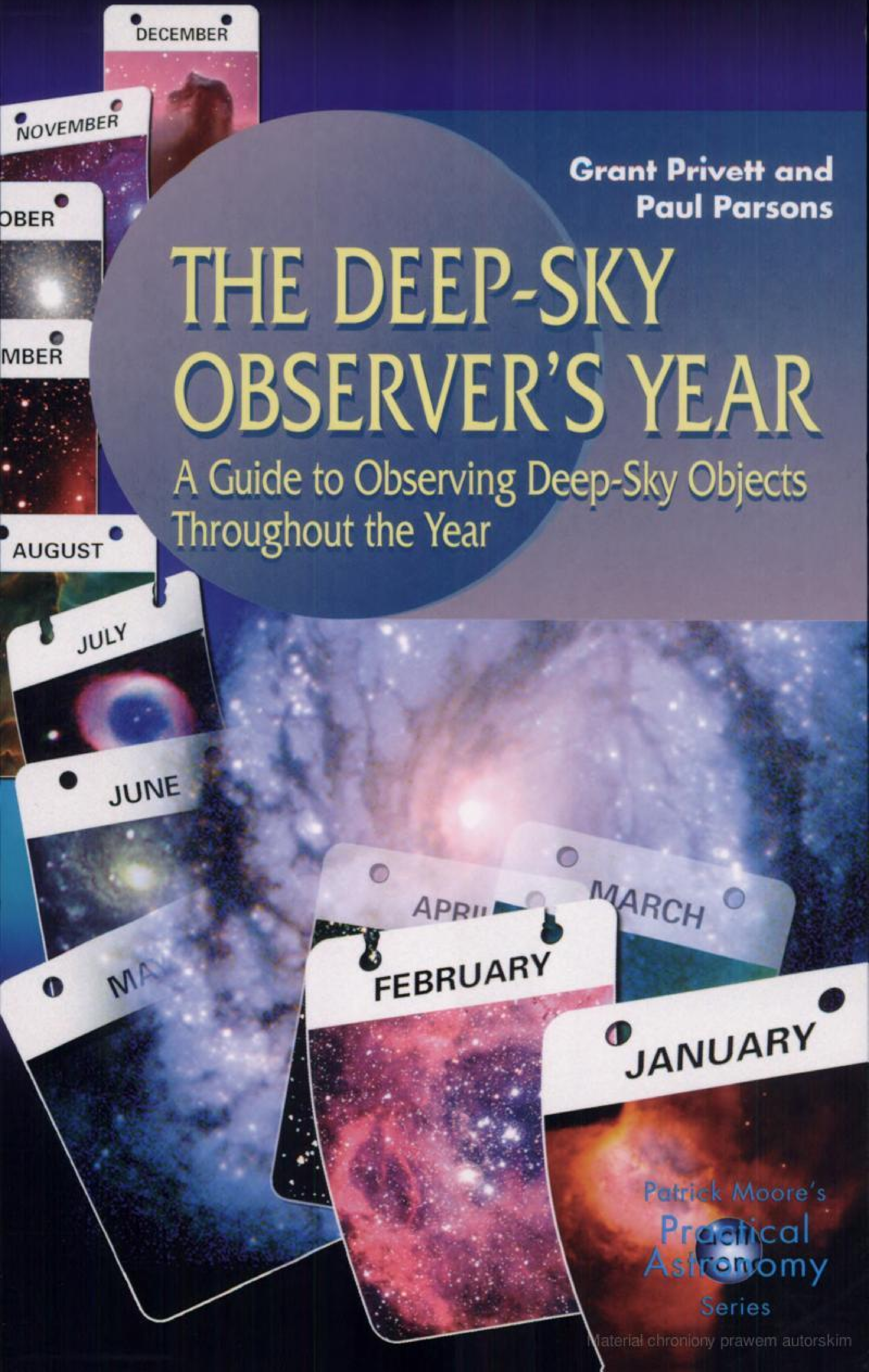
Grant Privett and
Paul Parsons

THE DEEP-SKY OBSERVER'S YEAR

A Guide to Observing Deep-Sky Objects Throughout the Year



Patrick Moore's
Practical
Astronomy
Series

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Part I

Preparing for Deep-Sky Observing

Chapter 1

Introduction

The world sometimes seems to be divided into two groups of people: those who look up at the sky, and those who do not. Many people, perhaps the majority in the industrialised West, will go through their entire lives without raising their heads to the sky and *really* looking. For them the planets, the Moon and the galaxies will always remain references in a book or the backdrop upon which the likes of Ellen Ripley or Luke Skywalker will play out their adventures. But, for some, the stars are very real and close to hand, the planets old friends and the galaxies quarry to be admired, revisited or pursued as spare time permits. These are the people who call themselves astronomers. For them the dark isn't something to be feared and held at bay with security lights, but instead an experience to be cherished and revelled in for the beauty it holds and the wonder it inspires.

Although it sometimes seems as though there is little peace in the world, especially in the cities and urban sprawl that for many of us are home, astronomers alone know the tranquillity that's to be found in the predawn hours, when the hum of the world is at its lowest and a hush descends. Whether gazing upwards from a garden chair at the Milky Way arcing overhead, or seeking out obscure glimmers of light from far away across the Universe, this is when, if you are an astronomer, you become truly alive. The worries and distractions of day-to-day living seem to melt away. And for a while at least, it is just you, alone with the Universe.

Sadly, for most of us, these moments come rarely. Cloud is the astronomer's worst enemy, closely followed by light pollution. And even when the sky outside may be clear and dark, and the heavens clearly visible, real life often conspires to spoil things. It presents us with visiting relatives, recalcitrant children or simply fatigue that leads to an early bed. So, for the majority of observers, making the most of every available night is of the utmost importance. This becomes very much easier if you have a guide to show you what's on offer each night.

For planetary and lunar observers this is quite straightforward. There aren't that many objects to see, and finding them is trivial. But for observers of deep-sky objects the situation is rather different. Galaxies and nebulae are often faint, making them tough to find and not always rewarding to observe. Not only that, there are many hundreds of objects, and so it's difficult to know where to start. If you wanted to, you could observe every one of the thousands of deep-sky objects described in the *New General Catalogue* (*NGC*) of nebulae and clusters of stars, but that would be rather like looking at every blade of grass in a field to find a single flower. Yes, you can do it, but why bother when leisure time is short – at least for those of us lacking winning lottery tickets – and help is at hand.

This book is a one-stop guide to deep-sky astronomy. It cuts out the dross and presents data and observing tips for the objects most worth looking at in an easily accessible form. By flicking through these pages you should be able to find something interesting to observe every night of the year, whether you are equipped with a pair of 10 × 50 binoculars or a hernia-inducing 24-inch Dobsonian telescope.

The early chapters describe hardware, observing techniques and resources available to the modern amateur, with discussion of their relative advantages or limitations. The later chapters provide a month-by-month selection of the best targets for the deep-sky observer, with advice on how to see them, together with some finder charts and images.

We have organised the month-by-month guide so that for each object we cover a detailed description appears for the month in which it's most prominently placed in the sky (i.e. highest above the horizon at midnight). For example, M31, the Andromeda Galaxy, is best viewed in October, when the constellation Andromeda is high in the sky. Of course, many objects are reasonably well placed for viewing during several months of the year. However, to avoid repetition (not to mention high printing costs and tree consumption) we have confined our discussion of all but the brightest objects to one chapter only.

We have also included a chapter detailing just what the various types of deep-sky object really are. So if, for example, after looking through the scope at the Seyfert galaxy M77, you are curious as to what it is that makes a Seyfert galaxy different from any other, then the information is close to hand.

Compiling the monthly chapters has been difficult. It's simple to say glibly that each chapter tells you what there is to observe during a particular month. But with over 100 objects identified by Charles Messier and more than 7,000 NGC objects to choose from, it would be a simple matter to provide in excess of 500 noteworthy objects a month and still ignore fainter galaxies, dark nebulae, Abell galaxy clusters, quasars and Palomar globular clusters. Clearly, tough decisions have been made to prevent the book growing into a hefty tome, better suited to unarmed combat than deep-sky astronomy.

The problem is compounded by the fact that not all astronomers will agree which objects fall into the "must see" category, and which are simply not worth the effort on a frozen February night. All would agree that the Orion Nebula and the Andromeda Galaxy must be included, but what about NGC7023 and NGC7510 – which would you prefer? Or, is a 14th magnitude Abell cluster in Hercules better than a small 12th magnitude planetary nebula in Cygnus? Where do you draw the line?

Figure 1.1
NGC7023, a lovely reflection nebula in Cepheus. © Grant Privett

Most people observe from their garden or back yard. And so our greatest selection bias has been for objects that attain a respectable distance above the horizon, as viewed from suburban locations with latitudes above 45° north. The details will vary from observer to observer, but most will have at least some portion of their sky view obstructed. For instance, one of the authors (GJP) cannot see the Helix Nebula, in Aquarius, from his garden; it can only be seen from an upstairs bedroom window using binoculars to look out across the rooftops of adjacent houses. And if the trees nearby grow a few more feet even this view will vanish. Light pollution is another altitude-limiting factor. Even if you could see through the house next door, many targets are simply too low to observe because of the creeping glow from street lights. Deep-sky astronomers can combat light pollution to some extent by employing suitable filters.

The upshot of all this is that we have chosen to give short shrift to most objects with a declination of less than −25°. A notable casualty is the splendour of the Sculptor Galaxy group.

In the same way that it's impossible to tell a joke without offending someone, somewhere, it's impossible to compose a list of targets to observe without leaving out someone's favourite. For instance, one of us (GJP) has something of a soft spot for NGC7023, but is less than impressed by the rather better-known Owl Nebula (M97). Not everyone shares this view and inevitably there will be objects we have missed out that some of you will consider essential viewing. All we can say is that we have done our best in the space available and apologise for anything you believe us to have wrongly omitted. If you should spot any glaring oversights, why not let us know, so they can be considered for inclusion in a future edition?

Hopefully, though, these pages will provide you with plenty of deep-sky targets to keep you occupied for a few years. Whatever you choose to observe, have fun.

Chapter 2

Deep-Sky Observing

Binoculars

What Do You Need?

Unfortunately, whilst it's possible to observe meteors or aurorae without purchasing equipment any more complicated than a pen and paper, observing deep-sky objects does require some kind of optical aid. And binoculars are the most inexpensive and readily available form this can take. The good news is that almost any binoculars – with the exception of trendy compact designs – are worth having. The most important single attribute of a pair of binoculars is the size of the objective lenses, which defines how much light they can collect. The other important attribute is, obviously, magnification, which determines the amount of detail that you will be able to make out in target objects. The sizes that you will commonly find are: 10×50, 10×60 and 12×80 – the first number is the magnification, the second is the size of the objective lens in millimetres. All of these are very suitable for deep-sky work.

Another important point to look for in a pair of binoculars is whether the lenses have anti-reflection coatings. These ensure that most of the light reaching the binoculars is transmitted to your eyes and so help you see fainter magnitudes. Some cheaper makes have only the front lens coated, meaning that you will not see as many faint objects as you would with fully coated surfaces. The difference can be a significant fraction of a magnitude. Check the specification before buying.

Figure 2.1 M17, the Omega nebula, in Sagittarius. © AURA/NOAO

Hand-shake is another major factor limiting the faintness of the objects you can see, so consider carefully the weight of the binoculars before you buy. How will they feel in two hours' time? If they are quite heavy, look for a pair with a tripod fixing point or make a suitable fitting yourself. Making a tripod mount or tripod adapter can be time consuming, but it will not be beyond most reasonably able DIY enthusiasts. After all, what are cloudy nights for?

Using Binoculars

Using binoculars to observe galaxies and clusters is very different from using them in daylight. In daylight, it's easy to identify what you are looking at and so determine whether you need to move left, right, up or down to go where you want. But if you point binoculars at Cygnus and find a field crowded with 7th and 8th magnitude stars it is very unlikely that you will immediately recognise it and know in which direction to go to find your target. To improve your chances, practise finding several bright stars without having to sweep the binoculars back and forth across the sky. Gaining this experience should greatly reduce the time wasted searching for fainter objects.

Stars are easier to find than faint galaxies and nebulae. For this reason, the best way to locate deep-sky objects is often by finding a nearby bright star as a starting point and then moving towards your quarry by moving from star to star. This star hopping requires a good star atlas though, such as those produced by Wil Tirion.

What Can You Observe with Binoculars?

The simple, and rather surprising answer is that even with a battered, secondhand pair of 10 × 50s you can observe a lot. The main constraint is the amount of light collected by the objective lens of your binoculars. A pair of 8 × 40s will only be able to see stars down to about 9th magnitude, while on a good night those fortunate people brandishing 20 × 80s will probably see objects of 12th magnitude if the binoculars are firmly held or tripod-mounted.

You will be restricted by how dark your observing site is and how much practice you've had. It's probably fair to say that at a given site an experienced observer will be able to see about 0.5–1.0 magnitudes fainter than a beginner – their grip will be steadier, they will be practised at using averted vision (looking slightly to the side of an object so that its light falls on more sensitive parts of the retina) and will take dark adaption more seriously.

With a pair of 10 × 50s you will, from a moderately light-polluted site, be able to see many Messier objects, a number of NGCs and lots of wider-angle star patterns, or asterisms. Clearly, there is a need to be realistic. You are never going to see quasars, gravitational lenses or black holes through binoculars. But without too much trouble, you should be able to pick out 100+ of the brighter objects like M42 (the Great Orion Nebula), the beautiful blue Pleiades star cluster in Taurus and M31 – the Andromeda Galaxy.

With practice, you can move on to fainter quarry. The face-on spiral galaxy M33, in Triangulum, is 1° across, making it easily locatable with binoculars. How about M51, the Whirlpool Galaxy in Ursa Major, so beloved of coffee-table astronomy books? M92 in Hercules? Telescope only? Think again. They are not as hard to see as you might expect.

Once you are experienced, why not seek out M81, the Seyfert galaxy M77 or even the Veil Nebula in Cygnus? They can be seen with binoculars, but require a good dark site and that your eyes have avoided exposure to light for at least 40 minutes. If serious (and monied), you can purchase filters (see telescope section) to enhance the contrast of objects against the night sky, and so help you go after fainter and more challenging objects like Barnard's Loop, in Orion, or the California Nebula.

To summarise: observing deep-sky objects is not restricted to owners of telescopes; much can be achieved with the humblest of optical aids. Fine detail may not be visible in what you observe through binoculars, but the satisfaction of selecting, locating and looking at a distant conglomeration of stars or a cloud of interstellar gas can be achieved from your garden for a relatively small outlay of money.

Accessories

Unlike telescopes, binoculars are fairly self-contained. You do not need finderscopes, motorised drives or a range of eyepieces. When it comes down to it, all you need to do is stand in the garden and look at the sky. But that can be a problem. If you want to look at a star field overhead you will quickly get a stiff neck. This discomfort can be avoided by using a garden lounger or deckchair to recline on, leaving your neck at a much more comfortable angle to observe the sky. A chair has the added advantage that you can easily drape a sleeping-bag over yourself, thereby making long winter observing sessions more tolerable. A useful alternative to a recliner is a camping ground sheet and foam mat. They are surprisingly comfortable!

Finally, it seems unfair to leave the subject of binoculars without mentioning a range being manufactured by Canon (other companies are now following) that employ camcorder technology to reduce the effect of hand-shake. Once you have found your target, pressing a small button tells the binoculars that you want the current image to hold still. Thereafter they sense the movement caused by trembling and modify the light path to compensate for it. Reports indicate that this

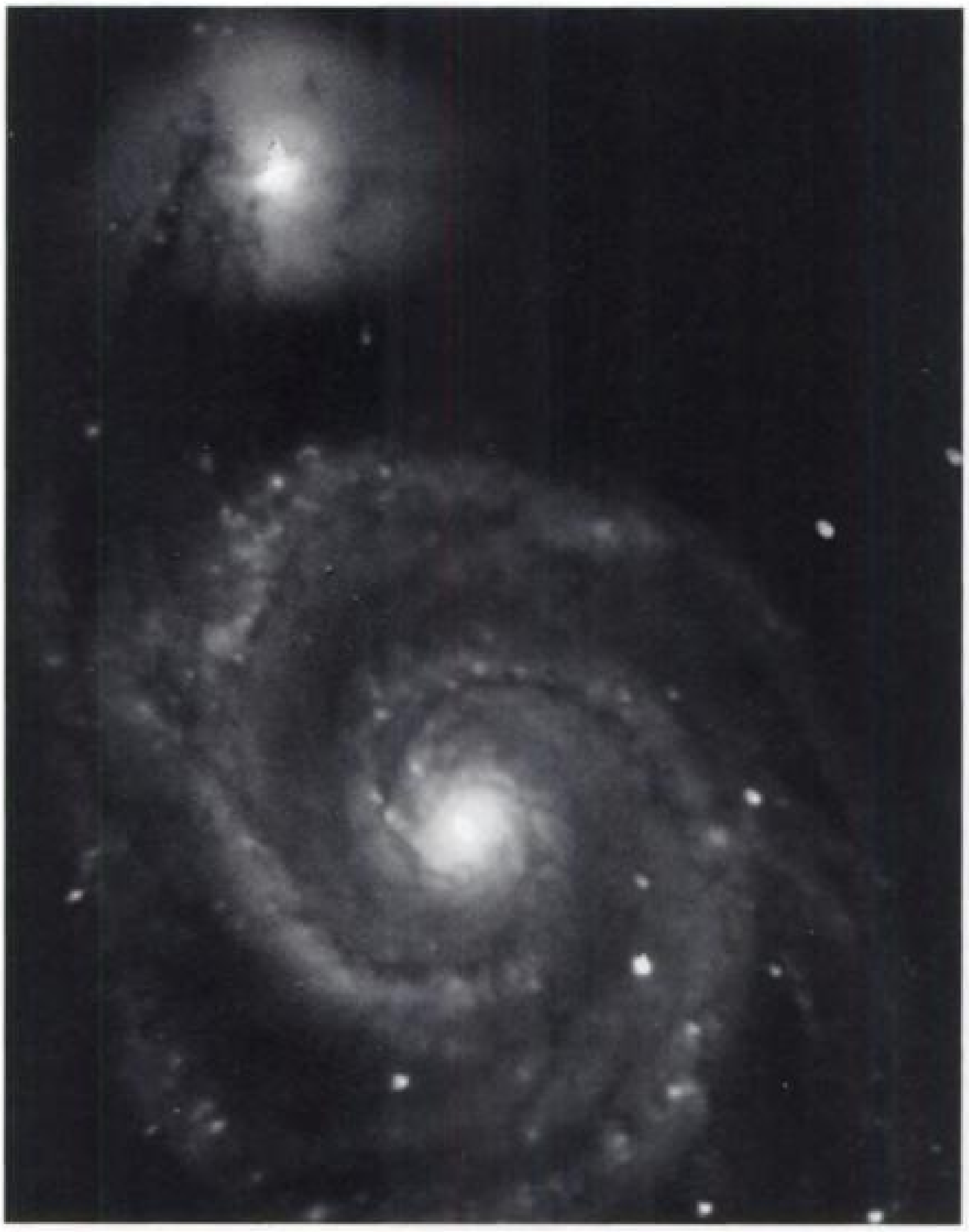


Figure 2.2 The Whirlpool galaxy, M51, from the Lowell Observatory.
© W.C. Keel

leads to rock-steady views, which must inevitably mean that you can see fainter objects. The down side is that the 10 × 45 version sells for around £700 ($1100) and that they get through batteries at a speed. It is probable, however, that the price will drop substantially with time.

Telescopes

Many amateurs, having becoming experienced with binoculars, choose to move on to a telescope. For others, the telescope will be their first piece of astronomical equipment.

As with binoculars, the most important feature of any telescope is its ability to gather light. Broadly speaking, the bigger the aperture, the brighter galaxies or nebulae will appear at the eyepiece. For deep-sky observing, where most of what you look at is intrinsically faint, you will clearly need to use a telescope of the largest aperture available. Commonly found apertures are: 75, 100, 150, 200, 250, 300, 400 and 450 mm (3, 4, 6, 8, 10, 12, 16, 18 inches respectively). But be warned – large telescopes are frequently heavy, unwieldy and expensive.

Types

Telescopes come in two different types: reflectors and refractors. The choice between them is made easier by the fact that, inch-for-inch, refractors are rather more expensive, costing up to twice as much as a reflector of similar aperture.

True, the refractor usually has a light grasp slightly superior to that of a reflector of equal aperture and is normally a touch better at resolving fine detail – under good seeing conditions. But the additional cost will be prohibitive for many people and has made the market for instruments of greater than 175 mm aperture quite small. On the plus side, however, the high-quality, low-focal-ratio apochromatic refractors made by the likes of Takahashi and Astro-Physics, provide great views with little false colour and have become the system of choice for many serious film-based astrophotographers – as browsing through *Sky & Telescope* magazine will testify. At smaller apertures Celestron, Meade, Vixen, Tele Vue and Parks also make worthwhile instruments.

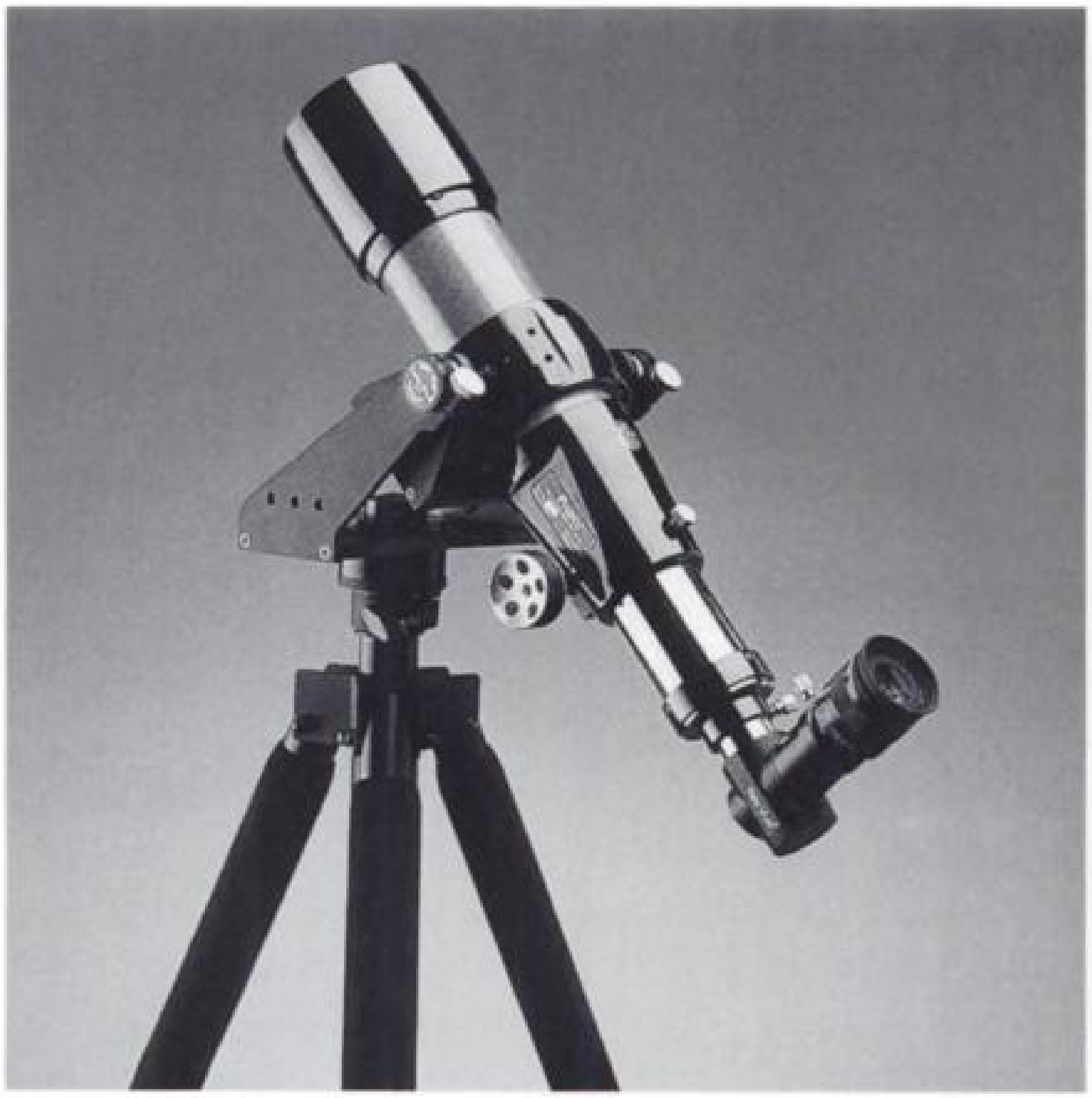


Figure 2.3 The popular Tele Vue Pronto. © SCS Astro

Reflectors are available in a number of different mirror configurations of which Newtonians and Schmidt–Cassegrains (SCTs) are probably best suited to deep-sky observing. The overriding concern for any type of scope is the quality of the optics. A slightly distorted mirror surface – and the distortion need only be a fraction of a micron (thousandth of a millimetre) – can make the difference between crisp diffraction-limited images and views that are reminiscent of looking through the bottom of a wine bottle. The deviation of a mirror from the perfect shape is often expressed as a fraction of the wavelength of light. So the mirror figuring accuracy might be quoted as being, say, $\frac{1}{4}$-wave accuracy, which would be of adequate quality for most observing. Some manufacturers, particularly those of instruments with mediocre optics, blur (sorry) the truth by not telling you if they mean $\frac{1}{4}$-wave is the largest deviation of the mirror from the perfect shape in *both* directions or just in one.

For reference, a $\frac{1}{2}$-wave accuracy mirror is unacceptable, whereas a $\frac{1}{8}$- or $\frac{1}{10}$-wave mirror is of high quality and suitable for any observing. This will be reflected in the price.

One aspect of a telescope that may prove important to you is the focal ratio, usually denoted F. This is a ratio between the focal length of the telescope and the width of the main mirror or lens. Commonly, values for refractors vary from F7 to F20, and reflectors from F4 to F10. Values at the upper end of these ranges will have smaller fields of view and longer telescope tubes. Tube length can be a problem for larger aperture Newtonian scopes and refractors because the tube must be approximately the same length as the mirror focal length. So, an F8 250 mm scope will have a 2 m tube, which means you have to stand on a stool to observe an object overhead. This problem does not apply to SCTs, where a hyperbolic secondary mirror passes the light back along the length of a short tube, making them roughly half the length of a Newtonian of the same focal ratio.

You might think that using an F3 mirror would cure the problem of unwieldy tubes, but that causes its own problems. Firstly, the secondary mirror has to be much larger, which means it obstructs the light getting into the telescope and degrades the image. Secondly, such low-focal-ratio optics tend to produce distorted star images (coma) at the edge of the field of view. Because of this, F4.5 scopes are quite common, but smaller ratio scopes are rare. Some observers even baulk at using F4.5 scopes for fear of poor image quality and some astrophotographers shun them because of unacceptable coma at the 35 mm field edge.

All reflector scopes have to be carefully collimated, to ensure that the mirrors are properly aligned with respect to the eyepiece and each other. This can be quite a task. Fairly accurate collimation can be achieved by inspection, using an eyepiece consisting of a solid plug of metal with a hole drilled through the centre, and lining up the optics as seen through the pinhole. The high-tech alternative is to buy a laser collimator. The former is cheap and will provide generally acceptable optical alignment. However, for a low-focal-ratio system, or if you want your scope *perfectly* aligned, a laser collimator such as the Lasermax is a great boon. It fits in the eyepiece mount and shines a beam (or beams in some cases) down the tube. The beams should hit the centre of the secondary mirror and then the centre of the primary and then bounce back to a hole in the collimator. If this is not the case, the beam path can be adjusted accordingly using mirror cell or the secondary mirror adjustments: a superbly simple and elegant idea. Unfortunately, laser collimators are still quite expensive at £100 or more but very useful for the demanding imager.

Mounts

There is little point in spending large amounts of money on a $\frac{1}{8}$-wave 300 mm mirror if the mount it is to be supported on bows under the weight, shakes in a gentle breeze or only tracks in jerks. The ideal telescope mount should be robust, smooth moving, vibration free, highly stable, easy to align/set up, lightweight and cheap to maintain. Well, we can dream. But several respected designs exist and in some cases you can significantly improve your scope by changing the mount.

Perhaps the most popular mount is the Dobsonian. In its most familiar format this comes in three parts. The first is a solid-walled telescope tube of either square or round cross-section. The tube assembly is supported on a cradle that allows the scope to be raised or lowered in altitude on a plastic ring and PTFE runners. The final part is a rotating flat table on which the cradle rests. This allows the telescope to be rotated around the sky in azimuth. The main drawbacks are that following an

Figure 2.4 A Dobsonian scope combines portability and aperture with reasonable prices. © David Hinds

object as it moves across the sky requires adjustments about two axes and imaging requires the use of a specialist device to compensate for the field rotation as the object moves across the sky. The plus side is that if you can work out which end of a hammer is used to hit things, they are easy to make, can be quickly disassembled to fit in the back of a small car and offer the biggest possible light gathering power for the money available. Those seeking further information on this type of mount might care to have a look at the *Obsession Telescopes* (http://www.globaldialog.com/~obsessiontscp/) web site which contains a wealth of information.

Another popular design is the familiar fork mount, beloved of Meade and Celestron. The tube is mounted between two arms which are supported on a shaft, the axis of which is inclined at an angle equal to the local latitude and aligned with the celestial pole. This simple mount design has the great advantage that once you have levelled the mount, aligned the main shaft with the Pole Star and rotated the fork to bring your target into view, you can follow it for the rest of the night

Figure 2.5 The classic 200mm SCT workhorse in a fork mount. © David Hinds

merely by moving the fork about the main axis. This design is very popular with Maksutov and SCT manufacturers as the compact length of the SCT tube means that the forks do not need to be very long and tube counterweights aren't needed. Because of its simplicity, the design lends itself to the skilled DIYer, particularly those who want to mount a large scope in a fixed location. The disadvantage is that when disassembled the fork and tube cannot normally be easily separated, so you may end up with 30 kg of expensive scope in your arms when disassembling.

An equatorial mount design also has an axis inclined at an angle equal to your latitude and aligned with the celestial pole, but the other (orthogonal) axis has a shaft on it with the telescope attached to one end and a counterweight on the other. This is probably the most common design for Newtonians and can be found in its modern form as the well respected Great Polaris (an inexpensive design now frequently cloned by Far

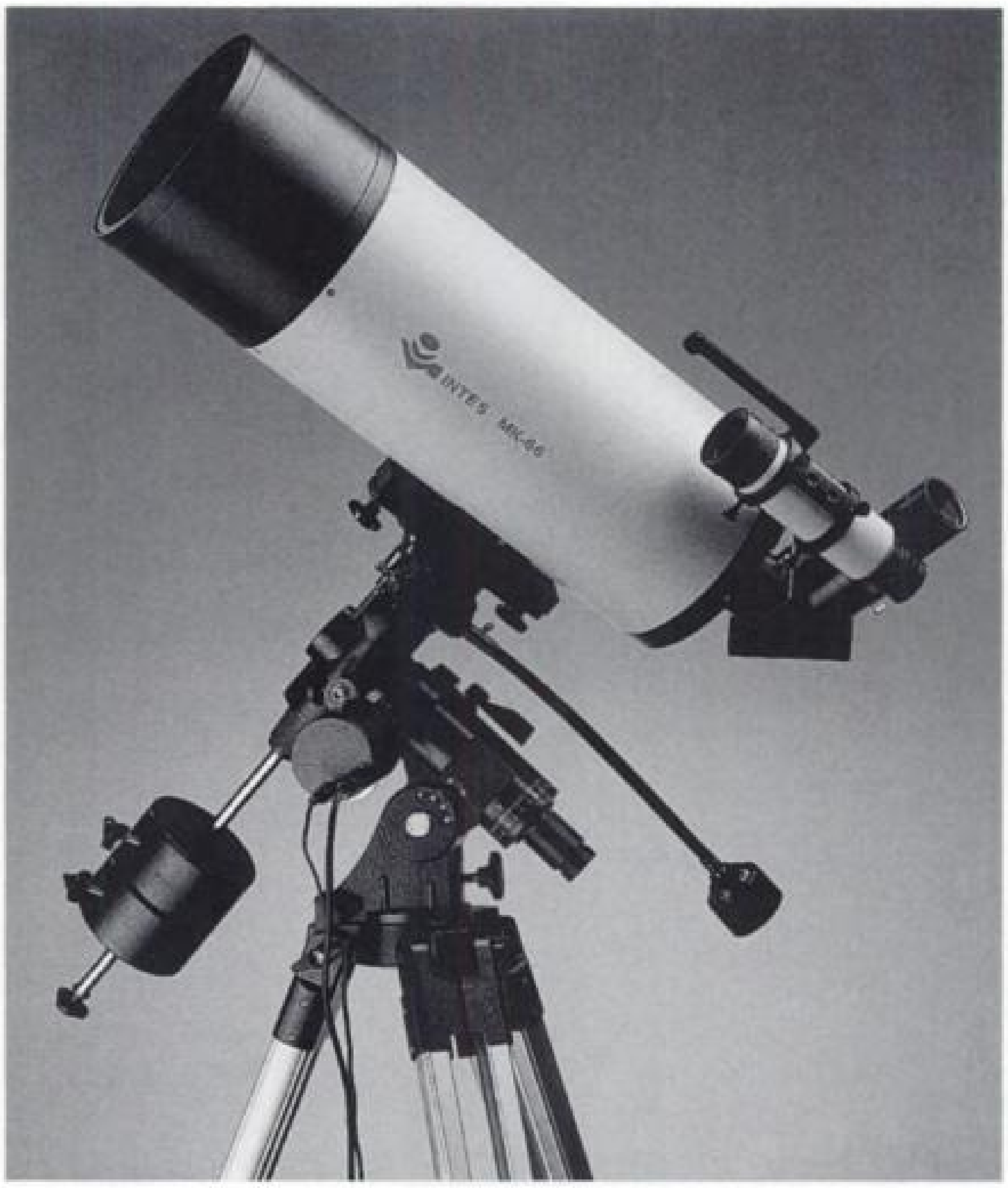


Figure 2.6 The Intes Mak Cassegrain. © SCS Astro

Eastern companies), the more up-market Losmandy and expensive Paramount designs. In the first two mounts celestial pole alignment may be adjusted very accurately by use of a small telescope that forms part of the main shaft. The telescope, mount, tripod and counterweights can also be dismantled quickly without giving yourself a hernia. These then are mobile mounts that may be quickly set up and brought to the point where they will track accurately. The Paramount deserves a more permanent site.

Any mount, no matter how well trained, will still suffer from some faults in guiding due to unavoidable manufacturing imperfections in the gear train from the motor. These may lead to trailed star images 10″–30″ long during a two minute exposure. This can be overcome (to a large extent) in some mounts – particularly SCTs – using a periodic error corrector (PEC). This device memorises or records a set of corrections to the drive speed and replays them over and over again. The corrections are inputted by the observer, by manually speeding up and slowing down the motors to keep a star centred on the eyepiece crosshairs for a complete gear train cycle, usually

Figure 2.7 A good starting point. 100mm Newtonian on a sturdy mount and tripod. © David Hinds

lasting a few minutes. This procedure is called the training or learning session. PECs can enormously reduce the influence of the gear errors and make the drive virtually perfect visually. The important thing is not so much the size of the residual tracking error that needs to be corrected, but the rate of change and predictability of the error. The slower and smoother the change, the better.

If you frequently set up your scope in a field or on grass, consider cutting squares of plywood 3 inches square and placing them under the feet of your tripod. This will avoid the tripod feet sinking slowly into wet ground and help maintain your polar alignment.

Figure 2.8 The Losmandy GM8 mount. © Venturescope

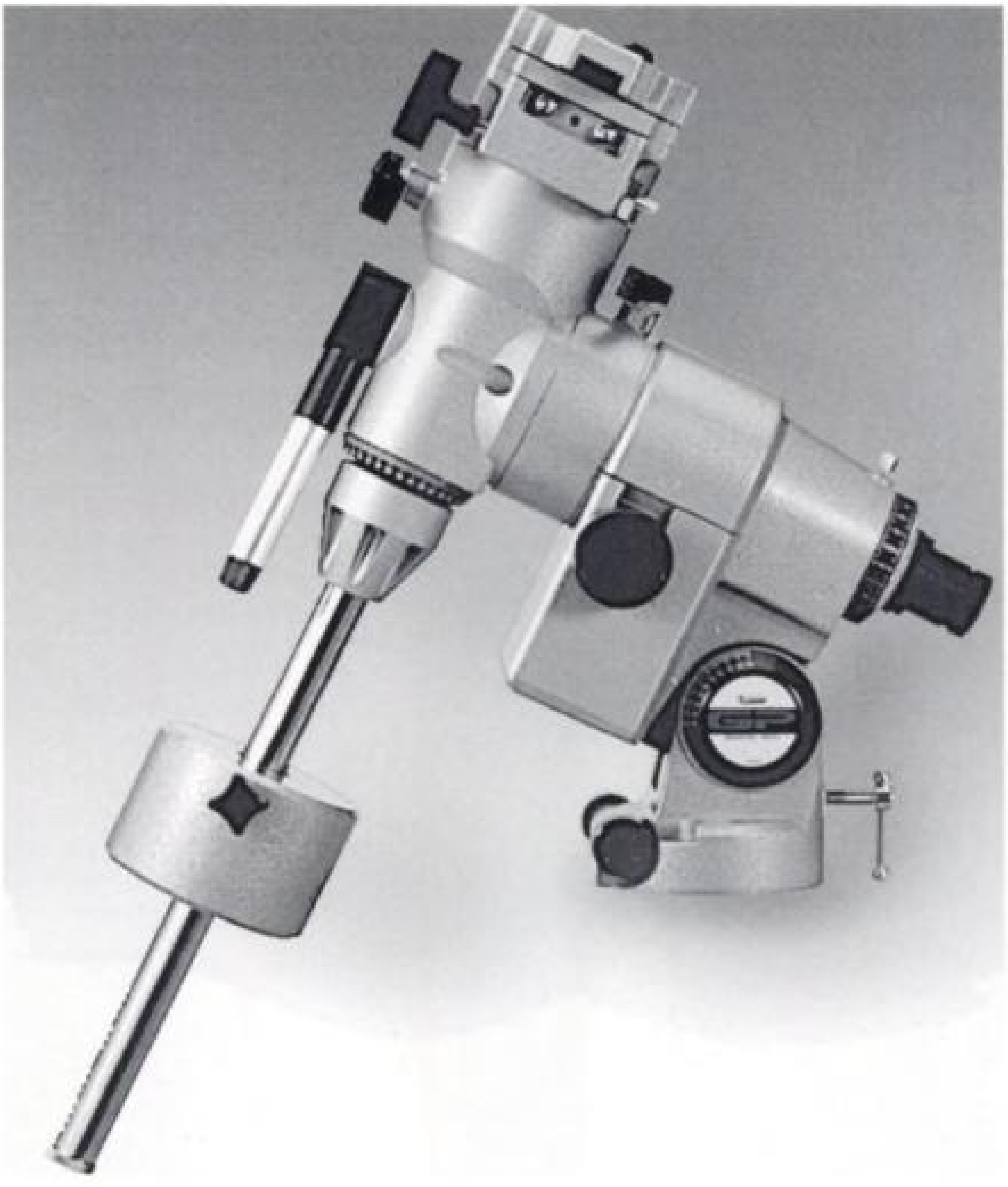


Figure 2.9 The ever reliable Great Polaris mount. © Orion Optics (UK)

Computer-Controlled Mounts

Locating faint deep-sky objects has become easier in recent years with the advent of computer-controlled mounts. The two best known proponents of these are Celestron and Meade who manufacture the Ultima/ Nexstar and LX200/ETX series of telescopes respectively. At the beginning of your observing session you level the scope and point it at a few bright stars, thereby providing reference points. Then, you simply type in the name or location of the object you are seeking and within a minute or so the mount will slew the telescope across the sky and stop with your chosen target located within the field of view of a low-power eyepiece. There is of course some error and for the LX200 and Ultima this is of the order of a few arc minutes, but for the ETX and Nexstar it should be a bit less than a degree if the telescopes have been reasonably well set up. Great Polaris users need not feel too left out, as SkySensor 2000 is available for that system and appears to operate quite well.

Figure 2.10 The computer-controlled Meade ETX. © SCS Astro

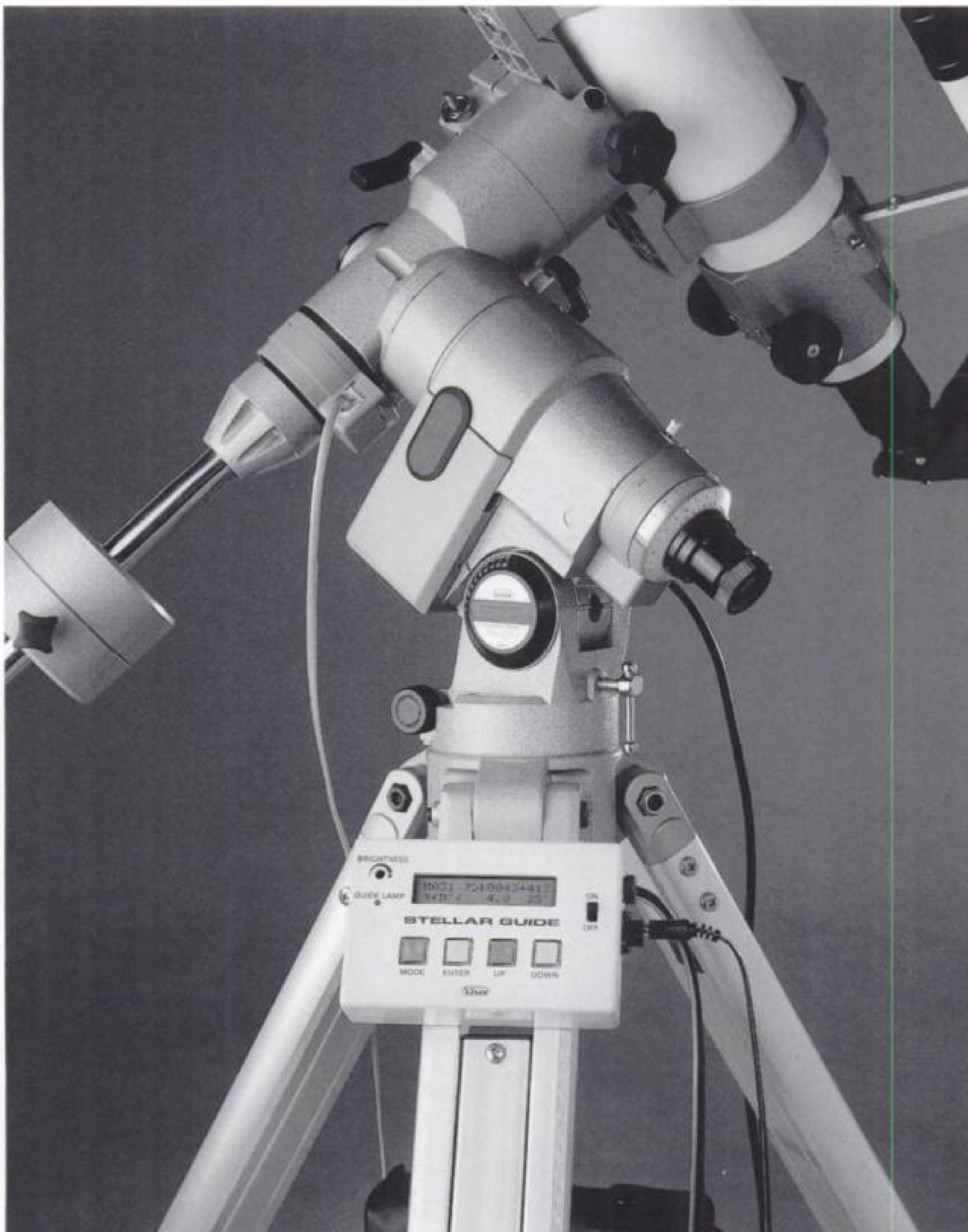
The ease of use of this type of telescope has made it a popular item with many observers - particularly those living in light-polluted locations. Although observing with a computer-driven scope can potentially become a bit like train spotting, observers who have spent 45 minutes looking in vain for a faint cluster in light-polluted sky will see the attraction immediately. Clear nights are rare; why waste them? In their defence it can be said that deep-sky observing takes practice and patience so while inexperienced observers using an LX200 or Ultima will find the right bit of sky immediately, they still have to learn how to observe - something only gained through experience.

One cheaper alternative to buying a complete computer-controlled scope is using digital setting circles on your existing scope. These detect the movement of the

Figure 2.11 The new Celestron Nexstar. A small aperture, but a capable GOTO scope. © David Hinds

telescope via encoders (usually optical) attached to the mount axes. Consequently, after first aligning with some reference stars, the digital setting circles tell you where the scope is pointing or in which direction you must move the scope to point at any object you choose. The circles usually involve a hand controller unit, but some require a cheap laptop computer. Digital circles are very effective and simple to use, and are frequently supplied in kit form, along with instructions for fitting

Figure 2.12 Polaris Mount and GOTO controller. © Orion Optics (UK)



them to a range of telescopes. Unfortunately, if the axes of your telescope are not orthogonal, then the majority of such systems will not cope well with a large sweep across the sky, requiring you to first align with bright stars near your chosen target. Systems like NGC-MAX and Sky Commander are very popular but you will find several others on the market.

A very recent addition to this field is the voice-controlled scope where, for example, saying things like "M1" into a microphone sends the scope off to look at the Crab Nebula. An amusing idea, but is it really worth the cash? For public observing sessions a system like DigitalSky Voice is probably a winner and would certainly look pretty impressive, but for normal use most of us will be content to stick with keypads.

Tube Assemblies

You might think that there is little to be said about the tube assembly but, like all parts of the scope, a little effort can result in a design suited to your specific needs. Ideally, the tube should be light-tight and its inner surface coated with matt black paint or some similar material to reduce internal reflections. Surprisingly, black anodised aluminium should be avoided if using CCD detectors sensitive to infra-red radiation, as it reflects infra-red quite well.

Tubes can be made from metal, wood, plastic or even resin-bonded paper. All are practical, though beware – some are heavier than an unaccompanied observer can safely lift. A resin-bonded 400 mm diameter tube assembly can easily weigh 50 lbs, while a metal tube may be rather lighter depending on the thickness of the metal used. You may need to compromise between a scope that is rigid, but heavy, and a scope that might flex, but is light. Obviously the weight is not a concern when the system is permanently mounted.

Open-frame tubes are much lighter, and also move much less in a breeze. They do have their drawbacks though. Stray light, perhaps from the Moon or street lights, can be a problem when trying to image faint deep-sky objects. In this case you will need to provide a cover for the tube that will block out the light while not significantly increasing its weight. Try a lightweight car tarpaulin, fixed in place using rubber tie ropes or possibly Velcro, but avoid loose ends or slack that may flap about in the breeze. Remember that even with a closed tube light may leak around the edge of the mirror cell as closed tubes are often built to allow plenty of ventilation.

One problem you will have to deal with is dewing. Late at night, as the telescope tube and optics cool, their temperature relative to the air can drop sufficiently for dew to form on the glass. This is particularly problematic for refractors and SCTs but can be partially overcome by extending the telescope tube for, say, 150 mm beyond the optics using a cardboard or plastic extension to form a dew shield. If dew persists, it may be necessary to use a dew-zapper – a very low-power heating element, placed around the edges of the lens, eyepieces, secondary or corrector plate, which raises the temperature just enough to stop dew forming. The gentle heating elements can be powered by a car or motorbike battery and pose no threat to life. Those observers who place a black cloth over their heads while observing to keep out extraneous light, may find that without heating the eyepiece will dew up as the humid air generated by breathing will be kept close to the cold eyepiece – a sure recipe for fogged-up lenses.

Hunting down deep-sky objects can be made vastly easier by fitting a small finderscope to the telescope tube and aligning it with the main scope. Then you just move the main telescope until the finderscope has the object you require centred. This very simple idea greatly speeds up finding faint objects and is far more efficient than sighting along the main telescope with your eye. Some finders incorporate faintly illuminated crosshairs that make things easier. For instruments larger than 150 mm aperture ensure that the finderscope has an aperture of at least 50 mm. Many commercial scopes come with 25 mm finders that are a complete waste of time from light-polluted sites. If your current scope has one, dump it in favour of something more substantial.

One alternative is the very easy-to-use Telrad. This zero-magnification instrument superimposes concentric red circles of light onto the view of the sky that it provides. It is even easier to use than a traditional finderscope and no crosshairs are necessary.

Finders of this sort have now been adopted by several companies and are increasingly popular. For larger scopes a normal finder is essential but a Telrad (or equivalent) is a great starting point and costs less than an eyepiece.

Figure 2.13 The Tele Vuc Qwik Point finder. © Venturescope

Consider painting the region of tube exterior within 300 mm of the focusing mount black. This will reduce the amount of light reflected from the tube toward your eye. In an urban environment a white painted tube can appear quite bright.

As a final remark on tube assemblies, it's worth mentioning the importance of keeping all your optics clean. When trying to observe faint or low-contrast objects it is essential that as much light as possible is collected. And a mirror covered with a layer of dirt or corrosion is far from ideal. To keep things as clean as possible ensure the tube is sealed at all times when not in use. Also, if the mirror is very dirty (as sometimes happens when you buy a secondhand scope) consider washing it or – better still – having it completely realuminised. For washing use distilled water and a small amount of gentle liquid detergent. Don't scrub or wipe the mirror, as this abrades the surface. Instead, sluice dirt away with very gently running water. For the final rinse use a mixture of distilled water and alcohol (wear gloves), agitating the water for some minutes. Finally, stand the mirror on its side to drain – don't wipe it dry. In addition, consider having your mirrors realuminised every two to three years if you live in an urban environment. To determine whether realuminisation is necessary, hold the mirror up to a strong light and look through the back of it at the light. If you can see anything more of the light than a few dozen brilliant pinpricks then realuminisation may be a good option.

Users of Newtonians might like to consider having their mirrors coated with dielectric or enhanced reflectivity materials. These can boost the aluminium reflectivity in the visible range by 4–5% – totalling an improvement of 8–10% after two reflections. In larger scopes this can be quite a useful addition.

A good focusing mount is very helpful when observing. A focuser where a small movement makes a large difference to the focus is not good. Ideally you want to be able to adjust the focus finely without the fear of accidentally overshooting the optimum position. Low-profile and Crayford mounts are particular favourites and motorised mounts are also becoming increasingly popular. A mount with a readable dial can be especially valuable as once you know the number at which each of your eyepieces focus you can save yourself some time, especially if a CCD or camera is being used. Oddly there appears to be no computer focuser widely available commercially at present. An obvious market niche perhaps.

No matter how finely focused a scope is, images of stars will still move and shimmer slightly due to atmospheric seeing, thereby blurring the detail that might otherwise be seen in the final image. SBIG together with Brad Wallis and Benoit Schilling, have created a system – the AO-7 accessory – suitable for use with some of their ST7 and ST8 cameras that helps overcome this. It does so by compensating for the shimmer using a moveable mirror to change the light path accordingly, but the AO-7 is quite expensive and works best only if a bright star is available just off the field of view as a reference point. When working well it provides much sharper and brighter star images and has a keen following among those seeking H-II regions in spiral galaxies as well as those keen on astrometry of asteroids.

Eyepieces

The eyepiece is a crucially important optical component of a telescope. It has the job of magnifying the image formed by your main mirror or lens and so should be as good as you can sensibly afford. In practice you will find that three powers are normally enough for general use one low-power, wide-angle view (60×), a high-power (say 250×) for nights of exceptional seeing, and another of around 100 × for general viewing. There are several good designs around, such as the Plössl and Orthoscopic (older readers will recall these were the eyepiece of

Figure 2.14 Tele Vue Nagler eyepieces. © Venturescope

choice in the 1970s) which sell at sensible prices. In addition, eyepieces such as Erfles, Naglers, Pentaxes or Superwides, which provide impressive large-field images of deep-sky objects, are now available. Unfortunately, these can be very expensive. Typically £40–80 ($60–120) is not unusual for the Plössls and Orthoscopics (both good all-rounders) while Naglers and Pentaxes change hand for hundreds of pounds.

Indeed the latest Type 5 Naglers, a triumph of optical design providing wide-field views, will probably cost you about the same as a secondhand ETX.

