Ben 129b	IC 1459	22	57	00	–36	28	Gru
Ben 130	NGC 7793	23	57	48	–32	35	Gru

Appendix 5: Abbreviations sometimes used in deepsky descriptions

app	appended
att	attached
A	arm
Af	form of the Nebula in Andromeda
b	brighter
bet	between
biN	binuclear
br	broad
B	bright
c	considerably
ch	chevelure (French: 'head of hair)
co	coarse, coarsely
com	cometic
cont	in contact
conn	connected
C	compressed
Ch	chain
d	diameter
def	defined
dif	diffused
diffic	difficult
dist	distance, distant
D	double
e	extremely, excessively
ee	most extremely
ell	elliptic
exc	excentric
E	extended
f	following
F	faint
g	gradually
gr	group
h	homogeneous
i	irregular
inv	involved, involving
iF	irregular figure
l	little (as adverb), long (as adjective)
L	large
m	much
mn	milky nebulosity
M	middle
n	north
neb	nebulous
nr	near
nw	narrow
N	nucleus
Neb	nebula
p	preceding
p	pretty (befpre R, F, B, L, S, etc.)
pg	pretty gradually
pm	pretty much
ps	pretty suddenly
P	poor
quad	quadrilateral
quar	quartile
R	round
RR	exactly round
s	suddenly, south
sev	several
susp	suspected
sh	shaped
stell	stellar
S	small
sm	smaller
tri N	trinuclear
trap	trapezium
v	very
vv	very, very
var	variable
W	wing
*	a star
*10	a star of 10th magnitude
**	double star
!	remarkable, !! very much so, etc.
st 9...13	stars from 9th to 13th magnitude

Appendix 6: Star colours

"Every tint that blooms in the flowers of summer, flames out in the stars as night"
– John D Steele, 1869

Looking for colours in stars can be a rewarding exercise, demonstrating not only the variety found in stars, but also highlighting the differences between observers.

Paul Merrill (1955) writes: "The stars exhibit a beautiful range of colour, even to the naked eye. The ruddy Betelgeuse presents a fine contrast to Rigel, its bluish neighbour in the constellation Orion. The ancients gave the name Antares to the fixed star Alpha Scorpii on account of its resemblance to the red planet Mars."

"The subject of star colours is fascinating as well as controversial. It is well known that hues assigned to double stars are often widely discordant and even bizarre. Involved are such complex factors as telescope optics, atmospheric conditions, contrast, colour perception, and the observer's 'preconditioning' from published descriptions."
– John Mullaney

An excellent overview of colour perception in astronomy may be found in Philip Steffey's (1992) article. He writes: "To the unaided eyes about 150 stars, mostly giants or supergiants of late spectral type (G, K and M), exhibit colours other than plain white or grey. Among the brightest 30 or so, in which colours appear the most distinct, the only definite hues are yellowish oranges, yellows, and pale blues. True reds appear only in a few objects visible with optical aid, principally carbon stars."

Glimpsing elusive star colours

While looking for colour in brighter stars, try shaking your binoculars. The vibration spreads out the image across the field of vision, blurring it and making the colours more easily visible. And, of course, don't use averted vision! Similar advice is offered by Mitton and MacRobert (1989), who say that colours in the brighter stars may become more apparent if you defocus your eyes to turn the stars into small disks.

Colours in double stars

Colour index: the higher the colour index, the more orange the star appears. Negative values are blue ... Colour index is defined as B–V, where B and V are magnitudes measured photoelectrically through standard blue and "visual" filters. *Sky & Telescope*, **84**(3), 273.

"Double stars have long been appreciated for their often gemlike colours. When two stars of contrasting hues are seen side by side, colour difference becomes very plain," note Mitton and MacRobert (1989). Check out their table "Some Vivid Double Stars of William Henry Smyth" for observing suggestions.

Colours in single stars

The table below, arranged by RA, lists stars brighter than 4th magnitude, that have a B-V greater than +1.6, and that lie south of declination +6°.

Star	V	B-V	RA (J2000.0)	Dec
Alp Cet	2.53	+1.64	03 02 16	+04 05.4
Tau4 Eri	3.69	+1.62	03 19 31	–21 45.5
Gam Hyi	3.24	+1.62	03 47 14	–74 14.3
Omi1 CMa	3.87	+1.73	06 54 07	–24 11.0
Sig CMa	3.47	+1.73	07 01 43	–27 56.1
Pi Pup	2.70	+1.62	07 17 08	–37 05.8
Lam Vel	2.21	+1.66	09 07 59	–43 25.9
Sig Lib	3.29	+1.70	15 04 04	–25 16.9
Alp Sco	0.96	+1.83	16 29 24	–26 25.9
Zet Ara	3.13	+1.60	16 58 37	–55 59.4
Bet Gru	2.10	+1.60	22 42 40	–46 53.1
Lam Aqr	3.74	+1.64	22 52 36	–07 34.8

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