One way of minimising the number of eyepieces required is to use a Barlow lens. This is interposed between the eyepiece and focusing mount and doubles (or in some cases more than doubles) the magnification provided by a given eyepiece, so that three eyepieces provide six different magnification values. At one time Barlows were shunned for their poor-quality optics, but there are now a number of companies producing extremely well-made lenses. As a poor Barlow lens will make all your eyepieces perform badly you should ensure it is of good quality or do not bother with it. Experiment with those used by friends if at all possible.

Filters

Filters are an increasingly popular accessory for astronomers trying to observe faint deep-sky objects against the ever more light-polluted night sky. They exploit the fact that many street lights and some nebulae generate light at particular, well-defined wavelengths. By observing through a filter that transmits the wavelengths emitted by deep-sky objects, while absorbing those from street lighting, it is possible to increase the contrast between your target and the sky. Such filters work very well for some sorts of object – planetary nebulae in particular – but are much less successful for galaxies.

Broadly speaking deep-sky filters come in two sorts. One type – light-pollution filters – which includes the Lumicon Deep Sky and Orion (US) Skyglow filters, attempts to filter out light pollution while preserving the hydrogen-beta, hydrogen-alpha and oxygen III lines emitted by some nebulae. The other type – nebula filters – which includes the Orion(UK) EHC, Meade Series 4000, Orion (US) Ultrablock and the Lumicon UHC, attempts to block everything except some of the nebula emission lines. Light pollution filters are better suited to general use from urban sites, while the nebula filters are particularly attractive for those seeking to identify faint emission nebulae and planetaries.

It is worth remembering that the filtered image of your desired object is actually *fainter* than the original image. However, the object is viewed against a darker background, making it easier to spot. Although filtering can make objects appear coloured and can greatly dim field stars, most observers would see this as a small price to pay to see an otherwise invisible nebula. Unfortunately, filters tend to be about the same price as eyepieces, and you probably need two to three to ensure that you have one which is tuned to each type of nebula. But they are undoubtedly worth it. In light-polluted areas their effect can be miraculous. Be sure to avoid even the faintest light sources when trying to use a nebula filter. You may even find it advantageous to paint your telescope tube black instead of white to avoid the minimal reflected light encountered as you approach the eyepiece.

Observatories

Nothing is more galling than spending an hour setting up your equipment, only for cloud to whisk in 30 seconds after you start observing. Building a permanent home for a telescope cannot overcome this problem but it will let you start observing within ten

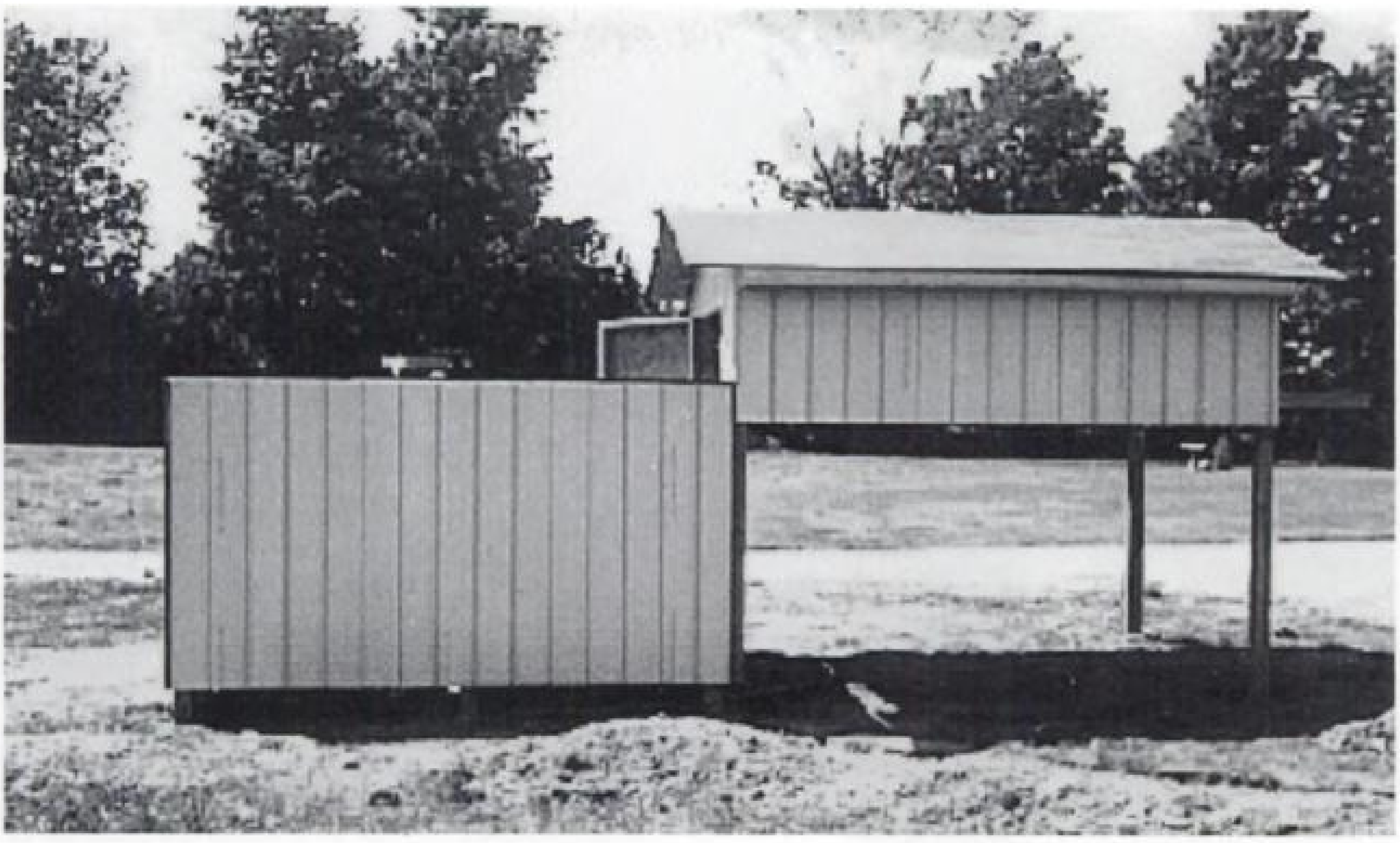


Figure 2.15 A classic run-off roof design observatory. Simple to make and use. © Bruce Johnston

minutes of getting outside. The difference made to your observing habits can be quite dramatic.

In astronomy magazines it's not uncommon to see readers' accounts of how they built their observatories – immense constructions that dwarf the average garden shed. This must be a very nice way to live, but not all of us have spouses willing to give up most the garden nor the time and skill to build such observatories. Fortunately, there are a number of simpler options available.

One is the run-off shed. This consists of a garden shed mounted on wheels that run on a short track. When you wish to observe, the end wall is removed and the rest of the shed is rolled along the track, thereby exposing the scope. A simple variation of this is a normal shed with a run-off roof, where just the roof section moves along a track. The roof support frame can be quite ugly but hanging plant pots from it and training plants to grow up the poles helps disguise them. Another idea is the fold-down shed. Here, four vertical poles support four walls that fold down to the floor when you want to observe. The sloping flat roof folds outwards to hang from the north or south wall. Alternatively, there is a construction where the walls and roof consist of one piece which normally rests on a small brick or breeze-block wall and can be folded back on a hinge or removed in one motion to expose the telescope.

Building an observatory yourself need not be difficult and can be fun. No longer will you have to fend

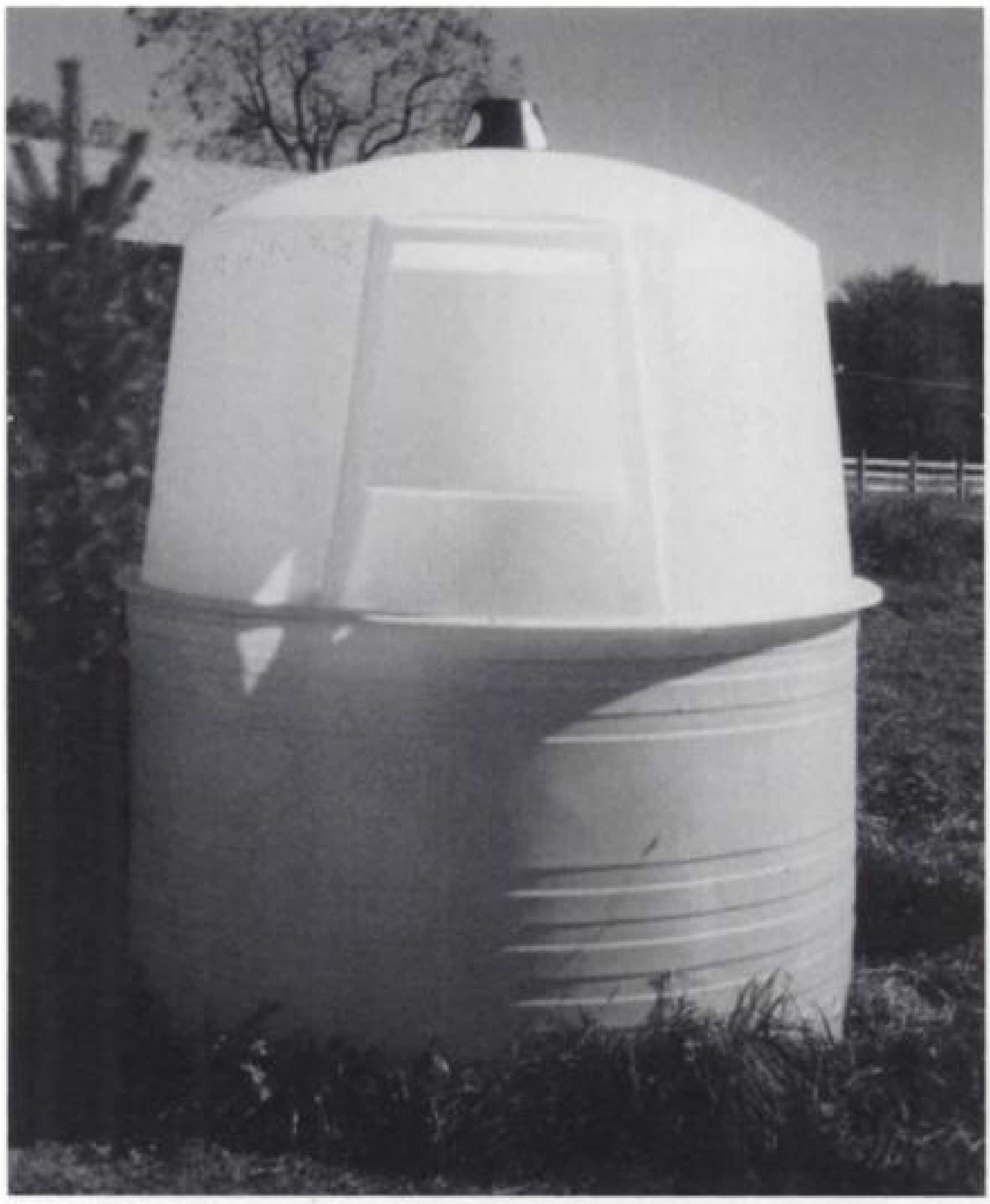


Figure 2.16 1200 gallon container + inspiration + hard work = observatory. © Dan Holler

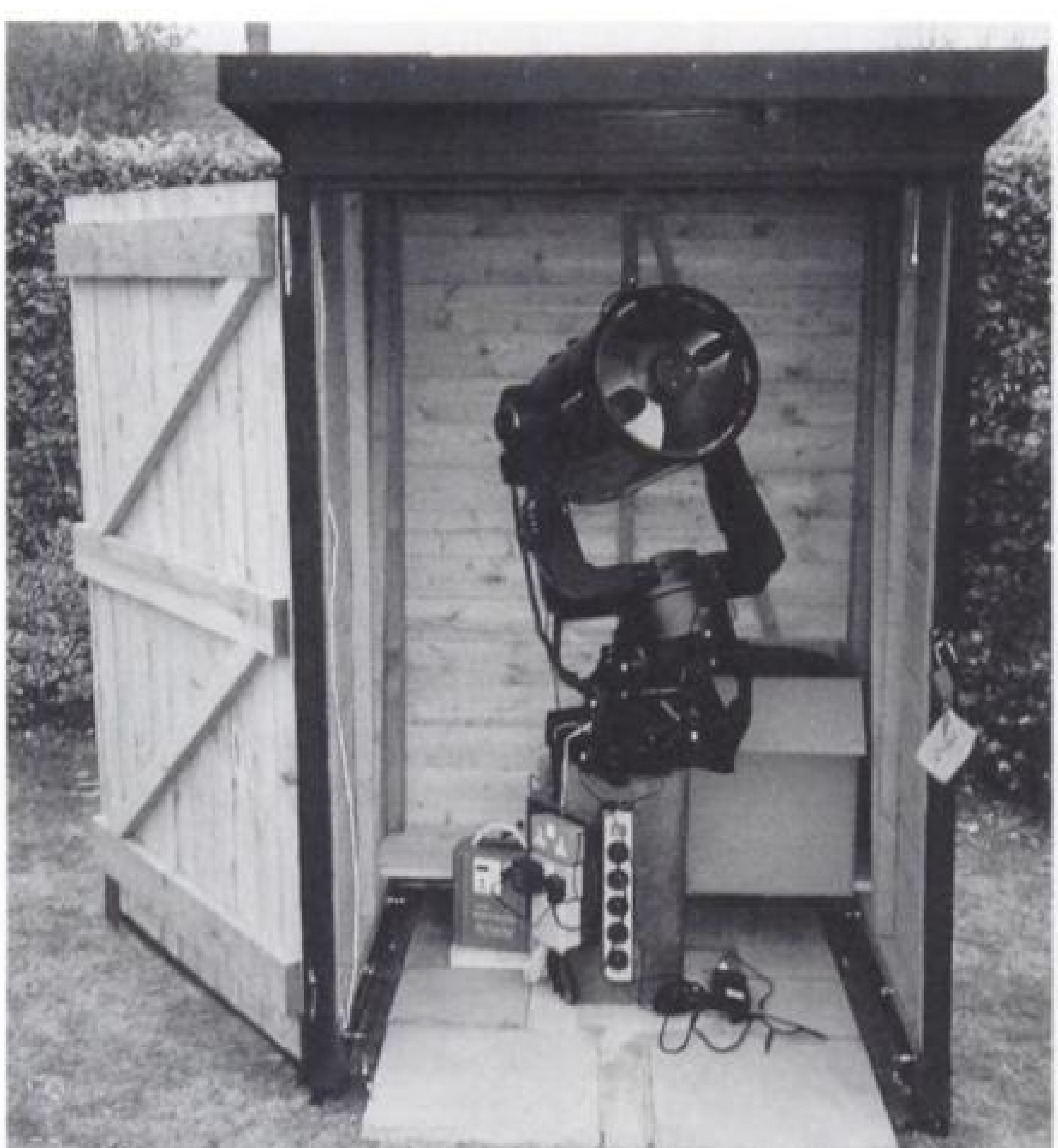


Figure 2.17 Martin Mobberley's 30cm LX200 with run-off shed. © Martin Mobberley

off ravenous hedgehogs keen to eat your computer cables or snails keen to explore your telescope tube. For more information, see the accompanying book in this series *Astronomical Equipment for Amateurs*, by Martin Mobberley. Not all observatories are boring white domes!

What Can You Observe with a Telescope?

This depends on the size of your telescope. The amount of light collected by a 300 mm is greater than a 100 mm can capture, indeed 9 times more, and so the images produced are correspondingly brighter. The upshot is that you'll be able to see more galaxies, clusters and nebulae. On the down side, while telescopes have in real terms become much cheaper in the last 20 years, light pollution has become very much worse and a 150 mm is probably needed to reveal what a 100 mm might have shown in the 1960s. The rough guide that follows is deliberately rather vague. A good or practised observer with a small scope can often outperform an inexperience yet better equipped observer who has not yet learnt how to really *see*.

Aperture 50–100 mm

With a scope of this size you should be able to see stars down to about 12th magnitude and galaxies and clusters down to about 11th. This means that the vast majority of the Messiers will be visible to you, as will some of the brighter NGC objects. The meaning of acronyms such as NGC, UGC, PK and IC will be explained later – for the moment just think of them as deep-sky catalogues referring to fainter objects. Asterisms and larger objects such as the Hyades, the Coma Berenices star cluster or the Beehive (M44) will still also provide good views. At the fainter end, sticking with higher-surface-brightness objects such as elliptical galaxies or globular clusters will be well rewarded, while large and faint objects such as M97 or M74 will probably prove quite tough, particularly from a light-polluted site. The range 50–100 mm is nice to use, as the instruments are eminently transportable and easy to set up.

Aperture 150–300 mm

A 200–250 mm scope is a great all-rounder. With a reasonably sited 200 mm you should be able to pick out 13th magnitude stars and 12th magnitude galaxies, some of them showing hints of structure. This means that the whole of the Messier and Caldwell catalogues (latitude permitting) are accessible to you, as well as a large number of NGC catalogue members. You should also be able to identify several quasars, many PK planetary nebulae, the occasional extragalactic supernova and even some IC and UGC catalogue galaxies. There will be enough objects visible to keep you going for several years, even with an automated scope.

Aperture 300–450 mm

A cure for aperture fever, a telescope of this size presents huge numbers of objects to observe, many of which will show detail. Several galaxies show clear spiral structure. Filaments will be visible in the Crab Nebula, and M82 – strangely lacking a popular name – will display a great wealth of detail. Distant galaxies will show both supernovae and globular clusters orbiting them. Indeed, with instruments in this range you begin to reach the point where the objects you can observe may not even be catalogued and the views of better-known objects like the Eskimo Nebula will be stunning.

What Can You Photograph?

It might have been thought that the advent of CCDs would mean the demise of photography. But nothing seems farther from the truth. Indeed, the emergence of the new technology seems only to have galvanised photographers to ever greater achievements, and astronomy magazines now abound with wide-angle colour shots of clusters, galaxies and the Milky Way that CCDs cannot (yet) hope to capture. At one time it might have been said that photography was a waste of time from light-polluted sites but improved emulsions, filters, hypersensitisation of films and digital scanning of slides have all contributed to making this a growth area once again. Some observers are now digging out pictures they took 15 years ago, and digitally scanning and image-processing the negatives and finding that they captured more than they thought. It's difficult to photograph stars of 17th to 18th magnitude from most sites but that still puts thousands of objects within range, many of which are too diffuse to be seen visually and too large to be imaged with a CCD. The northern Milky Way swarms with beautiful regions of large nebulae such as Simeis 147 and IC1805 which are only really accessible to photographers.

What Can You Image with a CCD?

Provided your telescope is reasonably aligned and has a steady drive mechanism, you should be able to capture CCD images of a vast number of deep-sky objects. By stacking 60 second CCD exposures (most telescope drives are good enough to drive smoothly for this period) you will be able to capture stars of 19th to 20th magnitude, even with a 250 mm scope located in a far-from-ideal site. With a telescope such as a Celestron C8 or an Orion (UK) 200 mm Newtonian you will be able to image objects such as M78 and, with diligence, produce results that would have rivalled the very best 1970s' professional photography.

With a larger scope, very faint galaxies and planetary nebulae can be imaged from urban sites. Results of near professional quality are easily attainable. Objects like Hoag's Galaxy in Serpens or the planetary nebula Abell 12, near nu Orionis, are relatively easy targets. The only limitation will be that a CCD's field of view is often small, ruling out larger objects and certainly making life difficult if you fancy imaging the Veil Nebula or Andromeda Galaxy.

The current CCD magnitude record for amateurs appears to be 24.1, using a 400 mm scope. This is very impressive – it means that amateur telescopes are now usable as scientific instruments.

Observing Techniques

A lot has happened in the last 40 years of amateur astronomy. It might be thought then that an amateur astronomer from the 1960s, brought up with the idea that a 200 mm was a large scope and Tri-X film the latest thing, would be at a loss in today's environment. But happily this is not the case, as most observers still look through the eyepiece just as their predecessors did 300 years ago and many of the skills needed then remain essentially unchanged today.

Visual

The most important factor in good observing is experience. There is no substitute, be it computerised or not, for hours put in at the eyepiece. The simple act of observing improves our ability to discern faint detail and pick out low-brightness sources. As time passes we learn which combinations of eyepiece and filter serve best for given types of object. We come to some understanding of the limits of our instrument, site and abilities. And, like all good experience, once gained this never leaves you.

One of the first things you learn is to avoid light sources at all times. By their very nature, deep-sky objects are not bright – the amount of light arriving at your eyepiece will be small. To ensure that the pupil of your eye is wide open to receive it, make sure that you don't look at bright sources such as street lights, car headlights or even light shining onto you from a neighbour's window. Ideally, you should see no light for 40 minutes prior to observing seriously. This can take some arranging as we are not all blessed with gardens shielded entirely from the rest of the world. But there is often somewhere in a garden where we can avoid stray light casually impinging on us. One solution, not quite so convenient when you need to get up for work the next morning, is to observe late – when most people have retired to bed and, in some towns, the street lights have turned themselves off.

Before leaving the house to observe, consider wearing dark glasses for a while. This usually raises some laughs from the kids but means that by the time you get outside your pupils will already be reasonably dilated. This also means that you are less likely to trip over obstacles outside and will need to use the torch less while setting up. It might also be worth asking members of your family to help you protect your adaption. Someone bringing you a very welcome drink may turn the garden light on to do so – putting you back 20 minutes and possibly 2–3 magnitudes in a few seconds. You can avoid this by taking a flask with you, or asking the well-wisher to leave the lights off while you come to them. You can still chat and take a break, but without ruining your dark adaption. There is an old joke that you know you are a deep-sky observer when you think the planets are just too bright to look at. There's some truth in it. Some observers only read star charts with the eye they don't use at the eyepiece. The idea is to preserve the sensitivity of the closed eye, and it seems to work quite well.

It's important to make yourself as comfortable as possible while you observe. Trying to use an eyepiece that is set at the wrong height certainly doesn't help. Your concentration will be diminished and you're not going to achieve your best results. So try to have two chairs of different heights, adjustable drumming stool, cushions, a small step ladder or a box to stand on.

If you use a large scope, consider building a strong lacquered wooden box with each of the sides a different length. This can be employed to allow you to stand at one of three different heights off the ground.

Sketching galaxies and nebulae at the eyepiece, in low light levels, is no easy matter. A small torch can be used but that leaves one less hand free, so it's quite common to use a stiff plywood or plastic board to fasten the paper and light to – possibly with bulldog clips or clothes pegs. Red LED lamps are particularly good. They damage your dark adaption only slightly and are inexpensive. They are also available as small clip-on units, and use batteries much more slowly than an equivalent torch bulb. The type of small lights that are worn on the front of a hat can be quite usable, if not too heavy. Some observers record their observations with dictaphones and other small tape recorders rather than by drawing, but a picture is, as the cliché has it, worth a thousand words, and pictures are far more fun to browse through.

Another useful item is a table on which to rest your observing equipment. Garden tables are good, as they are already in the garden and don't have to be put away again at the end of the night. Music stands can also be quite successful. These do, however, have the disadvantage that they accumulate dew, which makes papers left

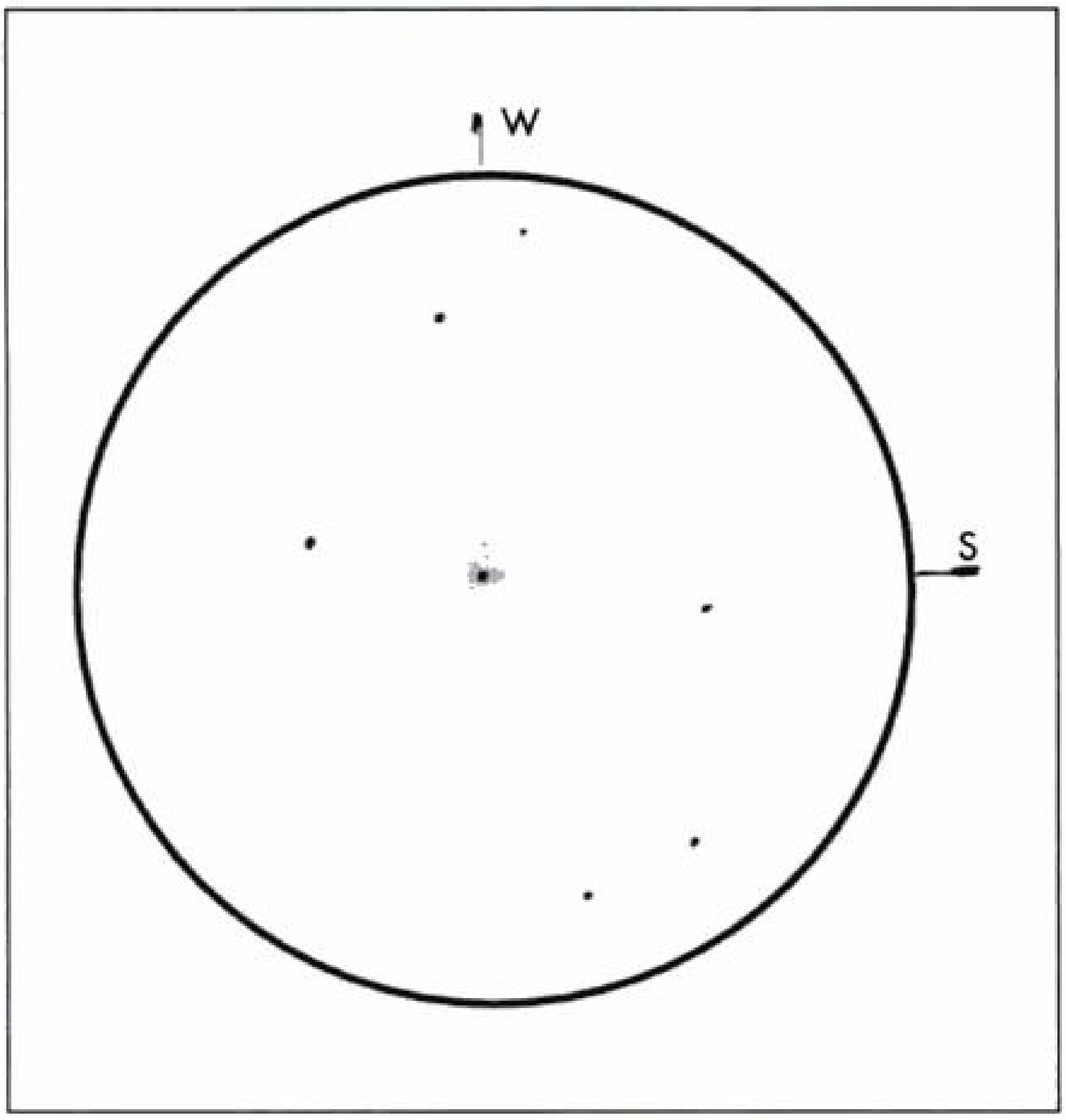


Figure 2.18 A drawing of the planetary nebula NGC1514 in Taurus.
Tel: 14″ F5.
Eyepiece: 26 mm.
Mag: ×68.
Seeing: III.
Filter: O–III.
Field: 42′.
© Stewart Moore

on them wet, and fogs up your eyepieces. One solution that you might consider investing in is an observing box – possibly a toolbox or wooden case with a handle, incorporating its own battery-powered heating system and a large silica gel package to eliminate damp. This will keep maps, atlases and eyepieces safe from the elements. Alternatively, the box can be warmed by rechargeable heat packs (these may be purchased from shops selling camping supplies) to keep the dew off. A heating pack in your pocket may also help a lot on particularly cold nights. The rechargeable packs are not as efficient as the one-use variety, but it works out cheaper in the long run to buy more of them. Whatever else you do, avoid using small light shrouded paraffin heaters in your observing box. We have been told of someone who had to move very fast to remove his Nagler eyepieces when smoke started to pour from the box. Don't let it happen to you.

When looking through the eyepiece, the first thing is to ensure that the focus is exact. Tune the focusing mount as finely as you can. Stars at the centre of the field should be tight point sources; anything else will degrade your view. Once focus has been achieved, compare the pattern of stars you see with your finder chart and see if the object you want is visible immediately. Often it will be and your view will just need a little centring. If you are seeking something very faint, check the field star pattern at least twice to ensure that you really are looking in the right place.

Faint objects are more easily seen by averting your vision slightly. It sounds strange, but this utilises the parts of the retina that are most sensitive to faint light. It's well worth learning. Averted vision will make it easier to discern the full extent of a diffuse source, as will tapping the tube gently – our eyes are very good at detecting faint objects that are moving. Also be prepared to spend some time changing eyepieces, to find the optimum magnification, and/or filter combination until you achieve the best view.

If you are sure that you're looking in the right place, but still can't see your target, don't despair – stay vigilant. Every second spent looking increases your chance of catching a moment of perfect seeing and transparency – poor seeing can be particularly damaging if trying to resolve a faint open or globular cluster. Some objects just take time to be seen. After a while, you may start to suspect that there is something where previously you saw nothing. This is often the case when observing a face-on spiral and looking for H-II regions – glowing clouds of ionised hydrogen gas.

It's times like these when a black cloth hung over the head can be useful to keep out even the merest hint of stray light. Sometimes perseverance can reveal something totally unexpected. After studying a bright galaxy for a few minutes, you might find a satellite galaxy at the edge of the field which you overlooked initially. This is where the fun is in astronomy – known challenges mixed with completely unexpected delights.

One final point is to breathe evenly. Some people hold their breath while searching a field. This only deprives your eyes of the oxygen they need to function optimally. The only time you should hold your breath is as you approach the eyepiece – to ensure that you don't breathe on the eyepiece lens.

Drawing

Draw a 60 mm-wide circle onto a piece of artist's watercolour paper and fix it with tape to the board. Note on it sky conditions, scope, date, the direction of north, etc. and then spend ten minutes just looking at the object. Once you are confident that you have a good grasp of what can be seen, start filling in the locations of the brighter stars and then carefully place the fainter stars. Search particularly for obvious geometric shapes (such as right-angled or isosceles triangles) and check the positions carefully, as they provide the framework for the rest of the picture. Once all the stars are located spend a little time extending the blobs for the brighter stars so that the blob size reflects each star's brightness. Then sketch faintly the outline of the central object and fill in gently using a combination of a soft pencil, clean eraser, cotton bud or fingertip to blur edges as necessary. Observe for a while longer looking for mottling or detail. Add only what you confidently observe – record in notes any features you merely suspect. You will find that an HB and an HB4 pencil are best. Make notches at the top of them with a hacksaw to ensure you can tell the difference between them in the dark and always carry a pencil sharpener with you.

While drawing, try various filter and eyepiece combinations to find the maximum level of detail. Small planetary nebulae, dark lanes in galaxies and fainter stars will respond well to magnifications normally reserved for planets on a night of good seeing.

Drawing is an essential part of an astronomical apprenticeship, the drawings accumulating to form a resource that you will look back on frequently as your experience increases. Your drawings may never rival results from observers using CCDs or photography, but they provide an accurate record of what you saw.

Photography

The most important item required for astrophotography is an SLR (single lens reflex) camera with a shutter that can be held open for many minutes – essential for imaging deep-sky targets. Most SLRs can be attached to the focusing mount of a telescope equipped with 1.25- or 2-inch eyepieces using a variety of fittings that can be obtained from good telescope shops. This provides a prime focus field of view usually of the order of between 0.5° and 1.5° across, which renders it ideal for all but the smallest objects. The bad news is that if the telescope is driven unattended, imperfections in the drive system will generally lead to star images that are banana-shaped. A popular piece of equipment used to overcome this is an off-axis guider.

In such a device most of the light from the main mirror goes to the camera but some is extracted to an eyepiece. The observer uses the eyepiece to centre a star on a crosshair and then adjusts the drive controls to ensure the star does not wander. This requires intense concentration and is very tiring, but the rewards are often well worth it. An alternative approach is an autoguider, such as the SBIG ST4 or Meade 208. Autoguiders replace the eyepiece and observer and monitor the position of the guide star using a CCD to issue commands to the telescope motors - thereby ensuring that the main image plane has little tracking error. This is an amazing technical achievement when you consider that until recently the Jacobus Kapteyn Telescope on La Palma used a 1980s' autoguider control box that was the size of a filing cabinet. Unfortunately, autoguiders are still quite expensive, hence the continuing popularity of manual off-axis guiders, such as the Taurus or Lumicon Easy-guider.

Wide-field photography can be undertaken by attaching an SLR and 200 mm focal length lens to the scope tube, and pointing it at the same part of the sky as the telescope. This is a very simple technique as you merely set the camera focus to infinity, the focal ratio to its lowest value and use a cable release to hold the shutter open for 10–20 minutes while the telescope tracks normally. Using this method a normal 35 mm camera can capture views roughly 6° by 4°, making it best suited to larger objects such as M44 in Cancer or the Double Cluster in Perseus. You can also image smaller objects, like the planetary nebulae M57 or M97, but they will probably be too small to show much detail. One advantage of the larger field of view, however, is that many commercial telescope drives are accurate enough to be left unattended during 10–20 minute exposures using this method. Some vignetting (image dimming at the edges) will be present, but good results can be obtained. Very long exposures (>60 min) should be avoided unless your mount is very well polar aligned as field rotation will ruin any picture taken. With wide-angle photography consider using a deep red filter such as the Cokin 003 for the last two-thirds of the exposure time. This helps avoid the sky saturating the image, enhances emission nebulae and allows star colours to be recorded.

A problem with some modern SLRs is that their shutters are battery-operated. During normal day-to-day use the shutter is held open for a small fraction of a

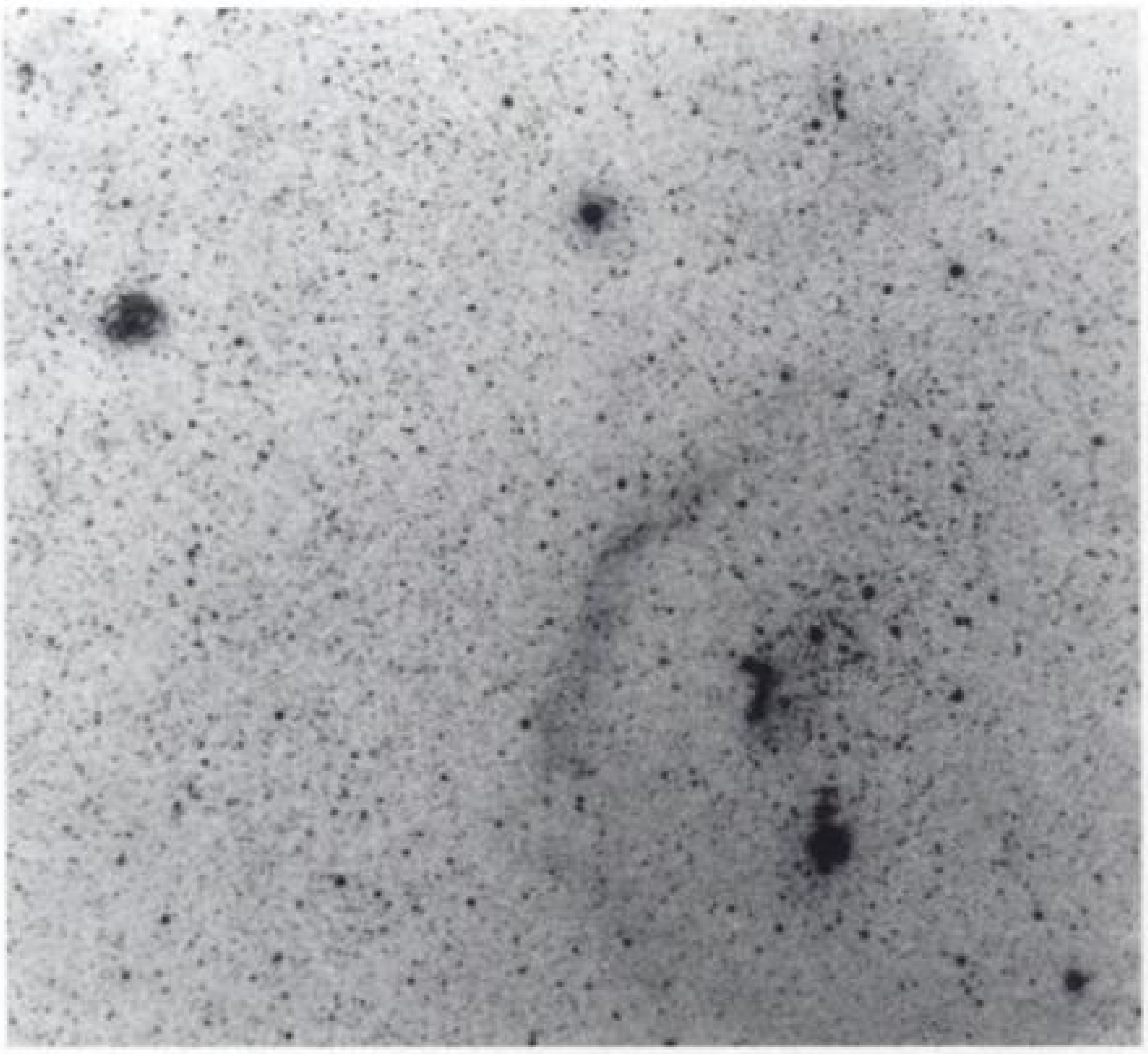


Figure 2.19 A wide-angle view of Orion in red light. © Bob Neville

second and the battery will last for months, if not years. But in astrophotography an exposure may easily last 20 minutes, which leads to a much reduced battery life, particularly if the ambient temperature is below zero. One solution is to buy a camera body such as the Russian Zenit, where the shutter is purely mechanical and batteries are not required. Alternatively, rig an external power supply to replace the battery.

Films

Recommending particular films is risky. Even before you finish reading this page the manufacturers may change the emulsion designs, so our advice is to buy a nice cheap film while learning the ropes and then progress to better and more expensive films as your skill increases. This doesn't mean that you'll initially be working with rubbish! Today's high-street consumer brands are of a quality that was unheard of only ten years ago and are very good value for money.

First, think about the speed of the film that you're buying. The fastest films you are likely to find will be similar to the Konica 3200 ISO. These are very sensitive and will provide quite impressive results when used to quickly image faint objects, but care must be taken to avoid the sky background glow saturating the whole picture. The price paid for the speed of these films comes in the form of image graininess, relatively poor contrast and poor extended low light sensitivity (reciprocity failure). So the faster the film, the more obvious the grains that make up the film's surface and the more care you will need to optimise the exposure. Fortunately, at speeds of 400 ISO the size of the grain is sufficiently small that it is no longer obtrusive, making 400 ISO a good first choice for a film speed. Kodak, Fuji and Konica all make respectable films at this speed. It's fair to say that a monochrome film, such as Kodak Tech Pan, Kodak T-Max or Ilford HP5 will be slightly less grainy than a colour film of the same speed. However, normal monochrome films suffer quite badly from reciprocity failure.

Another important consideration is the trade-off between slides and print films. This must inevitably be a matter of taste, but there can be little doubt that with slides the colours *seem* much stronger. They are also a very convenient way of displaying your efforts at meetings, but the digital revolution has made this virtue less important as digital projectors and slide/film scanners are now widely available and their price is dropping rapidly. As with print films, fast slide films are grainy and give poor contrast and a 400 ISO Ektachrome Elite II or its equivalent is more likely to give good results.

Processing and Printing

Having decided on a film, you must then decide whether to develop and print it yourself. For black-and-white film, developing is a simple process, requiring a developing tank, easily available developing chemicals and a thermometer. Subsequent printing can be accomplished by a commercial specialist or done yourself using an enlarger, a few trays, more chemicals and a modest investment of time to learn the process. Colour processing is a bit more demanding, although not beyond the ability of anyone able to make a good soufflé; both require care and patience. Unfortunately, the chemicals involved are pretty nasty and the task fiddly. As for colour printing, many people decide that it is just too time consuming and opt to use slide films instead, which are easy to process and handle.

The down side of not printing your own films is that commercial developers will not stack negatives – aligning two (or more) negatives one on top of the other and using that like a single negative from which to print the picture. This makes it difficult to get really high-quality images, as stacking dramatically improves colour saturation and grain. But the stacking of digitally scanned images can be accomplished using software such as Adobe Photoshop or the much more sensibly priced Picture Window from Digital Light & Color. This is particularly useful when you want to make a picture covering a large chunk of sky by combining several images and lining up their regions of overlap. Colour printers by the likes of Epson, Canon and Hewlett-Packard, that produce impressive results on photo-quality paper from an electronic image file, are available for computers at very reasonable prices.

Improving Films

As you become more familiar with photography and start to push your system to its limits you might find that you want to try some more advanced techniques to maximise the quality of your pictures. One of these is to replace your normal film with one that's been hypersensitised. This is a film that's been baked for some hours in an atmosphere of dry hydrogen and nitrogen: a process which greatly increases the sensitivity of the film at very low light levels, while only slightly modifying its colour balance. These films require special handling to ensure that they are not exposed to normal (i.e. damp) air before use, but they are otherwise used much like any other film. The process of hypersensitising is quite simple but does require some unusual specialist equipment, so many people buy it ready-made from a supplier and keep it in a sealed freezer container to increase its lifetime. Nonetheless, Lumicon do sell a hypering kit. Hypering is essential with slower films like Kodak Tech Pan which, once hypered, has an effective speed of >200 ISO combined with superb grain and little reciprocity failure.

Another possible way to make your films more responsive to light is to cool the film drastically during the exposure. This is done using dry ice, or liquid nitrogen. A very carefully designed camera is needed, so that ice doesn't form inside it, and the brittle film doesn't snap when it's wound on. Consequently, cold cameras aren't used by that many people any more and only a few manufacturers supply them.

Limitations of Photography

The greatest limitation of film is its fairly small dynamic range – the film's response to light of different brightnesses. This makes it difficult to image faint and bright objects on the same frame without one being totally saturated or the other one dreadfully underexposed. Fortunately, this isn't a huge issue as a greatly overexposed star often has an attractive diffraction pattern associated with it. So it's probably fair to say that photography has few major disadvantages. It isn't terribly expensive to undertake, can produce fine results for comparatively little effort and can be applied to wide-field views of the Milky Way or detailed studies of small planetary nebulae.

CCDs

Since their appearance on the amateur scene in the late 1980s, CCD (charge coupled device) cameras – eyepiece replacements that pass a digital image to a computer – have made an astonishing impact on amateur astronomy. Previously, amateur observers who had seen or imaged objects of 17th magnitude or fainter were few and far between. With a normal CCD more than 40% of all image-plane photons are recorded, which means you can image stars and galaxies down to 19th–21st magnitude, and create images of a quality that would have shocked observers from an earlier generation.

Some CCD users, such as Maurice Gavin, have gone further and taken spectra – charts of how light intensity varies with wavelength – of 14th magnitude supernovae in distant galaxies and have measured the redshifts of quasars. These activities were undreamed of only ten years ago. It's as if amateurs have suddenly gained access to professional scientific telescopes. The only drawback is that in order to take advantage of CCDs, as with photography, the amateur has to master a number of new techniques, each as demanding as drawing or photography.

First the observer must locate and centre the object of interest in the telescope field of view, and then replace the eyepiece with the CCD camera whilst avoiding jogging the scope view. Next the CCD must be focused. This also takes some time because each adjustment of the focus must be checked, which means capturing a test image on the CCD and seeing if focus has been achieved. If this takes 20 attempts and the exposure length for each image is 20 seconds, with an extra 10 seconds (say) to download the image from the CCD to the computer, then 10 minutes are used up just focusing. Remember, though, that focusing is an iterative process and you should never rush it. The quality of the final image will be determined largely by the quality of the focus. Remember, when trying to achieve perfect focus, that on a hot summer night the tube length will be different to its value on a cold winter night. Little things like this can make a noticeable difference. So think of it as time well invested, but learn to do it as efficiently as possible. When standing by a monitor in a cold garden with the chill seeping through the soles of your shoes, it's easy to say "that's good enough". This attitude leads only to mediocre pictures.

Attaining a perfect focus rather than just an acceptable focus can be made easier in a number of ways. One approach is to slowly adjust the focus mount, taking an image after each adjustment, and measuring the brightness or width of a star from one image to the next. When the star is at its brightest and smallest you can consider the CCD focused. This method isn't always easy, thanks to temporary variations in atmospheric seeing and thin clouds that tend to flit in and out of the field of view. So patience is required. Many of the automated focusing systems at professional observatories operate on this principle. Similar automatic systems may become popular with amateurs when motorised focusing mounts drop sufficiently in price.

Another solution is to place a mask over the clear aperture of the telescope. This can consist of two circles, letting light through, or thin strips that block light. The circles make unfocused stars produce two images, which merge as focus is approached. This results in an elliptical pattern when the image is slightly out of focus, which is easier to detect than slight differences in brightness or image width. A mask made up of thin strips leads to images where well-focused stars have pronounced diffraction spikes. When the star is well focused the diffraction spikes are clearest, narrowest and brightest. Again, this is quite easy to detect.

When a good focus has been attained, rotate the CCD in the eyepiece holder to achieve the most aesthetic composition, and then start taking pictures and storing them to your computer's hard drive.

Processing your raw image involves the removal of instrumental artefacts and requires some additional exposures. First, you will need to capture an image of the same exposure time, but with the telescope tube completely sealed. These "dark frames" will be used during image processing to remove the signal component generated by heat and electronics inside the tube. This is known as dark subtraction. You'll also need to take some images of the dusk sky. These are used during image processing to estimate and correct the pixel–pixel sensitivity variations of the CCD – a procedure called flat fielding.

Thereafter, some image processing is very similar to fiddling with the knobs on a television to get the best picture. The contrast and brightness are adjusted and some simple signal processing algorithms can be applied to enhance the image. You can even stack together many images of the same object, to maximise the signal-to-noise ratio. Recent years have seen the emergence of several good software packages such as WinMIPS and the more expensive MaxIm DL to do much of the hard work for you. For this reason, only experienced programmers with time on their hands or no spare funds should think about writing their own processing software.

Some observers also take pictures of objects through three different filters (red, green and blue; or cyan, mauve and yellow) and combine the result using software like Paintshop Pro or CCDOPS to create a "true colour" image. There are difficulties to overcome in doing this, however. The first is in correctly aligning the set of images that you take. The second is that many CCDs aren't very sensitive in the blue region of the visible spectrum, and so exposure times need adjusting to account for this. Getting it just right so that the final images are true can take practice. But the effort is worth it, as the results can be staggering. In recent years observers such as Ed Grafton, Al Kelly and Kunihiko Okano have shown just how good amateur observers can be, and their web pages are well worth examining.

The Limitations of CCDs

Unfortunately, using a CCD requires you to have a PC to perform the data processing, which can be inconvenient if you observe away from home or dislike taking your PC out into a wet garden. The price of CCD systems is also a major feature constraining their wider usage. Unsurprisingly, many people baulk at the idea of spending a lot on a CCD camera/computer, *on top of* the price of a good telescope, and so often opt to buy a bigger telescope and just observe visually.

Currently, the major reputable manufacturers of CCD cameras are SBIG, Starlight Xpress, Meade and Apogee. These companies sell good cameras, ranging from the humble SBIG ST4 camera/autoguider through the Starlight MX5 and Meade 216, right up to the top-end SBIG ST8, Meade 416, Starlight SX916 and the superb, but very expensive, back-illuminated CCDs supplied by Apogee. It must be said that the Starlight range currently represents extremely good value for money as they can now autoguide and image simultaneously almost as well as their more expensive SBIG counterparts. It'll be interesting to see how the other companies counter this relatively new development. Recently several of the SBIG cameras have been improved with the use of E series chips, which are more sensitive in the blue part of the spectrum. Additionally, the Starlight cameras will soon be using ExView chips. As a result, the quality of both these cameras may soon approach that of the very impressive range from Apogee, who have themselves recently introduced a new range of more reasonably priced cameras.

Currently this field is in flux but in a few years camera efficiencies in the region of 90% may be commonplace, after which point mirror and drive quality may become the main limiting factors determining what you can see.

Selecting a CCD

Selecting a CCD is no easy task. The most important considerations are: what do you want to observe, on which instrument will you be working and how much money do you have to spend?

Not surprisingly, most people want to be able to observe everything from the smallest planetary nebula right up to the large Cocoon Nebula. In reality, what you can image is constrained by your telescope. If you are using a 2 m focal length instrument there is little chance of going after really large objects, as your CCD is unlikely to see more than a small patch of sky a few arc minutes across. Similarly, if you are using an F4

200 mm (focal length 800 mm), the amount of sky captured by each pixel is likely to be so big that you won't be able to pick out detail in small planetaries, but you should get reasonable views of galaxies. One way around this, however, is to modify your scope set-up using an achromatic Barlow lens to increase the magnification or a focal reducer to decrease it.

To help you further in your selection, there's a useful mathematical formula (don't panic) for calculating the amount of sky covered by each pixel of a CCD:

$$P_s = \frac{200{,}000}{F_L} \times P_w$$

Here, P_s is the pixel width in arc seconds, F_L is the effective focal length in mm and P_w is the pixel width in mm. Given moderate continental seeing conditions, a pixel size of 2″ would not be unreasonable. If the size gets much bigger than 8″ you will find that the stars tend to be small squares rather than nice tight dots. Many people find this unacceptable aesthetically and I must agree – it does make the required drive accuracy rather less though.

The above formula also lets you work out the field of view of your CCD camera very easily – by multiplying P_s by the number of pixels spanning the CCD. If this turns out to be too small, you might want to consider employing a focal reducer, such as those manufactured by companies such as Optec or Meade. These act in an exactly opposite manner to a Barlow lens, decreasing the focal ratio, typically from F6 to F3.3 or F10 to F6.3, almost doubling the field of view. Be sure to buy a reducer designed for CCD work. Some reducers are not designed to focus near infrared or near ultraviolet light despite many CCDs – such as the Cookbook Camera, SBIG ST8E or Pixcel – being sensitive to these wavelengths. This can result in a star image having a tight centre surrounded by a large extended circle of light. Infrared blocking filters or so-called hot mirrors can help, but will still struggle to cope with red stars like Mira where the infrared flux is substantial. Optec specifically recommend the use of a yellow filter with their reducer.

Another point to be considered is the image sampling. Much has been said about 8-, 12- or 16-bit images and the effect they have on the number of shades of grey in the final pictures. The number of bits simply refers to the number of binary digits used to record the brightness of each pixel. The more bits, the finer the brightness graduations are and so the better the image quality.

Although it's possible to get a reasonable image with an 8-bit camera it's really not worth the hassle. There just isn't enough data there to do anything useful with – the image is said to be sample limited. High-quality work really requires at least a 12-bit or preferably a 16-bit CCD. With a 16-bit camera, your image processing is never likely to be limited by sampling.

On the down side, however, a 16-bit camera inevitably means bigger image files, and the 16-bit download time can be rather longer. This is probably not a concern for deep-sky work, but could be a minor hindrance if you also plan to undertake any planetary imaging, where you take dozens of images in quick succession in the hope of capturing a moment of good seeing. Fortunately, the plummeting price of computer hard disks makes the likelihood of running out of disk space during the course of a night quite low. This is different from the situation only a few years ago, when some observers had to stop and transfer data to back-up media such as ZIP drives halfway through the evening.

Ultimately, the overriding factor for most of us is going to be cash. Despite ten years' use in the amateur community, CCDs are still expensive. The bigger the CCD's surface area, the more you are likely to pay for it. Currently, CCDs with a sensitive area greater than 50 mm^2 are becoming more common, and so, hopefully, the price will eventually be driven down by competition. However, it remains unlikely that the cost will drop much below that of a second-hand 200 mm Newtonian scope within the next few years. Ultimately, you have to decide where your interests lie and make compromises based on the equipment you have (or are likely to obtain) and the cost of the CCDs available. There is a secondhand CCD market but, as with much astronomical equipment, the depreciation rate is small.

Chapter 3

Avoiding Common Mistakes

Battling with the elements is something that every amateur astronomer has to learn about. Having to contend with ice, winds and light pollution, only then to have your observing session cut short by cloud can be infuriating. So, of necessity, you have to learn to make the very best use of the observing time that you have. Half the battle is preparation. Here we offer a few quick tips on preparing to observe - information that could be useful to anyone longing for that next clear night.

Firstly, at 3 a.m. we are not at our best and it's easy to forget what caught our eye when we last browsed The Webb Society handbooks. So, on cloudy nights make a list of the objects that you want to see, in order of priority. Use an atlas, planisphere or planetarium software such as the excellent Skymap to determine at what time of night they will be visible. Alternatively, plan your evening's observing using software such as SACREP a shareware package from the Saguaro Astronomical Club web page to obtain a list of objects of the type that you are most interested in. When creating an observing list, remember to take your surroundings into account. Is the view limited in any direction by street lights or nearby trees and houses?

It's also useful to mark on your list the atlas page on which each object can be found, particularly if you are using something like the *SAO Star Atlas* or *Uranometria*, where each page covers only a small part of the sky. It's also worth grading each object on a scale of 1 to 3 - 1 for bright objects, 3 for nights when you push the envelope, 2 for average nights.

Unexpected clear nights can creep up on you, so keep your scope ready to go. Make sure equipment is well maintained, batteries are charged and eyepieces and filters are close to hand or packed and ready to go. Keep a checklist or plan of what you need - and use it!

Be sure you have to hand a torch fitted with a deep-red filter and a spare set of batteries and bulbs. Some are made from thermoplastics which become hard on cold nights and are impossible to switch on. It is also worthwhile checking how your rechargeable batteries respond to low temperatures. Some batteries and LCD displays are useless when things get really chilly.

As most active observers know, always show respect for the weather. If it's cold, dress as if you were off on a polar expedition - two pairs of socks, jogging bottoms over thick trousers, a t-shirt, fleece, padded shirt, coat, scarf, hat and gloves. Possibly even a balaclava. Ski jackets, gloves, boots or trousers are also winners. Consider taking an old telephone directory in a plastic bag with you. Standing on it will insulate your feet from the ground, keeping them a lot warmer - sounds silly but it works!

Figure 3.1 What the well-dressed observer is wearing. © Rachel Privett

Drawing or writing with gloves on takes practice, but try taking them off for a few minutes in winter and you'll soon discover that fingers numb with cold are even worse to work with. Even in the summer the metal cools very rapidly, making it uncomfortable to hold after only half an hour or so. Consequently, gloves or mittens are a must, even if they do make intricate work fiddly. Fingerless gloves can be quite a good compromise especially the sort that have an extra fold-over section that converts them to mittens.

Don't let warm summer evenings lull you into a false sense of security either. Cool breezes can quickly spring up, so make sure that you have a coat to hand. Mosquitoes can also be a problem during the summer months, so generously apply an insect repellent before you start. Equipment for repelling larger beasts may be necessary in remote spots.

Taking a couple of ten-minute breaks for coffee while observing is worthwhile. A warming drink is essential when observing from remote sites. The break of routine helps to keep you fresh, while the warmth and caffeine will keep you going that little bit longer.

A chocolate or fruit bar eaten slowly – over the space of an hour or so – can also offer welcome sustenance, boosting your blood sugar levels and maintaining eye sensitivity. Be sure to avoid heavy food or any alcoholic beverages since they will make you sleepy. Nibbling is better than gorging.

For those of you travelling for your observing, make sure you reconnoitre the site well beforehand. Be certain of your route. Driving around in the dark, wondering just which field it was, is a terrible waste of time, especially on a clear night. If your site is not public land make sure you have appropriate permission before entering. Also, if you are going to travel some distance, make sure you have selected the best possible location in the area. Go there on some cloudy nights and estimate how dark the site is. Can you see glow from nearby towns? Are there houses with security lights nearby? Are you well away from the main road? All are worth considering. There's no point travelling if you are not going to get the maximum possible return for the effort.

Make sure you take spare screwdrivers, lasso/gaffer/duct tape and fuses for any electrical equipment that you will be using. Turning on an LX200 after a two-hour drive and 30 minutes setting up to see the only fuse blow is awful (been there). Equally bad are conversations ending in: "But I thought you packed the

Figure 3.2 The essentials. Thermos, atlas, extra clothes, pens, batteries, sweets, mosquito repellent, torches. © Grant Privett

extension cable!". Double-check your list before leaving home. Storing items in toolboxes between trips is one approach. Whatever you choose to do, plan the work and work the plan.

Always take care with the "earthing" of electronics. Fields at night get very wet. Water and electricity do not mix well and so it's essential that you check the earthing of the equipment if high voltages are involved. Using a surge-detecting cut-out socket is also prudent as the risk is very real. Please be careful.

Another frequently neglected item is a first aid kit. It's also worth making sure that someone knows *exactly* where you are and when you should be home. Even better, take a mobile phone with you. Dark sites are sometimes quite remote or isolated and a broken leg is rather immobilising. It could be hours or days before someone finds you by chance.

A final item worth packing when going on a remote observing trip is a packet of strong mints. On the drive home, with the dawn approaching, it's easy to become drowsy and you may need help staying alert. If you get too tired, you should pull off the road and sleep for a couple of hours. Otherwise, if you feel any lessening of your concentration, slow down, chew half a dozen strong mints and then inhale sharply through your mouth. It's quite a jolt. Also, if you start getting too comfy, try winding down the window or stopping for another hot drink. You might also like to try a loud blast of music, something that stirs your blood.

These are just a few suggestions to think about when it seems that the sky will never clear. Planning ahead is the key to productive astronomy. Just a few hours invested in preparation can massively improve your chances of a truly memorable night.

Chapter 4

The Messier Marathon and Other Pursuits

People pursue astronomy, as they do many hobbies, for a variety of reasons. Some seek the beauty of a dark, star-studded sky overhead and the solitude of the

Figure 4.1 The man who takes the blame: Charles Messier. © SEDS

predawn hours. Some enjoy the thrill of a chase; the pleasure to be had in seeking out an obscure Local Group galaxy in Leo by patiently star hopping across the sky to finally glimpse a skein of gossamer light. For some, the pleasure can be in spurning commercial telescopes and building a precision instrument from scratch; perhaps even grinding the mirror themselves. Others find pleasure in rigorous, planned observations that make a contribution to science.

It's this diversity of activities that helps to make astronomy so enduring. In this chapter, we outline four "slightly different" deep-sky pursuits, should you ever feel the need to breathe new life into your own observing plans. Why not try one? It might be fun!

Messier Marathon

During the dark of the new moon nearest to the spring equinox, it is theoretically possible to observe all Messier's catalogue in one night. This occurs because the Messier objects are distributed in such a way that in late March some set in strong twilight, most are visible during dark hours and the remainder rise with the sky brightly lit by the coming dawn.

Some people might complain that this sounds like an astronomical bus tour, a manic rush with no time to enjoy the view. But this is an oversimplification; rushing only occurs at the start and end of the night and there is much time to select non-Messier objects in the early hours. As the marathon can only be attempted occasionally, it's worth having a go as an adjunct to normal observing – a bit of fun to be enjoyed with friends. Indeed, many societies turn the Messier marathon into a social occasion, drawing together disparate members to swap anecdotes, ideas and techniques. The marathon's ephemeral nature only enhances the experience: if it could be attempted at any time of the year, half the fun would be gone.

It sounds simple enough in principle. Just point your scope, find a Messier object, tick the box and then go on to the next one. But, in practice, it's quite difficult. There is precious little time spare at the start and end of the night, when you are observing deep-sky objects against a partially lit sky. The main trouble makers are M77, M74 and M33 at the start of the night, the poorly placed M6 and M7 later on and, finally, M30, M72/3 and M2 at the end of the night. Fortunately, M77 has a bright core and the globulars, M2, M72, M73 and M30, are also reasonably bright. But the low-surface-brightness M74 can be a real stumbling block. Also, M6 and M7 in Sagittarius are low from most of the temperate regions in the northern hemisphere and so demand a very clear southern horizon. You can greatly improve your chances by attempting the marathon from a southerly site such as Pumichel in France, the Centre of Observational Astronomy in the Algarve, or in any of the more southerly states of the USA, from where many successful marathons have been completed.

The middle part of the night is rather more leisurely than the beginning and end. But this is just as well since it involves observing in Virgo and Coma Berenices. For many less-experienced observers this can be a bit of a trial, as bright reference stars are few and far between. If you are planning a marathon, it's worth spending a few nights practising the Virgo cluster beforehand.

Those seriously undertaking a non-computer-aided Messier marathon deserve respect. It undeniably requires skill to identify 100+ objects using setting circles or by star hopping. If nothing else, eight hours of concentrated observing is going to teach you some tricks and improve your technique. Even owners of computer-controlled scopes are in for a challenge and anyone managing to manually chalk up 95+ Messier objects in one night should feel pretty pleased with themselves. Some societies even hand out certificates for the marathon, and also for managing to observe 400 or so of the best NGC objects – although not all in one night. This can encourage friendly rivalry between observers. Sadly, it can also lead to some people being dubbed unskilled observers, simply because they like to spend time admiring each object rather than rushing on to the next. So be sure to appreciate the Messier marathon for what it is: just a bit of harmless fun.

Supernovae Searches

One pursuit much in vogue at present is searching out supernovae in remote galaxies. As with the Messier marathon this sounds a bit of a doddle. Just point your telescope at a galaxy and see if it has a supernova in it. If it has, notify the staff of *The Astronomer* magazine (see page 104). Then sit back and wait for the International

Figure 4.2 NGC3877 with a supernova explosion in progress. © Grant Privett

Astronomical Union circular to announce your discovery around the world and the local newspaper to beat a path to your front door.

The problem, however, is that supernovae are not that common and you have to search an awful lot of galaxies to find one that has not already been observed (3,000+ for a 50:50 chance if the competition doesn't get there first). At the distance of most galaxies in the Messier and NGC catalogues a supernova is not often brighter than 14th magnitude, which for many observers is near their visual limit. Furthermore, new supernovae do not have a label next to them saying "Me me me!", and so a lot of checking and rechecking is required to distinguish the supernova from other stars. This requires much time and effort. Observers like Ron Arbour and others spent years refining their techniques, photographically creating finder charts to eliminate false alerts and religiously observing night after night.

Fortunately, the advent of CCDs and computer-controlled scopes – technology previously confined to professional observatories – has greatly improved the chances of finding one. Hardware like the Celestron Ultima and Meade LX200, with their GOTO facilities, allow an observer to move quickly from one galaxy to another without the delays normally imposed by fatigue or the need to star hop, while CCDs such as the SBIG ST7E make imaging a 17th magnitude supernova almost commonplace (a 30-second exposure on a 300 mm SCT should reach 19th mag) – Mark Armstrong alone has found three 17th–18th magnitude supernovae with an LX200. Object-locating software can even be used to compare the image created by the camera with a master reference image, either read from the *RealSky* CD, downloaded from a web archive or imaged during a previous session. If an anomaly is present it can quickly be identified.

Unfortunately, finding supernovae still requires a substantial investment of cash and effort. At today's (May 2000) prices, we are looking at a telescope costing £2,400 ($3850), a CCD camera costing at least £750 ($1200) and about £1,500 ($2400) of computer hardware and software. These sums of money are beyond what many people want to, or are able to, spend on their hobbies. Nonetheless, the practice has a hardened following worldwide, who have discovered a substantial number of supernovae and made a real contribution to science.

Finally, it's worth mentioning that just observing a galaxy containing a supernova can be fun. The supernova can transform the look of the galaxy dramatically and for some time. The 1998 supernova in NGC3877, gave the galaxy two quite distinct nuclei. The bright supernova in M51 in the early 1990s was unforgettable. Anyone giving serious thought to supernova searching should consider subscribing to *The Astronomer* magazine, or joining the BAA Deep-Sky Section.

Active Galactic Nuclei and Quasars

Another sideline for the deep-sky astronomer is observing the cores of bright galaxies and quasars, looking for variability. The procedure is very similar to variable star observing, where you compare the brightness of your target with the brightnesses of outlying stars in the same field of view. In fact, when it comes to quasars the two pursuits are indistinguishable – an amateur telescope will only ever show up a quasar as a star-like point of light. The brightest quasar – 3C273 in Virgo – is 12th magnitude and so should be accessible to observers with 150 mm or more of aperture.

As usual, there are pitfalls. Some active galactic nuclei (AGN) such as M77 are surrounded by a bright host galaxy which makes judging the brightness of the core rather difficult – as anyone who has searched for variability in the central star of M57 and other planetary nebulae will know. This can mean that for some galaxies you have to deliberately defocus the image

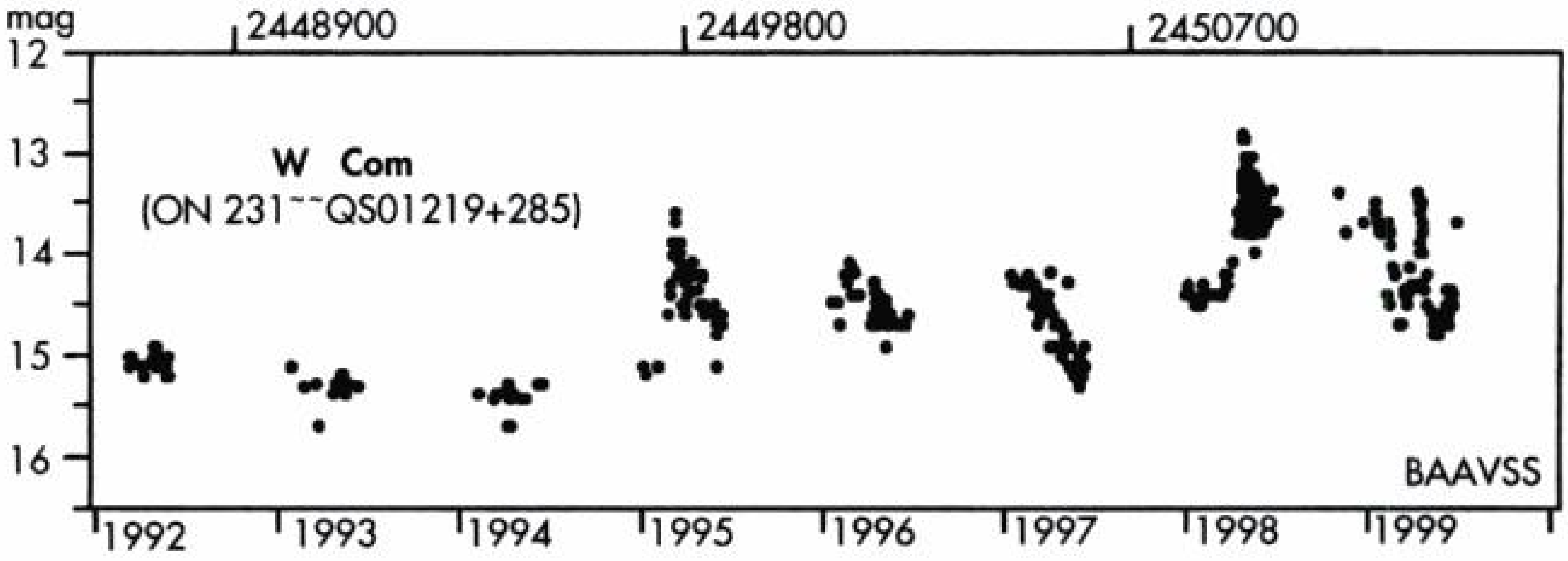


Figure 4.3 Light curve for AGN BL Lacertae. © John Toone

slightly to improve the contrast. But this in turn makes faint comparison stars vanish. The problem can be lessened if you use a CCD or photograph to image the AGN and then subtract the brightness of the surrounding galaxy. However, this is by no means easy, since the brightness of the galaxy varies rapidly as you move outwards from the core.

Despite these difficulties, groups like the BAA Variable Star Section follow a number of quasars and AGN, producing light curves that show astonishing amounts of activity deep in the cores of quasars. And these observations are useful to professional astronomers – not bad for small telescopes in the hands of a few amateur enthusiasts.

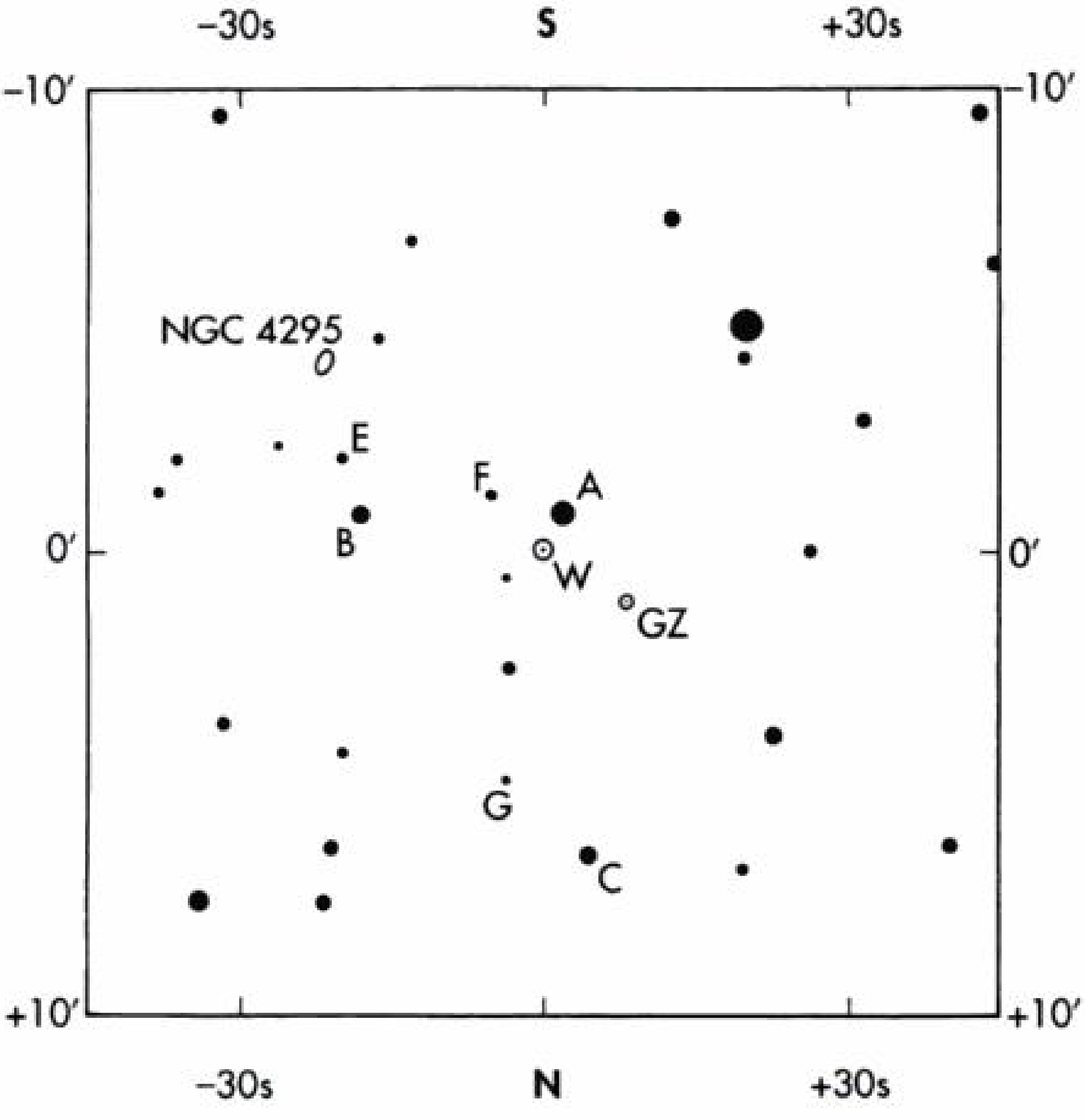


Figure 4.4 Finder chart for the AGN W Comae Berenices. © John Toone

148 02
20′ FIELD INVERTED
W COMAE BERENICIS
12h 21m 31.7s
+28°13′59″ (2000)

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APPROVED: R PICKARD

Figure 4.5 The faint variable nebula NGC1555 in Taurus. © Grant Privett

Variable Nebulae

Observers with access to CCD equipment or experienced in photography might enjoy a long-term observing project involving variable nebulae. These consist of nebulosity where the illuminating star is occasionally obscured by dark material near to it, thereby casting shadows on to the surrounding gas/dust clouds and fundamentally modifying the appearance. Well-known examples include the Hubble's and Hind's variable nebulae (NGC2261 and NGC1555). Less familiar are NGC6279 and the gloriously named Gyulbudaghians Nebula which is associated with the variable PV Cepheus. Observations of any of these objects with consistent filters and instrumentation would be very well received by the director of the BAA Deep-Sky Section and make a great addition to any astronomical society "members' evening".

List Observing

Many observers, upon finally tracking down their last unobserved Messier object, pause and wonder "what next?". Some stick to reobserving the Messiers, with the planets, double stars and, perhaps, a few of the brighter

NGC objects, such as the Double Cluster in Perseus, thrown in, and possibly experimenting with different eyepieces or filters to see what gives the best view. Others decide to take up observing all the objects on a "recommended" list such as the Caldwell list (see the Practical Astronomy title *Observing the Caldwell Objects*, by David Ratledge) or possibly even the more extensive Herschel 400 – the highlights of the objects discovered or catalogued by William Herschel, the renowned deep-sky observer and discoverer of the planet Uranus. Other common list-based observing pursuits are seeking out all the Local Group galaxies visible from your latitude, visiting Abell galaxy clusters and pushing your telescope and yourself to the limits.

One very popular pursuit that can be undertaken from most sites is examining faint planetary nebulae, such as those in the PK and Abell catalogues, using filters to counter the effects of light pollution and see which of them really are within the range of amateurs.

Alternatively, web sites like that of Bill Arnett and *Adventures in deep space* (see page 98) can provide lists

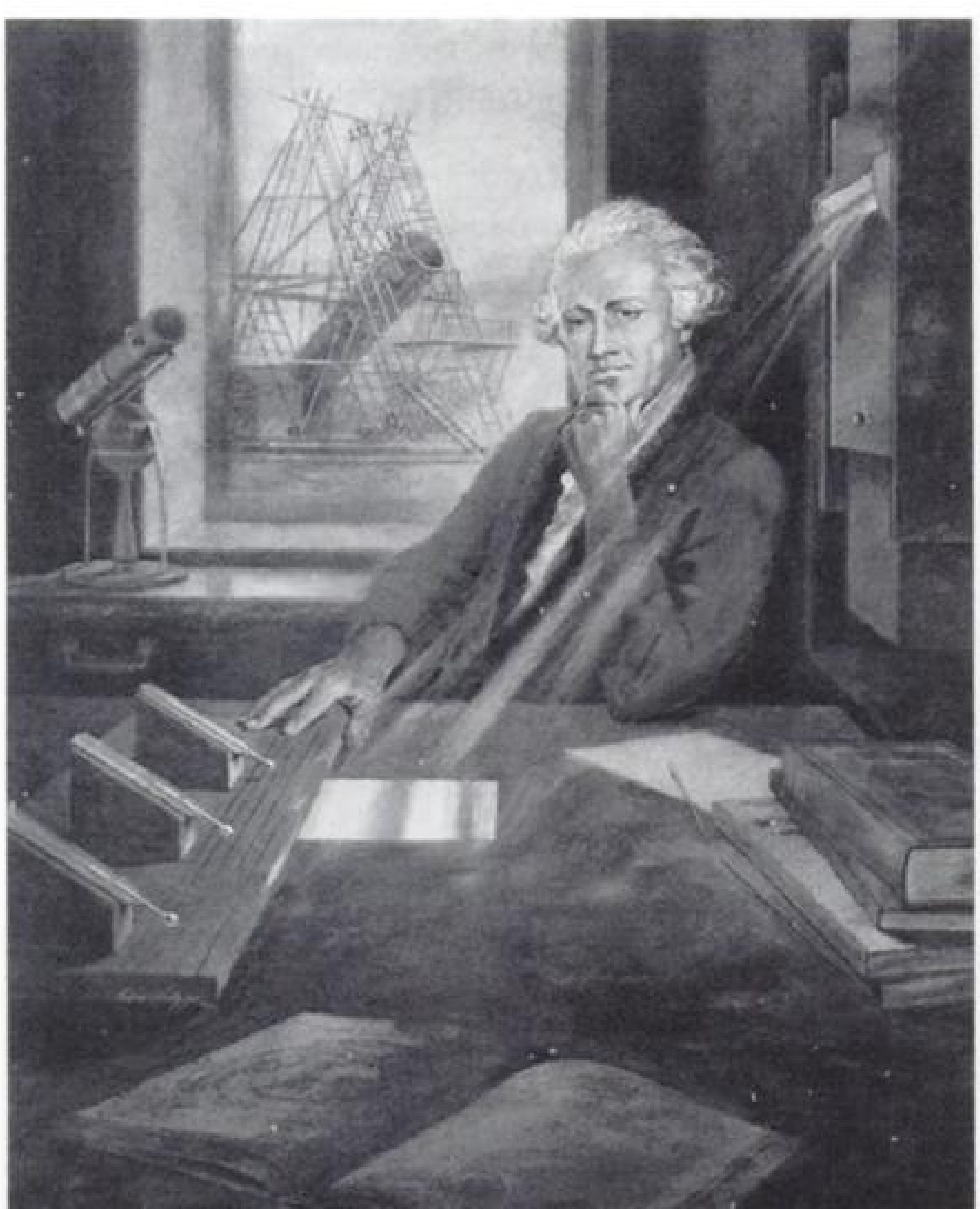


Figure 4.6 William Herschel discovering infrared radiation. © Infrared Processing and Analysis Center, Caltech/JPL

of objects that are certainly worth a glance and provide hours of pursuit and observing. But, it's important in all this to remember that astronomy is a hobby that you do for the fun of it. If browsing the best objects is what you want to do, have fun doing it. Similarly, if you get enjoyment seeking out some obscure globular cluster attached to M31 (there are lots) then may that also bring you pleasure. There is no right or wrong in choosing what to observe. The only advantage of a list is that it may include objects that push you to your limits, encouraging you to become a more proficient and more experienced observer. Try getting into the habit of making notes of interesting objects mentioned in books or magazines.

Star Parties

These are fun if you get the chance. Getting lots of observers together in the same place to observe for a week(end) provides a chance to see how everyone else does it. It's an opportunity to swap tips, compare notes and make friends in a hobby that is often seen as anti-social and the province of the loner. For example, if you've been having trouble with a mount and are considering a change, there will be lots of people to ask for opinions. If there's something you have tried to observe and failed then others can tell you what worked for them. The burst of infectious enthusiasm can remind you that astronomy is fun. Go to a star party, set up a scope and chat to those around you.

Chapter 5

What Are We Looking At?

As you slew the scope across the night sky, hopping from target to target, it's sometimes easy to forget that each beautiful scene the eyepiece presents you with is in fact a real object. Targets for the deep-sky astronomer break down into a wide selection of galaxies, nebulae and star clusters. Before proceeding to the chapter describing *where* everything is in the night sky, and how best to see it, it's worth spending a little while reminding ourselves just *what* these things really are. On the other hand, if it looks like being clear tonight, then move on quickly and return here when its raining again.

Nebulae

"Nebula", the Latin for "cloud", is one of the oldest terms in deep-sky astronomy. During the 18th and early 19th centuries it was used to describe any deep-sky object that was diffuse or fuzzy-looking. Charles Messier, for example, referred to all the wide and varied objects in his famous catalogue as nebulae, and later observers like Herschel assumed that if you had a big enough scope any deep-sky object would resolve itself into a cloud of faint stars.

Today, the word has taken on a much more specific meaning. This is due largely to the huge technical advantages we have over our predecessors, enabling us to see more of the distinguishing details of deep-sky objects. In particular, we now have spectrographs,

Figure 5.1 The spectacular reflection nebula NGC1435. © Yuugi Kitahara

which split the light from an object into its constituent colours and display the relative brightnesses of each. This creates a characteristic signature, giving the observer a clue as to the nature of the light's source. When this was done first done by Huygens, he found that while some nebulae exhibited the spectral signature of starlight, others didn't. Instead they were made mostly of gas and dust. Eventually objects made of stars took new names - like "galaxy" or "cluster" - while the new-found gaseous systems retained "nebula", in keeping with their origins.

It's now known that nebulae make up a significant proportion of many galaxies. For instance, they account for around 10% of the total mass of the Milky Way and can span several light years. Nebulae can be divided into three main types.

Reflection nebulae contain a large proportion of dust, which tends to reflect and scatter the light from nearby stars, making the nebula appear to glow with a bluish tinge. A fine example is the faint nebula surrounding Merope in the Pleiades cluster. If the cluster was not there the nebula would not be seen visually at all.

Figure 5.2 The Orion Nebula from the Hubble Space Telescope. © STScI/NASA

Next are the emission nebulae. Instead of reflecting or scattering light from nearby stars, they glow with a characteristic pink tinge because they absorb the starlight, becoming ionised and excited in the process, and then subsequently use the energy to make their own light. Most nebulae consist mainly of hydrogen gas, which in a near vacuum emits light only at a few well-defined frequencies such as those of the Balmer series, thereby leading to the faintly pinkish colour. The most-studied emission nebula is M42 (the Orion Nebula), which is powered by light from the Trapezium star cluster. But it should be remembered that both types of process can occur in a single nebula, an example being the Trifid Nebula.

Lastly there are the absorption or dark nebulae. As their name suggests, these absorb light, rather than emitting or reflecting it, blotting out any stars or bright objects situated behind them. This makes them appear as conspicuous dark patches on otherwise bright areas of the sky. Dark nebulae contain gas and dust, and usually have very low temperatures.

The most famous example is the Horsehead Nebula in Orion – silhouetted beautifully against the bright backdrop of the emission nebula IC434.

Because nebulae are such rich concentrations of gas, they are prime sites for star formation. Researchers

Figure 5.3 The Trifid Nebula, M20, imaged by the HST. © STScI/NASA

Figure 5.4 The Horsehead Nebula from Kitt Peak National Observatory. © AURA/NOAO

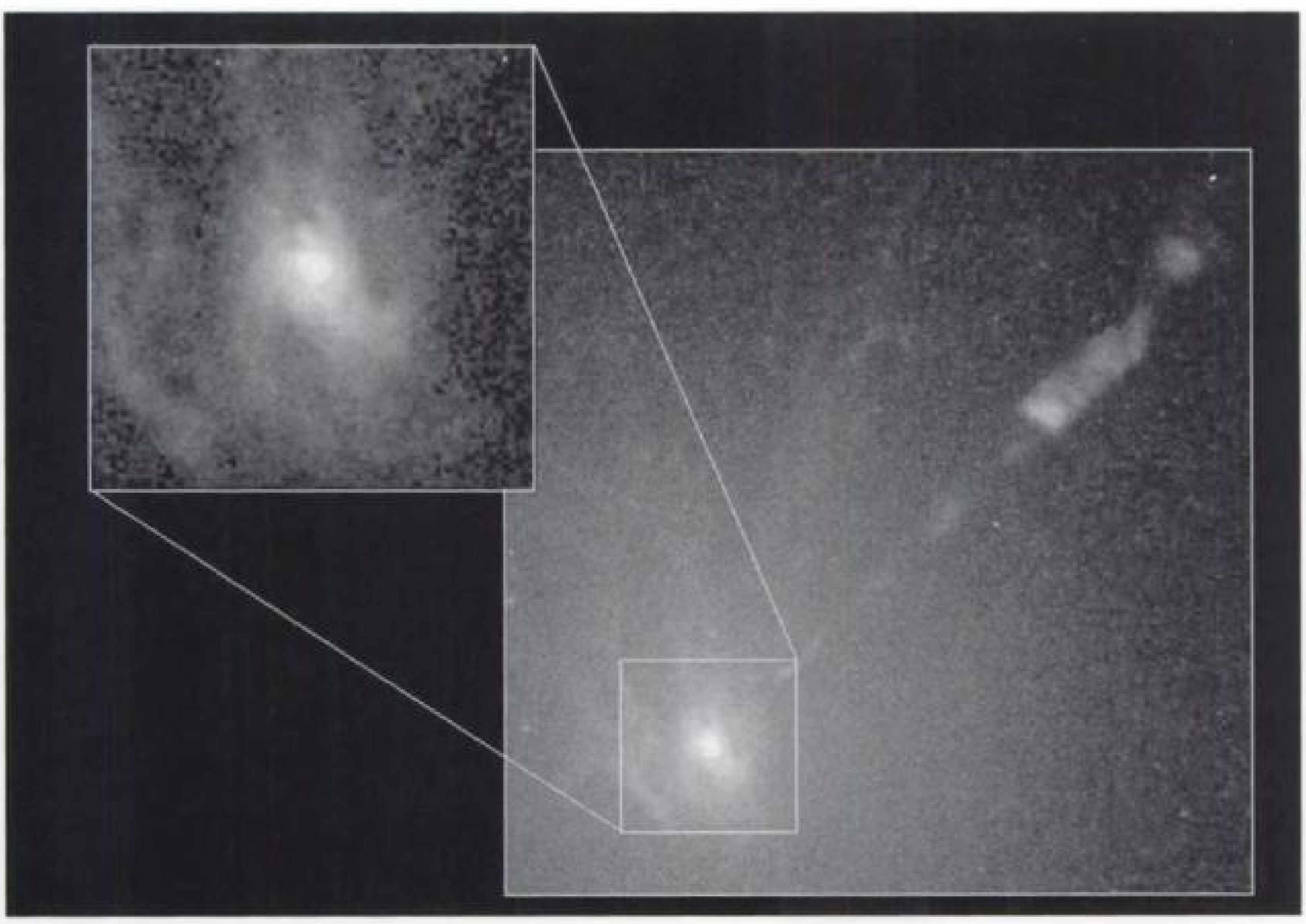
using the orbiting Hubble Space Telescope have gathered close-up images of newly formed stars behind the gas and dust in the Orion, Trifid and Lagoon nebulae.

Galaxies

Not all of Messier's old nebulae were found to be dominated by their gaseous component. Many are made of stars, orbiting around their common centre of gravity. Galaxies are the largest of these stellar gatherings, containing anything between 100,000 and, in the case of the giant M87, 3,000 billion Sun-like stars. The separations between galaxies are typically more than 1,000,000 light years and they tend to exist in groups. Roughly 50 billion galaxies can be seen with existing telescope technology.

The general heading "galaxies" breaks down into a number of sub-categories. Perhaps the most spectacular for the deep-sky astronomer are spiral galaxies. These concentrate their stars into a huge, flattened disk, often around 100,000 light years across and about 2,000 light years thick. The disk contains bright spiral-shaped arms. These are density waves that sweep around the galaxy, compressing gas and dust into new generations of stars. These bright young stars are what make the spiral arms shine. The first spiral galaxy to have its structure recognised was M51 (the Whirlpool Galaxy), observed by Irish astronomer Lord Rosse in 1845.

Figure 5.5 A disk of hot gas at the core of active galaxy M87. © STScI/NASA



But the arms are only part of a spiral galaxy. At the centre of the disk is a region known as the "bulge" - a spherical lump of stars, a few thousand light years across, that forms a central hub about which the rest of the galaxy revolves. Some spirals also contain a bright "bar" of material that passes through the bulge and from which the spiral arms trail. A classic barred spiral is M95, in Leo.

The disk of a spiral galaxy is also embedded inside a spherical cloud of material called the halo, which is about the same diameter as the disk and composed largely of stars and dark matter - which cannot be seen but its presence can be inferred from its gravitational influence on nearby bright objects. Unlike the stars in the disk - which are typically young, having formed recently in the spiral arms - halo stars are very old. They are concentrated into groups called globular clusters (see section below).

In contrast to the intricate structure of the spirals are the smooth, featureless forms of elliptical galaxies. Very little star formation occurs in ellipticals and con-

Figure 5.6 A cross section through a spiral galaxy.

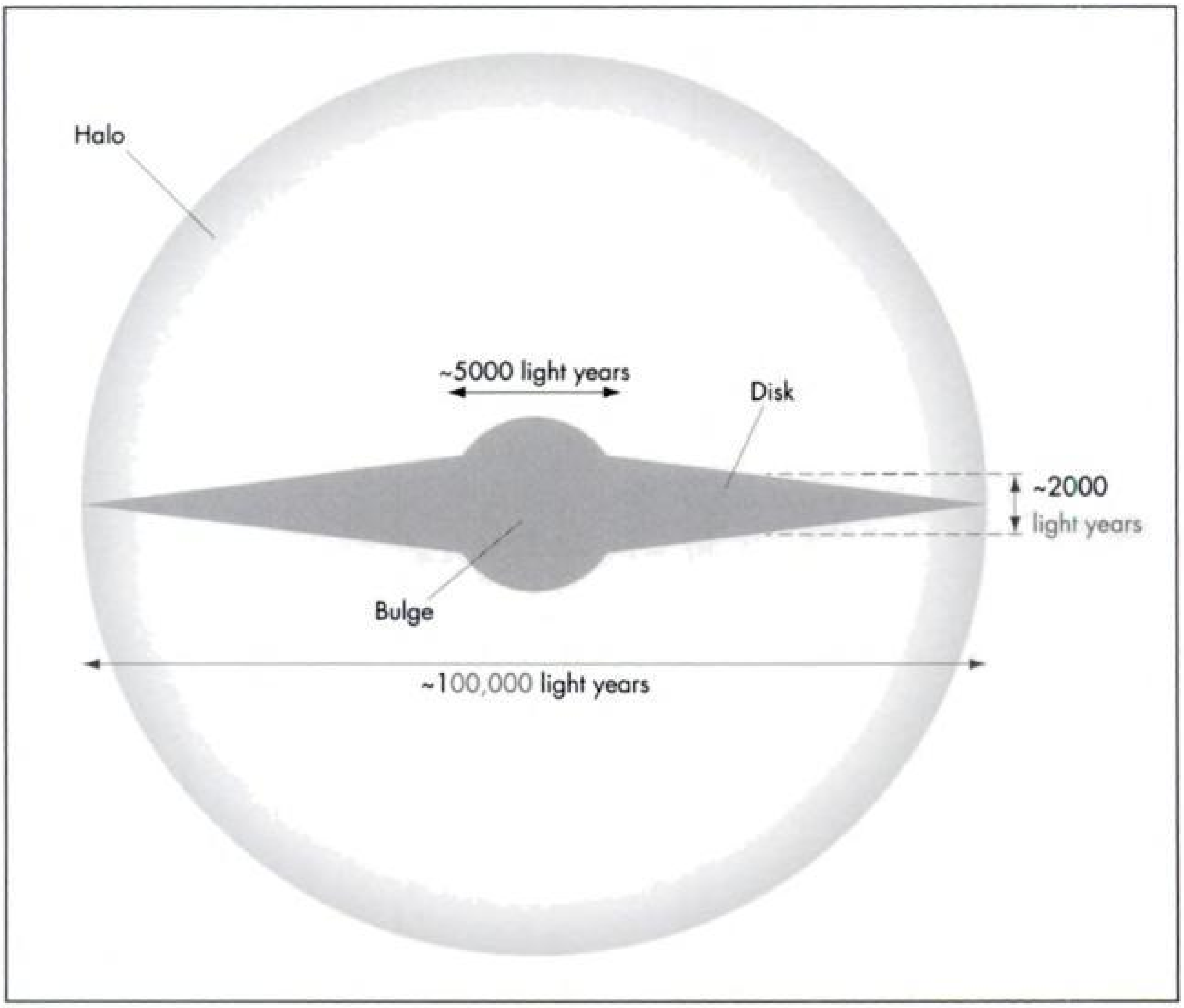


Figure 5.7 M95, a barred spiral in Leo. © Grant Privett

sequently most of the stars they contain are older than 10 billion years. Roughly 60% of all galaxies are ellipticals. They are sub-divided into dwarf ellipticals, denoted by the prefix "d", which contain about a million stars, and supergiant ellipticals, which can harbour thousands of billions of stars and are denoted by the prefix "c". Giant ellipticals are often over 20,000 times brighter than dwarf ellipticals, and 50 times the size.

In between the ellipticals and spirals lies an intermediate class of galaxies, known as the lenticulars, so named because their shape resembles that of a convex lens. These have a disk and a central bulge like a spiral galaxy, but no elaborate spiral structure. M84, in Virgo, is a good example.

In 1925, American astronomer Edwin Hubble incorporated this assortment of galaxy morphologies into a formal classification scheme. Known as the tuning fork diagram (see Fig 5.9), it splits elliptical galaxies into eight types, depending on their degree of flatness, ranging from E7 (very flat) down to E0 (roughly spherical). The Hubble classification also divides spiral galaxies into a range from Sa (large central bulge and tightly wound spiral arms) to Sc (small central bulge and loosely wound arms). In exactly the same way, spiral galaxies with a bar through the centre are classified SBa through SBc. Lenticulars fit into the diagram between spirals and ellipticals and are referred to as type S0.

Between the prongs of the tuning fork lies a special class, called "irregular". These galaxies have a fuzzy

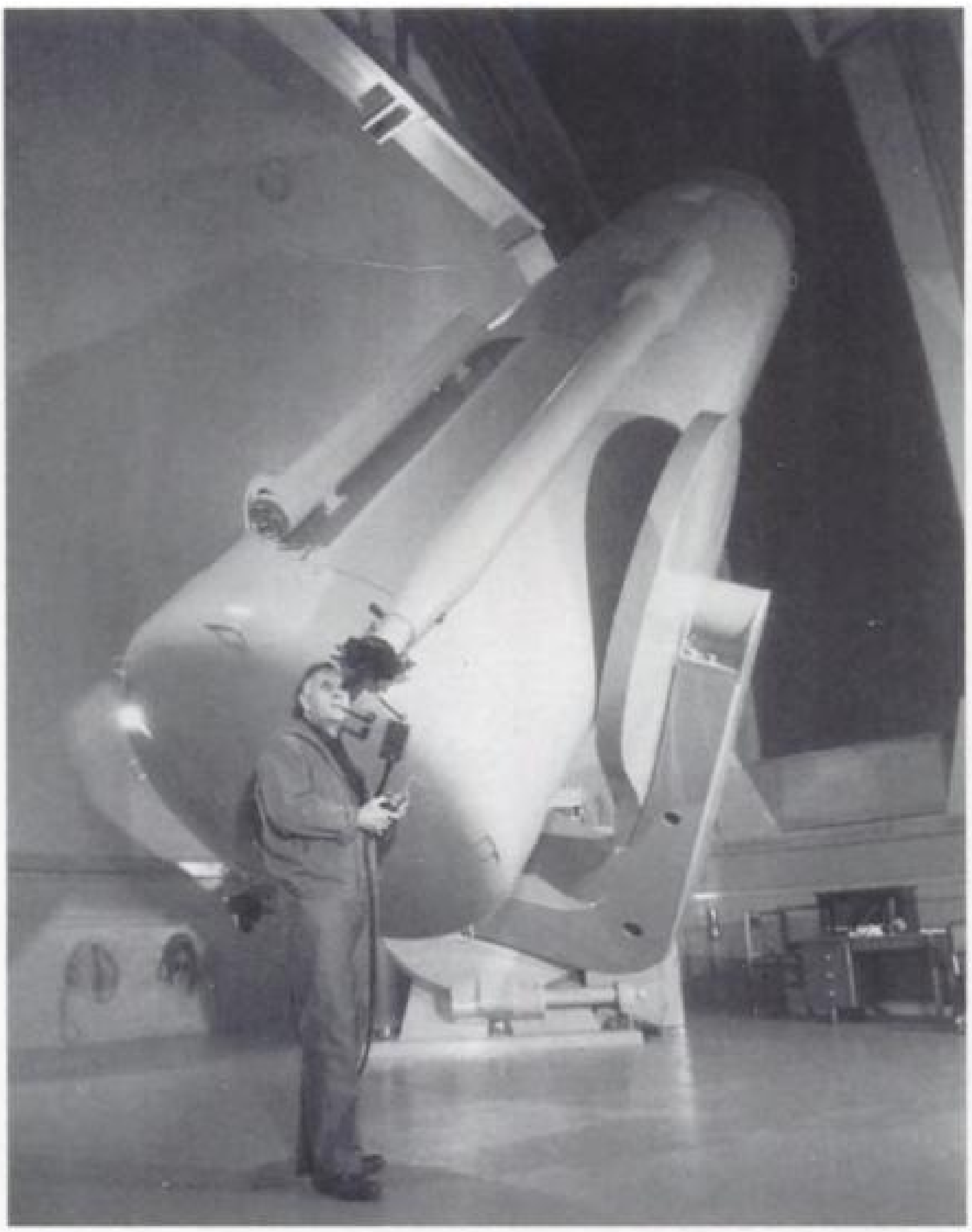
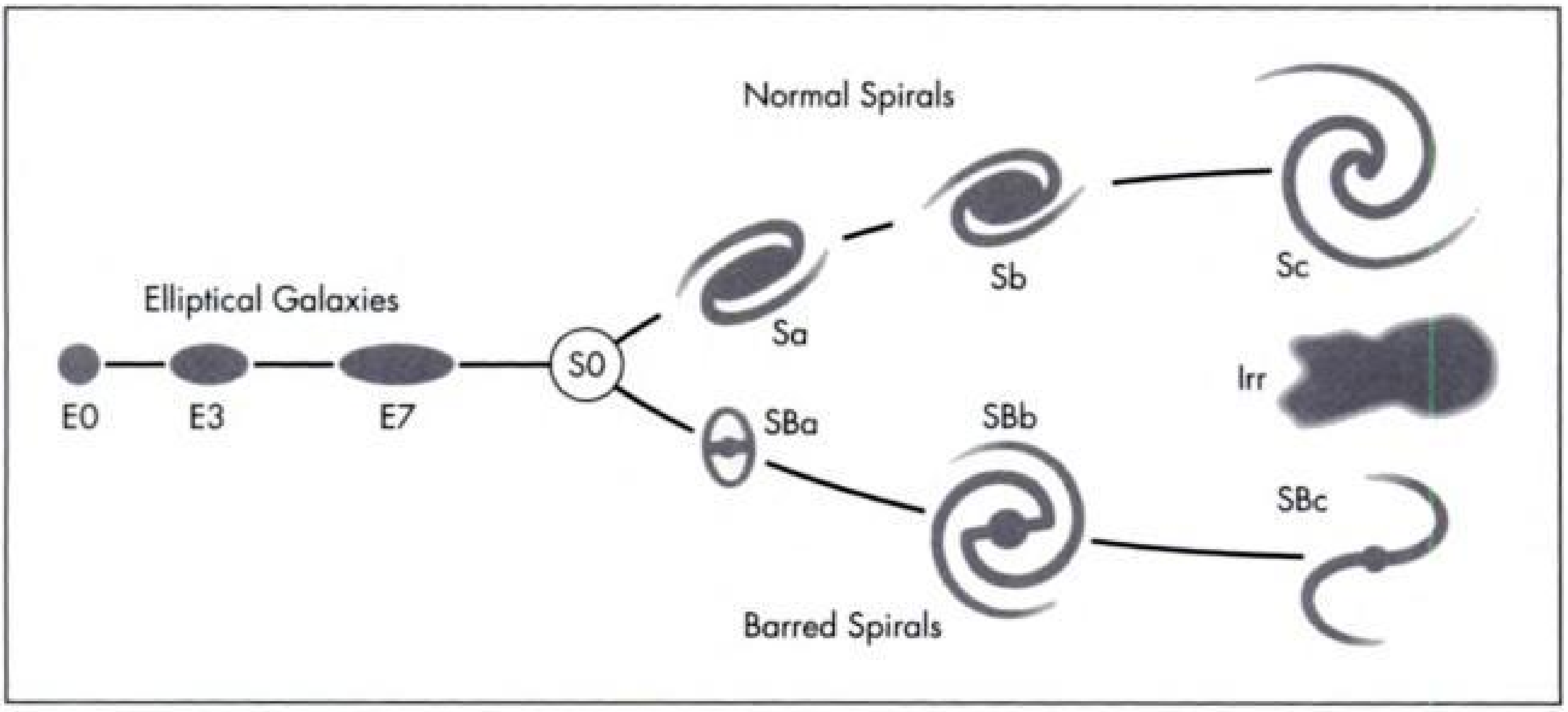


Figure 5.8 Edwin Hubble at the Schmidt telescope on Palomar. © Caltech

appearance and chaotic structure, preventing them from being placed in any of the other categories. Denoted either I or Irr, about a quarter of all known galaxies are irregular. Even stranger still are the "peculiar" galaxies. These have the standard shape of an elliptical or spiral, but with a distinguishing twist or

Figure 5.9 The tuning fork diagram, showing Edwin Hubble's galaxy classification scheme.



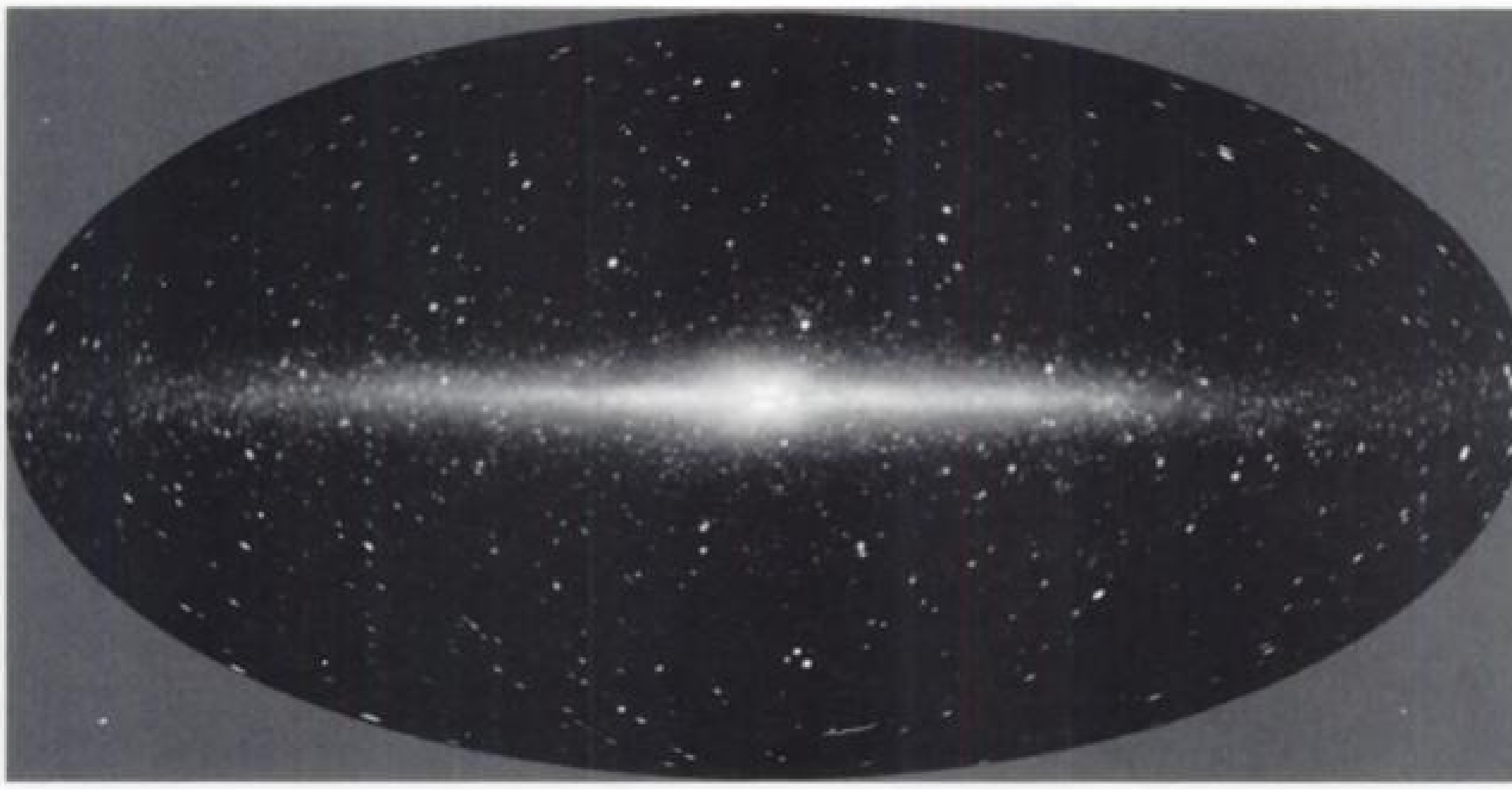


Figure 5.10 The Milky Way disk as seen by the COBE satellite. © NASA GSFC and COBE Science Working Group

anomaly. Many peculiar galaxies are thought to have been formed by collisions or close encounters with other galaxies.

Our Milky Way is a spiral galaxy of type Sb or Sc. It is 100,000 light years in diameter and contains in the region of 200 billion stars. The bright hazy band dividing the sky on a clear night is the Milky Way's disk, as seen from our vantage point within it – about 28,000 light years from the centre, on the trailing edge of a spiral arm. The Milky Way also has two smaller galaxies orbiting it: the Large and Small Magellanic Clouds. Each is an irregular dwarf elliptical galaxy, measuring approximately 5,000 light years across and containing between a few hundred thousand and a few million stars. Many similar satellites have been seen orbiting other galaxies.

Galaxy Formation and Evolution

English astronomer and physicist Sir Isaac Newton was one of the first to speculate about the origins of galaxies, in 1692. He imagined the universe starting off with a very low, but evenly distributed density of matter. This then collapsed under its own gravity and fragmented into smaller clouds. Newton supposed that as these clouds, or galaxies, collapsed further they would have fragmented again, creating even smaller structures – the stars.

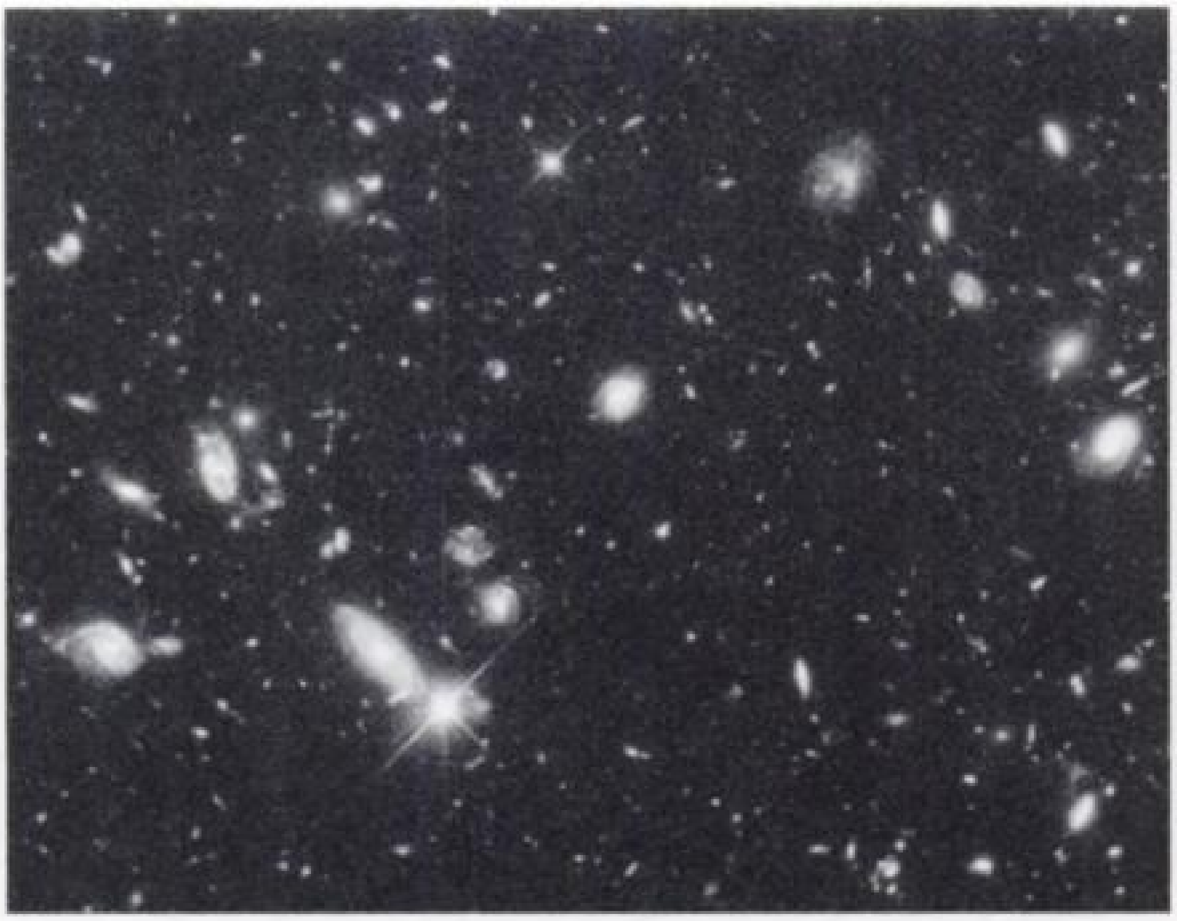


Figure 5.11 The Hubble Deep Field, the HST's deepest view of the universe. © STScI/NASA

This is what cosmologists call a top-down model of galaxy formation: the biggest structures form first and then split up to make progressively smaller ones. The other possibility is known as a bottom-up scenario. Here, the smallest objects (i.e. stars) form first and then cluster together gravitationally into larger aggregations. Which of these scenarios actually happened is determined by the specific kind of dark matter that astrophysicists believe makes up the dominant fraction of our universe.

The currently favoured view is that galaxies formed in our universe via a bottom-up scenario. The first stars would have started to form roughly a million years after the Big Bang, as the Universe became cool enough for matter to collapse under gravity. Approximately 500 million years later, these stars and the many that had formed since joined together into clouds called protogalaxies.

These galactic building blocks then clustered together to form the first generation of spirals. It would have taken many protogalaxies to make a full-size spiral galaxy. The Milky Way, for example, is thought to have formed from roughly a million of them. As the protogalaxies collided and merged, they often struck each other glancing blows, causing them to rotate, perhaps explaining the rotation of spiral galaxies seen today. It may even have been the impacts of larger protogalaxies that triggered the formation of spiral arms.

Shortly after their formation, the first baby galaxies were gripped by violent waves of star birth, spawning many young blue stars within them. Professional astronomers have seen scores of these small blue galaxies at large distances (see "Faint Blue Galaxies", page 86). The galaxies are visible today because of the look-back effect – objects which were present 3 billion years ago, can be seen by looking 3 billion light years out into space.

Some of these blue spirals could be the precursors to what we see in the Universe today as elliptical galaxies. Because there were so many spirals present at that time, mergers between them would have been frequent. Computer simulations have shown that when two spiral galaxies merge, their spiral structure gets completely disrupted, leaving behind just a smooth ellipsoidal blob of stars – an elliptical galaxy. This idea is further supported by the fact that most ellipticals are much heavier than the average spiral.

Some researchers believe there could also be more drastic evolution at work. They think that some spiral galaxies in the present-day Universe are the corpses of quasars (see "Active Galaxies", page 84). The huge energy output of a quasar is thought to be powered by the accretion of matter onto a black hole at its centre. But this process can't continue for ever: eventually the quasar's supply of matter must run out, at which point

Figure 5.12 A quasar, 9 billion ly distant, seen by the Hubble Telescope. © STScI/NASA

Figure 5.13 The Hubble Space Telescope's view of galaxy cluster Abell 2218. © STScI/NASA

its bright central engine switches off. The theory says that when this happens the quasar is demoted to a normal galaxy. Evidence for this idea is provided by recent detections of immense black holes lurking at the centres of many normal galaxies, including the Milky Way.

The gravitational bunching together of matter in the universe didn't stop at making galaxies. It also pulled the galaxies themselves into giant aggregations, or "clusters", often millions of light years across and containing thousands of members. The Milky Way belongs to a cluster known as the Local Group, that also includes M31, the Andromeda Galaxy.

Galaxy clusters are often part of even larger associations, known as superclusters. Each supercluster contains about a dozen clusters and is typically hundreds of millions of light years across. Our Local Group lies on the outskirts of, appropriately enough, the Local Supercluster – a gathering of galaxy clusters centred on the nearby Virgo Cluster. The Local Supercluster was first identified by French astronomer Gerard de Vaucouleurs in 1956.

Planetary Nebulae

The name "planetary nebula" was coined by astronomer William Herschel in 1785 and refers to the resemblance of some of these objects to the round disk of a planet. But it's there that the similarity ends. Today, planetary nebulae are known to be the outer

Figure 5.14 M27 in Vulpecula. Image autoguided using Starlight STAR software. © Terry Platt

layers of stars called red giants, cast off when the star collapsed at the end of its life to become a white dwarf.

A red giant forms when a main-sequence star, similar to our own Sun, runs out of nuclear fusion fuel - hydrogen - in its core. With no heat source, the core cools down and contracts.

This contraction quickly reheats the core, pushing the temperature up beyond the hydrogen-burning threshold, until it's hot enough to ignite the next most suitable fuel for fusion - helium. The outer layers of the star then swell to roughly 100 times the diameter of the Sun. The resulting object is a red giant.

Eventually, the core exhausts its supply of helium and all the other elements that are viable as fusion fuels. The core shrinks irreversibly, becoming denser and hotter as it does. All hot bodies radiate and the star's core becomes so hot (temperatures often reach 125,000°C) that the radiation blows away the star's outer layers. The gas cloud created is a planetary nebula. It will typically have a surface temperature of 12,000°C, weigh roughly a fifth of the mass of the Sun and have a diameter of anything up to 15 light years. The cloud often radiates light at particular wavelengths, making spectroscopy the most effective method for discovering new planetaries.

Planetary nebulae initially shine brightly, making them good targets for the deep-sky astronomer. Despite their name, the 1,500 known planetaries take

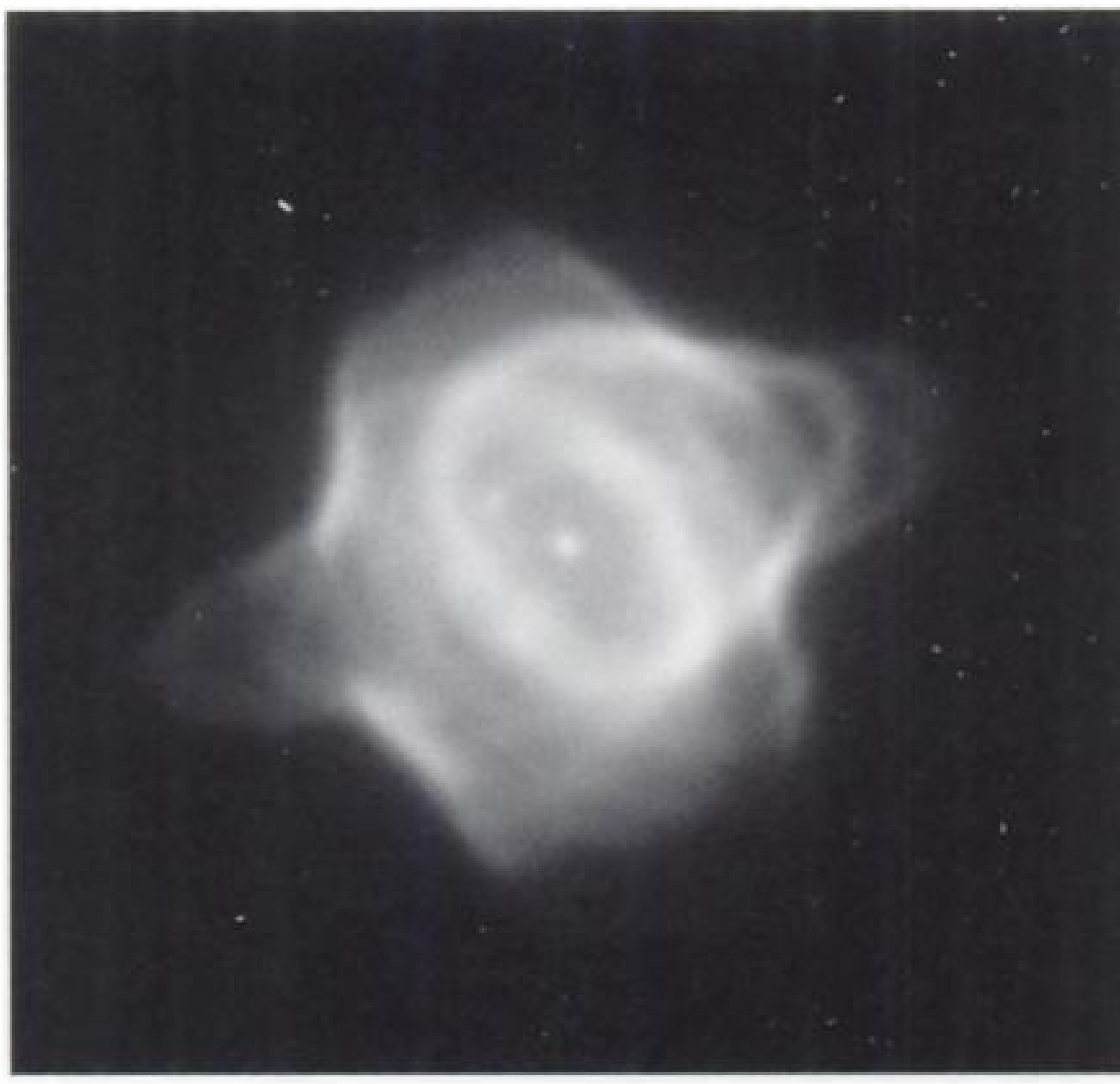


Figure 5.15 The Stingray is the youngest known planetary nebula. © STScI/NASA

a variety of different forms. Some are ring-shaped, such as M57 in Lyra. Others have a more dumbbell-like appearance, such as M76 in Perseus. Some defy classification entirely, but all fade as the centuries pass.

A planetary nebula usually has a dense white dwarf star at its centre. This is the hot remnant of the red

Figure 5.16 Butterfly-shaped planetary nebulae NGC2346 seen from Hubble. © STScI/NASA

giant's collapsed core. It is made of helium, carbon and oxygen and is compressed so tightly that, although only the size of the Earth, it contains the equivalent mass of the Sun. This makes the density of the star roughly a million times that of water.

Planetary nebulae expand rapidly - at speeds of around 20 kilometres per second - an expansion which can in some cases be detected by amateurs using CCDs. After 30–50 thousand years they often become too diffuse to detect, making them short-lived objects by cosmic standards. White dwarfs don't last forever either. Since they have no internal heat source they are constantly cooling, eventually becoming too cold and faint to be seen.

Globular Clusters

Globular clusters are roughly-spherical aggregations of stars that occupy the outer halos of spiral galaxies. They are generally between tens and hundreds of light years across, and contain between a few hundred thousand and a million stars.

Our own Milky Way Galaxy has around 150 globular clusters. In 1930, Edwin Hubble identified similar clusters orbiting in the halo of the Andromeda Galaxy,

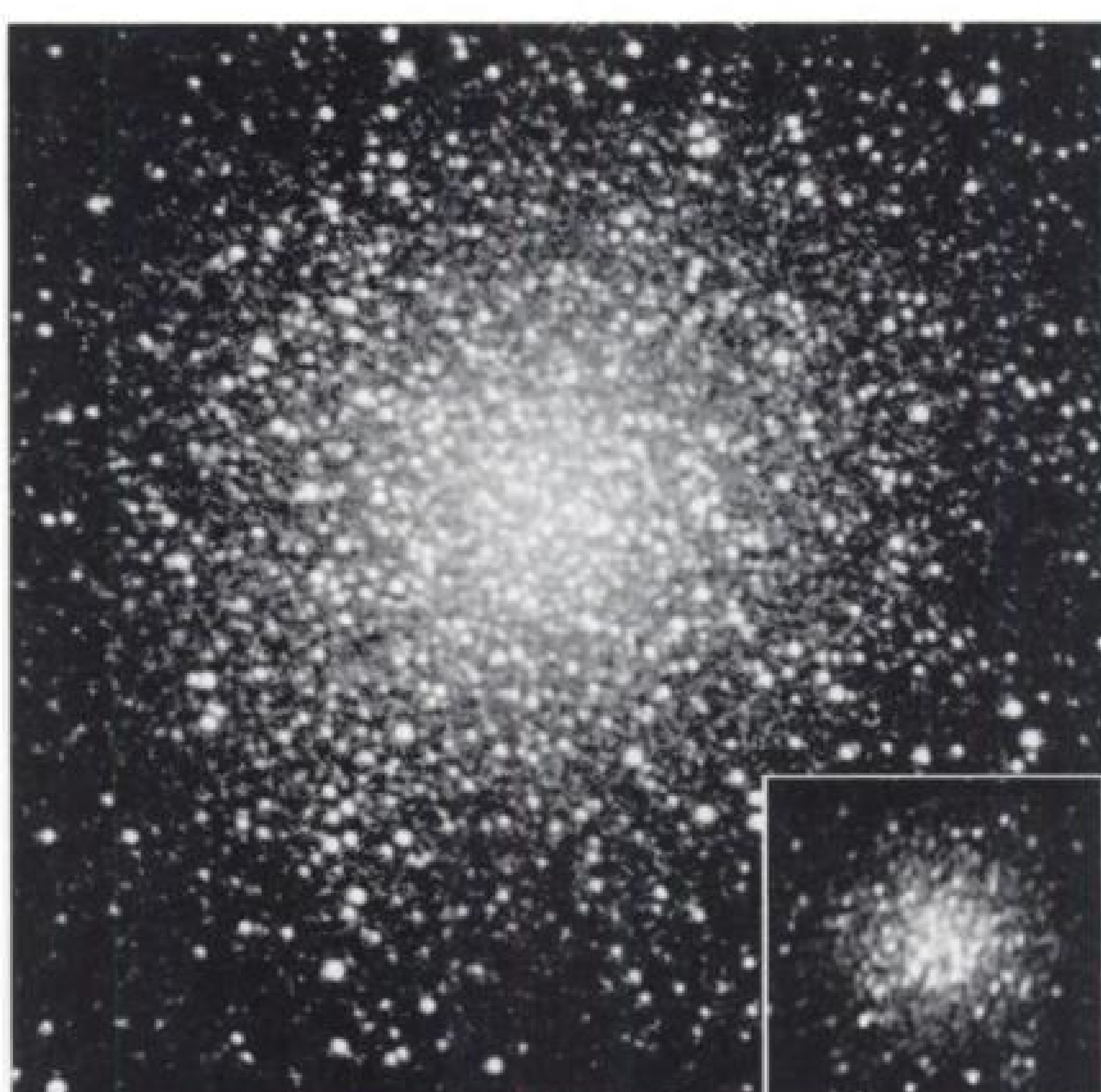


Figure 5.17 M13 and NGC2419 to the same scale. © Maurice Gavin

Figure 5.18 One of M31's numerous globular clusters lies close to M110.
© Grant Privett

M31, and they've since been detected around other galaxies. Although appearing "woolly" around the edges, globular clusters are very dense at their centres, with perhaps as many as 1,000 stars occupying a single cubic parsec of space (one parsec is 3.26 light years). To put this figure in perspective, there are no stars within one parsec of our Sun. Astrophysicists think that globular cluster stars formed up to 15 billion years ago, making them some of the oldest stars in existence.

A wide selection of the Milky Way's globular clusters can be seen in the night sky. The closest is 9,000 light years from Earth, but some are more than 50,000 light years distant. The most striking in the northern hemisphere is M13, in Hercules. M13 appears to the naked eye and binoculars as a slightly fuzzy star.

A small telescope soon reveals its true identity, however, resolving the extended disk of light into many stars.

In 1918, American astronomer Harlow Shapley used observations of globular clusters to prove that the Sun and the Solar System are not at the centre of our Milky Way Galaxy. More recently, globular clusters have caused consternation among astrophysicists, as some clusters seem to contain stars that are older than the Universe itself.

Figure 5.19
Globular cluster G1, orbiting the Andromeda galaxy. © STScI/NASA

Open Clusters

Open clusters are concentrations of stars which lie in the plane of a spiral galaxy. For this reason, you will sometimes hear them referred to as galactic clusters. They are much smaller than an average globular cluster, typically between a few and 25 light years in diameter. They contain far fewer stars than globulars, although the exact number can vary greatly. M18 in the constellation of Sagittarius has no more than a dozen stars inside it; M11 in Scutum contains about 500.

Open clusters usually form inside the spiral arms of their parent galaxy. The stars in a newly formed cluster are only very loosely associated, and drift apart in a relatively short space of time. For this reason, most open clusters are normally less than 50 million years old. There are occasional exceptions though. The open clusters NGC188, in Cepheus, and NGC6791, in Lyra, are thought to have retained their formations for over 5 billion years.

There are over 1,000 known open clusters in our Galaxy. Because they are so young by astronomical standards, open clusters often contain hot, bright stars, of various colours. Framed against the dark backdrop of space, these make a highly aesthetic target for the deep-sky astronomer, photographer or CCDer. Suitable

Figure 5.20 Open cluster NGC2244 at the centre of the Rosette Nebula.
© AURA/NOAO/NSF

examples are the Pleiades (blue) and Hyades (orange), both in Taurus.

Supernova Remnants

Wispy tendrils of glowing gas, framed against a deep black backdrop makes a supernova remnant a memorable sight to behold through the telescope. As their name suggests, these objects are the leftovers from supernovae - explosions marking the deaths of stars heavier than ten times the mass of the Sun. They are diffuse, gassy nebulae, created by the shell of gas ejected during the explosion.

Initially a supernova remnant is not easily visible. Its constituent gas is heated to such high temperatures by the explosion that formed it that most of the energy it radiates comes out as X-rays rather than visible light. After a few hundred years, however, its outer layers cool sufficiently to make it easily visible. This stage can last many thousands of years. Then, eventually, the remnant disperses - its density and pressure fall to levels that are comparable with interstellar gas and it becomes indistinguishable from its surroundings.

The dense core of a supernova's progenitor star usually remains at the centre of the remnant and is

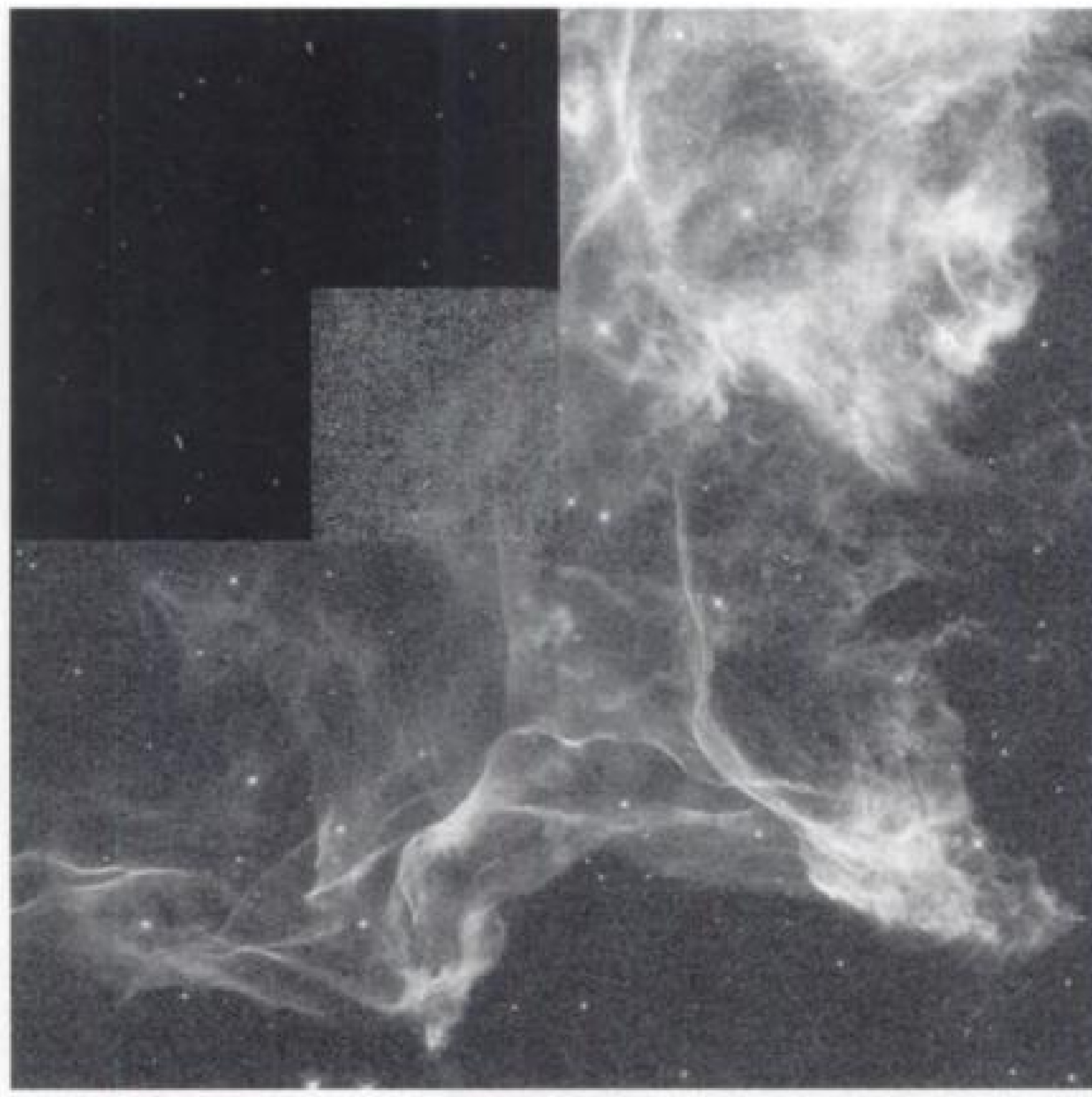


Figure 5.21 The Cygnus Loop supernova remnant as seen by the HST. © STScI/NASA

called a neutron star. These often spin rapidly and are highly magnetised. If so, the neutron star becomes a rotating magnetic dipole that gives off two diametrically opposed beams of radio waves from its poles, making it wink on and off like a cosmic lighthouse as it rotates. Such a star is called a pulsar, short for pulsating radio source. The first pulsars were observed in 1967 by Jocelyn Bell-Burnell.

As well as pulsed radio emissions, many supernova remnants also give off a continuous background of radio waves. This is due to synchrotron radiation – a process whereby electromagnetic waves are emitted by electrically charged particles moving rapidly in a magnetic field. In a supernova remnant, the particles are electrons that have been accelerated to high speed by the supernova's blast wave; the magnetic field is provided by the neutron star.

Synchrotron radiation colours some supernova remnants with an eerie blue glow. Other colours are produced as atoms of gas are broken up by energy from the central neutron star and then recombine, re-emitting the energy at the gas's own characteristic wavelengths.

Perhaps the most famous supernova remnant is M1, the Crab Nebula, in Taurus. The Crab Nebula is the remnant of a supernova that exploded in 1054, and was recorded by the astronomers of the time in

China as a bright "guest star", visible during the day for three weeks. In 1928, American astronomer Edwin Hubble became the first to link the Crab with the 1054 supernova.

Much older than the Crab Nebula, at around 50,000 years, is the Veil Nebula, the remnant of a supernova in Cygnus. Also known as NGC6992, the Veil Nebula is an excellent example of the wispy form that is typical of most supernova remnants.

Active Galaxies

"Active galaxy" is a broad title, applied to any galaxies that are very much brighter than the norm. The source of the energy that makes an active galaxy so bright resides in its central region, also known as the nucleus. For this reason, active galaxies are more commonly called active galactic nuclei, abbreviated to AGN.

The first active galaxies were identified in 1943 by Carl Seyfert. Seyfert was conducting a survey of spiral galaxies and to his surprise found that roughly 1% of the galaxies he saw had brilliant point-like centres which outshone both their disks and their spiral arms. These so-called Seyfert galaxies are now a recognised class of active galaxy in their own right. They are highly variable objects, their brightnesses changing over periods of a few months. Some experts believe Seyferts are simply a stage in the evolution of normal spiral galaxies, taking up about 10% of a galaxy's entire lifespan. About 150 Seyfert galaxies are known today, the brightest of which is M77 in Cetus.

In the early 1960s, the most famous type of active galaxy known today - the quasar - was discovered. Quasars were originally named quasistellar objects, or QSOs, because of their point-like resemblance to stars rather than the more extended form of a galaxy. They were identified as galaxies in 1963, when the distance to the QSO 3C273 was measured to be many millions of light years, placing it well outside our own Milky Way. To shine with such brightness from such a great distance, 3C273 must be intrinsically very bright indeed, leading to the classification of quasars as a type of AGN.

Nowadays, quasars are known to shine with the equivalent energy output of hundreds of normal galaxies. Physically, they resemble normal galaxies, but with very bright cores. Examination of quasar host galaxies suggests that they form when galaxies are disrupted by a close encounter with another galaxy. The furthest quasars lie some 12 billion light years away, making them the most distant objects visible from Earth.

Quasars aren't the only AGN that weren't immediately recognised as galaxies. In 1929, the first BL Lacertae, or BL Lac object was discovered, in the constellation Lacerta. Rapid changes in its luminosity – rising in brightness by a factor of 100 in a matter of weeks – led researchers to believe that it was a variable star. It took until 1968 for BL Lacertae to be correctly identified as a distant AGN. Many similar BL Lac objects have now been found. Most lie at the centres of elliptical galaxies.

Active galaxies commonly emit a large amount of their energy at radio frequencies. Some spew twin jets of material hundreds of thousands of light years into intergalactic space from opposite sides of their nuclei. The jets contain electrons and other charged particles, which spiral around in the galaxy's magnetic field, emitting radio waves as they go. These radio-loud AGN are known as radio galaxies. The brightest radio galaxy is Cygnus A, which emits ten million times more energy at radio wavelengths than does a typical spiral galaxy.

Some radio galaxies exhibit extremely violent activity at visible wavelengths as well. These objects are called blazars and are thought to be radio galaxies with

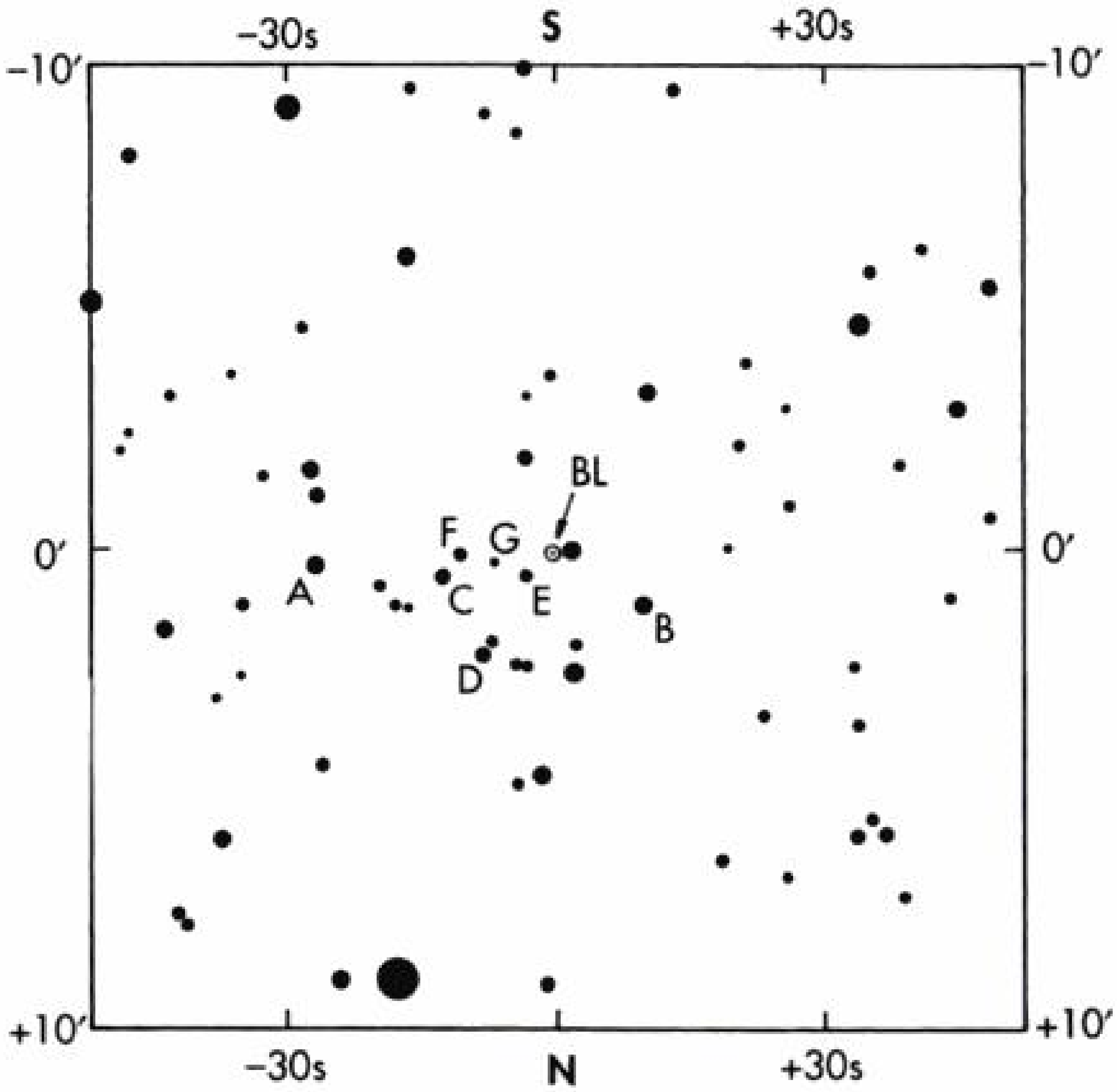


Figure 5.22 Finder chart for BL Lacertae. © John Toone

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BAA VSS
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DRAWN: JT 26-12-99
APPROVED: R PICKARD

one jet pointing directly towards us so that we are looking "down the nozzle", so to speak.

AGN have a lot of energy at their disposal. Where exactly this energy comes from was a source of debate for many years. But physicists now agree that black holes are the most likely candidate. A black hole is an object so dense that not even light can escape from it. If one forms at the centre of a galaxy, it will steadily draw in material, which speeds up as it falls in and rubs against other material also falling in. This process generates heat, which in turn releases large quantities of energy in the form of electromagnetic radiation – light, X-rays and radio waves – exactly what is seen pouring from AGN.

Measurements of the gravitational motions of some galaxies have revealed that galactic black holes must be very big, sometimes weighing billions of times the mass of the Sun. For this reason they are often called supermassive black holes. It's easy to imagine an active galaxy being devoured by its own central black hole in a very short space of time. But in actual fact the hole only needs to swallow one or two of its 100 billion stars every year to maintain the galaxy's luminosity.

Faint Blue Galaxies

Since 1980, researchers have been trying to solve the so-called faint blue galaxy problem – explaining why there are more blue galaxies at large distances than are seen nearby. There are between five and 15 times more faint blue galaxies 12 billion light years away than there are in our own cosmic neighbourhood.

Now researchers think the answer could lie in galaxy evolution. Because of the time it takes for light to travel from distant galaxies to Earth, looking 12 billion light years out into space is the same as looking 12 billion years back in time. And so if galaxies evolve with time they will appear to change with distance.

The theory supposes that, rather than disappearing, the excess of faint blue galaxies simply changed colour over the course of their lives. Early in their lives, galaxies contain a large number of young, hot stars – stars which are predominantly blue in colour.

But as the rate at which new stars form gradually dwindles a galaxy's overall colour becomes less blue. And it's thought that this is how the young blue galaxies

Figure 5.23 The HST picks out a number of distant faint blue galaxies.
© STScI/NASA

of the cosmic past turned into the redder specimens seen today.

In 1995 the orbiting Hubble Space Telescope was able to examine distant blue galaxies 100 times fainter than any studied previously. The observations were consistent with galaxies changing colour in exactly the way predicted by the theory.

Chapter 6

Atlases and Other Resources

Atlases

In sharp contrast to lunar, solar or planetary astronomy, the biggest difficulty involved in deep-sky observing lies in simply finding the object that you wish to examine. A planetary observer might line up a scope by sighting along the tube and then peering through a finder to align the bright planet in the crosshairs. But the deep-sky observer's quarry is frequently too faint to see with the naked eye and the finder may not be able to show the nearest reference points. Instead, the object must be found by identifying its location relative to its brighter neighbours. For this reason, the star atlas that you use should show as many stars as possible and be of a small enough scale that the paper is not horrendously cluttered. A cluttered map can make identifying star patterns very difficult.

Happily, there has been considerable progress over the years. At one time the choice of atlases available to amateurs was fairly small. Twenty years ago, the most commonly found atlases were *Norton's Star Atlas and Reference Handbook*, Becvar's *Atlas Coeli* and the *SAO Star Atlas*. First published just before World War I, Norton's dated from a time when Herschel's nomenclature for deep-sky objects was still in use (these have long since been abandoned in favour of NGC numbers). Its main problem, even today is its limiting magnitude. This is particularly true in crowded regions of the sky, like Virgo, where there are lots of targets but few stars brighter than 6th magnitude. There are just not enough reference points for thorough star hopping.

Another older book popular with younger observers was Menzel's *A Field Guide to the Stars and Planets* (which has also since been revamped). Each page contained a photograph of a chunk of sky. With the aid of a magnifying glass (not exactly ideal at the scope) it was possible to pick out many deep-sky objects.

Becvar's *Atlas of the Heavens – Atlas Coeli*, recently reissued by Stefanik Observatory in Prague, has much bigger format maps showing stars down to nearly magnitude 7.75 and is quite usable with a small, low-power telescope. It also identifies the shape and size of some nebulae and the size (but not brightness) of galaxies. The colour coding of deep-sky objects and the identification of the Milky Way makes it doubly useful. Its size, however, makes it a little unwieldy for use at the scope.

Among the more modern books on offer is *Sky Atlas 2000.0* by Tirion. Here we have more than 80,000 stars, 2,700 colour coded deep-sky objects, double stars and variables, all plotted to a very high degree of accuracy using (in the recently released second edition) Hipparcos satellite positions. It is a very attractive product. Care has clearly been taken to avoid clutter and make it easy to use.

Perhaps Tirion's greatest accomplishment, however, in collaboration with *Sky & Telescope* magazine

Figure 6.1 Hickson Compact Group 87, as imaged by the HST. © STScI/NASA

stalwarts Lovi and Rappaport, is the impressive *Uranometria 2000.0*. This two-volume set (roughly one volume per hemisphere) suffered from some minor faults in its first edition, but hopefully these will be fixed in the forthcoming second edition. If there are major failings, it is that the deep-sky objects are not colour coded and that the pages are not laminated to avoid dew damage. It's also irritating that volume 1's coverage stops at a declination of -5°, which means that many famous and accessible objects are absent. Most people would be willing to pay a little extra for coverage down to -20° declination. Nevertheless, with 10,000+ deep-sky objects plotted on 259 maps, it remains a must-have item for all but the rawest beginner.

Finally, the *Millennium Star Atlas* is perhaps as far as atlases printed on paper can go. The three-volume, £200 set is rather too expensive for most observers but offers unprecedented detail. This means that even the crowded region of sky in Virgo can be negotiated with confidence. It's an awesome piece of work, made possible by computer print setting and extensive databases. It is, however, very impractical at the scope unless you plan ahead carefully and photocopy the pages containing the objects that you intend to observe.

Atlases – List of Details

Philip's 10″ Planisphere; Philip's (1991); ISBN: 0–540–01234–3

Norton's Star Atlas and Reference Handbook (19th edn); Arthur P Norton and Ian Ridpath (eds.); Pitman Publishing (1998); ISBN: 0–582–31283–3

A Field Guide to the Stars and Planets; Jay M Pasachoff and Donald H Menzel; Mariner Books (1998); ISBN: 0–395–91099–4

Sky Atlas 2000.0 Deluxe; Wil Tirion and Roger W Sinnott; Cambridge University Press (2000); ISBN: 0–521–65434–3

Atlas of the Heavens – Atlas Coeli Novus; Antonin Becvar; Stefanik Observatory, Prague (1998)

Uranometria 2000.0; Wil Tirion, Barry Rappaport and George Lovi; Willmann-Bell (2000); ISBN: 0–943396–14–X (North) ISBN: 0–943396–15–8 (South)

Millennium Star Atlas; Roger W Sinnott; Sky Publishing (1997); ISBN: 0-933-34684-0

Whatever atlas or charts you choose to use, it is worth considering photocopying the pages relevant to the objects you most want to observe and keeping them in the thin plastic holders/pockets of the sort used with clipfiles. This will keep the damp off them and make filing them easier. Alternatively, some atlases come in laminated waterproof editions and are worth considering.

Other Useful Books and Articles

Deep-Sky Objects

A Deep-Sky Catalogue; Handbook No. 3; Owen Brazell and Nick Hewitt, Deep-Sky Section, British Astronomical Association (1997)

Burnham's Celestial Handbook; Volumes 1–3; Robert Burnham Jr; Dover (1978); ISBN: 0-486-23567-X (Vol. 1), 0-486-23568-8 (Vol. 2), 0-486-23673-0 (Vol. 3)

Celestial Objects for Common Telescopes; Volume 2: The Stars; Thomas W Webb; Dover (1962)

Observing Handbook and Catalogue of Deep-Sky Objects; Christopher C Luginbuhl and Brian A Skiff; Cambridge University Press (1998); ISBN: 0-521-62556-4

Observing the Caldwell Objects; David Ratledge; Springer-Verlag, London (2000); ISBN: 1-85233-628-5

The Cambridge Deep Sky Album; Jack Newton and Philip Teece; Cambridge University Press (1984); ISBN: 0-521-25668-2

The Deep Sky: An Introduction; Philip S Harrington; Sky Publishing (1999); ISBN 9-933346-80-8

The Messier Objects; Stephen J O'Meara; Cambridge University Press (1999); ISBN: 0-521-55332-6

The Night Sky Observer's Guide; Volumes 1–2; George R Kepple and Glen W Sanner; Willmann-Bell (1998); ISBN: 0–943–39658–1

The "Non-Existent" Star Clusters of the RNGC; Brent A Archinal, Webb Society Monograph 1, ISSN: 1350–6951

The Webb Society Deep-Sky Observer's Handbook; Volumes 2–6; Kenneth Glyn Jones (ed.); Enslow Publishers, Hillside, New Jersey (1978–1990); ISBN: 0–7188–2434–2 (Vol. 2), ISBN: 0–7188–2468–7 (Vol. 3), ISBN: 0–89490–050–1 (Vol. 4), ISBN: 0–7188–2552–7 (Vol. 5), ISBN: 0–89490–133–8 (Vol. 6)

Telescopes

A DIY Dome Observatory; Curtis D MacDonald; Sky & Telescope, (May, 1998)

A Swingback Hut for a Telescope; J. British Astronomical Association; 108; 4; (1998)

Design and Construction of a Roll-off Roof Observatory, Mark K Herbert; J. British Astronomical Association, 109, 1 (1999)

The Wolanski Ultralight Telescope, Sky & Telescope (August, 1999)

General Observing Guides and Useful Articles

Advanced Amateur Astronomy; Gerald North; Cambridge University Press (1997); ISBN 0–521–57430–7

Binocular Astronomy, Craig Crossen and Wil Tirion; Willmann-Bell (1992); ISBN: 0–943–39636–0

Cosmic Rainbows – The Revival of Amateur Spectroscopy, Maurice Gavin, Sky & Telescope (August, 1999)

Information Sources for Deep Sky Astronomy; Owen Brazell; J. British Astronomical Association, 108, 2 (1998)

Nebular Filters in Deep Sky Astronomy; Owen Brazell; J. British Astronomial Association, 104, 5 (1994)

The Lord of Braeside – The Center for Backyard Astrophysics, Stephen J O'Meara, Sky & Telescope (June, 1999)

Imaging

A Practical Guide to CCD Astronomy; Patrick Martinez and Alain Klotz; Cambridge University Press (1997); ISBN 0-521-59950-4

Astrophotography for the Amateur; Michael A Covington; Cambridge University Press (1999); ISBN: 0-521-62740-0

CCD Astronomy; Christian Buil; Willmann-Bell (1991); ISBN: 0-943396-29-8

Electronic Imaging in Astronomy; Ian S McLean; Springer-Verlag (1996); ISBN: 0-471-96971-0

High Resolution Astrophotography; Jean Dragesco; Cambridge University Press (1995); ISBN: 0-521-41588-8

Sketching the Deep Sky; Lee T MacDonald; Astronomy (January, 1996)

UBVRI Photometry using CCDs; R Miles; J. British Astronomical Association; 108; 2 (1998)

Visual Recording of Deep-Sky Objects; Lee T MacDonald; J. British Astronomical Association, 103, 2 (1993)

Computer-Based Systems

Software

The advent of computers has made a great impact on amateur astronomy and a huge range of electronic

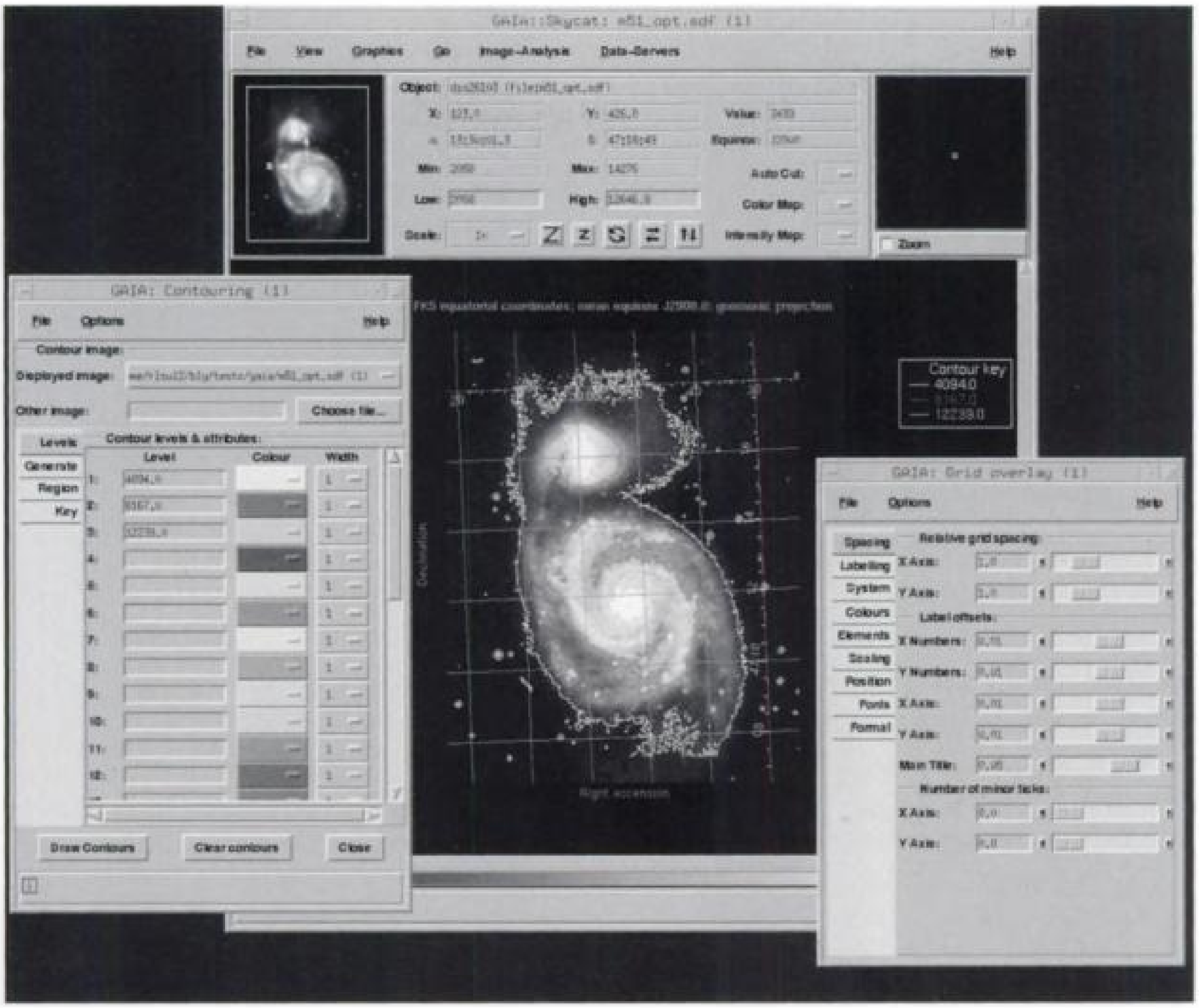


Figure 6.2 The Starlink GAIA software at work on an image of M51. © Starlink/ESO/AURA

resources is now available. The most important of these is software. The range of packages on offer runs from simple PC-based planetaria such as SkyGlobe, through to image and data analysis suites such as the STARLINK Software Collection, which allows the user to perform full professional-quality image processing on a normal home PC.

The list of software provided here is far from definitive. Indeed, it barely scratches the surface. We have chosen to list the software which we (or trusted friends and associates) can confidently recommend. They are all PC-compatible, running on the Microsoft DOS, Windows 3.11, Windows 95/98 or NT operating systems.

GrayStel – Versions available for DOS and upwards. Planetarium including a full-sky photographic atlas. GrayStel Software. http://members.aol.com/graystel

Guide – Slightly clunky interface, but otherwise worthwhile planetarium. Good astrometric properties. Project Pluto. http://www.projectpluto.com

Megastar – Planetarium program intended for the deep-sky observer. It includes an impressive number of obscure objects. Willmann-Bell. http://www.willbell.com

Redshift – Very slickly put together package and reference source. Maris Multimedia. http://www.maris.com

Paintshop Pro – Inexpensive but impressively featured and usable image processing and conversion package. Plug-ins are available. JASC Software. http://www.jasc.com

RealSky – Scanned photographic image of the whole sky to 20th mag. The ultimate chart-making program. http://www.aspsky.org

SkyGlobe – Very simple and inexpensive shareware planetarium program that runs from DOS and uses little disk space. KlassM Software.

SkyMap Pro – Possibly the most accurate planetarium program. SkyMap Software. http://www.skymap.com

Starry Night – General star map and reference program in the same class as Redshift. Attractive and aimed at the classroom. Sienna Software. http://www.siennasoft.com

The Sky Level 5 – Very impressive, but quite expensive planetarium program. A wide range of plug-ins such as Pat Wallace's excellent T-Point are available. Software Bisque. http://www.bisque.com

By the time you read this, most packages listed above will probably be able to do considerably more than they can now (May 2000). Indeed several are already supplying versions that control Nexstars or ETXs. So when selecting a package be sure to obtain up-to-date information from the manufacturer and, preferably, some users. It's at times like this that membership of an active astronomical society can be very helpful – word-of-mouth advice can save you a lot of money. All the products mentioned above are impressive and worthwhile but there are others on the market and everyone's needs and preferences are different, so shop around.

Other packages which appear to be quite successful include Megafix/CCDSOFT (camera control and image reduction), Adobe Photoshop (image processing), FITSVIEW (FITS image display), Picture Window

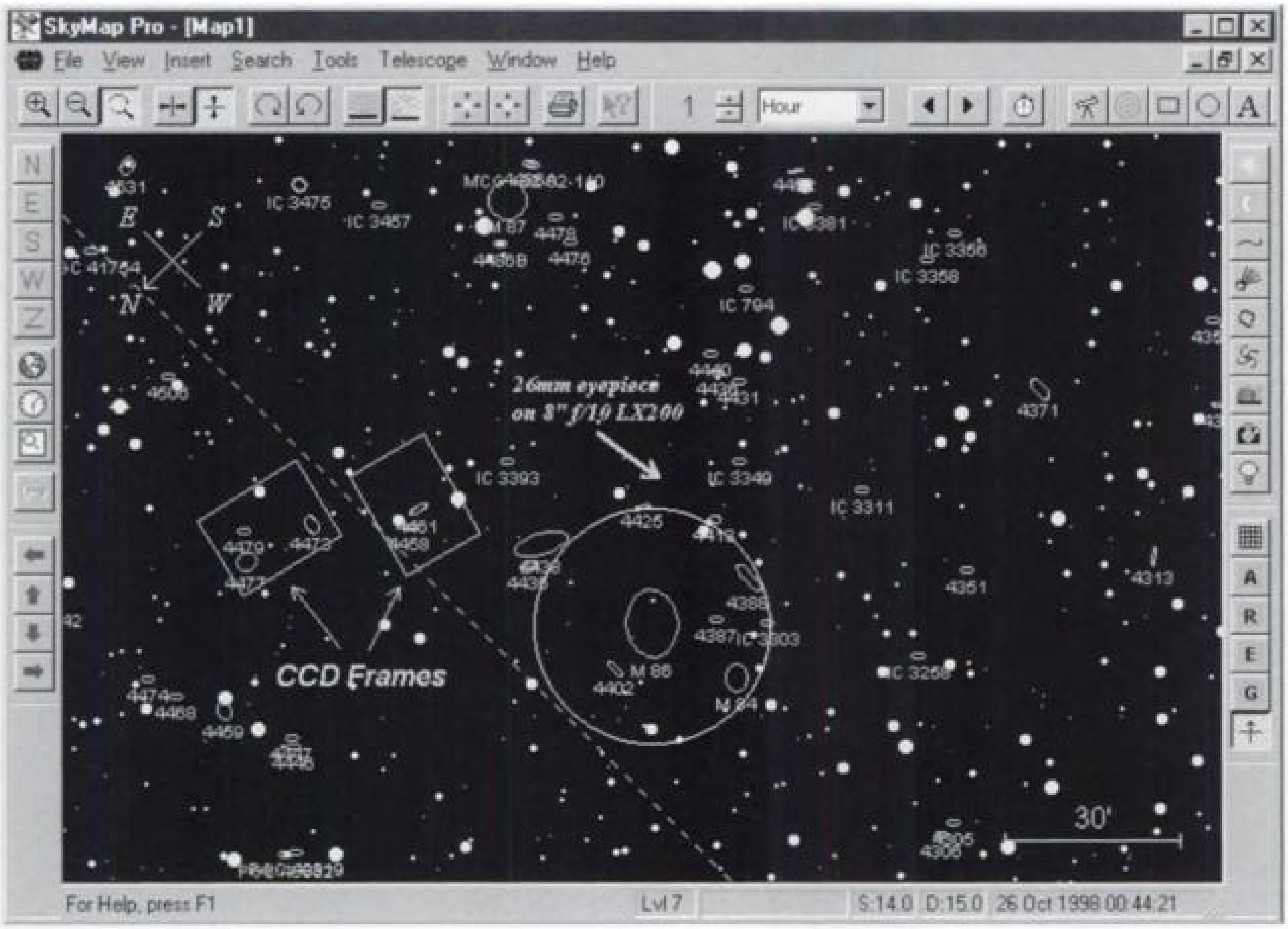


Figure 6.3 SkyMap Pro planetarium software in action. © SkyMap Software

(16-bit colour image stacking), SkyTools/Hypersky (observation-planning databases) and Iris/Quantum Image (sophisticated image enhancement). These all have significant followings but we have no experience of these software packages in their most recent versions.

Web Sites

The World Wide Web's electronic acres hold information on pretty much everything, so this round-up of astronomical resources wouldn't be complete without a run-down of useful web sites for the deep-sky astronomer.

As the web grows in popularity so the amount of information is also growing. It means that by phrasing your web searcher request well you can find information on almost any aspect of astronomy. For example, one of us (GJP) managed to find a complete list of all known quasars observed by ground-based telescopes. In the past, tracking down such information would have meant seeking permission to use a specialist or university library and then spending hours trawling through vast amounts of turgid professional literature. Now it's all there at the touch of a button.

Figure 6.4 The BAA has an active deep-sky section.

Unfortunately, the nature of web sites is such that by tomorrow you may find everything we recommend today (May 2000) is out of date. Consequently, if any of the following URLs change, use a web searcher such as Yahoo (http://www.yahoo.com), Alta Vista (http://www.altavista.com) or Infoseek (http://www.infoseek.com) to find them.

AstroWeb
http://www.cv.nrao.edu/fits/www/ astronomy.html

Bill Arnett
http://www.seds.org/billa

British Astronomical Association
http://www.ast. cam.ac.uk/~baa/baamain.html

Deep-Sky Astronomy Resources at SEDS
http://www.seds.org/~spider/spider/deepsky/deepsky.html

Jim Shield's Adventures in Deep Space
http://www. angelfire.com/id/jsredshift/

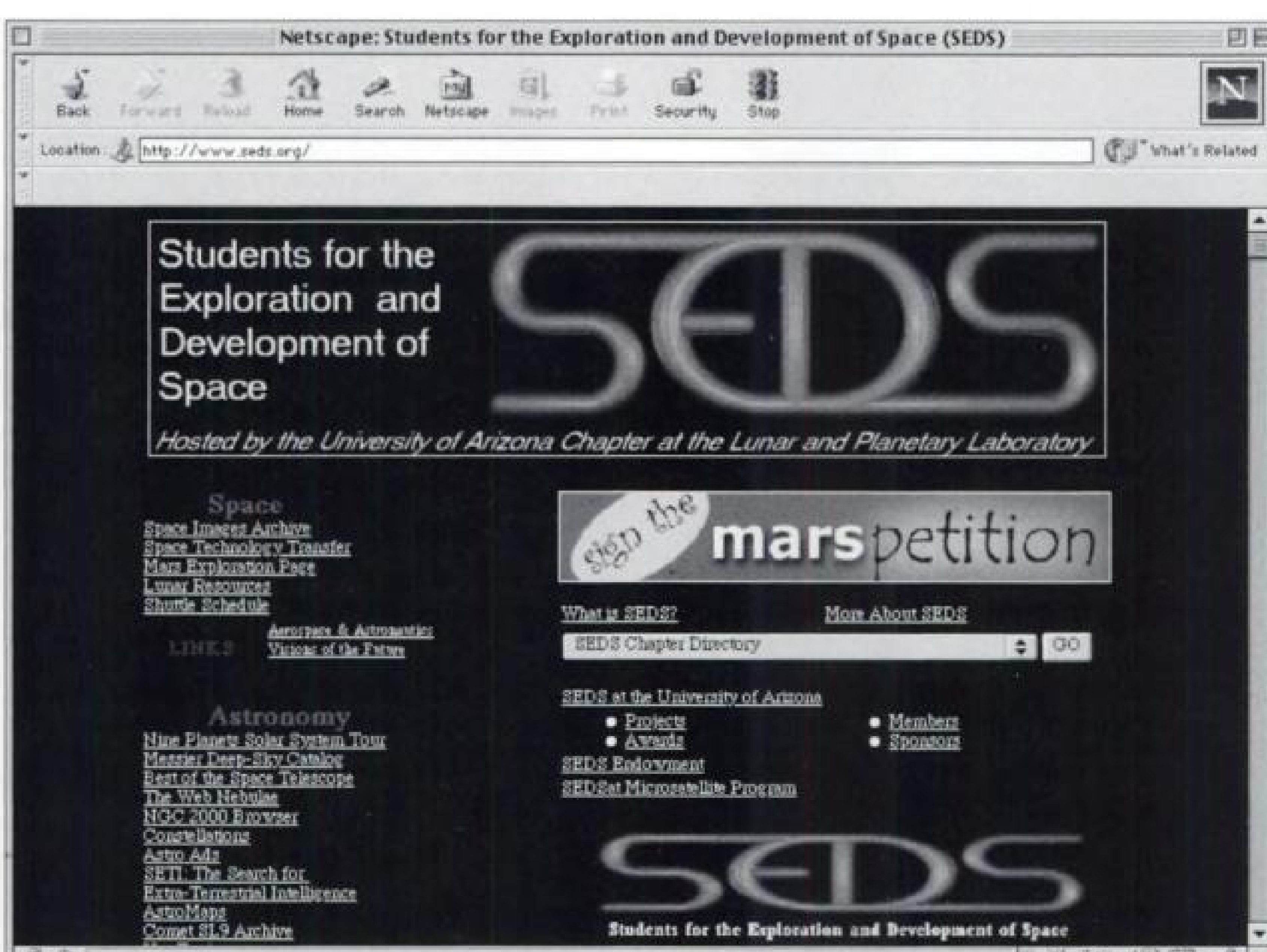
NGC/IC Project
http://www.ngcic.org

Planetary Nebulae and Astronomy Resources
http://www.blackskies.com/links.html

Saguaro Astronomy Club
http://www.saguaroastro.org

Figure 6.5 The web site for the astronomy magazine *The Astronomer*.

Figure 6.6 The web pages of Students for the Exploration and Development of Space (SEDS).



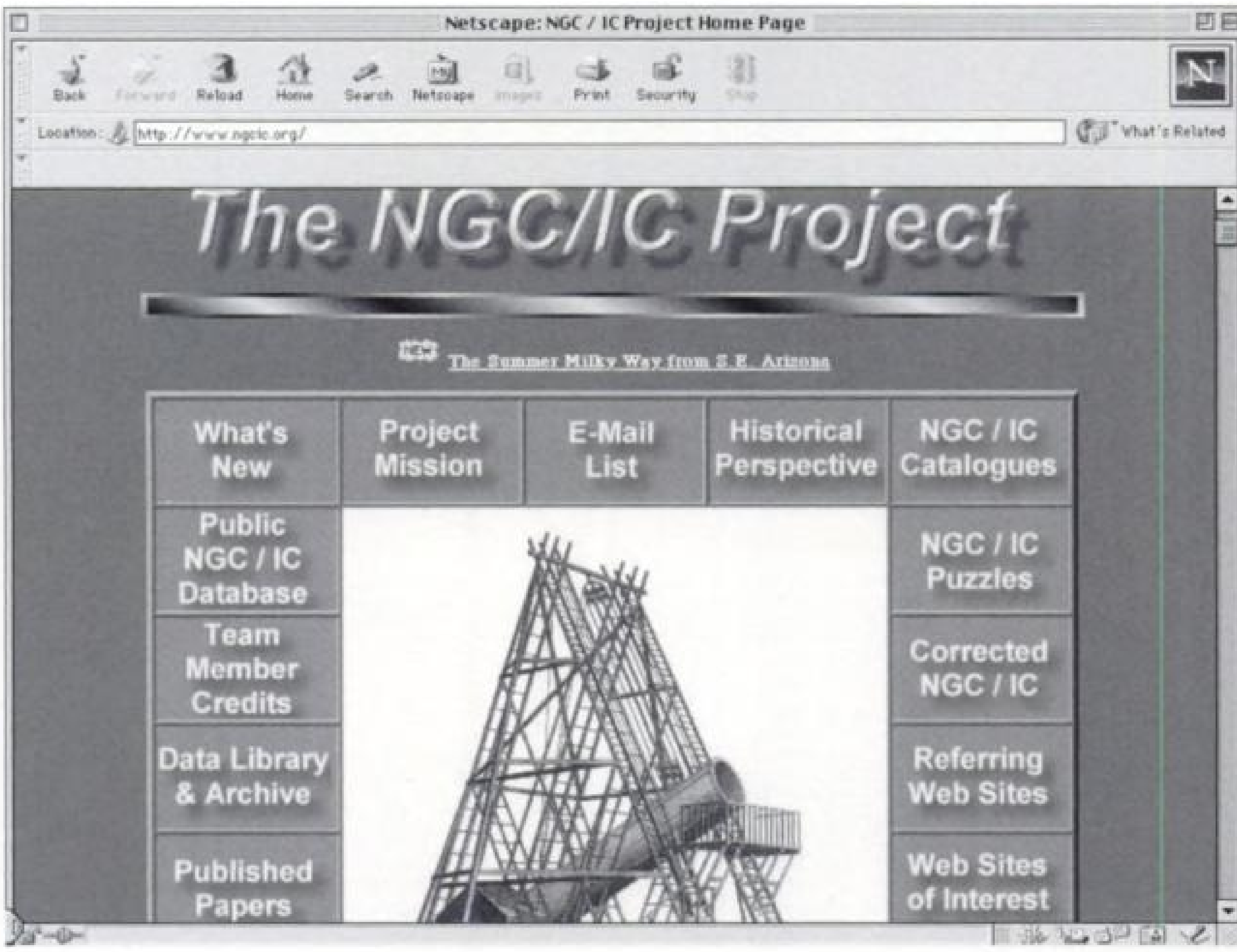
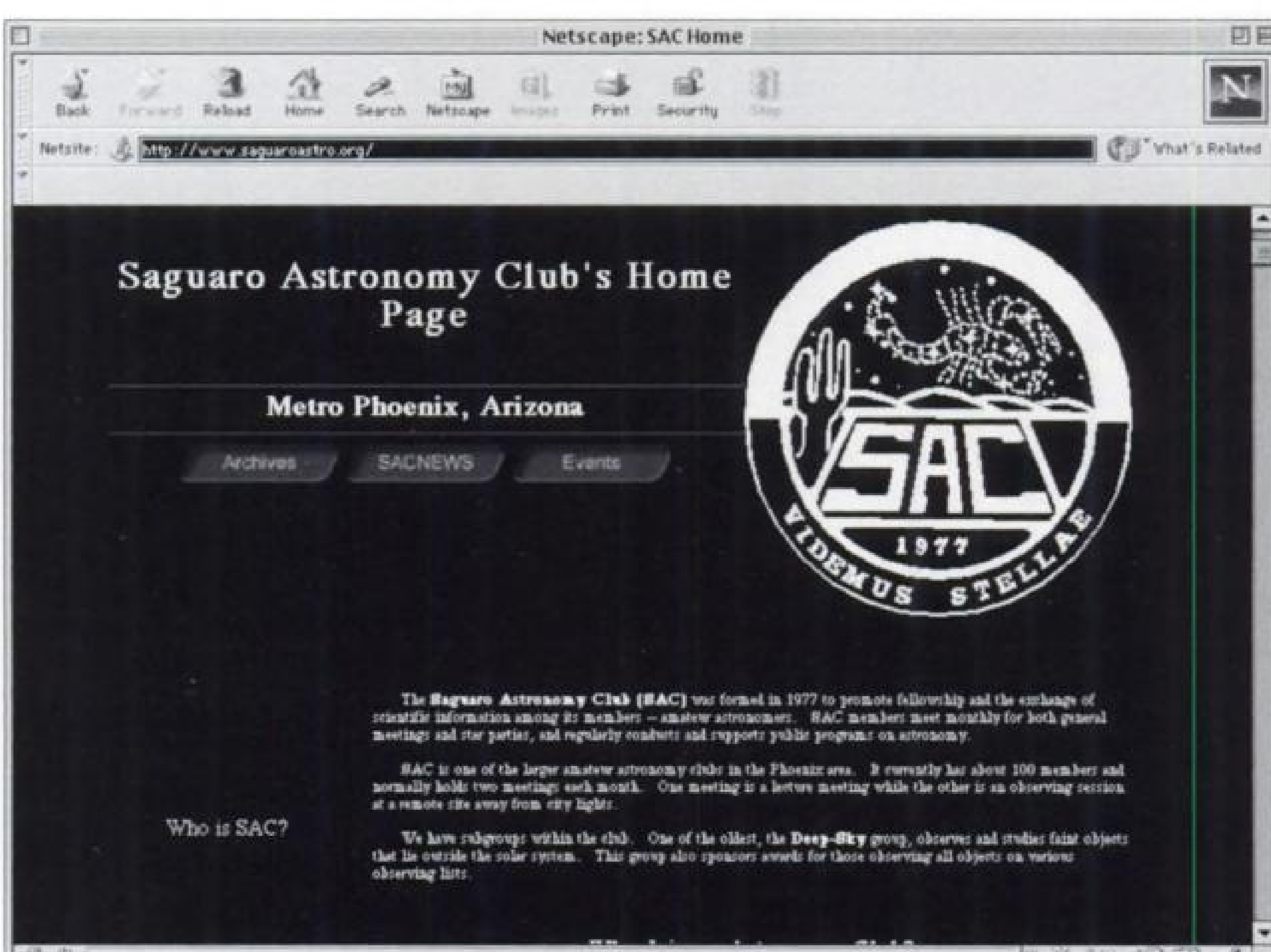


Figure 6.7 The ambitious NGC/IC Project web pages.

Figure 6.8 Saguaro Astronomy Club's web site.



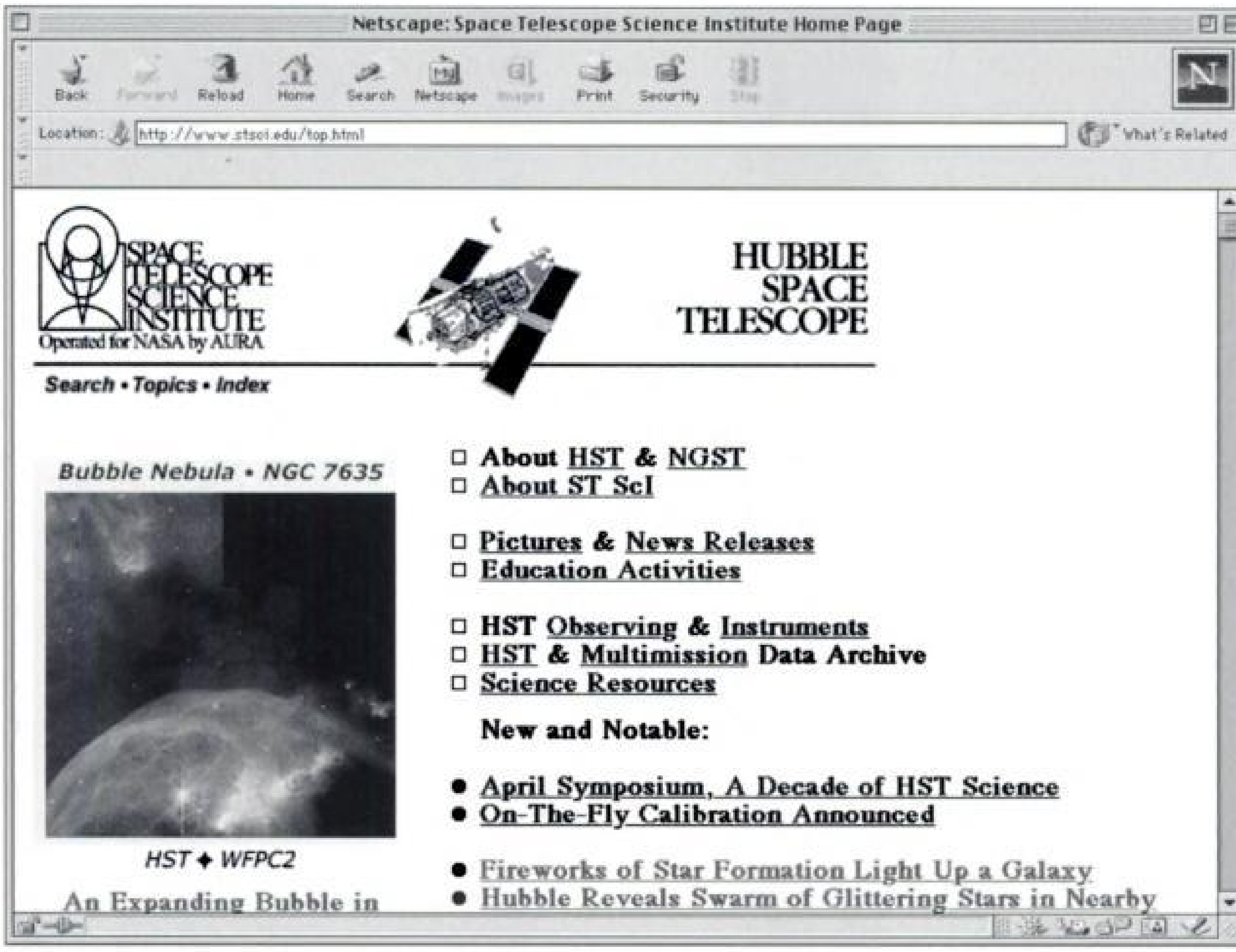


Figure 6.9 The Space Telescope Science Institute web site.

Sky Publishing
http://www.skypub.com

Space Telescope Science Institute
http://www.stsci.edu/ top.html

The Astronomer Magazine
http://www.demon.co.uk/ astronomer

Webb Society
http://www.webbsociety.freeserve.co.uk

One great advance that deserves a more detailed mention is NASA's Sky View site (http://skyview.gsfc.nasa.gov/skyview.html). This allows you to enter a set of sky co-ordinates, in the form of RA and declination, and a field of view, and then supplies you with a FITS or GIF format image showing that part of the sky as seen by a large Schmidt telescope. This is a boon for those having trouble finding very faint targets, particularly as it allows you to overlay catalogue positions for many different object types.

CD-ROMs

CD-ROMs are an easy-to-use, portable and inexpensive way to store large amounts of information. They have been employed by many publishers to store vast databases and image libraries that would at one time have filled entire bookcases, so that it is now possible to obtain cheap CDs containing lists of galaxies, clusters, planetary nebulae and quasars that contain more objects than you could sensibly hope to observe in a lifetime. This has come at just the right time, as some obscure objects, described only in bulky low-circulation catalogues not previously considered by amateurs, are now coming within range as advancing scope technology gives the amateur access to ever fainter magnitudes.

Similarly, pictures taken by many of the world's best astro-imagers are now available on CD-ROMs at modest prices. The complete *HST Guide Star Catalogue* and the *Hipparcos* catalogues are also available and are often included as part of planetarium programs. Of greater practical use for deep-sky observers are products like RealSky, which contain digitised photographs of the whole sky as seen by the Schmidt cameras at Palomar and in Australia. This contains the whole sky down to 20th magnitude on a couple of CDs, allowing the creation of high-quality finder charts of varying scales. For example, you might like a 1° chart to help you find the approximate region of sky that you're after through a low-power eyepiece, and then work with a 20′ field for higher powers or for CCD imaging. This is tremendously useful, as most printed atlases run out at about 10th magnitude.

One limitation with RealSky is that its images are much-compressed copies of the original scans taken from the Schmidt plates. Sophisticated wavelet compression techniques have been applied to reduce the number of CDs required without sacrificing image quality, but some degradation, particularly on brighter objects, is apparent. Nonetheless, RealSky is a superb addition to any deep-sky astronomer's library and many planetarium programs now use it if available.

Useful Contacts

The best resources you can hope for are other people. No matter how proficient you may have become, you can bet that somewhere there is someone more experienced than you are. And so it's vital to interact with other astronomers. You can either do this directly, by joining a society, or from the comfort of your own home by subscribing to a good astronomy magazine. It's probably best to do both. Below are some useful points of contact.

Societies

Royal Astronomical Society
Burlington House
Piccadilly
London W1V 0NL, UK
Tel: +44 (0)20 7734 3307
Fax: +44 (0)20 7494 0166
Email: ronw@ras.org.uk (Ronald Wiltshire - Membership Secretary)

British Astronomical Association
Burlington House
Piccadilly
London W1V 9AG, UK
Tel: +44 (0)20 7734 4145
Email: office@baahq.demon.co.uk

American Astronomical Society
2000 Florida Avenue NW
Suite 300
Washington DC 20009
USA
Tel: +1 202 328 2010
Fax: +1 202 234 2560
Email: aas@aas.org

Canadian Astronomical Society
Secretary: Serge Demers
Département de Physique
Université de Montréal
Montréal, QC
H3C 3J7, Canada
Tel: +1 514 343 2364
Fax: +1 514 343 2071
Email: casca@astro.umontreal.ca

Webb Society (USA and Canada)
John Isles (Secretary)
11105 Tremont Lane
Plymouth, MI 48170
USA
Email: jisles@voyager.net

Webb Society (rest of the world)
Mike Swan (Secretary)
Carrowreagh Kilshanny
Kilfenora

County Clare
Ireland
Email: zubenel@iol.ie

Magazines

Astronomy Now
Astronomy Now Subscriptions
AIM Ltd
PO Box 10
Gateshead NE11 0GA, UK
Tel: +44 (0)191 487 6444
Fax: +44 (0)191 487 6333

Astronomy
Kalmbach Publishing Co.
21027 Crossroads Circle
PO Box 1612
Waukesha, WI 53187, USA
Tel (from USA or Canada): 800 533 6644
Tel (from elsewhere): +1 414 796 8776
Fax: +1 414 796 1615
Email: customerservice@kalmbach.com

Journal of the British Astronomical Association
See British Astronomical Association details above

Sky & Telescope
PO Box 9111
Belmont, MA 02178-9111
USA
Tel: +1 617 864 7360
Fax: +1 617 864 6117
Email: orders@skypub.com

The Astronomer
Peter Meadows (Secretary)
6 Chelmerton Avenue
Great Baddow
Chelmsford
Essex CM2 9RE, UK
Tel: +44 (0) 1245 475885
Email: peter@meadows3.demon.co.uk

Webb Society Magazine
See Webb Society details above

Part II

The Night Sky Month by Month

Chapter 7

The Star System and Nomenclature

To help you select deep-sky targets that match your ability and/or equipment, the objects that we describe in the following sections are each assigned to one of three categories – denoted *, ** and ***. The number of stars given is a measure of how easy the object is to observe. An object denoted as *** will generally be bright and discernible in small-aperture instruments. The view of a *** will usually be quite spectacular. On the other hand, objects given a rating of * are generally harder to see, require a larger instrument and are often less impressive. Objects denoted ** fall somewhere between the two.

You will find that all but the best-known objects are referred to by prefix followed by a number. An example would be NGC663, where the object being referred to (a rather nice open cluster) is the 663rd member of the *New General Catalogue*. Catalogues mentioned in the following pages include:

Abell	Clusters of galaxies compiled by Abell.
B	Catalogue of dark nebulae compiled by Barnard.
IC	*Index Catalogues*. Supplement to the NGC published in 1895 and 1908.
Hickson	Compact groupings of galaxies.
Melotte	A catalogue of open clusters.
M	The catalogue of Charles Messier. Contains many bright objects.
NGC	*New General Catalogue*. Published in 1888 by Dreyer.

PK	*Catalogue of Galactic Planetary Nebulae.* Perek and Kohoutek, 1967.
SAO	Smithsonian Astrophysical Observatory catalogue of bright stars.
Stock	A catalogue of open clusters.
UGC	*Uppsala General Catalogue of Galaxies.* Compiled by Nilson in 1973.

It should be remembered that many objects appear in more than one of these catalogues. The names employed herein are those most commonly used.

Chapter 8

January
08 Hours RA

This Month

The constellations at their best this month include: Gemini, Lynx, Canis Minor, Monoceros, Canis Major and Puppis. Those of you hoping to see anything in Puppis - once part of the vast conglomeration known as Argo Navis - or the southern parts of Canis Major will need to find an observing site with a clear southern horizon and should look to the east of Canis Major.

When planning your observing bear in mind that early in the evening Perseus and Taurus are well placed. Later in the night the stars of Virgo, Leo and Ursa Major will be riding high. The truly dedicated (or early risers) will see the summer constellations of Hercules and Lyra start to rise from the east. Be sure to wrap up warm or you will not last the night.

Compulsory Viewing

Binoculars and smaller telescopes:	M35, M41, NGC2392
Moderate telescopes:	M35, NGC2371/2, NGC2158
Larger telescopes and CCDs:	NGC2438, IC2157, NGC2207

Gemini – Something for Everyone

It's fortunate that the winter nights are so long, as there is much to be seen. Before progressing to targets in fainter constellations why not start with Gemini?

To allow your eyes time to become truly dark adapted, try searching out the famous Eskimo Nebula, **NGC2392*****. You should be able to find this planetary nebula in the same low-power field as 63 Geminorum, a wide double star. With a magnitude of 8.3 spread out over only 45″, it can be picked up with a 60 mm scope as a star-like point, but you will need a high magnification for the nebula's non-stellar nature to be apparent. Larger apertures will show that it's made up of a faint, pale blue central disk surrounded by a less bright outer ring. The irregularities in the nebula that give rise to its name are only evident in big instruments, but at 10th magnitude the central star will pose few problems. A beautiful object.

A little under 2° north of 59/60 Geminorum is the nebula **NGC2371/2****. Ignore the numbering – it is actually a single object, a planetary nebula that appears, with instruments of around 250 mm aperture and reasonable seeing, to have two lobes divided by a dark

Figure 8.1 The Eskimo Nebula. Good with any scope. © Paul Curtis

central rift. You may find that you need 300 mm or more of aperture to resolve the two separate halves. The southerly part of the nebula is the brighter of the two. Despite the 12th magnitude attributed to NGC2371/2, its 1′ diameter means that with care and good skies you should be able to identify it with a 200 mm scope or possibly, from a better site, a 150 mm. There is a central star in the void between the halves. This may prove elusive for instruments of 300 mm, but is not difficult to spot through a 400 mm. Long exposures using film or CCDs will show evidence of a beautiful outer ring of nearly 2′ diameter, but much of this will certainly be beyond visual detection.

Next, try moving back to 63 Geminorum and then sweeping slowly eastwards. After about 2.5° you should come across **NGC2420****, an 8th magnitude open cluster. This is approximately 10′ across and sits in a rather nice field on the boundary of the Milky Way. Another nearby object is the open cluster **NGC2266****, which can be easily located just under 2° north of epsilon Geminorum. Its 50 or so constituent stars give it an integrated magnitude of about 9. The cluster is roughly 7′ wide, with the central portion particularly well populated. Like NGC2392, it's a good target for observers wishing to move beyond the easier Messier objects and pursue more subtle quarry.

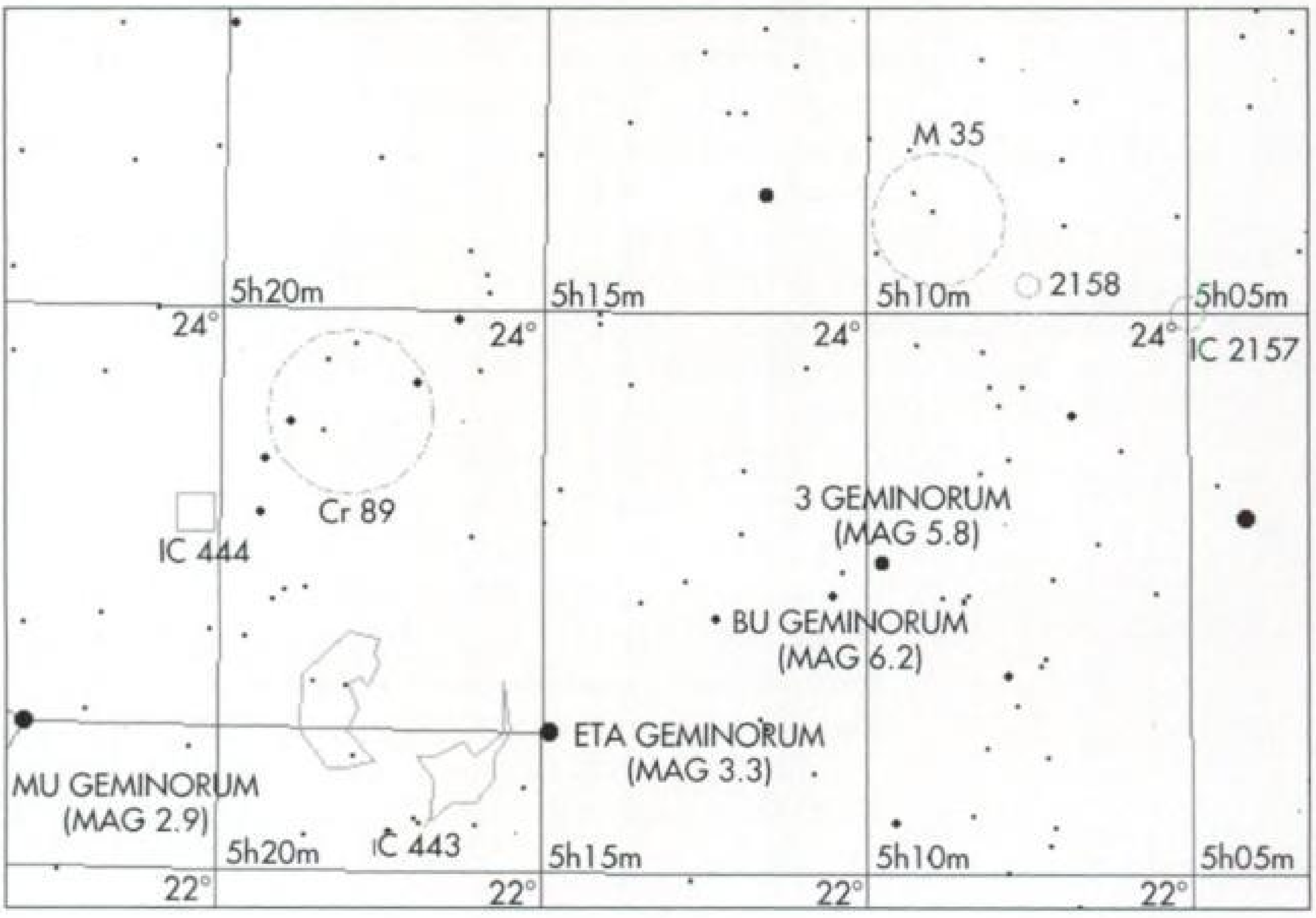
It's impossible to ignore Gemini's best-known open cluster, the magnificent **M35*****. Although barely visible to the naked eye, it's readily apparent through 8 × 35 binoculars and resolvable into dozens of stars in small scopes. Through larger apertures, M35's 150+ stars, many of which are bright and reddish, make it a breathtaking sight. The only drawback is that the cluster is spread out over at least 20′, meaning that it can only be viewed in its entirety through low-power eyepieces.

While looking at M35 you may notice a fainter, smaller glow on its southwestern edge. It should be discernible with a 150 mm scope, clearly visible in a 200 mm, and partially resolvable with 300 mm. The hazy patch, more formally known as **NGC2158****, is a very compact open cluster which shines at about 11th magnitude. Despite its small size it contains at least 100 stars within its 5′ width and so images well onto a CCD. The cluster's brightest members are 15th magnitude.

Truly adventurous souls might like to try for **IC2157***, a small and inconspicuous clumping about two-thirds the size of NGC2158. It has a little over a

Figure 8.2 M35 with the nearby compact cluster NGC2158. © Marty Germano

Figure 8.3 Finder chart for M35. Courtesy SkyMap Software



dozen members, none of which exceed 10th magnitude. Given the richness of the fields in this region of Gemini, it may prove difficult to identify. Walter Scott Houston, the renowned deep-sky observer and columnist, referred to it as "challenging" for small telescopes, so be prepared for an interesting, and possibly protracted search.

Unlike the galaxy-cluttered sky in Leo, Gemini and Lynx are not well stocked with bright galaxies. In fact, a glance at your *Norton's* might lead you to assume that there are none. But be assured, **NGC2339**** is there for those of you in the mood for galaxy observing. It's an 11th magnitude spiral, roughly $3 \times 3'$, that lies 2° southeast of zeta Geminorum. You should be able to find it easily with a 200 mm scope, but it may prove elusive with 100 mm or less.

Before leaving Gemini, those of you with larger scopes and a nebula filter might like to have a look for **IC443***. It's one of the few fairly bright supernova remnants (like M1 and Simeis147) and may be just detectable as a faint band of light between mu and eta Geminorum. This object falls into the category of extremely difficult, but if you don't try how can you ever hope to see it? This will not be an easy target but how many supernova remnants have you seen? To photograph it, use a deep-red filter and a long exposure. Visually, try an O-III filter.

The Lynx

Probably the best-known object in the rather barren chunk of sky improbably named the Lynx, is the remote globular cluster **NGC2419****. Its only claim to fame is that it's one of our Galaxy's most remote globulars. It appears as an 11th magnitude hazy patch less than 3′ across and requires a 450 mm to resolve. A long-exposure photograph should reveal the brighter individual stars, while a 20- or 30-second CCD shot should break up the edge of the cluster with no difficulty. Fortunately, it is quite easy to find due to 5th (SAO60257) and 7th (SAO60232) magnitude stars nearby. NGC2419 appears to be mottled when seen through instruments in the 400 mm class, but a close examination of images suggests that tight pairings of bright stars may be responsible for this. The cluster's brightest member is of roughly 17th magnitude.

Another interesting target in the Lynx is a 10th magnitude spiral, **NGC2859****, lying about 40′ east of alpha

Lyncis. This means that the galaxy should appear in the same low-power field as alpha Lyncis. If trying to draw the galaxy, you may find it best to keep the star out of the field.

Users of larger scopes may like to investigate the area around **NGC2832***. A glance at *Uranometria* or a PC package like SkyMap or Guide will quickly show why. At least ten galaxies, each bright enough to be picked up in a 200 mm scope, are packed inside a 20′ radius. Given the ease with which this clump of galaxies can be found (1° south of alpha Lyncis) it should be time very well spent. Take heed though; this is an activity best suited to moonless nights.

Monoceros

Moving south of Gemini and into the rather indistinct constellation of Monoceros we find a region of great interest to the deep-sky observer.

It's nice to know that there are times when users of binoculars can have the advantage over the more expensively equipped. The Hyades and M45 (the Pleiades) are two good examples in the January sky. **NGC2237****, the Rosette Nebula, is another, albeit less familiar instance. At more than 1° across, this big, low-contrast nebula can be tough to identify with any instrument larger than 100 mm. But in good binoculars it's quite easily seen when the sky is truly dark and free of light pollution. Both binocular and telescope observers will also be able to see the 6th magnitude open cluster **NGC2244**** that the Rosette encompasses. Of course, in the real (overlit) world probably the best views of NGC2237/2244 are to be had when using light-pollution or nebula filters, which enhance the contrast between emission nebulae and the background. NGC2237 often features in coffee-table astronomy picture books – it is very beautiful – so take a look if skies permit.

If you find it's a sight that you want to record and you have a guided scope, then why not try piggybacking a 200 mm lens and an SLR to the back of the scope and take a 15 minute exposure on hypered ISO 400 film. With a little experimentation it should be possible to capture quite an impressive image.

A little over 4° northeast of the Rosette is the equally famous **NGC2261****, otherwise known as Hubble's Variable Nebula. This is a misnomer, of course, since it's the 11th magnitude variable star R Monocerotis within the nebula that does the varying and not the nebula itself. But the net effect is that the appearance and brightness of this finely structured 10th magnitude diffuse nebula change on a month-to-month timescale. If you have two images of it separated by a few months, inspect them closely for changes. Better still, image NGC2261 at every opportunity from late autumn until late spring and make a "movie" of the changes as they unfold. The nebula is about 2′ across and has a surface brightness that makes it visible through any instrument of more than 100 mm aperture, sited favourably. Medium-sized scopes should reveal the fan-like shape of the nebula and the star within it: very pretty with nicely defined edges that make it look vaguely like an arrowhead.

Another Monoceros showpiece is the star cluster **NGC2264*****, the so-called Christmas Tree Cluster. Use a low-power eyepiece with this sparse cluster. It can be identified by its characteristic arrowhead shape and the 4th magnitude star 15 (S) Monocerotis, which is about 2′ to the northwest. On clear nights, those of you with a keen eye and good optics may be able to detect hints of nebulosity around 15 Monocerotis. Deep images of this nebula show a beautiful extended structure including the Cone Nebula which may just be discernible with a 450 mm and a filter. NGC2264 is another binocular object, visible through 10 × 50s.

Monoceros boasts a number of other worthwhile clusters including **M50*****, **NGC2506*****, **NGC2353**** and **NGC2286*****, to name but a few. Of these, M50 is perhaps the most spectacular. Although it's visible with binoculars, a small scope will reveal a dozen or so stars. Better resolution is attained in medium-sized scopes, while larger instruments show 100 or so stars strewn over 20′. The cluster will appear smaller through smaller apertures, with a haze of unresolved stars giving the impression of nebulosity. The other clusters in Monoceros will be more challenging for small scopes, with only a few stars visible through instruments smaller than 150 mm. All are roughly 15′ across with their brightest members at 10th–11th magnitude. NGC2506 is especially worthwhile observing with a large-aperture scope, which will reveal more than a hundred stars.

While not a showpiece, **NGC2346*** is also worth a look while in the area. It's a 12th magnitude planetary nebula, spanning 1′ around a 10th magnitude central star. The central star is a close eclipsing binary, varying from 11th to 13th magnitude, making the nebula's appearance change greatly from night to night.

Canis Major

It's a shame that for many northern observers Canis Major never rises very high in the sky. Not just because it contains the brilliant star Sirius, but because open clusters like **M41*** ** are never seen at their best. However, despite its low altitude M41 is still an impressive sight in almost any instrument and observers dwelling further south will be able to see it with the naked eye, roughly 4° south of Sirius. It appears as a cluster of some 25 readily resolved stars, ten of which are brighter than magnitude 8.5, covering about 30′ of sky. Larger scopes will be able to pick out many faint members. Even modest instruments will be able to discern the string-like patterns of stars that make the cluster so attractive. Look out for a yellowish-red star near the centre and a brighter star on the southern edge. A visit to M41 is observing time well spent.

NGC2360** is a rather fainter (9th magnitude) but interestingly asymmetric open cluster that can be located by sweeping eastward nearly 3.5° from gamma Canis Majoris. It lies a couple of arc minutes from a 9th magnitude star. The cluster's apparent width varies from about 12′, for users of 150 mm scopes, to 20′ or so for 300 mm of aperture. However, the 80–100 or so stars making up NGC2360 merge into the galactic background and so estimating its size is tricky.

A third easily located cluster in Canis Major is **NGC2362****. This smallish cluster (diameter 5′) yields ten or so stars to smaller instruments and many more to larger apertures. Many of the members appear blue in colour but at a declination of −25° it may be too near to the southern horizon for many observers and just seeing it will be accomplishment enough. The cluster is additionally awkward for photographers and CCD users, as it contains a 4th magnitude star, tau Canis Majoris, which limits exposure times to between two and five seconds to avoid saturation.

CCDers might have some fun with **NGC2207***, a tidally distorted interacting galaxy, not far from the Canis Major/Lepus border. The object has a companion galaxy, **IC2163***, about 1.5′ away. However, at 12th magnitude and just a few degrees above the horizon, seeing it may prove problematic. NGC2207 is best found by star hopping from beta Canis Majoris to the 5th magnitude star SAO151334 and then going 80′ further south and slightly west. At its low altitude, the background brightness will vary strongly across any CCD frame taken, meaning that some careful image processing will be needed. There are other galaxies in Canis Major that the hardened collector might also care to search out, horizon permitting – **NGC2280***, **NGC2272*** or the group of three faint galaxies including **NGC2293***.

Those of you who like to observe something from every constellation can cross off Canis Minor from your lists by sparing a few minutes to search out 10th magnitude **NGC2394***. It's not terribly impressive, but given its position – adjacent to eta Canis Minoris – locating it isn't hard. Oddly, this is one of those objects that some commercial planetarium programs do not have, presumably because it is down as non-existent in the revised NGC catalogue. For reference, SkyMap is one package not so afflicted. Luginbuhl and Skiff seem pretty convinced that they have found it as well – stating that 17 stars were present. Have a look for it on the next clear night.

As we have been looking at some objects with fairly large southerly declinations why not have a bash at finding three of the more southerly winter Messiers? **M46*****, **M47***** and **M93***** are very nice clusters, that would be much better known in northern hemisphere countries if they were better placed for observation. M46 and M47 can be found by sweeping 5° south of alpha Monocerotis. They lie roughly 1.5° apart and so will be difficult to miss in a low-power eyepiece. Respective integrated magnitudes of 4.5 and 6.0 mean that from good sites, like Florida, M47 is a naked-eye object and M46 is visible with binoculars. Although it contains no stars brighter than 8th magnitude, M46 is a very rich cluster – a beautiful mass of over 200 stars. M47 has fewer (around 30 are visible in a 150 mm), but they are brighter and include a 7th magnitude double with both components of about the same magnitude. M46 becomes even more interesting once you notice the attractive 1′ wide, 11th magnitude planetary nebula **NGC2438**** near its northern edge, accessible with medium-sized scopes. The central star of NGC2438 is 16th or 17th magnitude – tough for a 400 mm but it also contains a 13th magnitude star which is rather easier to identify. A nice nebula in a rich field.

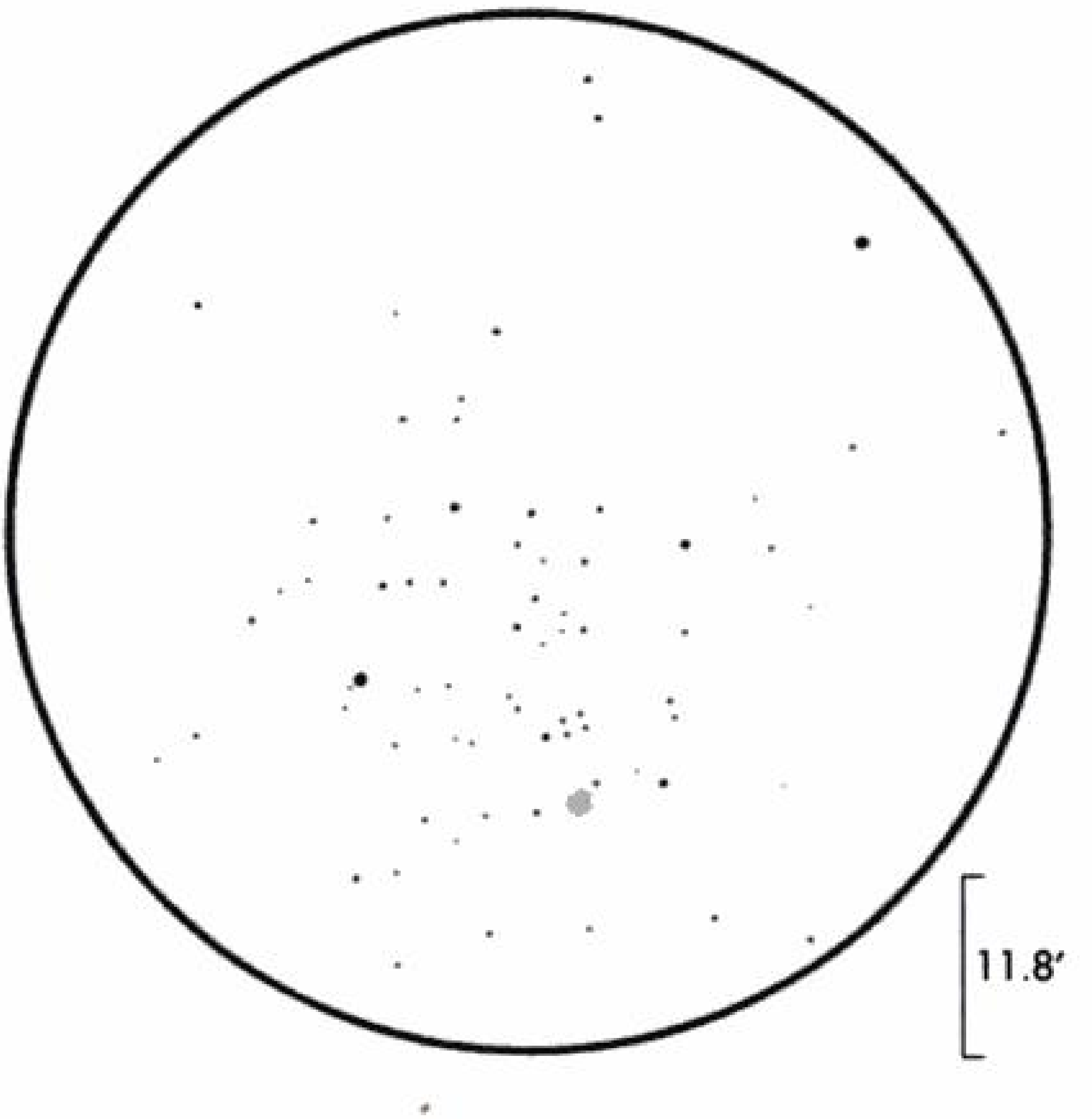


Figure 8.4 NGC2438 nestling on the edge of M46 in Puppis. © Lee Macdonald

The 6th magnitude M93 is most easily found by sweeping from M46/47 or xi Puppis. Like M46 and M47, it is approximately 20′ across. With some of its 100 or so stars clumping near its centre it is well worth a look. An easy find with good binoculars, if conditions permit – for many, houses, trees or the glow of urban lighting will all but drown it out.

Canis Major also contains the very attractive Thor's Helmet or Duck Nebula, **NGC2359****. This is a bright,

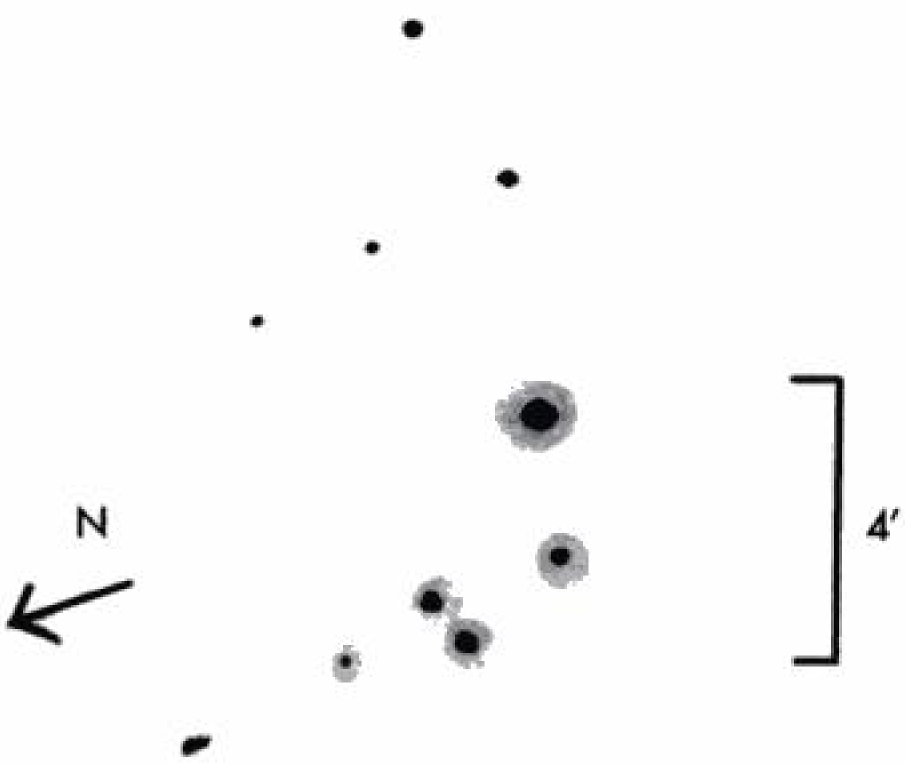


Figure 8.5 Nebulosity and cluster NGC2174/5 as seen in a 260 mm. © Guy Hurst

splendidly intricate diffuse nebula. It provides plenty of scope for drawing or imaging – colour imagers can do particularly well with this object. Its 10′ × 8′ form responds well to nebula and O-III filters. However, you may require an instrument with 200 mm or more of aperture to see it from less than ideal sites.

Also Worth a Look

NGC2129***	Cluster, Gemini, 7th mag, 40 stars.
NGC2174/5**	Cluster + nebulosity, Orion, 7th mag.
NGC2345***	Cluster, Canis Major, 7th mag.
NGC2355**	Cluster, Gemini, 10th mag, 40 stars.
NGC2423***	Cluster, Puppis, 6th mag, large, near M47.
NGC2440*	Planetary nebula, Puppis, 50″ × 20″, 11th mag.
NGC2474/5*	Galaxies, Lynx, 13th mag, near PK164 + 31.1.
NGC2610*	Planetary nebula, Hydra, 13th mag, good for imaging.
PK164 + 31.1*	Planetary nebula, Lynx, 13th mag, bipolar, good for imaging.

Figure 8.6
PK164+31.1: a faint planetary nebula in Lynx. © Jan Wisniewski

Chapter 9

February
10 Hours RA

This Month

The constellations well placed at midnight include: western Ursa Major, Cancer, Leo, Leo Minor, Sextans, western Hydra and part of the Lynx.

Early risers can look forward to the Coma and Virgo clusters crossing the meridian in the early morning, while those of us setting up early in the evening will still be able to sample the delights of Orion and Taurus.

Compulsory Viewing

Binoculars and smaller telescopes:	M44, M48, M81
Moderate telescopes:	M82, M67, NGC2903
Larger telescopes and CCDs:	NGC2872/3, M97, NGC3184

The Bear Essentials

Ursa Major, or the Great Bear, is a big constellation and, especially from light-polluted sites, it's easy to forget that there's more to it than the familiar form of the Big Dipper (the Plough). To star hop to the constellation's first target, you will need to find the 4th magnitude star 24 Ursae Majoris, situated near the bear's head, and move slowly a couple of degrees eastwards. If you are using a reasonably low magnification you will

Figure 9.1 M82 in Ursa Major. Image autoguided using Starlight STAR software. © Terry Platt

quickly sweep up the well-known **M81***** and **M82***** galaxies, lying about 40′ apart and on a north–south line. They are easy to distinguish. M82 is the nearer of the two to the pole, while M81 is the brightest.

The nice thing about these galaxies is that they are big, bright and close together. M82 looks like an edge-on spiral galaxy spanning 11′ × 4.5′, with a magnitude of 8.4, while M81 is a large and impressive inclined spiral galaxy, roughly 20′ × 10′ in size, which shines at about 7th magnitude; quite impressive for galaxies that are some 12 million light years away. While a 75 mm refractor or a 100 mm reflector is sufficient to locate the pair, their fine details are, sadly, not visible through telescopes this small. A more impressive view, picking out several 11th magnitude stars in the same field, can be obtained through a 250 mm, or larger. Such scopes will also reveal the two brightest regions of M82's structure. More features are visible through larger scopes. For example, 400 mm of aperture shows four to five dark dust lanes. In good skies, binocular observers will find M81 to be one of the easier Messier galaxies to locate.

CCDers and photographers will need little skill to create fine images showing evidence of the chaotic internal structure for which M82 is rightly famous. A 15-minute photograph with a medium-sized instrument, possibly printed on high-contrast paper, should be quite impressive if the sky background is not too bright. Although there are other places in the sky where you can catch two bright galaxies in the same

Figure 9.4 A grouping of galaxies around NGC2820. © David Briggs

You may also choose to seek out an 11th magnitude edge-on spiral sometimes known as **M108****, but more commonly as NGC3556. It's situated roughly one third of the way along the line connecting M97 and the star beta Ursae Majoris, and slightly to the north.

In the same field of view as mu Ursae Majoris is the equally photogenic, but unsung galaxy, **NGC3184****. Despite being face-on, 11th magnitude and 9′ across, it's easy to see through a 200 mm telescope, even when less than ideally placed in the sky. Its high visibility and the ease with which it can be found is good news for users of smaller scopes. Indeed, observers with good eyesight may be able to find NGC3184 with just 100 mm of aperture. Visually, it's very nearly featureless, but with a CCD and eight minutes or more of integration time you will find a graceful spiral structure

Figure 9.5 Nearly edge-on but detailed galaxy M108 in Ursa Major. © Paul Curtis

will need to use a focal reducer to really appreciate this object. A 100 mm reflector is an ideal instrument for M44; binoculars also provide fine views.

Intriguingly, recent work examining cluster dynamics has suggested that M44 may contain a sub-cluster with its own distinct internal motions. While this will not be apparent to amateur observers, it goes to show how even a well-known object can sometimes be more complicated than appearances suggest.

As users of detailed atlases already know, there seems to be no area of the sky that's devoid of background galaxies. The Beehive is no exception. An examination of long-exposure photographs of the region shows a number of specks that are rather more distant than the stars in M44. These galaxies are all very hard to see though – the brightest, **NGC2624***, is 15th magnitude and measures just 1′ × 1′. A reasonably high magnification helps in this instance and all but one or two should be located with a 200 mm. Observers looking for more accessible galaxies should seek out **NGC2775****, to the southeast of the constellation. It measures 3′ × 4′ and is 10th magnitude with a bright core. Users of moderate scopes may detect hints of mottling.

Not far southwest of M44 is another Messier object, the 7th magnitude open cluster **M67*****. This is considerably smaller than M44, being less than 20′ or so across, but is easily found by sweeping a little over 1° westward from alpha Cancri. The brightest stars in M67 are mainly 10th magnitude and can be seen clearly in a 100 mm telescope. With larger scopes, look out for dozens of stars brighter than 13th magnitude. The cluster is also visible through 10 × 50 binoculars, although a dark, clear sky is needed.

The Lynx

The Lynx is still high in the sky this month, making it an ideal time to search out some of the constellation's resident galaxies. *Burnham's Celestial Handbook*, Volume 2 alone notes 13, the majority of which are around 12th–13th magnitude. But don't be put off by the figures – have a look. **NGC2683**** is a particularly bright (10th magnitude) example and can be located just 1° to the north of sigma 1 Cancri. It's a near edge-on spiral, about 10′ × 2′ in size. Imagers should also look out for the fainter elongated galaxy in the background.

Figure 9.9 The galaxy NGC2683 in Lynx. © Gordon Rogers

Leo and Below

Moving into northern Leo, a little time can be spent observing the very fine spiral galaxy **NGC2903*****. A fairly bright object at 9th magnitude, this galaxy is found by sweeping roughly 1.5° south from the 4th magnitude star lambda Leonis. Although even a 200 mm telescope can often only pick out part of the 12′ × 6′ diameter attributed to NGC2903 in catalogues, it is nonetheless a pleasing find. Visually, the core of the galaxy dominates the view, but users of medium- and larger-aperture telescopes should have some fun searching out detail. NGC2903 is suitable for any instrument and is a good candidate for a beginner's first non-Messier galaxy.

Just across the border from Leo into Virgo is **NGC4216****. This 10th magnitude galaxy has a brightly visible nucleus. Users of larger instruments will be able to see a dark rift across NGC4216, plus two edge-on galaxies (NGC4206 and NGC4222) and a 15th magnitude elliptical galaxy, all in the same field of view. This sight is a worthwhile reward for the difficult star hop from the 6th magnitude star 12 Virginis, needed to find the grouping.

Several worthwhile galaxies brighten up the otherwise unexciting constellation of Sextans. One particularly fine object, **NGC3115****, the so-called Spindle Galaxy, is a 10th magnitude edge-on galaxy, measuring approximately 9′ × 3′ photographically. It should be visible in a small scope from a good site and may be located using a nearby pair of 9th magnitude stars. Roughly a magnitude fainter are the two galaxies **NGC3169**** and **NGC3166****, which appear to be interacting; a 250 mm scope may be needed to resolve the pair clearly. Owners of larger scopes might also look for the 14th magnitude **NGC3165*** in the same field of view.

Moving into Hydra brings us to the open star cluster **M48*****. While this object is not particularly easy to identify, requiring a 3.5° hop southwest from the star 30 Hydrae, the route does involve some reasonably bright stars that can be used for guidance. M48 itself encloses at least 45 stars brighter than 13th magnitude within a patch almost as large as the full Moon. Its integrated magnitude is about 6, so it can be observed with binoculars. Almost any telescope will allow you to

Figure 9.10 M81 and M82 in Ursa Major. Very different but both bright. © Dennis Webb

Chapter 10
March
12 Hours RA

This Month

Clearly, this is one of the great months of the year as riding high are the bowl of Ursa Major, Leo, Leo Minor, Virgo, Coma, Corvus, Crater and, in the south, the middle section of Hydra.

Those of us able to start observing as soon as it gets dark will still be able to catch objects in Gemini and Auriga before they become too low. Late-night observers will instead find Hercules and Draco becoming well placed.

Compulsory Viewing

Binoculars and smaller telescopes:	Melotte 111, M66, M104
Moderate telescopes:	M96, NGC4565, NGC4361
Larger telescopes and CCDs:	NGC3190, Double Quasar, Leo 1

Leo

Given the ease with which they may be found, the five famous Messier galaxies in Leo (four if you are a purist who recognises only the 103 entries in Messier's original list of 1784) are probably a good place to warm up.

Figure 10.2 M66, a bright and detailed spiral galaxy in Leo. © Peter Ward

The other well-known grouping of bright galaxies in Leo is located about 1° to the east of the 5th magnitude star 73 Leonis. The members are **M65*****, **M66**** and **NGC3628***** – all spiral galaxies. Although they are separated from each other by just 30′, it would be difficult to mix them up. They shine at 9th, 8th and 10th magnitudes respectively, and are considerably bigger than M95 and M96, being ellipses of 9′ × 2′, 9′ × 3′ and 12′ × 3′. A 150 mm scope should allow a careful user to observe mottling and shape within M66, but a 300 mm will generally be needed to glimpse detail in the other two. In a low-power field all three can just be seen simultaneously – a memorable sight.

Some of you might like to look 2° north of gamma Leonis to hunt out the rather fainter galaxy group surrounding the galaxy **NGC3190***. The 12th and 13th magnitude galaxies **NGC3193***, **NGC3185*** and **NGC3187*** are all within 30′ of this 11th magnitude, 4′-long, near-edge-on spiral, making it easy to compare their appearances. The faint glow of 13th magnitude spiral galaxy NGC3187 may be a challenge for a 300 mm scope in polluted skies, but the elliptical NGC3193 is rather easier.

While still in Leo why not try another couple of galaxy groups? Lying 2° northeast of 5th magnitude 72 Leonis is **NGC3651*** which is the heart of a group of five galaxies, the brightest of which are NGC3651 and **NGC3653*** (both 13th magnitude). The others are rather more difficult at 14th and 15th magnitude. Take care not to confuse these two dimmer galaxies with

Figure 10.3 M65, M66 and NGC3628 in Leo. Good for small scopes. © Dennis Webb

Figure 10.4 Finder chart for M95 and M96. Courtesy SkyMap Software

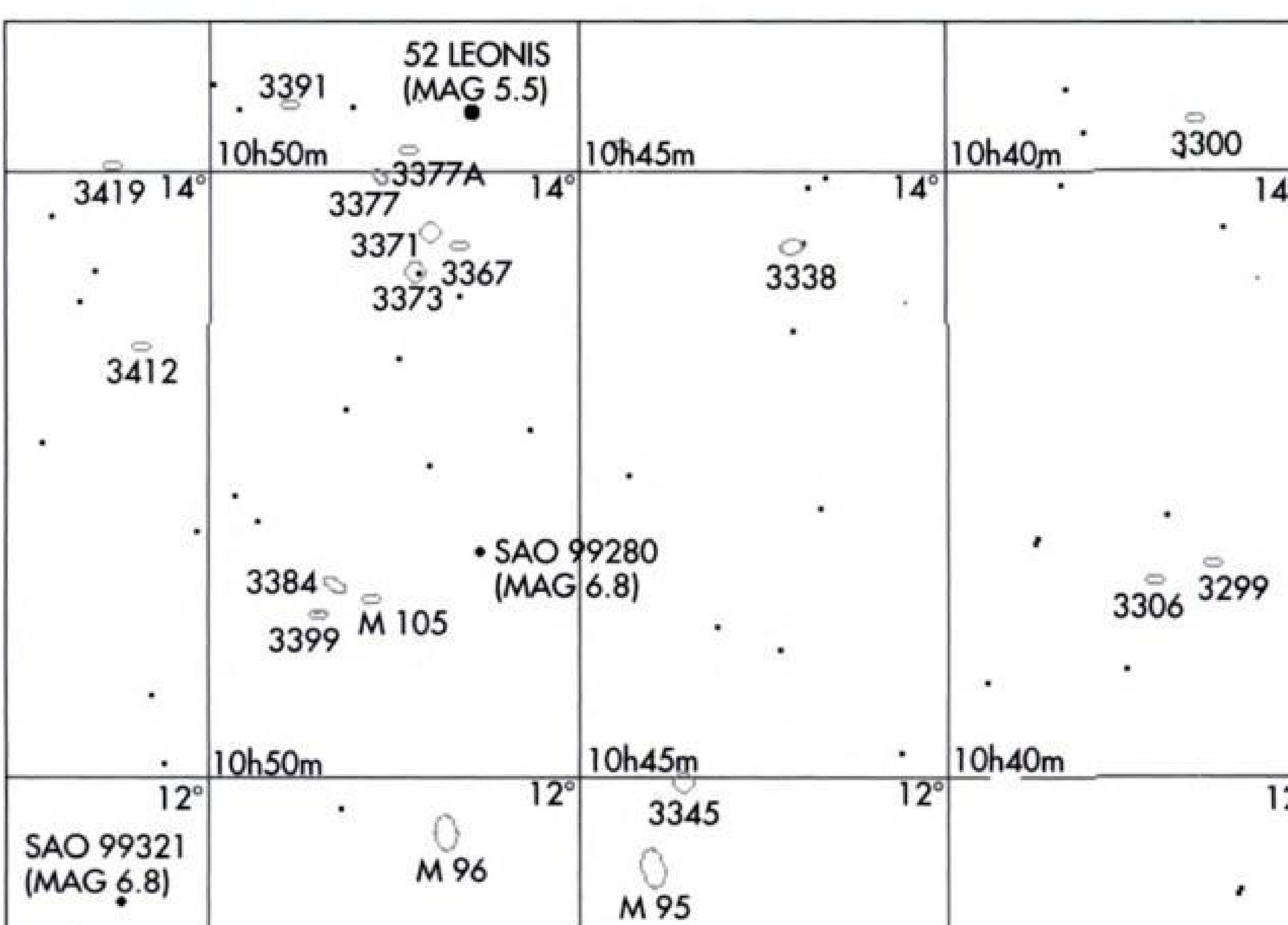


Figure 10.5 M65, a bright spiral 35 million ly away. © W.C. Keel

NGC3615* and **NGC3618***, which lie between NGC3651 and 72 Leonis.

Copeland's Septet, a group of seven galaxies about 1° northwest of 92 Leonis, requires very large scopes, dark skies and an experienced eye. The brightest member is **NGC3753*** which, at 13th magnitude, is within the reach of a 250 mm scope. The six remaining NGC galaxies are 14th to 15th magnitude and fairly small but probably detectable with a 300 mm visually. The cluster also has a very faint 17th magnitude non-NGC galaxy associated with it. This will be readily imaged but is visually beyond all but those observers who find the Double Quasar in Ursa Major (see below) easy. Seven NGC galaxies within a region 6′ across is a sight worth pursuing. Good preparation will help. Make up detailed charts before observing – these will help you avoid confusing foreground stars for galaxies, and vice versa.

Photographers and CCDers might like to seek out **Hickson58*** – an attractive group of 13th–15th magnitude galaxies, 2.5° northwest of the star 4 Virginis. The brightest members are **NGC3825*** and **NGC3822***.

There are a final few galaxies that you might like to try for. **Leo1*** is a Local Group galaxy that is very easy to locate but rather tougher to see. It lies 9′ north of Regulus. Despite its size – 9′ × 7′ – you will probably need a 400 mm scope to pick out its very faint glow.

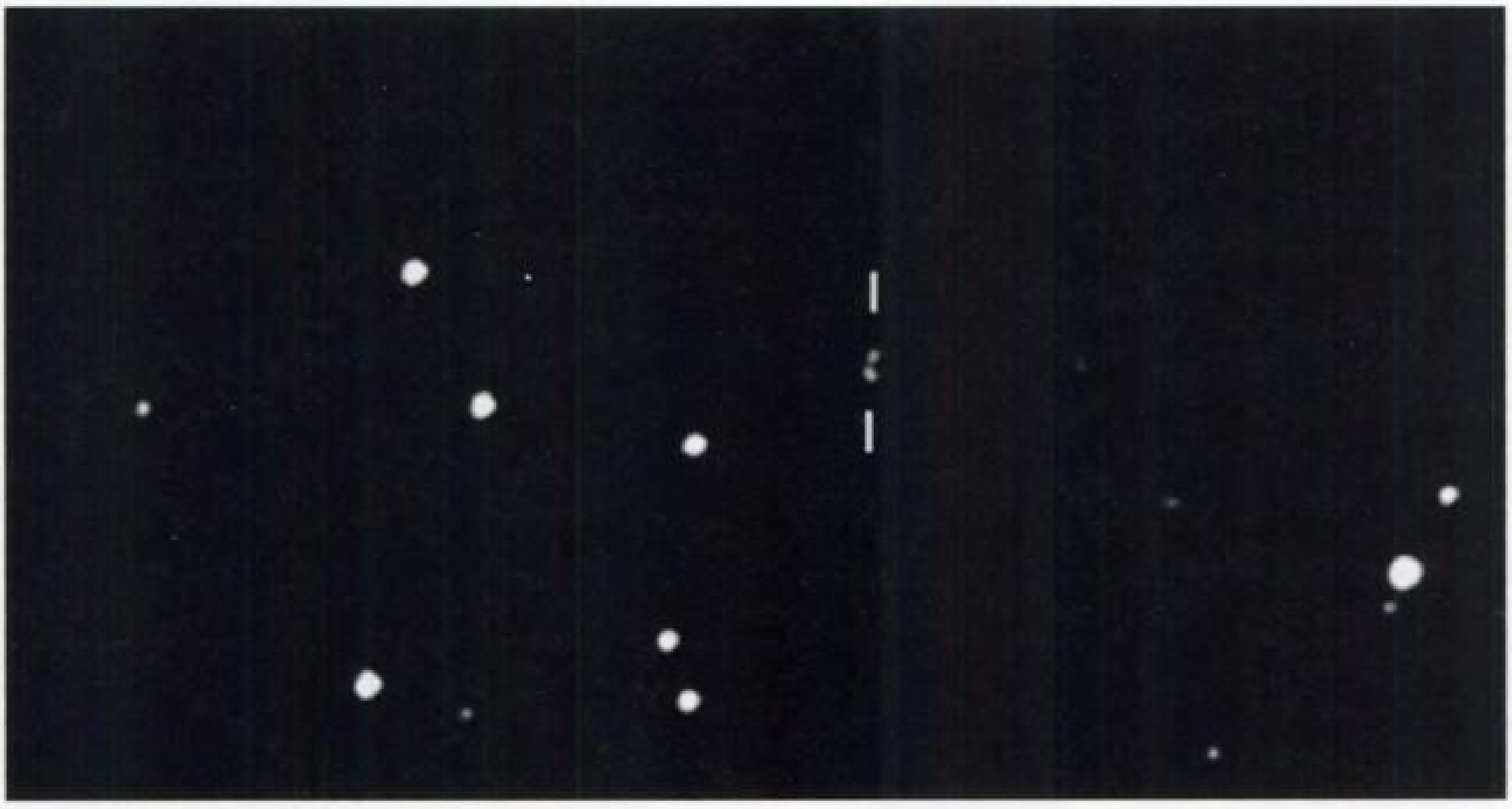


Figure 10.7 The gravitationally lensed Double Quasar in Ursa Major. © Maurice Gavin

Ursa Major holds a challenge for users of big scopes, in the form of the famous Double Quasar, **0957 + 561A/B***. The quasar is a fine example of gravitational lensing – where light rays from a single source are bent by the gravity of an intervening object to produce two images. It lies 10′ northwest of the galaxy **NGC3079****. At 10th magnitude NGC3079 is not too difficult and may show a little mottling to the more diligent and persistent observer with a medium-sized scope. The field containing the quasar is about a third of the way from NGC3079 to the 9th magnitude star GSC3817:737. The two quasar images are only a few arc seconds apart and faint by any visual standard. Nevertheless, they have been observed from a site in the southeast of England with a limiting magnitude of 5.8, using a 450 mm scope, so they will probably be just accessible with a 400 mm from better sites. Do not expect the view to be spectacular – remember, you are looking across 7.3 billion light years of space. True, there are brighter quasars that are more distant. But there are few opportunities to see a gravitational lens in action so it's fun to have a go for, whether visually or by CCD.

North of the bowl of Ursa Major, near the end of Draco and close to the star chi Draconis, lies the galaxy **NGC4236***. It is situated roughly 13′ south southwest of an 8th magnitude star and 13′ north northwest of a 10th magnitude star. Although 9th magnitude, its size – 22′ × 5′ – means that it is not particularly easy to spot. Indeed, it's probably not worth trying for unless you have a 200 mm, or preferably 300 mm, scope available.

Coma Berenices

The region around Coma is blessed with many interesting galaxies, but one of the most impressive is surely **NGC4565*****. This large, 9th magnitude edge-on spiral galaxy is one of the great sights of the spring. The dimensions seen will depend on aperture, appearing clearly elongated in small scopes and growing to an impressive 15′ long in larger instruments. The galaxy has a dust lane, which will probably be evident in a 200 mm–250 mm scope. Although placed in a sparse field, NGC4565 is a great object for CCD imaging. A 250 mm F6 scope should be able to get a nice image of this with a 40-minute exposure. Imagers with smaller CCDs may need to place the object diagonally on the chip.

While in Coma, be sure to use binoculars to observe the stars of the cluster **Melotte111*****, which make up the majority of the constellation around gamma Comae Berenices. These are spread over 5°–8°, forming a vaguely triangular shape and are nice to return to after looking for fainter, more obscure quarry.

For anyone keen on galaxy groupings this is a good month. **The Box***, also known as Hickson61, is visible 3° west and 1° north of 4th magnitude gamma Comae Berenices. Look for the elongated and aligned images of 13th magnitude **NGC4175*** and the elusive **NGC4170*** making up one side of a rectangle 3′ × 1′ across with two other galaxies, including the 12th magnitude **NGC4169***.

Figure 10.8 An edge-on galaxy plus pronounced dust lane is NGC4565. © Gordon Rogers

The Antennae

Moving south into Corvus we can observe the enigmatic Antennae or Ringtail Galaxies – otherwise known as **NGC4038/4039****. On a good night this pair of 10th magnitude interacting galaxies can be found fairly easily by star hopping from eta Crateris or gamma Corvi. Unfortunately, the antennae never rise very high from many northern locations, and the 2′ × 2′ patch will probably be lost in the haze near the horizon through anything less than a 200 mm. An 8th magnitude star, SAO157048, lies close by, making them slightly easier to find after a short star hop from eta Crateris. Scopes of 200 mm should be able to distinguish NGC4038 from NGC4039 and scopes larger than 450 mm may show the faint tidally distorted tails stretching out from them. A little to the west of the pair lies the 11th magnitude galaxy **NGC4027**** and its apparently interacting companion, the considerably fainter **NGC4027A***.

Photographing the antennae can be quite rewarding with scopes larger than 250 mm but be prepared for long exposures (50 minutes plus). Hypered ISO 400 film, or possibly TP2415 can produce satisfactory results. Ideally stack negatives before printing.

Despite its size, Corvus also boasts the 10th magnitude **NGC4361**** – a 1.5′ × 1.5′ planetary nebula, that

Figure 10.9 The HST resolves the Antennae – colliding galaxies in Corvus. © STScI/NASA

can be found by star hopping a couple of degrees from delta or gamma Corvi. It contains a 13th magnitude central star but the poor contrast against the sky, due to its low altitude, may make both the nebula and star difficult to spot. The nebula's faint outer shell may be difficult even in large instruments. Higher magnification should help separate the star from the nebula, and this is probably a case where a filter of some form could prove valuable. William Herschel appears to have had no trouble resolving the central star. But that was before overlit roads and outdoor security lighting.

Another pair of interacting galaxies - though not as impressive as the antennae - are **NGC4782**** and **NGC4783****. Both are 11th magnitude and at low magnifications merge to form a small faint patch, a little over 1′ across.

South and a bit east from the star beta Corvi is the 8th magnitude globular cluster **M68*****. Its 12th magnitude individual stars should become apparent with a 200 mm scope. The diameter obviously depends on the aperture that you are using but expect to see a glowing patch typically 5′ across, although not perfectly symmetrical at some powers. This cluster would be far more impressive and better known if it was higher in the sky.

In nearby Crater, the best object is probably the 10th magnitude galaxy **NGC3962****. But galaxy enthusiasts will find enough 11th–13th magnitude galaxies dotted about to keep them amused for some time.

Just across the northern border of Corvus into Virgo lies the splendid **M104***** – the Sombrero Galaxy, a spiral galaxy, inclined towards us at an angle of just 5°. At 8th magnitude it is one of the brightest galaxies visible in the northern hemisphere. An attractive star field makes it an additionally rewarding target. The Sombrero gets its name from a dark dust lane, which makes the galaxy resemble a Mexican hat. While very prominent in professional photographs, this feature will be hard to discern through an amateur scope. Fortunately though, M104 responds well to magnification, which makes its 10′ × 3′ shape and bulge fairly easy to spot. Professional images also show a huge spherical halo of globular clusters encompassing the galaxy. While you are near M104, sweep a little northwest from it to see a small asterism, resembling the constellation Sagitta, but a mere 7′ across.

If M104 is obscured by trees or houses, there are a couple of slightly higher galaxies nearby. Try the 9th

Figure 10.10
M106, an inclined spiral galaxy in Canes Venatici. © Peter Ward

magnitude **NGC4697****, lying about 3° north and 1° further east. It has a brightish core and covers an area 1.5′ × 1′. CCDers can have fun trying to image the faint galaxy interacting with it. About 3.5° northeast of M104 is the 9th magnitude galaxy **NGC4699****. This is also worth a visit, appearing as a small, brightish patch, roughly 2′ × 2′. The core is particularly bright, standing out from the fainter parts of the galaxy, especially when you use averted vision (see Chapter 2).

Remember too that March is the month for the Messier marathon. If you plan to attempt it, be sure to get plenty of sleep on cloudy nights and have finder charts prepared well in advance.

Also Worth a Look

M106**	Spiral galaxy, Canes Venatici, 8th mag, elongated, **NGC4217*** nearby.
NGC3550*	Galaxy, Ursa Major, part of galaxy cluster **Abell1185***.
NGC3585**	Galaxy, Hydra, 11th mag.
NGC3607**	Galaxy, Leo, 10th mag, NGC3608 and NGC3605 nearby.
NGC3610**	Galaxy, Ursa Major, 10th mag.
NGC3626**	Galaxy, Leo, 11th mag, west of 86 Leonis.
NGC3675**	Galaxy, Ursa Major, 10th mag, near 56 Ursae Majoris.
NGC3726**	Galaxy, Ursa Major, 10th mag, close to 60 Ursae Majoris.

Whatever the official current total, there are thousands of galaxies involved, of which at least 12 are brighter than 10th magnitude, 180 are brighter than 13th magnitude, and probably a thousand or so are detectable using a CCD or photography. Clearly we are spoilt for choice. Any observer with a scope larger than 75 mm should have enough to keep them going for several evenings.

It's easy to forget that Virgo cluster members are not the only galaxies on show at this time of year. Examining a star atlas, such as *Atlas Coeli*, shows that galaxies can be found in profusion from south of gamma Virginis, northward through Coma and Canes Venatici and into Ursa Major. Examining a more extensive atlas such as the SAO, or using a PC program, such as The Sky, reveals swarms of galaxies along this path. There are so many that, when observing, it's often hard to tell which galaxy is which.

Galaxies, Galaxies, Everywhere

When looking for deep-sky objects, it's worthwhile starting with the less demanding targets and then working up to the fainter stuff. This gives you a chance to get well dark adapted before you push things to the limit. For example, in Ursa Major, try observing **M81/82*** ** while your eyes adapt, and then move on to fainter objects like The Owl, **M97****. Similarly, when in Virgo, why not start with the 8th magnitude **M64***** and then progress to 9th magnitude M61.

Figure 11.1 M61, a spiral galaxy in Virgo. © Grant Privett

M64 is an 8th magnitude spiral galaxy, roughly 10′ × 5′ in size. Its main point of interest is the dark region near the centre that gives rise to its popular title, the Blackeye Galaxy. Photographs and CCD images show what appears to be a huge swathe of dust above one of the spiral arms, that extends some way round the galaxy's disk and a little towards the core. The ease with which this can be seen varies considerably depending on seeing, transparency, dark adaption and aperture. It is readily spotted with a 300 mm and there are rare reports of it being seen using scopes of just 100 mm, so give it a try. This is one of the few galaxies where small apertures can detect structure. M64 is easy to find – just offset about 1° northeast from 35 Comae Berenices. A very pleasing object to start off an evening with.

To locate **M61*****, first centre your scope on eta Virginis, then sweep due north for about 4° until you find the star 16 Virginis. M61 should now be found just off the edge of a low-power field, a fraction over 1° to the north and slightly to the east. When you have the galaxy centred you should also have two 8th magnitude stars in the same field of view. One of them makes a rhomboid with an 11th magnitude star and two 10th magnitude stars that lie about 15′ away from M61.

M61 appears as a compact and brightish patch of light, between 2.5′ and 4′ across, depending on the aperture used. Despite being 9th magnitude, it should be identifiable with a 100 mm reflector. Through a 200 mm, it presents an obvious glowing patch which,

Figure 11.2 The aptly named Blackeye Galaxy, M64, in Coma Berenices. © Gordon Rogers

Figure 11.4 The classic spiral M51 with its neighbour in Canes Venatici. © Grant Privett

250 mm or more of aperture. An interesting twin target for imagers.

Our last visit to the Virgo cluster is in the region of the 5th magnitude star 6 Comae Berenices. From this reference point, try sweeping about 30′ west until you reach the inclined spiral **M98****. Some people find this large (6′ × 1.5′), 10th magnitude galaxy difficult to see, but with care you may be able to spot mottling and other hints of structure. Finally, try sweeping southeast from 6 Comae Berenices. After traversing about 1° you should come across **M99****. This galaxy is also of 10th magnitude but is nearly face-on. A 300 mm scope should clearly show signs of one of the spiral arms. There is a particularly bright cloud of ionised hydrogen (an H-II region) on the southerly side of the galaxy.

Into the Whirlpool

One of the most beautiful deep-sky targets is **M51*****, the Whirlpool Galaxy. Positioned in Canes Venatici around 2° south of 4th magnitude 24 Canes Venaticorum and a little to the east, it should be very easy to track down. This 8th magnitude face-on spiral and its peculiar companion **NGC5195**** are ideal targets for any observer. They are detectable in 10 × 50 binoculars or even finderscopes at a pinch. A 150 mm shows that the galaxy M51 is somewhat granular, while a 250 mm will – under very good conditions – show hints of the spiral arms and H-II regions, and the star formation within them. It took Earl Rosse's 72-inch speculum to show the arms originally, but modern optics make the structure discernible using much smaller instruments. A modern 400 mm light bucket shows the arms very clearly with much detail. Sadly, however, for many of us NGC5195 will remain featureless.

Other attractive galaxies in Canes Venatici include **NGC4449****, **NGC5005**** and **NGC4244****. Although 9th magnitude, NGC4449 should be observable as a faint patch even with a small instrument and shows hints of detail at apertures of 150 mm–200 mm. Larger scopes will reveal an elliptical core with hints of spiral arms. NGC4449 may be located by sweeping 2.5° north (and slightly west) from beta Canum Venaticorum. This is an area strewn with galaxies. Using beta Canum Venaticorum as the starting point and sweeping 4.5° southwest will bring you to the irregular galaxy, NGC4244. This is a fine sight in any scope, appearing as a 15′ × 2′ sliver of light with a magnitude of 10. No obscuring dust lanes are present but some detail may be discernible with scopes of 300 mm or bigger. If you sweep along an imaginary line passing through beta and then alpha Canum Venaticorum to 3° beyond alpha you will reach a small group of galaxies dominated by 9th magnitude spiral galaxy **NGC5005****.

Although visible in small instruments, this 4′ × 10′ object shows little detail. However, the close proximity of the larger, 10th magnitude **NGC5033****, complete with its dark dust lane, makes it well worth finding.

Not far away are two pairs of NGC objects, each separated by just a few arc minutes. The first pair is formed by the long, thin, 9th magnitude edge-on spiral **NGC4631****, and its 12th magnitude companion **NGC4627***. The other is the even longer, 10th magnitude **NGC4656**** and the smaller, 10th magnitude

Figure 11.5 NGC4244 in Canes Venatici. © Peter Ward

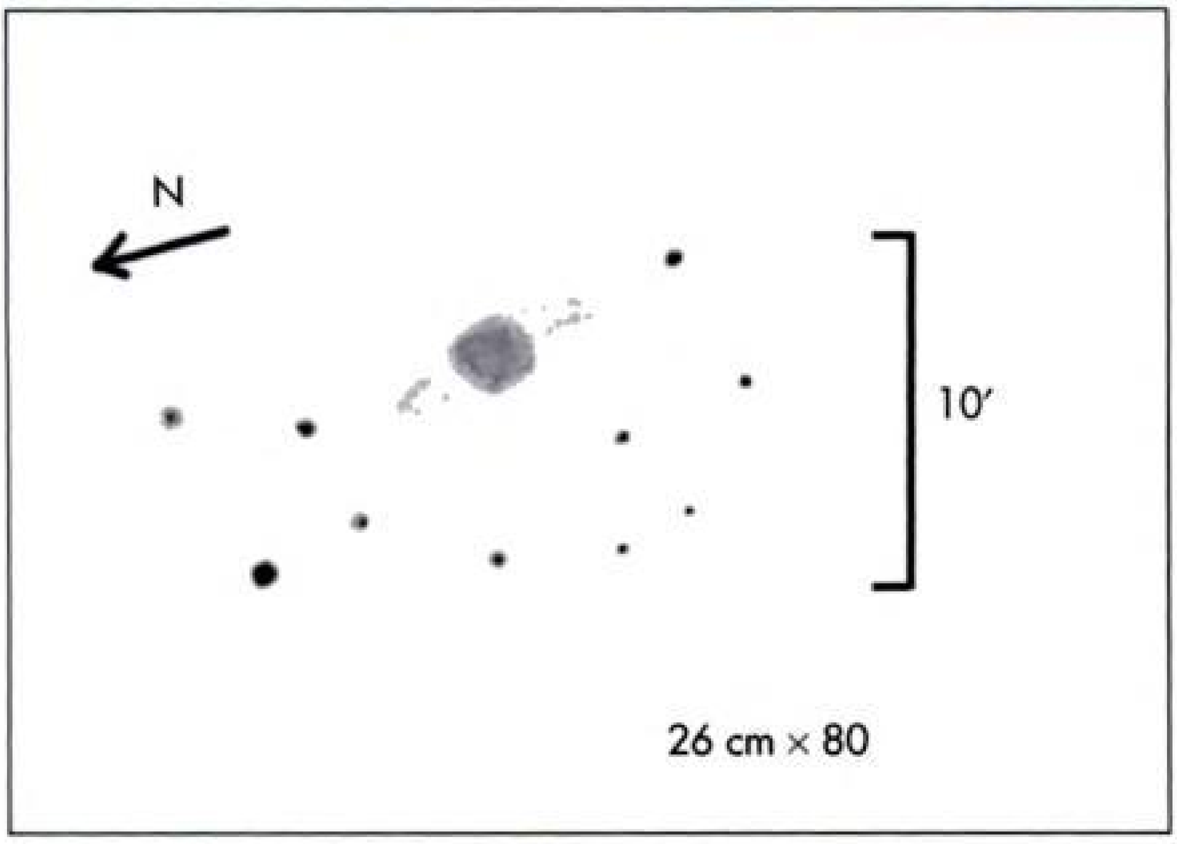


Figure 11.6 The galaxy NGC4656 in Canes Venatici using a 260 mm scope. © Guy Hurst

NGC4657**. Both pairs are worth a look. Under good conditions, at least the brighter galaxy in each should be discernible with instruments of 100 mm aperture.

Before leaving the area be sure to sweep up the wonderful **M3*****. This globular cluster appears as a spectacular 6th magnitude splash of stars, a little under 7° east of beta Comae Berenices. It can be partially resolved in a 100–150 mm scope, and is a splendid sight in a large instrument. M3 can be seen in binoculars as a small, slightly blurred star-like point. Users of large instruments can also look out for a 14th magnitude galaxy – **NGC5263*** – on the western fringe of the cluster.

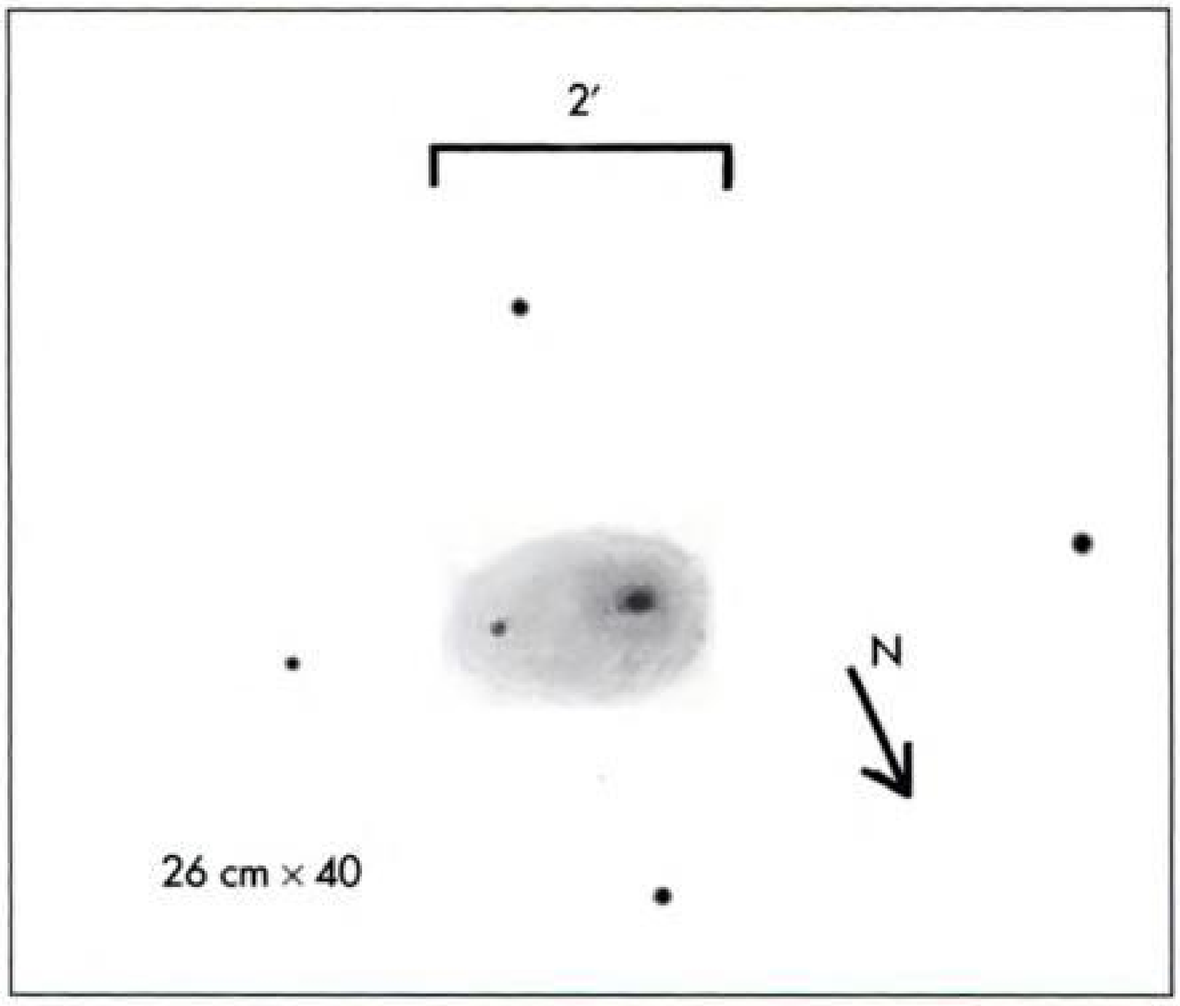


Figure 11.7 A drawing of Virgo galaxy NGC4608 using a 260 mm scope. © Guy Hurst

Chapter 12

May
16 Hours RA

This Month

Unfortunately, by May the rich hunting of Virgo is being relegated toward the western horizon. But it's being replaced by Ursa Minor, the central portion of Draco, Boötes, Corona Borealis, Serpens Caput, Libra, the eastern end of Hydra and Scorpius, offering something of a change from the all-galaxy diet of recent months.

Early in the evening Leo will still be reasonably placed, while those braving the early hours will find the rich star fields of the summer Milky Way becoming visible.

Compulsory Viewing

Binoculars and smaller telescopes:	M4, M83, M63
Moderate telescopes:	M101, M4, M80
Larger telescopes and CCDs:	NGC6027, UGC9749, NGC4402

The Not-So-Barren North

It must be said that Ursa Minor is not an exciting constellation. However, it does have a few galaxies that might attract the serious deep-sky observer. The brightest of these is **NGC6217***, an 11th magnitude galaxy that appears as a faint elongated blob roughly 1.5′ × 1′. It can be found by sweeping east about 2.5° from zeta Ursae Minoris. There are others, such as the 13th magnitude **NGC6048*** or **NGC5939***, but these aren't easy targets to the visual observer.

Those seeking a very severe challenge might have a go at the large 13th magnitude Local Group dwarf galaxy **UGC9749***. It covers over 30′ of sky and so has an extremely low surface brightness. Consequently, it will be extremely difficult to spot without a really good dark sky, a wide field of view, a large aperture and an immaculate finder chart. Visually, it requires a scope larger than 450 mm, using a low-power eyepiece under pristine skies. Obtaining an image is also difficult. If you can simply tell that this galaxy is there, then you are doing very well! It is probably the most difficult object in this book and verges on the edge of what is feasible for amateurs.

The region around Corona Borealis is similarly quite bleak for the deep-sky observer. It boasts faintish galaxies – such as **NGC5958***, **NGC5961*** and **NGC6001*** – together with a variety of IC and UGC catalogue galaxies of 14th and 15th magnitude, with a particularly strong concentration near beta Coronae. Many of these will be easy fodder for CCD users, who may also like to have a bash at the Corona galaxy cluster **Abell2065*** which can be found lurking near 15 hr 22 m RA and 27° 40″ (2000).

One object very worthwhile seeing, which was also well placed last month, is the magnificent face-on spiral **M101****, which sits about 6° east of Alcor and Mizar and a further 1° south. Do not expect something small – a frequent mistake. For many amateur scopes M101 will be between 7′ and 10′ across, and a touch oval. Despite an integrated magnitude of 8, its large size makes for a surprisingly elusive object.

While just about detectable in scopes of 100–150 mm aperture, averted vision and complete dark adaption are essential. A low magnification also helps. The galaxy's nucleus becomes apparent through medium apertures, with some hints of structure that resolve into clumpiness and spiral arms for scopes in the 400 mm league. In addition, several NGC numbers have been assigned to clumps within the spiral arms of M101, which can provide entertainment for users of larger scopes.

NGC6643**, in Draco, is also visible at this time of year. At 11th magnitude, it would be awkward to find

Figure 12.1 M101, its arms a mass of knotty condensations and HII regions. © Nik Szymanek

were it not 2° north of chi Draconis and adjacent to two 12th magnitude stars, with a 10th magnitude star in the same field. Look for an elongated oval patch, extending roughly 4′ × 1′. Imaging shows this galaxy to be an attractive inclined spiral with delicate structure.

Figure 12.2 M63, the Sunflower Galaxy in Canes Venatici. © Grant Privett

Figure 12.3 The easy-to-find NGC6643 in Draco. © David Briggs

Serpens Caput

Serpens Caput, like Corona, boasts a lot of IC and UGC galaxies, but there are also a few bright NGC catalogue galaxies. Of particular interest is **NGC5921****, an 11th magnitude galaxy, found by sweeping about 1° east from M5 and then 3° north. In moderate skies it will probably appear roughly 1.5′ across, growing to 4′ × 4′ in CCD frames and long-exposure photographs.

Another interesting sight in Serpens is the 8′-wide group of apparently interacting galaxies surrounding **NGC6027****. Unfortunately, the brightest member in the group is only 14th magnitude, and the faintest 17th, which makes it a tough target visually. When imaged by CCDers, however, it can be every bit as attractive as Stephan's Quintet. The galaxies vary from about 1′ across to less than 0.5′. The grouping can be found about 2° east of rho Serpentis, and less than 30′ northeast of a 9th magnitude star.

The foremost deep-sky object in Libra is **NGC5897****, a diffuse and rather sprawling globular cluster that appears roughly 8′ across and not entirely circular. The brighter members of the cluster are 11th and 12th magnitude, making resolution possible with 150 mm scopes, but rather easier with bigger instruments. Skiff and Luginbuhl, in their *Observing Handbook and Catalogue of Deep-Sky Objects*, report it as having more outliers to the east than the west, a feature well worth looking out for. NGC5897 shines with an integrated magnitude of 8, making it slightly more difficult to spot than a globular like M5. This problem is compounded by the cluster's low altitude from some latitudes.

M83** is a large, 8th magnitude, face-on spiral galaxy in Hydra. It has a bright nucleus and spiral arms that show up as mottling in scopes of 200 mm aperture. It's a great object to image, with numerous H-II regions (clouds of ionised hydrogen gas) that can only be seen visually in large instruments. It is low in the sky, making it a hard target for many of us, but the 5th magnitude star SAO181825 lies close by, providing a good reference point.

Virgo Again

Although the Virgo/Coma region was examined in depth last month, it's worth returning there. True, it doesn't culminate this month but given the huge number of objects that it encompasses, especially compared to the dearth in Corona and Ursa Minor, it cannot be ignored. If you get some spare time in the early evening have a look for the heart of the Coma galaxy cluster in the region around 11th magnitude **NGC4889*** and **NGC4874***. It isn't easy to spot visually with smaller scopes, but a 200 mm allows the two brightest and half a dozen or so other cluster members to be picked out. A 300 mm should allow more than ten to be detected.

Alternatively, why not have a look at the nearby **M63***** in Canes Venatici, a large and bright (8th magnitude) inclined spiral galaxy. It lies not far from alpha Canum Venaticorum, close to the 4th magnitude star 20 Canum Venaticorum and still closer to a magnitude 8 star. Although M63 is detectable with a 60 mm telescope, none of its fine spiral structure can be seen visually with anything but the largest scopes. An exposure of 40 minutes on an ISO 400 film should produce quite a respectable image. How far towards the nearby 9th magnitude star can you trace M63's spiral arms?

A bright target in Coma is **M98****, which shines at 9th magnitude and is some $8' \times 2'$ in size. It will show structure with surprisingly small scopes. M98 also has a neighbour, the 14th magnitude **NGC4186***, which in turn has a 17th magnitude attendant, **NGC4192A***. This all makes for striking views, and pictures. Search for them 6° east of beta Leonis.

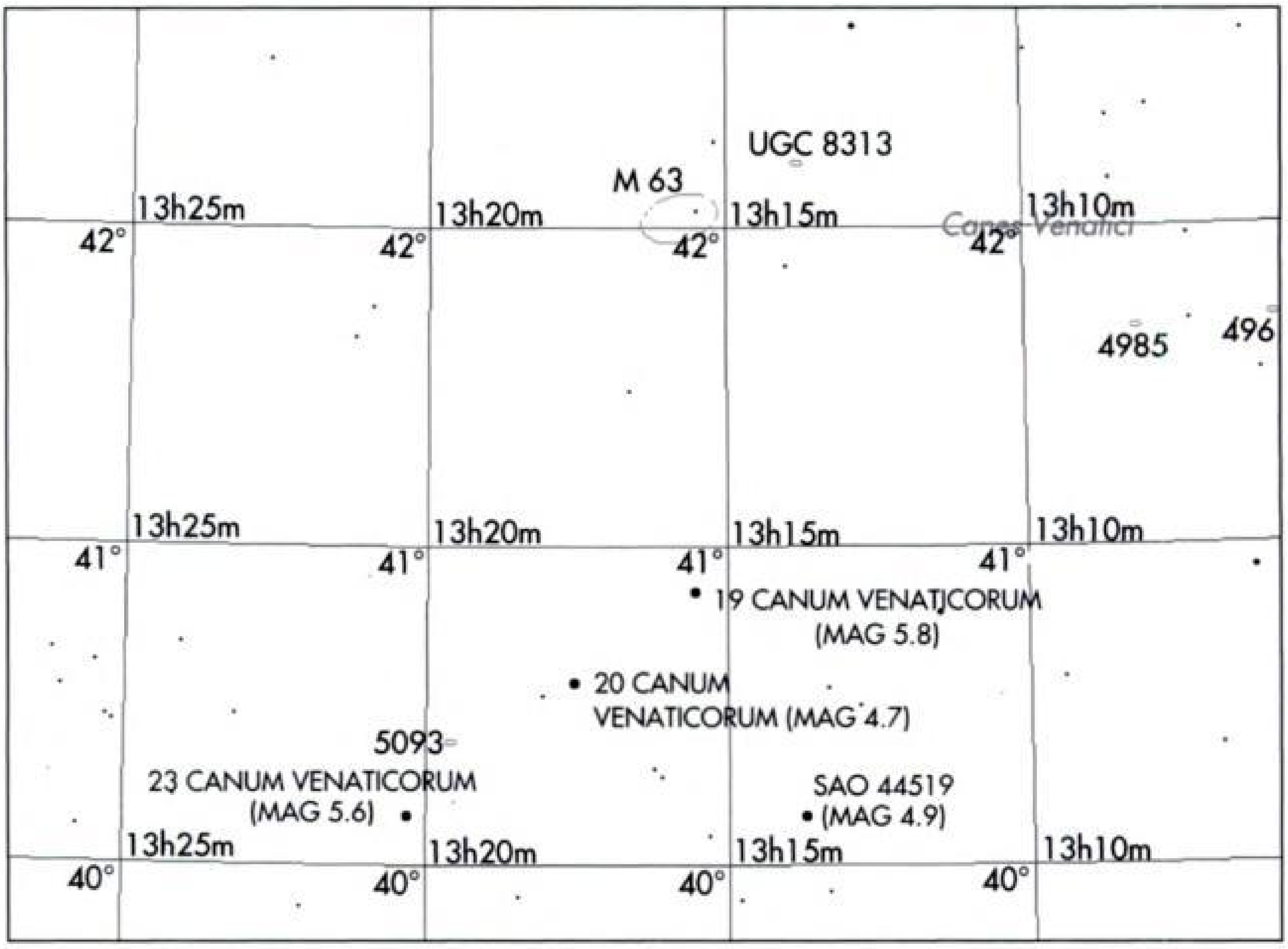


Figure 12.4 Finder chart for M63. Courtesy SkyMap Software

A further 2° east (via 6 Comae Berenices) and then 1° north brings us to **M100*****. This 9th magnitude face-on spiral is between 4′ and 5′ across. It has a strong core and two main spiral arms – look for hints of mottling with all scopes larger than 150 mm. M63, M98 and

Figure 12.5 The spiral galaxy M100 in Coma Berenices. © Jeff MacQuarrie

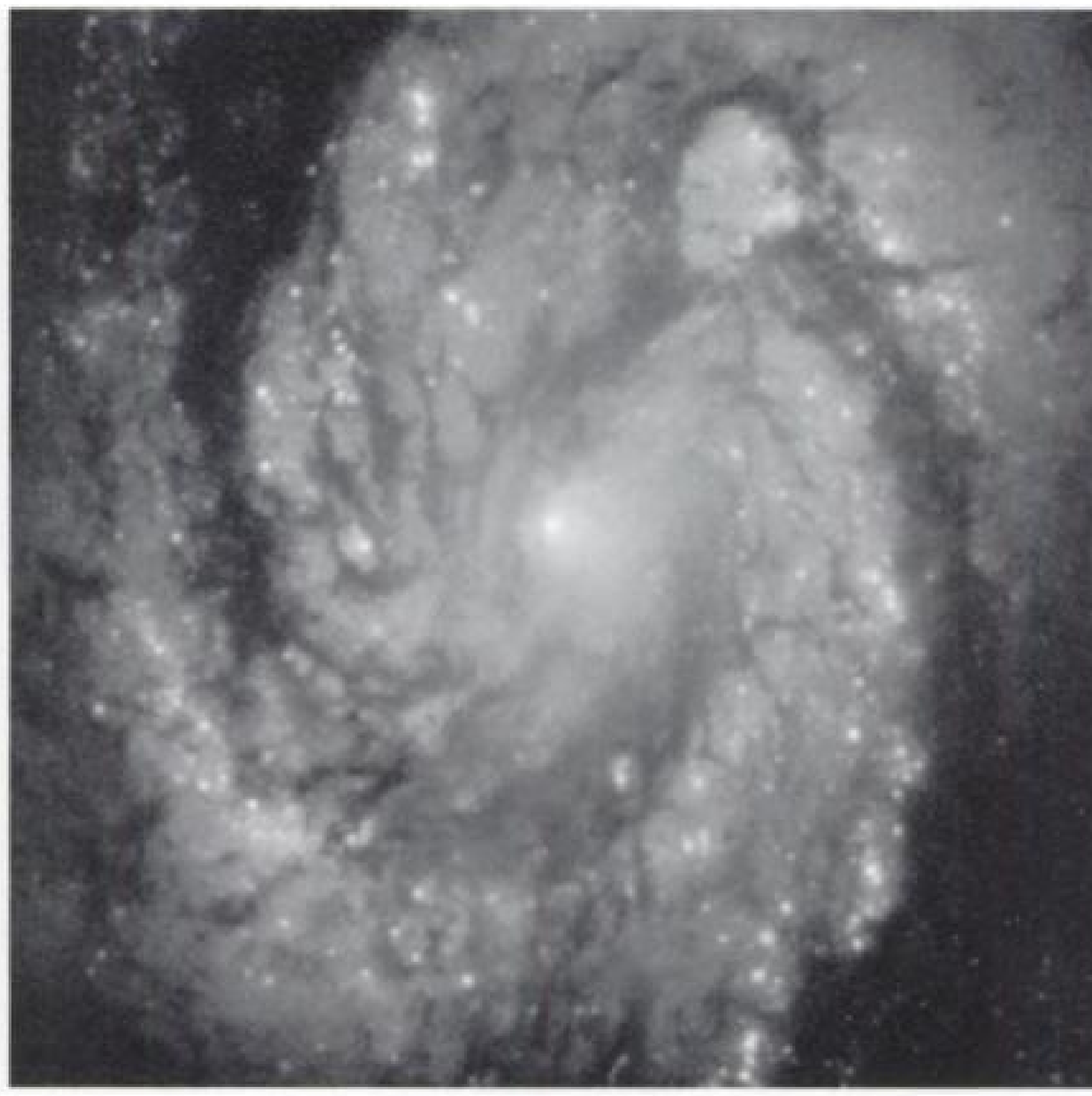


Figure 12.6 Grand-design spiral galaxy M100, from the HST. © STScI/NASA

M100 are all easily located and present little problem for the careful observer.

Right on the eastern edge of Virgo lies the 3rd magnitude star 109 Virginis. A little to the west of this is the 10th magnitude galaxy **NGC5746****. The galaxy's proximity to 109 makes it easy to find – it should be visible in a 150 mm scope. Larger instruments will show evidence of detail and reveal the galaxy's true dimensions of roughly 8′ × 2′. Nearby are the fainter galaxies **NGC5740*** and **NGC5738***, with magnitudes 12 and 14 respectively. The former is quite accessible in medium-sized scopes; the latter may be rather difficult.

Another borderline galaxy is **NGC4438****, which appears on the north Virgo/Coma boundary. It has a close neighbour, **NGC4435****, and the two make a very impressive sight, having similar brightnesses (they are both 10th magnitude) but very different shapes. They provide a fine opportunity for imaging. Not far away is another pairing – **M84**** and **M86****. These are both reasonably large (4′ across) and bright, at 9th magnitude. A low-power eyepiece should show M84, M86, NGC4435, NGC4438, **NGC4402*** and **NGC4388*** all in the same field of view. Both M84 and M86 should be visible in a 100 mm aperture scope, but their location in the heart of the bowl of Virgo, and the lack of nearby bright stars, may make locating them tricky. Imaging will reveal a dark dust lane running through NGC4402.

Figure 12.7 A deep view of M86 in Virgo. © Benoit Schillings

Another target worth mentioning is the highly elongated galaxy **NGC4762****, which lies close to epsilon Virginis. It shines at 10th magnitude and appears visually as a thin splinter of light, about 5′ × 1′ in size. A CCD image or photograph will reveal its true extent of 9′ × 2′. Indeed, the galaxy is a superb object to image, particularly if you can get its close 10th magnitude neighbour galaxy, **NGC4754****, into the same picture. The contrast is quite striking as one is long and thin, while the other is broader and rather more diffuse.

Scorpius

Scorpius is surely one of the most attractive constellations in the sky. Unfortunately, when viewed from some parts of Europe and the USA, its tail doesn't rise above the horizon, so we never get to see the constellation in all its glory.

Indeed for many city dwellers in northern climes just catching a glimpse of Antares between buildings would be considered an achievement. As you might imagine, then, the deep-sky objects in Scorpius are not seen at their best from the northern hemisphere. Nevertheless, **M4*****, a large globular cluster approximately 1° west of Antares, remains an impressive sight. Under perfect skies, or from more southerly latitudes, it is detectable

Figure 12.8 The starfields of Scorpius. Antares centre top. © Nik Szymanek

with the naked eye as a faint fuzzy patch. In small instruments it appears as a largely unresolved globe, 3′ or 4′ across. A scope of aperture 150–200 mm or larger, however, will show the entire 10′-wide cluster, and resolve individual sub-groups of stars within it. Some observers also claim to have seen a "bar" structure passing through the cluster's core.

Not far from M4 is another globular cluster, **M80****. This smaller, 8th magnitude cluster can be swept up using delta Scorpii as the starting point. It appears to have a greater density of stars than M4 and is about half the size. It may take a 150 mm or more to discern the cluster's edges.

For those of you tiring of this month's globular/galaxy bias, have a look at the open clusters **M6***** and **M7*****. They are both naked-eye objects but they hug the horizon from many northern locations, and so are pretty awkward to spot. Those of you that do get to see them will find that they can be partially resolved with a pair of binoculars (they are equivalent to a 5th magnitude star). M7 is the bigger of the two, at almost 1° across, but both are very attractive. They can be captured using an SLR camera with a 200 mm lens, making an excellent picture.

Also Worth a Look

M53* **	Globular cluster, Coma, 7th mag, 1° NE of alpha Comae Berenices.
NGC5053 **	Globular cluster, Coma, 10th mag, loose, close to M53.
NGC5363 **	Galaxy, Virgo, 8th mag star and **NGC5364**** nearby.
NGC5694 **	Globular cluster, Hydra, 10th mag, quite loose, distant.
NGC5248*	Galaxy, Boötes, 10th mag, detailed in CCD.
NGC6144 **	Globular cluster, Scorpius, 9th mag, 3′ across, very near Antares.

Chapter 13

June

18 Hours RA

This Month

This month sees the shortest nights of the year where, from some latitudes, it never strictly gets dark. But there are still treats to be found in Draco, Hercules, Ophiuchus, Serpens Cauda and Sagittarius as they cross the meridian.

At this time of the year an all-nighter is about as easy as it ever gets with, perhaps, only four or five usable hours of near darkness available. So it should be pretty difficult to run out of targets before the horizon starts to brighten again.

June marks the return of shirt-sleeves observing for many of us, but nevertheless the follicularly challenged may want to retain their hats to reduce heat loss.

Compulsory Viewing

Binoculars and smaller telescopes:	M13, NGC6543, M5
Moderate telescopes:	M13, M92, NGC6229
Larger telescopes and CCDs:	NGC6207, Abell2151, IC4617

Globulars, Globulars, Everywhere

When in Hercules, where better to start than **M13***** For many of us M13 is the first globular cluster that we

Figure 13.1 M13 in Hercules. Image autoguided using Starlight STAR software. © Terry Platt

ever observe. It's very easy to find, lying a third of the way from eta to zeta Herculis – two of Hercules' keystone stars. And, with an integrated magnitude of around 5.5, it's visible to the naked eye from dark sites, albeit as a faint fuzzy blob. Viewed through a pair of binoculars, the cluster remains unresolved but is attractively flanked by two 7th magnitude stars, with which it forms a distinctive isosceles triangle. A small scope, such as a 75 mm refractor or 100 mm reflector, should resolve the periphery of this 10′-wide cluster, converting it from a hazy fog to a mass of faint (> 10th magnitude) stars. Larger scopes reveal more of the cluster's 750,000 members. Users of scopes larger than 150 mm aperture may care to look for **NGC6207****, lying around 35′ northeast of M13. In light-polluted skies this inclined barred spiral galaxy is just visible through a 200 mm. Look for an elongated (2′ × 1′) 11th magnitude glow. Visually, the core is not obvious, but with a CCD it becomes readily apparent and clumps can also be seen in the galaxy's arms.

Photographing M13 will take something like a 25-minute exposure on a 200 mm F6 scope when using a 400 ISO film. This makes M13 a good "first globular" to photograph. With more globular clusters nearby there's no shortage of guide stars! The experienced photographer, CCD user, or light bucket owner might like to have a go at identifying the 16th magnitude galaxy **IC4617***, which lies roughly midway between M13 and NGC6207. Detecting its core is possible in good skies, but recording its fainter outlying regions and telling them apart from M13's outliers will be trickier. Look out for a small object only slightly bigger than a star.

Six degrees north of the readily found star 69 Herculis, is the smaller and fainter globular **M92****. With an integrated magnitude slightly below 6, the cluster probably isn't naked-eye visible, although this has been reported by some observers far from urban lighting.

It is certainly not difficult to find with binoculars but does require a slightly larger scope to resolve it into stars and show how much more condensed (8′ wide) it is than its more famous neighbour. The Rev. Webb thought this a fine object. Earl Rosse thought it might have a spiral shape. But then again he seemed to think that of almost everything. Although greatly overlooked – probably because of the spectacular comparisons nearby – this is a cluster not to be missed.

By now your eyes should be reaching some degree of dark adaption so it's worth trying for the globular cluster **NGC6229****, slightly northwest of M92. This cluster is three times further away than M13 and so is quite a challenging target. Indeed, with a diameter of around 1.5′ and its magnitude of nearly 10, it is far beyond the naked eye and all but the very largest binoculars. It might even prove a struggle for those using scopes of less than 100 mm from light-polluted sites. Identification is aided, however, by the proximity of two 6th magnitude stars to the southeast. From the

Figure 13.2 NGC6229 in Hercules. Overshadowed but worthwhile. © Paul Curtis

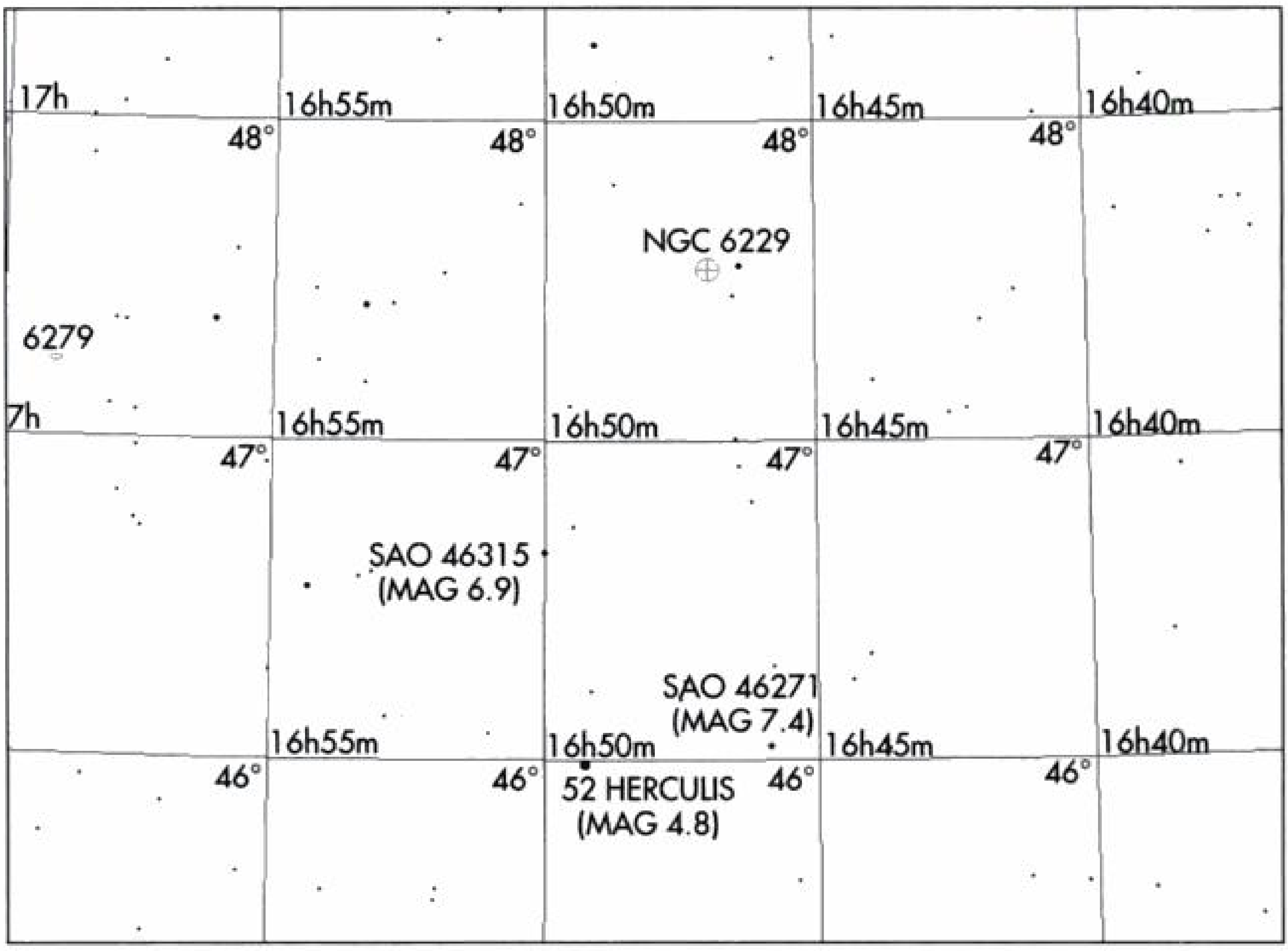


Figure 13.3 Finder chart for NGC6229. Courtesy Sky Map Software

darker skies of Victorian England, the Rev. Webb saw NGC6229 clearly with a 94 mm refractor. However, he was unable to resolve it into its individual stars – a feat which large amateur scopes are now capable of.

Hercules is also home to a number of galaxy clusters identified by George Abell. Several, such as **Abell2147***, **Abell2151*** and **Abell2199***, provide great opportunities for well equipped visual observers and deep imagers alike. The cluster of 15th magnitude (and fainter) galaxies making up Abell2151 is very prominent in June and is easy to find thanks to a 7th magnitude foreground star, SAO101900, nearby. A 300 mm should show up four to five members. Deep imaging of this supercluster is a rewarding challenge, revealing many of its fainter members. Another easily found grouping of galaxies lies about 40′ northwest of M92. The brightest member, **NGC6329***, lies amidst several NGC galaxies in the 13th–15th magnitude range.

Before leaving Hercules, spare a few minutes for a look at the small, blue-tinted planetary nebula **NGC6210*****. With dimensions the order of 30″ × 12″ this compact 9th magnitude nebula has an interesting disk structure that is readily picked up at higher magnifications with a small to medium-sized scope. Use of a nebula filter is recommended. NGC6210 is located roughly one third of the way from 51 Herculis to beta Herculis. CCDers may also want to try for the faint (14th magnitude) glow of **UGC10528***, just over 1° southwest of the nearby 7th magnitude star SAO84572.

Moving away from Hercules for the moment, we can travel south to the globular **M5***** in Serpens, near the constellation's boundary with Virgo. This lies approximately 8° east of 3rd magnitude star 109 Virginis, and 20′ from the double star 5 Serpentis, making it very easy to find. M5 shines at around magnitude 6.5 and is easily picked out with binoculars. The cluster is so impressive that it's a little odd no one noticed it until 1702, when it was discovered by Gottfried Kirch. As with M13, even a modest scope breaks its fuzzy glow up into a mass of 11th–15th magnitude stars. With a diameter of 11′, it appears as one of the brighter globulars and so must be another leading contestant for the "Best Globular Cluster in the Sky" award. Other candidates are M13 – and the splendid Omega Centauri and 47 Tucanae (both well worth a look if you ever get a chance to go south). As ever, though, the winner will be very much a matter of personal taste. It's a shame that we don't get to see these spectacular globulars from the north. Nevertheless, M92, M5 and M13 in a few minutes is a good start.

Figure 13.4 The easy-to-locate M5 globular cluster in Serpens. © Grant Privett

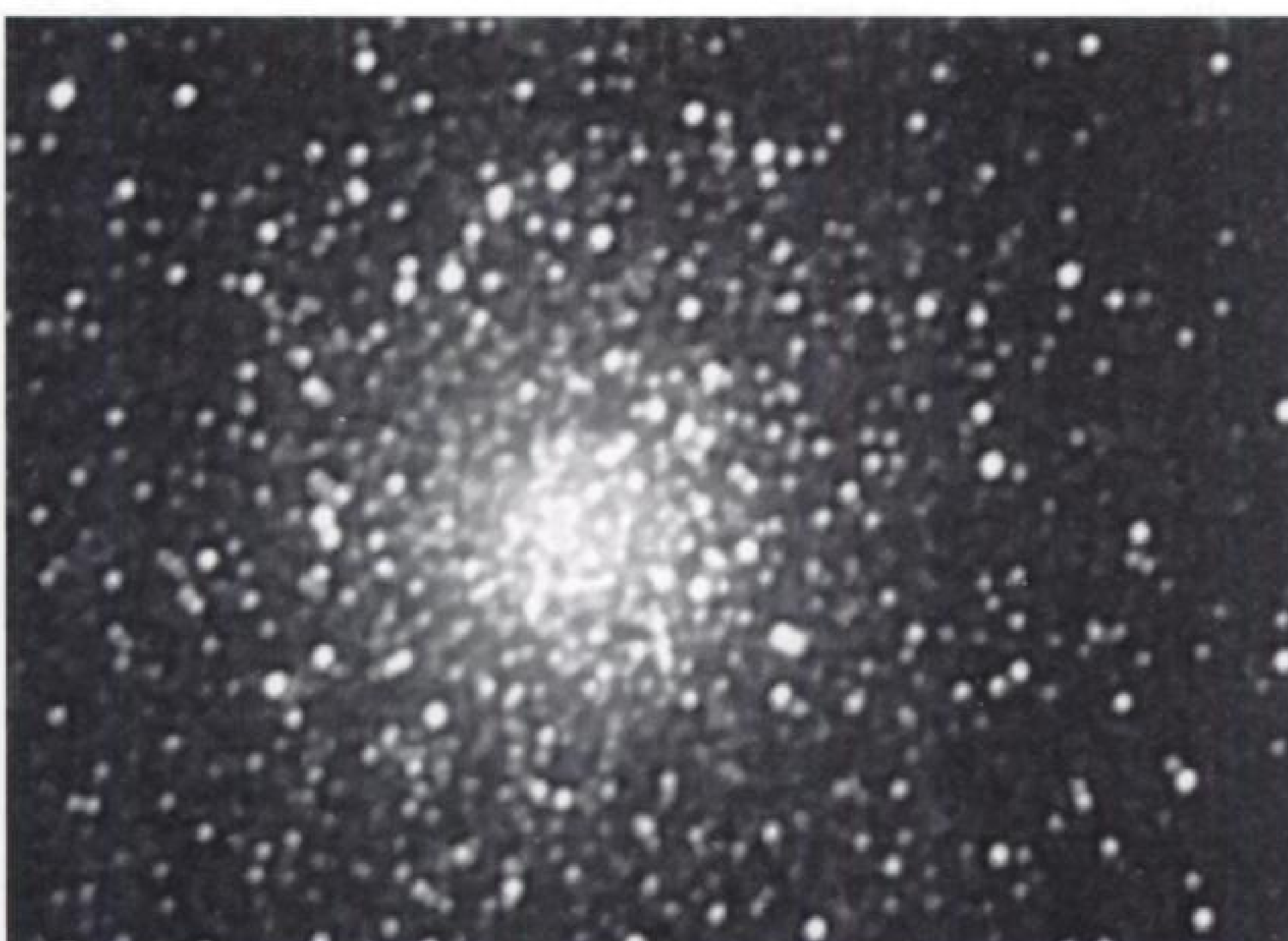


Figure 13.5 Hoag's object: a faint galaxy in Serpens. © Benoit Schillings

Immediately south of M5 is the much fainter and looser globular cluster, **Palomar5***. Despite being 11th magnitude and spanning 7′, its low surface brightness may elude users of medium-sized scopes less than 250 mm in aperture. The 5th magnitude star 4 Serpentis lies about 1° north though, providing a good reference point.

The Dragon

By now you may be feeling like a change from globular clusters, so give the planetary nebula **NGC6543*****, in Draco, a good long look. At 9th magnitude, the Cat's Eye Nebula, as it's sometimes known, is one of the brighter planetaries. It will appear as a 15″ × 20″ oval of light, similar to an out-of-focus star. Users of larger scopes may detect its pale blue colour, and should also be able to pick out its 11th magnitude central star, particularly with higher magnifications. Owners of scopes with 300 mm or more of aperture should try drawing the structure that they see. Sadly, owners of scopes of 75 mm aperture may find this object to be near their limit. CCD users could try to image some of the faint outer areas (4′ from the centre). These are remnants of an older shell of material, which may be seen on

Figure 13.8 Thin, pale and sharp – NGC5907, an edge-on spiral in Draco.
© Grant Privett

smaller scopes and is quite impressive in larger instruments. Also in Draco is the fine edge-on spiral galaxy, **NGC5907****, sometimes known as the Splinter Galaxy, and found southeast of iota Draconis. Some books report this 11th magnitude sliver of light as difficult, or even fail to mention it at all, but it is a simple find with a 200 mm scope, and accessible to a 150 mm. Smaller apertures could have a problem. Visually, the galaxy appears about 1′ wide and between 5′ and 8′ long, depending on the light grasp of your scope. CCDers may find that they need to use a focal reducer to squeeze all of NGC5907 onto their chips. This will be particularly true if using an older camera, such as the ST4, ST5 or the Lynxx, which all have quite small imaging surfaces. The prime object to compare NGC5907 with is **NGC4565*****, in Coma Berenices, which is bigger and broader and has a more obvious core. Both are visible in June, so the comparison can easily be made. One final point – NGC5907 sometimes has the number NGC5906 also assigned to it but this is in error. One well-known computer planetarium program oddly leaves NGC5907 out entirely. See if yours does!

Ophiuchus

This is a nice place to pick up some bright Messier objects and recover from the rigours of squinting at 13th magnitude galaxies in Hercules. In fact, Ophiuchus hosts seven Messier objects. Let's start in the north and proceed toward the horizon. Across the middle of the constellation lie **M14*****, **M10***** and

M12***. These globular clusters are of 7th magnitude, making them all binocular objects and ideal for smaller scopes. M12 and M10 are rather loose affairs, while M14 is a rich cluster. The stars in M14 will require a scope of 200 mm to resolve, while smaller instruments may be able to resolve M10 and M12. Further south are more globulars still – **M107*****, **M19*****, **M9***** and **M62***** – all of which will be visible in small scopes and binoculars if they are not too far south for your observing site. M19 is of particular interest as it is significantly oblate. From far enough south, it may be possible to see that M9 lies at the eastern end of a dark nebula, **B64***, while from northern latitudes seeing this cluster at all is quite an accomplishment.

For those of you demanding something other than globulars (this is after all a good time of year for them), **IC4665***** is a 4th magnitude open cluster of 20 or so stars, that can be found using binoculars to search the sky 1° northeast of beta Ophiuchi. Further east, just on the border with Serpens Cauda, is another bright cluster, **NGC6633*****. It's a naked-eye object with an integrated brightness of around 4th–5th magnitude. Look out for a grouping of more than 25 stars, spread out over a little less than 1° of sky near SAO123516. Continuing on a little further east will bring you to **IC4756**** – another naked-eye cluster. This contains at least 50 stars accessible to a 150 mm scope and extends to more than 1° wide. All three should provide entertainment for binocular users.

Observers with a taste for planetary nebulae might seek the 11th magnitude glow of the Box Nebula, **NGC6309****. A medium to large scope will probably be needed to see this nebula, adjacent to the 7th magnitude star SAO160374. It's not very large, at 10″–20″ across, and seeing its 13th magnitude central star will require a large scope. NGC6309, which can be picked up by sweeping west from nu Serpentis, would probably be better known if it rose higher in the sky and was not located in such a rich field.

Also Worth a Look

M62**	Globular cluster, Ophiuchus, 6th mag, large, non-symmetrical.
M107**	Globular cluster, Ophiuchus, 8th mag.
NGC6058*	Planetary nebula, Hercules, 13th mag, 20″ across.

NGC6181*	Galaxy, Hercules, 12th mag, smallish, near beta Herculis.
NGC6366**	Cluster, Ophiuchus, 9th mag, adjacent to SAO141665.
NGC6369**	Planetary nebula, Ophiuchus, 11th mag.
NGC6445*	Planetary nebula, Sagittarius, 13th mag, small ring.
NGC6572**	Planetary nebula, Ophiuchus, 9th mag, very small, coloured.
NGC6574*	Galaxy, Hercules, 12th mag.
Hoag's Galaxy	Galaxy, Serpens, 15th mag.

about 1.5° east from the 4th magnitude star theta Cygni. A modest scope should show it as a 9th magnitude star, within a disk of light. This is a nebula best observed with a scope of 200 mm or less, as the central star seems to pop in and out of sight as the observer changes from averted to direct viewing. Instruments in the 250–450 mm range will show the 11th magnitude central star too clearly, however, and ruin the effect to some extent. A winner for the small telescope user.

Also in Cygnus is the planetary nebula **NGC7008***. This is much more difficult to spot, boasting a 13th magnitude star and an envelope of gas covering 1.4′ × 1.1′. It appears as a ring with one side noticeably brighter than the other and should be visible in a 150 mm from a good site. As with all planetary nebulae, an O-III filter is worth experimenting with. Look for NGC7008 3° south and 2° east of the 4th magnitude Cepheus star SAO32862. Obviously, this object will be easier for those observing with computer-controlled scopes. But in this area of sky attractive fields abound, so star hopping is far from a chore.

Between gamma and beta Lyrae is the most famous planetary nebula of all, **M57*****, the Ring Nebula. An easily found oval of light, roughly 60″ × 80″ in size and of 9th magnitude, it can be spotted with small scopes or even a good-quality finder. You may find that when

Figure 14.1
NGC7008, a wispy planetary nebula in Cygnus. © Peter Ward

Figure 14.2 The must-see planetary nebula M57 in Lyra. © Maurice Gavin

seen from a light-polluted urban site, the nebula will require a scope of 200 mm or more to reveal structure clearly without the use of filters. There are two stars of about 13th and 15th magnitude within M57. However, the contrast is such that seeing them visually will require at least a 250 mm scope, excellent skies and high magnification to be sure.

Keen photographers and CCD owners might care to try some really deep exposures of this field. With care and practice they show up two interesting features. First, M57 itself has an extremely faint outer shell of gas (see page 1172 of *Burnham's Celestial Handbook*). Hints of the shell's presence can be picked up when taking very long exposures and stacking them. Second, the field contains a 15th magnitude, face-on spiral galaxy, **IC1296**, just 5′ away from M57.

This shows up on exposures greater than a minute or so, and becomes clearer when several such exposures are stacked. IC1296 should be within the range of instruments bigger than 300 mm aperture.

Although a small constellation, Lyra boasts another Messier object – globular cluster **M56****. This 9th magnitude cluster may be found a little over halfway from gamma Lyrae to beta Cygni. High in the sky during July, it's an easy object for almost any instrument, although, at less than 5′ across, it's not an awe-inspiring sight. Lying in a part of the sky so attractive for sweeping, it is well worth the search and provides a good excuse for a

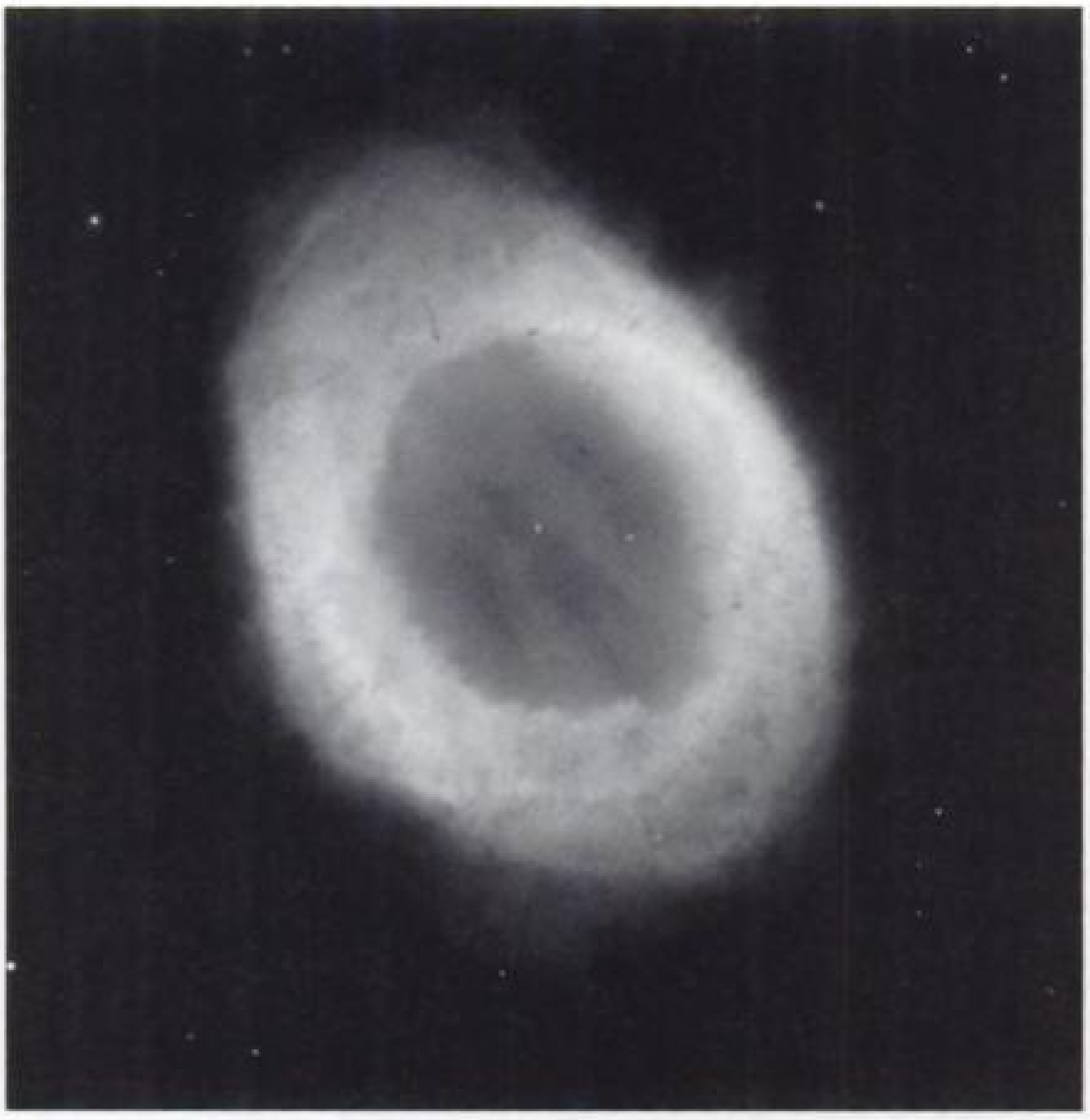


Figure 14.3 The Ring Nebula imaged by the Hubble Space Telescope. © STScI/NASA

Figure 14.4 The underrated globular in Lyra, M56. © Grant Privett

quick look at the beautiful, and nearby, beta Cygni. A 150 mm scope should resolve some of M56's brighter (11th magnitude) stars.

The Dumbbell

Moving still further southeast, you soon arrive at **M27*****, the wonderful Dumbbell planetary nebula in

Figure 14.5 The splendid M27 in Vulpecula. © Ian Inglis

Vulpecula. With dimensions 2′ × 4′, it is much bigger than M57, but its integrated magnitude of 7.6 makes it nonetheless easy to find. In dark skies, it's obvious through 10 × 50 binoculars. The amount of detail that you see will depend very much on aperture and the quality of the sky, but it certainly sent the Rev. Webb off into Latin rhapsodies for half a page at the end of his famous book. Most observers will detect two patches of light next to each other, or a single extended oval. Those with light buckets at their disposal can have some fun, progressively stopping down and seeing how the appearance of the nebula changes with diminishing effective aperture. Again, the field is very attractive and busy, lying in the plane of the Milky Way. How many stars can you count within M27? Answering isn't as easy as it sounds, despite the richness of the field, as the nebulous haze reduces the contrast, making stars rather more difficult to spot. Nevertheless, photographs show many, and a 300 mm will allow the central star to be seen visually.

Given its brightness, M27 is a prime target for astrophotography and CCD imaging. The current generation of fast emulsions should generate good images in only 10 or 15 minutes (even single 20-second exposures are of surprisingly good quality), and CCD owners will find that the exposures needed for three-colour filter imaging with a respectable signal-to-noise ratio are no problem at all. ST6/7/8 and Pictor 416 owners will see the benefit of their large CCD chips, as these will frame the nebula beautifully against a nice star field. M27 is another good opportunity to apply close together – a mere 6′ apart – and so observable in the same field of view. NGC6885 is centred on the yellow star 20 Vulpeculae. The cluster is fairly bright with 30 members of 6th magnitude and fainter, encompassed within 20′. NGC6882 lies to the northwest and boasts no star brighter than 10th magnitude. It's of similar size to NGC6885 and has an integrated magnitude of 8.

Owners of binoculars should turn them on the area surrounding the stars 4, 5 and 7 Vulpeculae. Here, spread out over 2°–3° of sky, is **Brocchi's Cluster*****, otherwise known as the Coathanger Cluster. The reason why will be obvious the moment you see it. It's a lovely collection of a dozen or so bright stars, of surprisingly even brilliance.

A glance at *Norton's Star Atlas* will show you that our movements southeast from Lyra have very nearly followed a straight line. Extending this just a touch further into Delphinus, we come to another planetary, the so-called Blue Flash Nebula, **NGC6905****.

At 12th magnitude and spanning 40″ × 30″, it may prove a challenge to those using smaller scopes, although its oval shape should still be apparent. The nebula's 14th magnitude central star may evade users of even moderate scopes, as will its internal structure which will also require very good viewing conditions. Another challenging object in Delphinus is the remote

Figure 14.8 Drawing of Brocchi's Cluster, a stellar coathanger in Vulpecula, seen with 10 × 50 bins. © Grant Privett

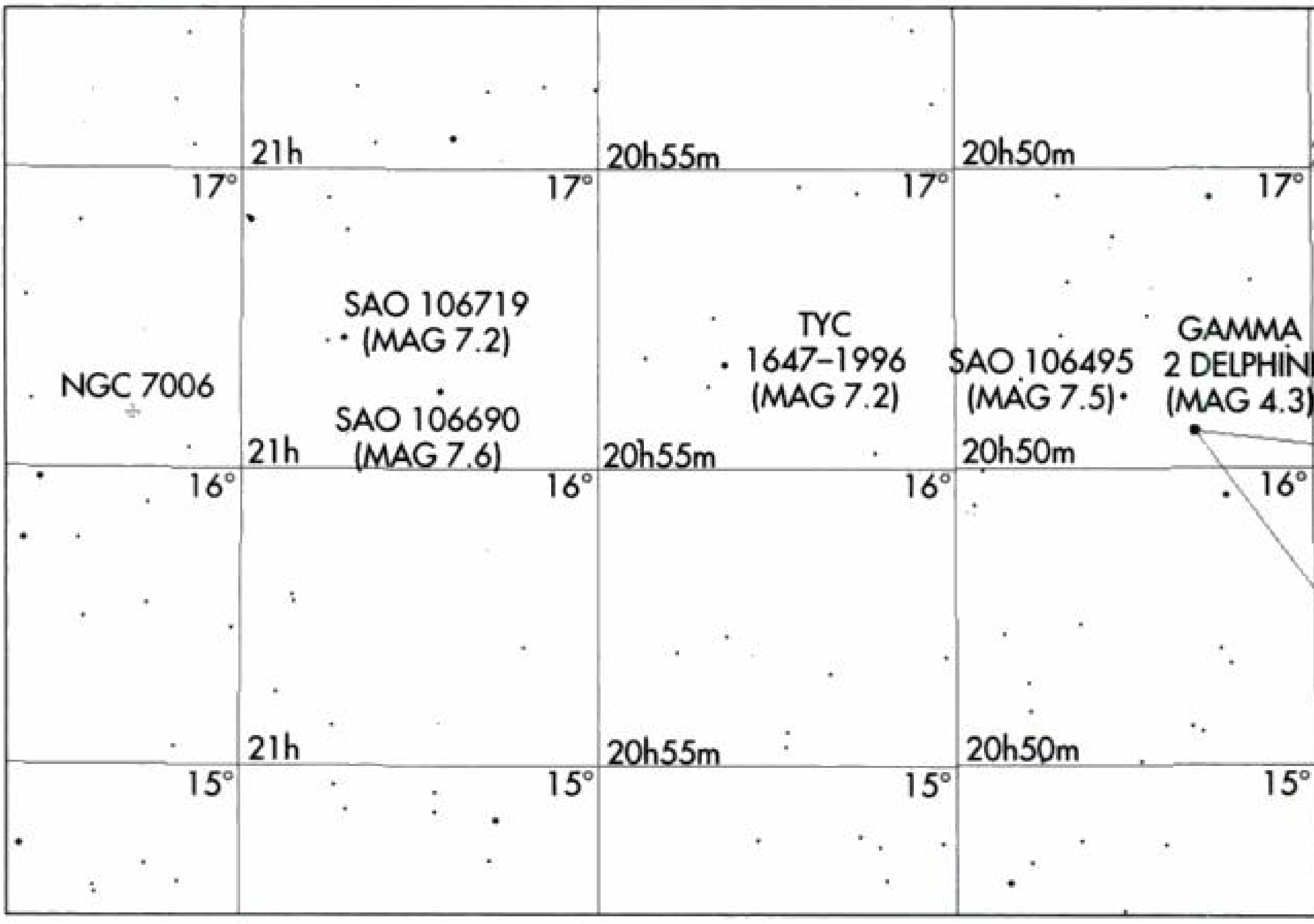


Figure 14.9 Finder chart for NGC7006. Courtesy SkyMap Software

globular cluster **NGC7006****. This looks like an 11th magnitude fuzzy ball, about 1.5′ across and lying a few degrees east of gamma Delphini, which makes it easy to sweep up. Shining feebly at 16th magnitude, the individual members of this far-flung galactic outpost are visually beyond all but the biggest scopes. But a 30-second CCD shot captures them easily. A rather easier globular cluster in Delphinus is **NGC6934****. At 8th magnitude this will be just detectable in a pair of 10 × 50 binoculars. Small telescopes will show a 10th magnitude star lying close by this 2′-wide cluster. Resolution will require a high power on a scope of 250 mm or so.

A Wonderful Sight

Abandoning our line across the sky, we move further south into the tiny constellation of Scutum. This is home to two open clusters from the Messier catalogue: **M11*****, the well-known 6th magnitude Wild Duck Cluster, and the rather less celebrated 9th magnitude **M26****. It's interesting to move quickly between the two and contrast the 300+ stars spread over 12′ in M11, and the 25 or so stars in the smaller M26. Both objects are attractive and quite compact. The inexperienced

Figure 14.10 The Lagoon nebula, M8, in Sagittarius, near M20. Good for astrophotographers. © Nik Szymanek

observer could certainly be excused for, at first glance, mistaking M11 for a globular. Through smaller scopes, many of the fainter stars in M11 remain unresolved, giving the impression of a slightly dewed eyepiece. M11 should be visible through binoculars.

Still further south, we are looking towards the centre of the Milky Way, where there are several objects that can be picked up in binoculars or even by the naked eye. **M8****, the Lagoon Nebula, forms an extended glow around the star 9 Sagittarii, and also encompasses the 7th magnitude open cluster **NGC6530****. Given its low altitude from some locales and its gaseous nature, M8 is an ideal object on which to use your nebula filters. The difference these make can be spectacular, showing the nebula extending more than 30′, with a dark rift running across it. As a cluster with nebulosity, M8 is a truly beautiful sight in almost any instrument, but is probably most attractive in a scope larger than 200 mm. It's a good target for photographers, although quite a challenge for those observers keen on drawing.

As mentioned earlier, this is a good month for nebulae. Another fine planetary is **NGC6781**** in Aquila. At 11th to 12th magnitude, you might expect this to be a tough target for even a moderate scope, but in fact it's fairly easy with a 200 mm, and under good conditions can be found by diligent use of a 150 mm. To locate it star hop from the nearby 22 Aquilae.

laboured to find the modest NGC6664 or NGC6704, return to M11 for a real shock and see the 300 stars that give it an integrated magnitude of 6. The Rev. Webb described it as "noble", but he did neglect to mention what a pig its fan shape is to draw.

Teapot Time

At a declination of -24° is **M22*****, a splendid 6th magnitude globular cluster, spreading across more than 13′ of sky, and lying a couple of degrees northeast of lambda Sagittarii (the apex of the teapot lid). Its brighter stars, at around 11th magnitude, should be easily resolved, allowing users of larger scopes to discern hundreds of stars within its bounds - well worth the effort of finding it. It's considered by some to be one of the all-time best globular clusters. See what you make of it.

It's almost as easy to catch a nebula or cluster in Sagittarius as it was to find a galaxy in Virgo. For example, starting with the star mu Sagittarii, drift a little over 1° north and east about 1°, via the 5th magnitude star 15 Sagittarii, and you'll come to a field containing nebula **NGC6590***, the poor 11th magnitude cluster/asterism **NGC6595*** and the nebulosity **IC1284***, centred on the 7th magnitude star SAO161273. But these aren't the targets that we are seeking. Sweeping on 3° east leads to **M25*****. Or, sweeping 5° west takes you to **M23*****. Sweeping 1° north, on the other hand,

Figure 14.12 M22: A grand globular cluster in Sagittarius. © Mike Fleenor

brings you to **M24****. M23 is an 8th magnitude cluster. Its brightest member is 10th magnitude, with 100 other stars strewn over roughly 40′. The rich background sky may make M23 less obvious than might be expected. However, the dark nebula **Barnard84*** to the north makes things more interesting. M24 is less impressive, being just **NGC6603***** superimposed against a strong clumping of naked-eye Milky Way stars. The clump is quite large (over 1° across), while NGC6603 itself is compact but sadly not that bright – its brightest members being 11th and 12th magnitude. M25 is a cluster nearly 25′ across, and including 7th magnitude SAO161571. M23, M24 and M25 are all worth a visit.

Having located M24, why not take a little excursion 4.5° north to **M16*****, the Eagle Nebula. This is an attractive 6th magnitude cluster of 80 or so stars, embedded in a nebula that should be apparent to observers using instruments of 100 mm or greater. With larger instruments the nebula can be seen to contain mottling. Very large (450 mm +) instruments may show two of the three pillars that are so prominent in the beautiful Hubble Space Telescope image which made M16 so well known to the public. Something to look for on a night when the air is clean and transparent. A UHC filter will help with the pillars themselves.

Sagittarius is best known for its nebulae and open clusters. But it also has some nice globulars, such as **M54**** and **M55*****. M54 is easily found 1.75° southwest of zeta Sagittarii. Although its brightest stars are 13th magnitude, it shines as an 8th magnitude ball,

Figure 14.13 The Pillars of Life, in M16, amidst a scattered cluster in Serpens. © Mike Fleenor

Figure 14.15 The trifurcated Trifid Nebula, M20, in Sagittarius. © Neil McMickle

as pale hazy patches, and even some structure in the hands of a careful observer. M20 is the larger of the two, with a diameter of nearly 20′, and displays three radial dark lanes when observed with a scope larger than 150 mm. The contrast drops slightly through scopes in excess of 300 mm, because the field of view shrinks. This makes it easier to spot the stars embedded within the nebula; there's a bright double star at its heart. Filters have an interesting effect on M20, improving the visibility of its emitting regions over

Figure 14.16 M17, a swan-shaped nebula around a Sagittarius cluster. © Nik Szymanek

Figure 14.17 NGC6894, a perfect-ring-structure planetary in Cygnus. © Nick Hewitt

those that are simply reflecting light from stars. It's a great shame that this nebula never rises high in the sky for many of us. M17 is also a star cluster with associated nebulosity, but this time the cluster is less obvious, and the main feature is a single bar of light with an upraised end, resembling a tick mark. Imaging reveals a wealth of detail, as will a decent nebula filter, but a medium-sized scope may be needed to see much visually.

Also Worth a Look

NGC6638**	Globular cluster, Sagittarius, 9th mag, near lambda Sagittarii.
NGC6712**	Globular cluster, Scutum, 8th mag, IC1295 close by, east of M26.
NGC6802**	Cluster, Vulpecula, 9th mag, small, near Coathanger Cluster.
NGC6818**	Planetary nebula, Sagittarius, 10th mag, well defined, 1° N of NGC6822.
NGC6819***	Cluster, Cygnus, 7th mag, visible in binoculars.
NGC6842**	Planetary nebula, Vulpecula, 13th mag, some structure visible in images.
NGC6894**	Planetary nebula, Cygnus, 12th mag, ring-like, pretty.

Chapter 15
August
22 Hours RA

This Month

Although the evenings are now starting to draw in noticeably, there may still be some summer haze in the air which may diminish the sky's transparency. However, there are still many deep-sky attractions to be found in Cepheus, Cygnus, Delphinus, Pegasus, Aquarius and Capricornus.

Late-night revellers of an astronomical persuasion will be pleased to see the Pleiades, Taurus and Auriga putting in a show. Those who have to observe rather earlier in the night instead have an opportunity to say farewell to Scorpius and reaquaint themselves with the globular clusters of Hercules.

Compulsory Viewing

Binoculars and smaller telescopes:	M39, NGC7000, M15
Moderate telescopes:	NGC7023, NGC6939, NGC7009
Larger telescopes and CCDs:	NGC188, NGC6946

Ancient Stars

A good place to start the night's fun is Cepheus. Those of you with computer-controlled scopes might like to use delta Cephei as a reference point and to set the

Figure 15.2 The graceful curves of NGC6946 in Cygnus. © Grant Privett

ficulty is ensuring that the overexposed SAO star does not ruin the shot.

Still further south and west lies the spiral galaxy **NGC6946**** and the open cluster **NGC6939****. This line-of-sight pairing is found near eta and theta Cephei, on the border with Cygnus. It provides a great opportunity to observe both types of object in the same low-power field, and is a perfect target for the ambitious astrophotographer. Due to its fairly low surface brightness (it's virtually face-on and 8′ across) and its magnitude of 11, NGC6946 may prove a bit elusive, especially in urban skies. But there is a parallelogram of stars about a quarter of a degree to the west, which may aid identification.

If imaging NGC6946 with a CCD, be sure to collect light for at least 35 minutes. The galaxy is beautiful and well worth the effort. NGC6939, on the other hand, is a rich cluster of integrated magnitude 9, consisting of more than 100 stars of 12th magnitude and fainter, scattered over 8′ of sky. Photographs suggest that some of its brighter stars appear to form a straight line along one edge of the cluster. Detecting the cluster should be simple, but observing this chance alignment may require just the right combination of aperture and magnification.

A worthwhile binocular object in the region is **M39****, a 5th magnitude scattering of 30 stars, sprawling across more than 30′ of sky. It is easily found, by offsetting 2.5° southwest from pi2 Cygni, but its loose nature requires a low magnification coupled with a wide field. For this reason it's probably best seen with a 100 mm reflector, a 75 mm refractor, or good binoculars. If you're confined to an instrument with a very small field of view, this probably isn't the object for you. In binoculars, however, the cluster is well resolved. It's fun to draw it and compare your sketches with photographs, although steady hands will be required.

Equuleus – A Waste of Space?

A first inspection of *Norton's* or *Atlas Coeli* might suggest that Equuleus, the second smallest constellation, is a bit of a dead loss for deep-sky observers. This is broadly true, but there are a few faint targets that you might like to try for. For instance, there is a small cluster of galaxies about 45′ south and 1′ to the west of alpha Equuleus. It is, however, 15th magnitude and quite unimpressive. Slightly better are two galaxies to the west of alpha Equulei. They are described by the GrayStel software as **IC1360/1***, 15th magnitude galaxies about 2′ across. Finally, there is **NGC7040***, a 14th magnitude 2′ × 1′ galaxy within the Equuleus asterism. NGC7040 should prove no serious problem for CCD imaging, but will probably be tough photographically, and possibly beyond the majority of visual observers. None of the objects mentioned above are worth staying up really late for, but it might be fun to image one just for the novelty value!

To be honest, at first glance Lacerta doesn't seem hugely exciting either. But it does have **NGC7243****, a 6th magnitude clumping of 40 stars, **NGC7209****, a 9th magnitude conglomeration of a few dozen 9th–12th magnitude stars, and **NGC7245***, a compact 10th magnitude open cluster about 6′ across. Of these, NGC7243 with its bright stars strewn over 20′ is probably the most immediately interesting, though the other two are well worth a look, especially the compact NGC7245. The fields of both alpha and beta Lacertae are also attractive, so they will repay the trivial effort of searching them out. Just across the border with Cygnus is **IC5146*** – the Cocoon Nebula. This lies about 2.5° southeast of the star pi2 Cygni. It is roughly 10′ across and contains a sparse cluster that includes two 9th magnitude members. It should generate some attractive photographs, particularly if the nearby dark nebula **B168*** can also be captured. A 100 mm scope will pick out the brightest cluster members, although a 150–200 mm may be required to detect the nebula. Owners of larger scopes observing from dark sites can

Figure 15.3 A cluster and nebulosity. The Cocoon Nebula in Cygnus. © Ian Inglis

have fun seeing how far they can trace B168. Using a light-pollution or possibly a hydrogen-beta filter will prove useful visually when looking at IC5146, but a deep-red filter may prove just as useful (and rather cheaper) photographically.

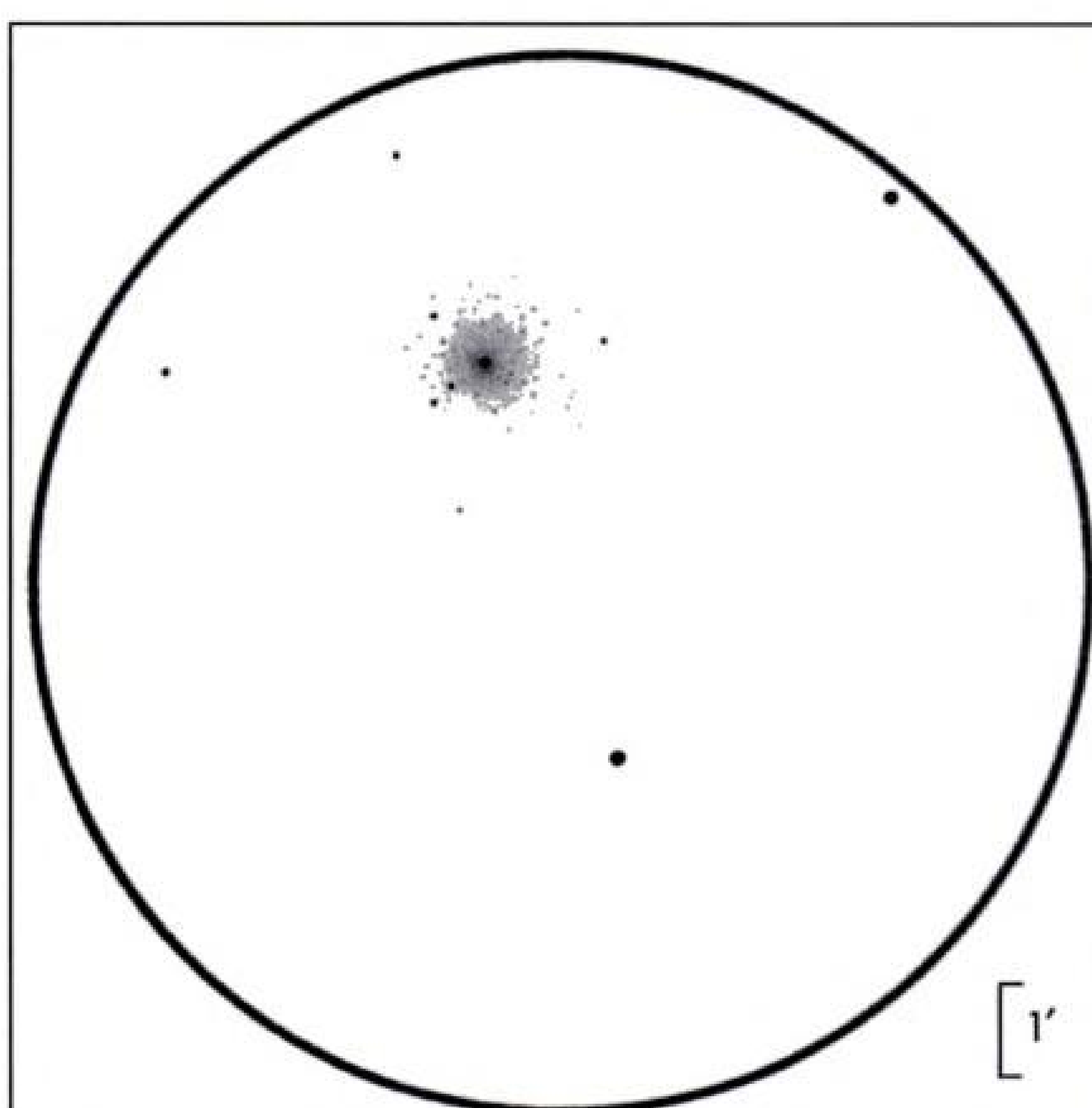


Figure 15.4 The often overlooked M15 in Pegasus. © Lee Macdonald

Figure 15.6 A mosaic of the intricate Veil Nebula in Cygnus. © Gordon Rogers

the 8th magnitude star SAO88869, and stands out well from the rich area of sky that it occupies. This cluster should be detectable in binoculars, not quite resolved in a 60 mm scope but crisply resolved in a 150 mm. A scope of 300 mm aperture will show more than 100 stars.

If you are in the mood for further nebulae, those of you with scopes larger than 200 mm might like to try

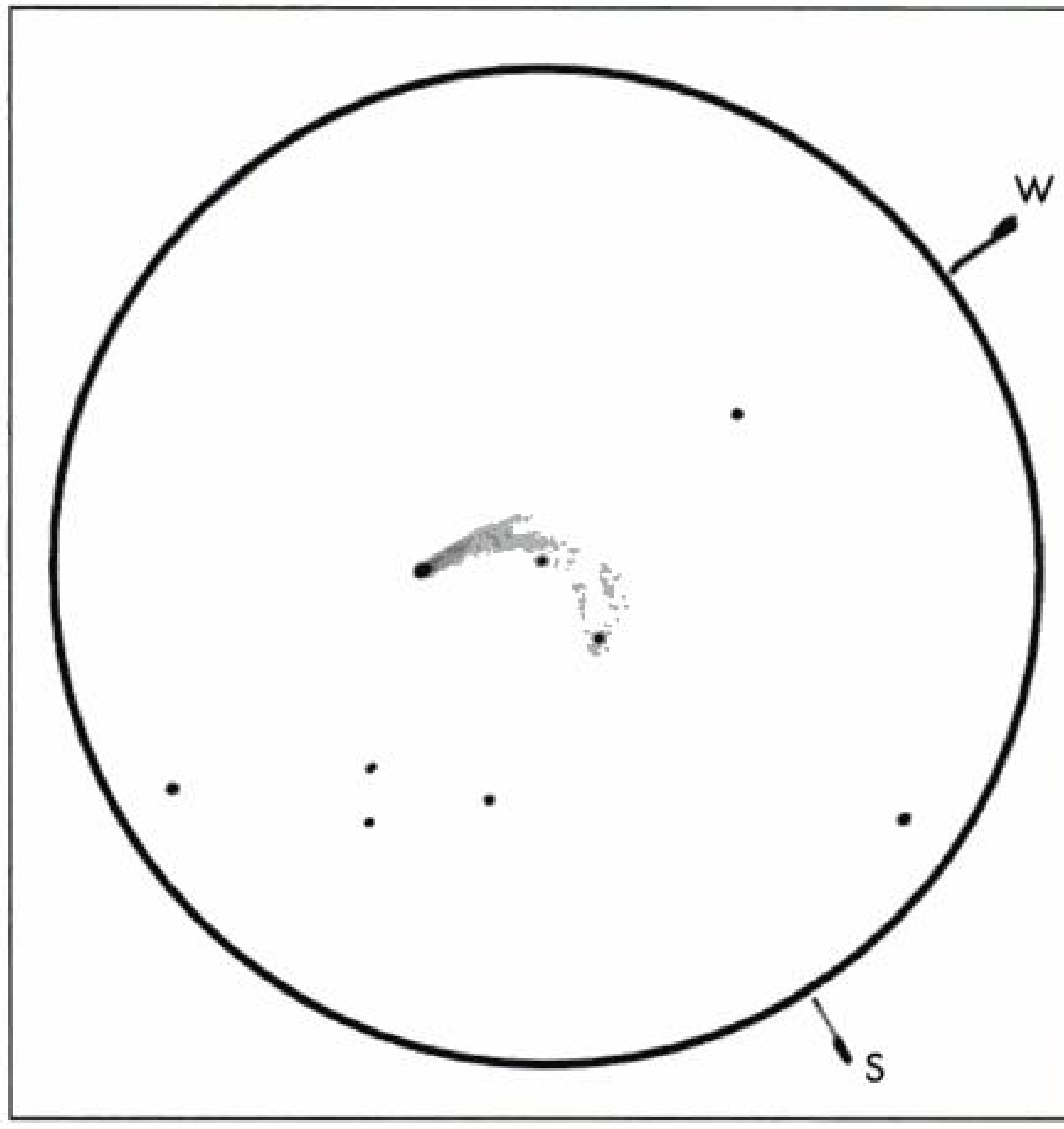


Figure 15.7 A drawing of the Crescent Nebula in Cygnus.
Tel: 14″ fs.
Eyepiece: 18 mm.
Mag: × 100.
Seeing: III.
Filter: UHC.
Field: 30′.
© Stewart Moore

for the Crescent Nebula, **NGC6888****, which lies close to 7th magnitude SAO69592 and nearly 3° southwest of gamma Cygni. With care you may be able to see that the nebula appears visually as two unequal parts, lying close to a triangle of stars. Although too big for many CCDs, it makes an interesting photographic target. Some believe it is one of the objects that benefit from being observed through a hydrogen-beta filter while others prefer an O-III filter. Try whatever you have to hand.

Capricorn

Capricornus is not noted for its plethora of deep-sky objects, but it does nevertheless contain the 12th magnitude galaxy **NGC6907*** and several other faint galaxies, including **NGC6903*** (look 2° east and a little south of sigma Capricorni). Visually, expect faint ovals of light, approximately 1′–2′ across. CCD shots or photography may show more. NGC6907 is located in quite a sparse part of the sky, so while not very faint, an arduous star-hopping exercise over 6° may be required to reach it.

Not very far from M15 is the globular cluster **M2*****. Lying a little over 4° north of beta Aquarii, this 7th

Figure 15.8
The region around gamma Cygni: astrophotographer heaven. © Brad Wallis+Robert Provin

Figure 15.9
Galaxy grouping Hickson93 seen through a 300 mm scope. © Laurence Hall

NGC7331**. Shining at 10th magnitude, it is reasonably easy to find by star hopping the short distance from eta Pegasi, or offsetting a little over 2° from 38 Pegasi. From good sites it should be within the range of a 150 mm reflector. Bigger scopes will find it a very attractive target, appearing like a smaller (10′ × 2′) version of M31. Also like M31, NGC7331 has some satellite galaxies – **NGC7335*/NGC7336*/NGC7340*/NGC7337*** – 3′ or 4′ to its east. At 14th magnitude these will probably be quite tough targets for visual observers using scopes in the sub-300 mm range. CCDers will have no trouble imaging its prominent off-centre dust lane, or the sweep of the associated spiral arm. Photography will also produce nice results if the exposure is long – with a medium-sized scope, three stacked 30-minute exposures on hypered 400 ISO film should do it.

About 25′ to the southwest of NGC7331 is a compact group of more distant galaxies, the famous Stephan's Quintet. This is a conglomeration of apparently interacting spiral and elliptical galaxies, the brightest of which is **NGC7320****, at 12th magnitude, and the faintest the 15th magnitude **NGC7317***. The other members are: **NGC7319***, **NGC7318A/B*** and **NGC7317***. The nearby **NGC7320C*** is probably not an outlying member of the group. Twenty five years ago, Stephan's Quintet was a Holy Grail for the serious observer. If you had managed to see it, or better still, photograph it (CCDs were still the stuff of wild fantasies at that time), then you had arrived. Even today it can be a tough challenge to see all five galaxies visually, as they are over 320 million light years removed from us – apart from NGC7320, which is rather closer. But the advent of big Dobsonians has put countless fainter objects within range of the humble amateur observer, and the CCD means that anything down to 20th magnitude (about the limit of the UK Schmidt survey plates) is fair game. None of the galaxies in the Quintet are very big, the largest appearing roughly 1′ across. Both NGC7317 and NGC7319 are quite faint and will probably take patience, a good night and a 200 mm scope to discern.

South of NGC7331, but remaining in Pegasus, is **NGC7332****. This 11th magnitude galaxy appears as an elongated blob, 2′ × 1′ across. Users of 150 mm scopes will probably find this galaxy quite a test, although its bright core should be discernible using averted vision. Fourth magnitude lambda Pegasi can be used as a crude starting point for a sweep westward to find this object.

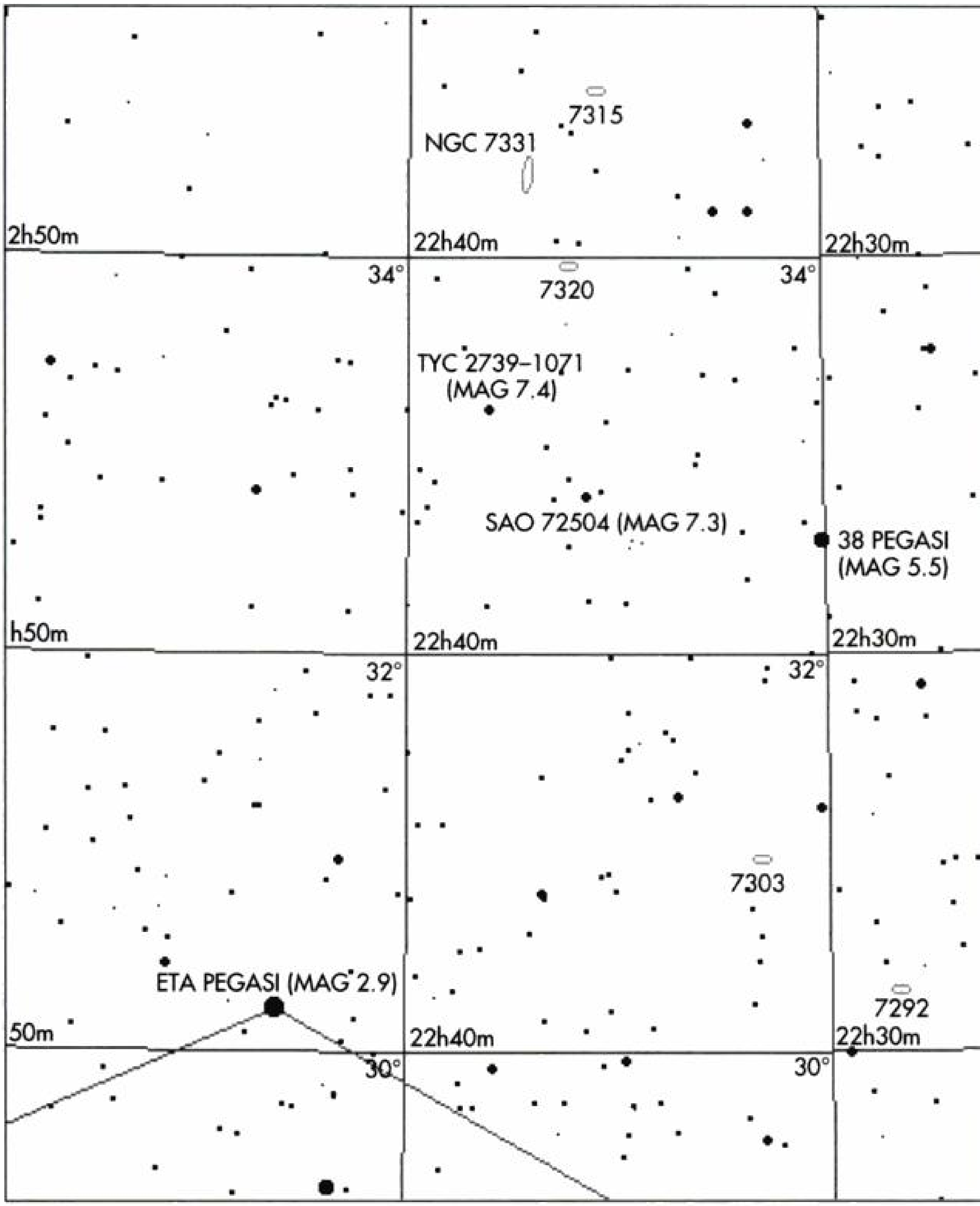


Figure 16.1 Finder chart for NGC7331. Courtesy SkyMap Software

In the southern reaches of Pegasus many galaxies can be found – either by themselves or in small clumps, such as the one slightly northwest of alpha Pegasi. An impressive 11th magnitude galaxy, **NGC7479****, can be found roughly 3° due south of alpha Pegasi. It's a classic s-shaped barred spiral with loose arms. It images well, but is a bit faint for small instruments. The southern arm should be the easiest to pick out on a good night and should be within reach of a 300 mm. Smaller scopes will be able to pick out the nucleus and possibly the central bar.

Figure 16.3 The distinctive Blue Snowball, NGC7662. © Grant Privett

– as reference points. Then bring the planetary's disk into view by stepping up the magnification. Not much will be needed. Many people report this nebula as appearing faintly blue or greenish. See what you think. Also look out for the odd seagull-like shape, visible within the ring on some images. NGC7662 is within the range of a 75 mm refractor, and so is an interesting object for any observer. A larger scope, bigger than 150 mm, can detect structure visually, however a 200 mm or 300 mm with high magnification is needed to resolve these details with any clarity. There is plenty of structure to see – so much that the nebula's central star blurs into it. NGC7662 is a nice bright alternative to the low-surface-brightness galaxies visited earlier.

Cepheus

Cepheus contains a number of modest open clusters. One prominent example is **NGC7235****, a 7th magnitude clustering of some 20 or so stars, packed within a 5′ radius. Its appearance is unlikely to get it into any coffee-table books but, lying a little northwest of the 4th magnitude epsilon Cephei and close to a 9th magnitude star, it will be easily spotted with a 150 mm or better. Easy location is always a virtue when your eyes are still dark adapting or when you are observing from less-than-ideal sites.

Astrophotographers with good dark skies might want to slap a deep-red filter on a mounted camera, equipped with a 135 mm lens, and point it at the region of sky 5° west of the triangle formed by delta, epsilon and zeta Cephei. There, centred on a 6th magnitude star, is the large emission nebula **IC1396***. It's a sprawling 2.5° loose cluster embedded in a cloud of hydrogen gas, containing some splendid fine detail amidst the rich star fields of this part of the sky. The deep-red filter should suppress the skyglow and emphasise emission from the hydrogen. Photographically, a 400 ISO film combined with a 20-minute exposure should do the trick. If you succeed, try a similar tack with **IC1805*** and **IC1848***, both not far from the nearby Double Cluster in Perseus.

A final point of interest in Cepheus is the bright planetary nebula **NGC40****. It measures roughly 40″ × 20″ and is readily picked out, even using low powers. The central star is of 12th magnitude and will be visible in a 200 mm if a high power is used. Large scopes will reveal structure in the nebula, but a 200 mm should be enough to provide the first hints. To improve your view of NGC40, try any nebula filter that you have available - you can sometimes be surprised by what works best. Some observers advise against using O-III filters on this planetary. CCDers may seek out the nebula's faint outer ring of gas. Gamma Cephei is a good place to begin the star hop to NGC40.

Figure 16.5 The bright planetary NGC40 in Cepheus. © Nick Hewitt

Another Change of Scenery

Moving a little southwest into Cassiopeia we find **M52*****, an impressive 7th magnitude open cluster, 13′ across. In smaller apertures its 150+ members (8th magnitude and fainter) make it look like a pale patch of mist with a sprinkling of stars strewn across it. It's an attractive open cluster and not difficult to find – just move 1° south from the star 4 Cassiopeiae. It should be accessible to binocular users. Not to be mistaken for a globular.

Not far from M52 is the well known and much imaged Bubble Nebula, **NGC7635***. In pictures this is a beautiful ring of gas, roughly 3′ across. Visually it is rather dimmer and will be difficult to spot in polluted skies with anything less than a 400 mm; 300 mm if the sky is very dark. Happily, due to the proximity of the nearby 7th magnitude star SAO20562, locating the correct field, 1° southwest of M52, should be a simple matter. Take care to ensure that you are very well dark adapted before attempting to find this wisp of light, which is just 1′ across visually. In long-exposure images, faint tendrils of nebula spread out far beyond its famous ring structure. The fainter parts of the ring are probably beyond most visual observers. But those of you using film or large format CCDs can have lots of fun picking out these tendrils. It's a nice test of your image-processing technique. Get it wrong and the nebula will quickly vanish into the background.

Before moving away from NGC7635, spare a moment to have a look at the small open cluster **NGC7510****. In good conditions it's a very nice find. Most of the stars lie in a bunch between two fairly bright members, giving the entirely false impression of nebulosity. The integrated magnitude is 9 and the diameter roughly 5′.

Rather easier to find in Cassiopeia is the 10th magnitude cluster **NGC559****. This is a cluster of stars, all fainter than 11th magnitude and spread out over 3′ × 5′. It can be seen with small scopes under reasonable conditions as an unresolved glow. Further west in Cassiopeia but remaining within the confines of the W shape is **NGC129****. This quietly attractive 6th magnitude cluster of 30 or so stars can be picked out in good binoculars. Through medium-sized scopes it is a pleasing sight. Moving west yet again to a point almost 1.5° east of beta Cassiopeiae brings us to the 4′ × 2′, 11th

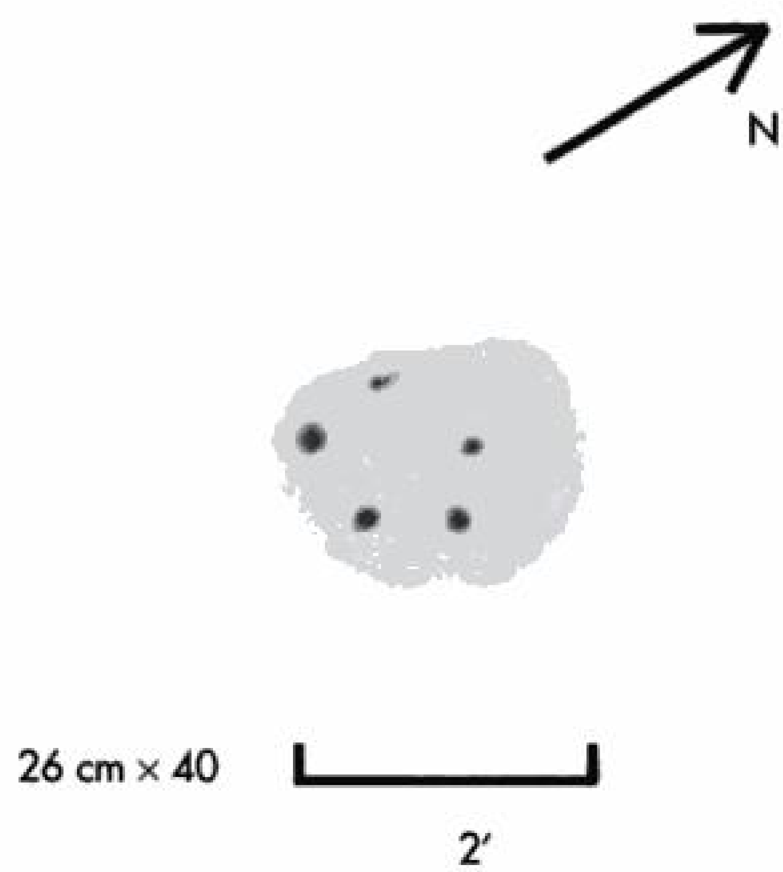


Figure 16.7 Cluster NGC7128 as seen in a 260 mm scope. © Guy Hurst

Also Worth a Look

NGC55* **	Fine detailed galaxy, Sculptor, 8th mag, very low (dec. –39°).
NGC253***	Fine galaxy, Sculptor, 8th magnitude, rather low (dec. –25°).
NGC7139*	Planetary nebula, Cepheus, not far from NGC7160.
NGC7128**	Open cluster, Cepheus, 9th mag, 30 stars.
NGC7339*	Galaxy, Pegasus, 13th mag, near NGC7332.
BL Lac**	The original BL Lac object, Lacerta, 12th–15th mag.
IC289*	Planetary nebula, 12th mag, in Camelopardalis, very difficult.

Figure 17.1 M31 with neighbouring galaxies M32 and M110. © Brad Wallis+Robert Provin

for your eyes to adjust to their full sensitivity, or while the sky is still darkening. When its satellite galaxy **M110**** becomes visible in a 60 mm scope you know that you can move on to fainter targets. Happily, M31 itself is very easy to locate and always impressive. To find it, sweep a little west of nu Andromedae and look for an elongated hazy patch. On a reasonably clear night it will be easily visible to the naked eye and prominent in any finderscope. Low-power binoculars will give a hint of its full extent, with Schmidt plates and good-quality amateur photographs registering its inclined spiral structure covering 3°–4° of sky.

Observers using scopes with an aperture greater than 150 mm should be able to detect the small bright nucleus of M31, but a 250 mm may be required to show evidence of the dust lanes within the spiral arms. The dust lanes are of fairly low contrast and can't be seen easily from urban sites. The better equipped observer will be able to see **NGC206***, a clustering of stars and nebulosity in the southwest quadrant of the galaxy. Others include **NGC203*** and **NGC202*** which are both visible using a 250 mm scope – even from the UK. Users of bigger scopes, astrophotographers and CCDers will have no trouble picking up some of M31's

Figure 17.6 M33 in Triangulum as seen through binoculars. © Grant Privett

NGC588*, **NGC592*** and **NGC595***, which can all be seen on a good night. M33 is very rewarding for persistent photographers and CCDers, but a little disappointing for the observer expecting another M31.

What, More Galaxies?

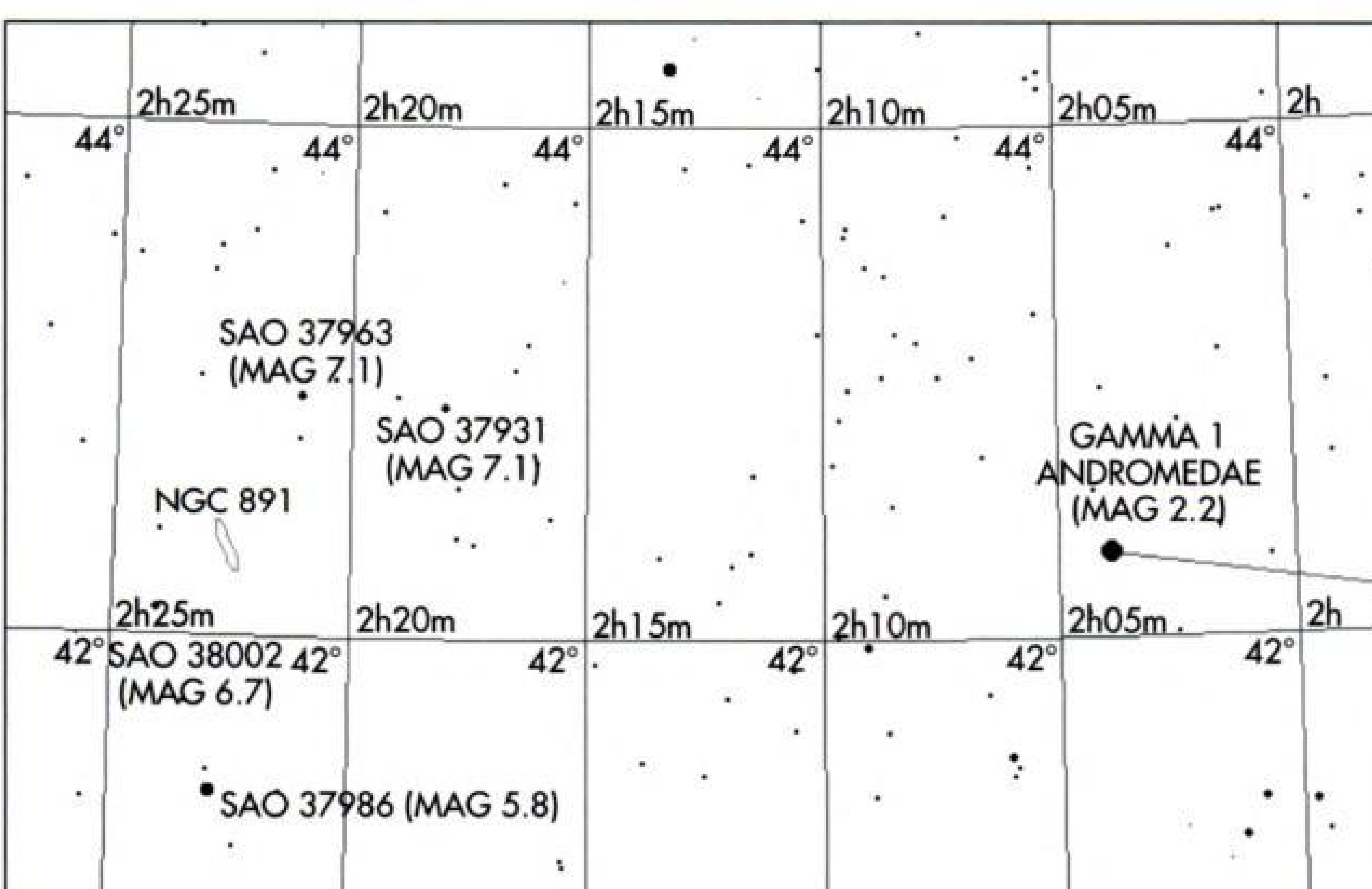
One particularly easy-to-locate, but difficult to see target is **NGC404****. This face-on, 10th magnitude galaxy shares a low-power field of view with beta Andromedae. The distracting brilliance of this 2nd magnitude yellow star means that NGC404 is most easily found if beta Andromedae and its diffraction pattern are kept out of the field of view. The galaxy's core is not difficult to spot but the outlying regions may require a larger instrument. When you think you've found it change the eyepiece and check again to ensure that you are not picking up a faint internal reflection artefact.

Near the eastern boundary of Andromeda is a splendid edge-on galaxy, sporting an obscuring dust lane along its length. **NGC891**** is about 3.5° east of gamma

Figure 17.7 A classic edge-on spiral. NGC891 in Andromeda. © Ian Inglis

Andromedae, but may prove awkward for some people to find – it is quite large (14′ × 3′) and of 10th magnitude, giving it a fairly low surface brightness. Nevertheless, the galaxy lies in a rich star field, making it an attractive scene that's worth pursuing. The dust lane will not be easily detectable in smaller apertures and will not appear nearly as prominently as it does in CCD images. A 300 mm aperture may be necessary to find the lane if observing under urban skies.

Figure 17.8 Finder chart for NGC891. Courtesy SkyMap Software



A little under 1° to the southeast of NGC891 is **Abell347***, a cluster of faint galaxies that includes **NGC912***. Abell347 is rather more difficult to see, as the galaxies are all 13th magnitude or fainter, but if the night is clear and you fancy going deeper it's worth searching for. Also, not far from NGC891, is the BL Lac object **3C66A***. If you have a CCD camera or large scope, observe this over some months and see how the brightness varies from 14th to 16th magnitude. The BAA will be very glad to receive your observations. Not spectacular to behold, but worth searching out.

Not too far away in Aries is the 10th magnitude spiral galaxy **NGC772****. In medium instruments it should appear with dimensions 3′ × 2′, having a strong nucleus and hints of mottling. Smaller instruments, 150 mm and less, may have trouble picking it up. Photographers and owners of big scopes might like to search for the 14th magnitude **NGC770*** very close by.

Another galaxy well placed at present is **M74**** in Pisces. This 9th magnitude face-on spiral is roughly 10′ across and, despite a brightish core, has a reputation of being difficult with smaller instruments. This is due to the low surface brightness of the spiral arms, which leads to the galaxy often being missed or the core mistaken for a star. Users of scopes with at least 200 mm of aperture may be able to detect the graininess of the core and possibly hints of the H-II condensations present in the spiral arms. Careful users of 300 mm scopes may, in good conditions, discern a significant proportion of the galaxy's spiral structure.

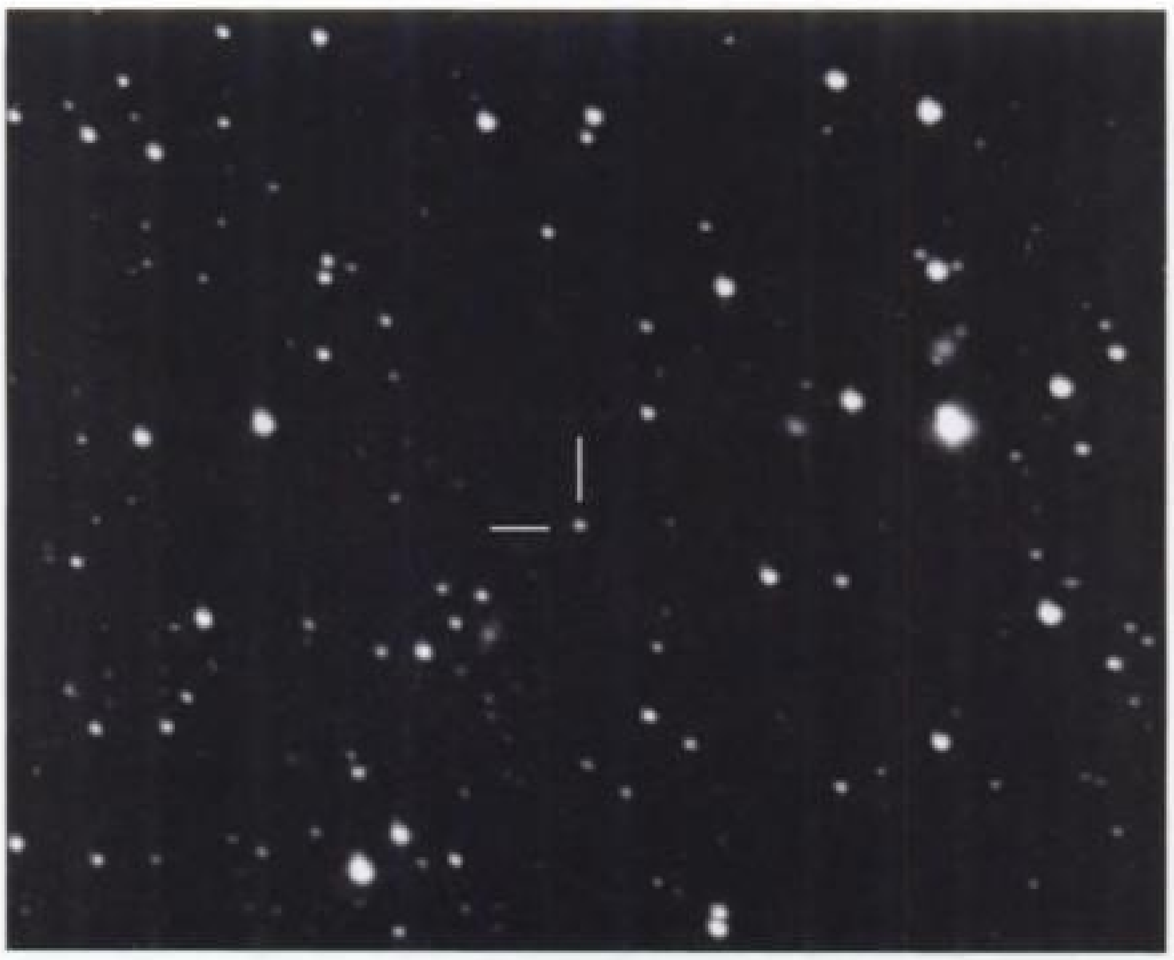


Figure 17.9
3C66A, an AGN monitored by the BAA.
© Nick Hewitt

Figure 17.11 Nice in smaller scopes, NGC663 in Cassiopeia. © Grant Privett

Cassiopeia swarms with clusters, some great and many small. **NGC7789*****, discovered by Caroline Herschel, is one of the greats. In smaller scopes it appears as a broad hazy patch with faint hints of resolution, but as the aperture is increased it resolves readily into over 150 faint dots distributed across an area of sky the size of the Moon. None of the members are especially bright, but there are lots of them, some fairly strongly coloured. So try using a low-power eyepiece to search the sky between rho and sigma Cassiopeiae. Contrast NGC7789's appearance with the nearby, and rather dimmer, **NGC7790****. The latter's 30 or so stars are not as impressive but aren't difficult to find.

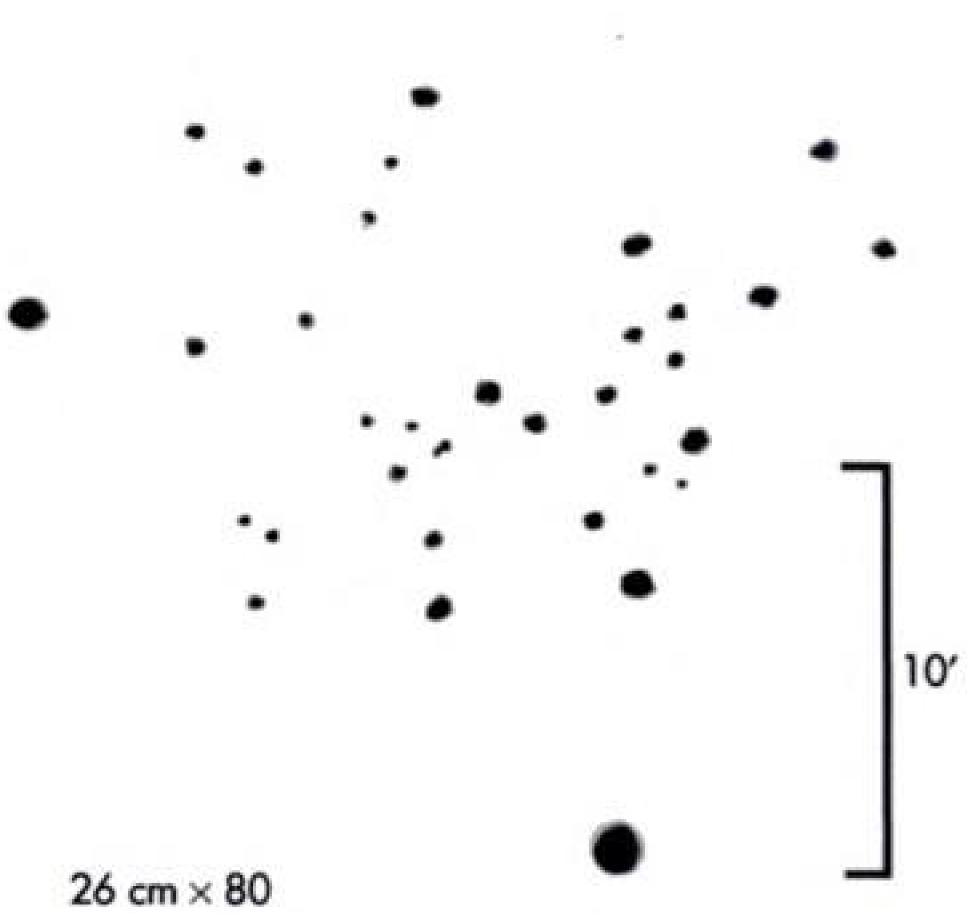


Figure 17.12 A drawing of the cluster NGC7789 in Cassiopeia. © Guy Hurst

the outer parts only spring out at you when you change from direct to averted vision. For this reason M77's full 7′ × 8′ size may be hard to discern. Structure in the inner regions, however, can be glimpsed in scopes as small as 200 mm. M77 radiates strongly at radio frequencies and has been classified as a Seyfert galaxy, suggesting that there is probably a supermassive black hole lurking at its centre. As is usual of a Seyfert, the core varies in brightness - in this case from 10th to 11th magnitude.

There are a number of other brightish galaxies in the neighbourhood of M77. These include **NGC1055****, **NGC1073**** and **NGC1087****, which are all 10th magnitude and will appear as ovals of 8′ × 4′, 4′ × 2′ and 4′ × 3′ respectively. The lack of background stars in this area of the sky makes them stand out well - easily visible in medium-sized scopes. Close by is the 13th–14th magnitude **NGC1038***. This face-on spiral has a nice clear structure when imaged and the added bonus of three quasars in the same frame. The quasars are well below the limit for visual observing (18th and 19th magnitude!) but a 20-minute CCD integration on a 300 mm scope should record all of them with a respectable signal-to-noise ratio.

Also Worth a Look

NGC247*	Galaxy, Cetus, large, very low surface brightness, difficult.
NGC281**	Cluster + nebulosity, Cassiopeia, 7th mag, large, faint.
NGC524**	Galaxy, Pisces, 10th mag, several galaxies nearby.
NGC584**	Galaxy, Cetus, 10th mag, near NGC589.
NGC654**	Cluster, Cassiopeia, 9th mag, loose, small, near NGC663.
NGC779**	Galaxy, Cetus, 11th mag, elongated.
NGC936**	Barred spiral, Cetus, 11th mag, close to M77.
IC1613*	Galaxy, local group, large, 9th mag.

a curious V-shaped grouping of seven or eight stars, which includes amongst its brightest members the 5th magnitude 52 and 53 Cassiopeiae. It's a nice little asterism and pleasing to find, particularly as the star cluster **Stock5**** lies adjacent to it. Stock5 is 15′ across and contains 25 stars. The brightest is 7th magnitude but the others are all fainter than 9th.

The Double Cluster

Just a little southeast of Cassiopeia, and across the border into the constellation of Perseus, is the famous **Double Cluster***** - NGC869 and NGC884, a pair of rich open clusters just over 30′ apart. To fully appreciate these you will definitely need a wide-field instrument, operating at a low power to capture as many of their 500 total stars as possible. Visible to the naked eye as a diffuse haze-like patch, the Double Cluster is an easy target with any binoculars; a 100 mm reflector or 75 mm refractor will give an impressive view. Beware of using bigger scopes – they may constrain the field of view too tightly to do this pair justice. Both clusters

Figure 18.1 The Double Cluster and IC1805 in red light. © Bob Neville

observed visually with a 100 mm Genesis scope using a hydrogen-beta filter.

Before leaving Perseus, be sure to look at **M76****, the Little Dumbbell. It's one of the fainter Messier objects but nonetheless well worth seeing. Look for a small bar of light (2′ × 1′) in smaller instruments; details and a larger faint envelope of gas in 200 mm scopes; and a detailed and interesting structure in large instruments. It's also a great target for imaging of any sort. To find it, sweep about 1° north of phi Persei to a 6th magnitude star, and then a little to the west.

Old Favourites

There are two targets prominent during October that prove what a good time of year this is for the deep-sky observer. The first is **M45*****, the Pleiades star cluster in Taurus. It goes by a number of colloquial names, including the Seven Sisters and the Hen and Chicks, depending where you live. But whatever you choose to call this grouping, it's a glorious splash of glinting blue stars, framed against a deep black sky. At first glance it looks vaguely like a truncated Big Dipper, with a fading row of fainter stars running away toward the southeast, and several close pairings among its members. Overall, the cluster covers about 1.5° of sky.

Figure 18.3 M45 in Taurus, a winter gem. © Adrian Catterall

M45 is sometimes used to test how dark the sky is. Once dark adapted, most people can pick out six or seven of the members with the unaided eye. But in particularly dark locations, such as the Canaries or New Mexico, it should be possible to see more. Have a look sometime, draw what you see and then compare your sketch with a photograph to see which stars you picked out.

Aside from being a favourite visual object, M45 has always been a popular target for photographers. An impressive feature of the photographs, besides the brilliant blue colour of the stars, is the gas and dust that can be seen in faint cirrus-like clouds surrounding some of the brighter members – Merope particularly. Under ideal conditions the clouds can be picked up as delicate webs of light with a 250 mm scope, but normally a bigger instrument is necessary. Observing these nebulae will really test the darkness of the sky, your

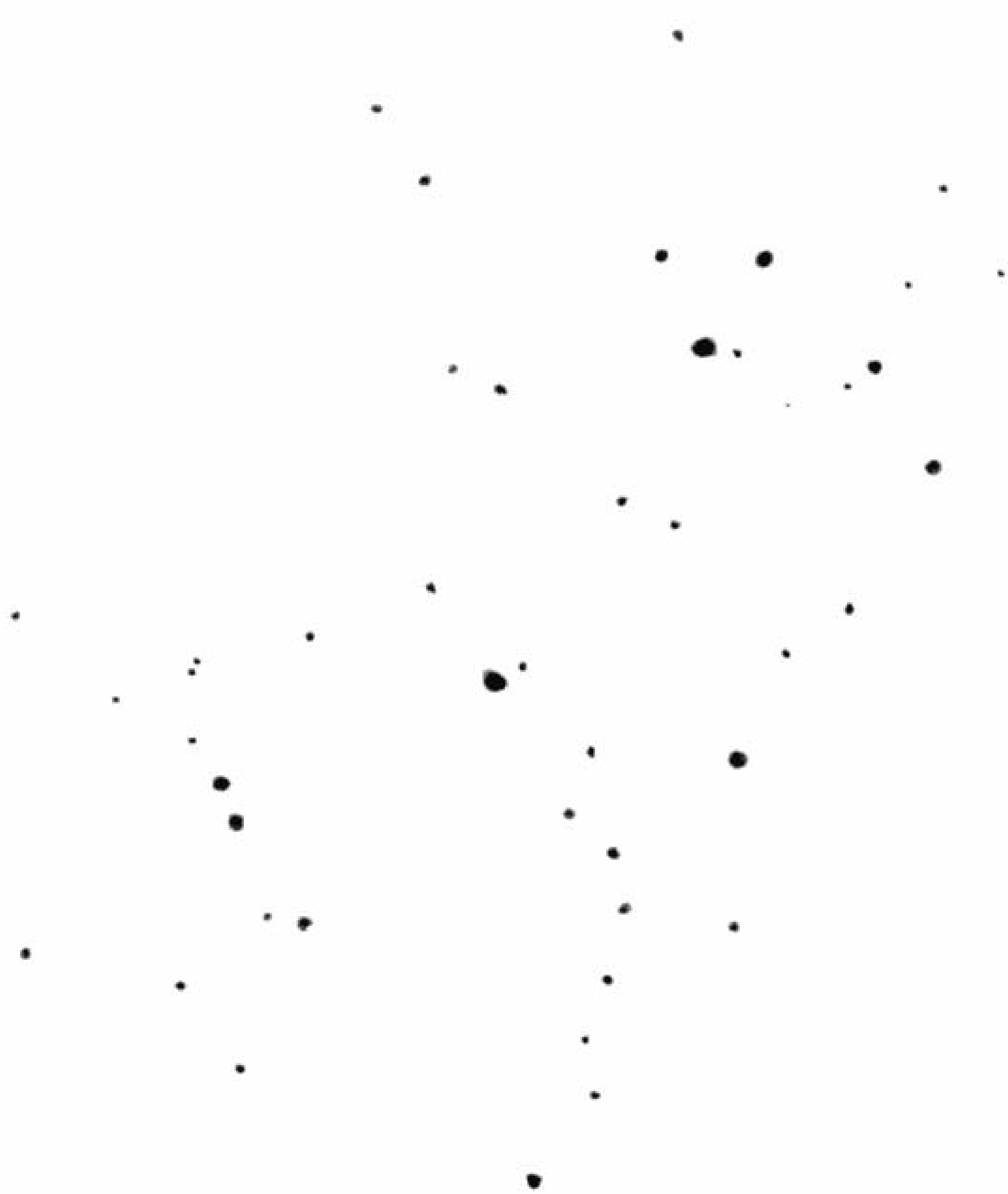


Figure 18.4 The Pleiades with binoculars. © Grant Privett

dark adaption and the quality of your scope's optics. To improve your chances you must be extra careful to preserve your dark adaption - avoid looking at even reflected lights. Observe from a rural location if possible and make sure that your telescope optics are clean and carefully aligned so as to scatter as little light as possible. Some people find that draping a dark cloth over their heads as they look through the eyepiece helps to avoid extraneous light. Others sit with their eyes closed for some time before observing. Indeed, given the presence of bright stars in the cluster it may even be worthwhile arranging your view so that stars like Merope lie just outside the field, thereby reducing the glare. Alternatively, examine the image of the stars close to Merope and then move away from the Pleiades (and nebula) and compare the star image. Are they different?

Having looked at one large and bright open cluster, let's try another. Scattered above and to the west of Aldebaran is the **Hyades*****. The brighter members (ten of which are brighter than 6th magnitude) form a V-shaped grouping roughly 5° across, with outliers spread across 30° or so of sky. Despite appearances, Aldebaran is not really part of the Hyades and does not appear to share the cluster's movement across the sky. Its membership is merely a line-of-sight effect. Unlike the Pleiades, the Hyades is fairly old, as can be seen from its dearth of young blue stars. A splendid object for binoculars.

For those trying astrophotography for the first time, why not have a go at getting both M45 and the Hyades on the same colour frame? Even if the camera is fixed, i.e. does not follow the sky as the Earth rotates, you will still be able to compare the colours of the stars in each cluster.

If you're having fun finding clusters, **M34***** in Perseus is well worth looking at. It is easily found with binoculars and hovers on the verge of naked-eye detection in dark skies. Its 50 or so brighter members will fill a 30′ field. In small scopes the "X" shape made by the brighter members is very distinctive: a particular favourite of the Rev. Webb.

To finish off this tour of clusters, look about 3° southwest of alpha Persei for **NGC1245****, a 9th magnitude cluster of over 150 members occupying about 10′. A great contrast to the larger clusters mentioned earlier.

Switching to galaxies, the 30′ wide galaxy cluster **Abell426**** can be found 2° east of the variable star

Algol. The rich field in this region can be a little distracting, however, especially since the brightest galaxy in the cluster, **NGC1275****, is quite faint at 12th magnitude. NGC1275 is an X-ray source that appears visually as a small ellipse of light. CCDs and photography will reveal structure within it. Any reasonably deep image of this area of sky should show several more of the galaxies in Abell426, including the 12th magnitude **NGC1272**** to the west.

Also in Perseus is another galaxy, **NGC1023****. It's quite an elongated object (11′ × 34′), shining at 9th magnitude in – as might be expected – quite a busy field. NGC1023 is accompanied by a 14th magnitude dwarf galaxy neighbour and several rather fainter galaxies that may only be seen on images. NGC1023 can be found by looking 1.75° south from 5th magnitude 12 Persei and then 0.5° west.

The Giraffe

Further north lies the nondescript form of Camelopardalis which, despite its unimpressive naked-eye appearance, holds the large (20′ across), 9th magnitude galaxy **IC342***. This galaxy's size gives it a very low surface brightness, making it quite difficult to see. Indeed, even a 300 mm may only show a faint smudge of light around its 1′ core. Locating the galaxy is made slightly easier by its proximity to half a dozen stars of 11th magnitude running close by. IC342 is a member of a galaxy group that also includes **Maffei1/2*** and the more accessible 11th magnitude **NGC1569**** and **NGC1560****. Some other members of the group are heavily obscured by intervening dust in our own Galaxy, losing as much as five magnitudes. One member that was found only in recent years – **Dwingeloo1***, in Cassiopeia – should be just detectable visually in a large scope and in a medium-sized scope with a CCD.

The Crab Nebula

Another Messier object well placed this month is the well-known supernova remnant, **M1*****, the Crab Nebula. Although rediscovered as an elongated patch of hazy light by John Bevis, in 1731 – very much a tribute to his abilities, given the equipment of the time

– it must have been seen by thousands of people in July AD 1054 when it first appeared in the early morning sky as a bright supernova explosion. The Crab is one of only a handful of supernovae that have been observed in our Galaxy in the last 1,000 years. As such, it's been intensely studied and photographed. It's not a particularly easy target for small telescopes. From the light-polluted outskirts of London it was marginally visible with a 100 mm reflector. It lies a short distance northwest from 3rd magnitude zeta Tauri. A 200 mm scope will show a pale uncoloured $5' \times 3'$ elliptical glow of 9th magnitude, but with care and patience a 300 mm scope may start to show evidence of the filamentary remnants of the expanding gas cloud so prominently seen in photographs. M1 is the sort of object where light buckets really do come into their own.

Given the size of M1 and its brightness, it makes a great target for any CCD owner or photographer. If the seeing conditions are good, a number of stars can be imaged within the cloud and its filaments will be clearly visible if the contrast is handled properly. Those of you using colour emulsions or a tri-colour CCD will be able to catch the red glow of the filaments and get a very nice picture indeed. The remains of the supernova's progenitor star is a dense object called a neutron star, lurking at the centre of the nebula. This shines at 16th magnitude, so while almost certainly out of the range of visual observers it should prove no problem with CCDs or film. Filters are of marginal use but try them anyway.

Those of you with a taste for planetary nebulae might like to seek out **NGC1501**** in Camelopardalis. It

Figure 18.5 The wonderful Crab Nebula in Taurus © Grant Privett

Figure 18.6 The planetary nebula NGC1501 in Camelopardalis. © Neil McMickle

appears as a 12th magnitude, slightly elliptical patch, a touch under 60″ across. The centre is occupied by a 13th magnitude star which should be within range of a 300 mm scope. Unfortunately, this is not a particularly easy object to observe and the mottling between the ring and the central star is not so obvious. Webb found NGC1501 pale, but CCDers and photographers should have a great time, with the ring showing considerable detail. NGC1501 can just about share the same low-power field as the 5th magnitude star SAO12968 and the 7th magnitude **NGC1502*** – a cluster of 20 stars some 8′ across. Locating it is made easier by the presence of Kemble's Cascade, a line of 7th–8th magnitude stars running away from NGC1502 to the northwest.

Just over the border into Taurus from Perseus is another fine planetary nebula, **NGC1514****. It takes the form of a 10th magnitude, 3′ ring of light enclosing a 9th magnitude star, and can be reached by a relatively easy star hop from nearby zeta Persei via a string of 7th and 8th magnitude stars. The planetary's central star is very easy to spot but the nebulosity may prove elusive in scopes smaller than 200 mm. Try using a O-III filter, if you have one, to bring out hints of structure.

Further south, in the northern part of Eridanus, is the annular planetary nebula **NGC1535****. It's not large – just 20″ across – but at 9th magnitude it won't be hard to find by sweeping 4° east from gamma Eridani and then 1° northwards. This is an object best suited to scopes in the 200 mm+ range but shows hints of structure in the centre even in a 200 mm. Look for structure with a high magnification on nights of good seeing.

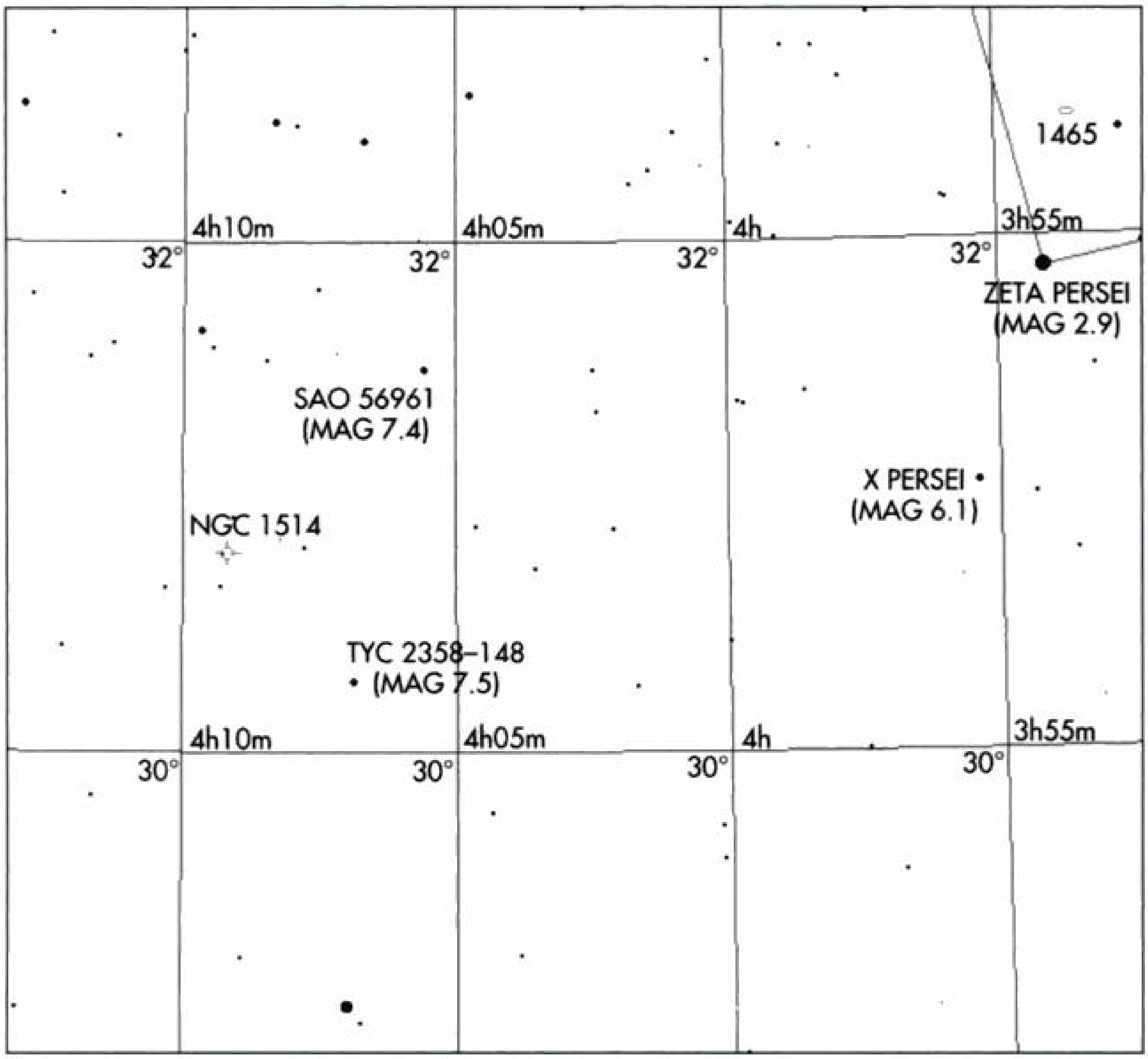


Figure 18.7 Finder chart for NGC1514. Courtesy SkyMap Software

Also Worth a Look

NGC1232**	Galaxy, Eridanus, 10th mag.
NGC1491**	Nebula, Perseus, 11th mag, near lambda Persei, brightish.
NGC1647***	Cluster, Taurus, 6th mag, rich.
NGC1746***	Cluster, Taurus, 6th mag, large, clumpy.
NGC1788*	Nebula + stars, Orion, north of beta Eridani.
NGC2301***	Cluster, Monoceros, 6th mag, 80 stars.
IC3568*	Planetary nebula, Camelopardalis, small.

Chapter 19
December
06 Hours RA

This Month

This month sees the longest nights of the year, making an all-night observing session very much a marathon event. But for those unable to spend all night at the scope, the midnight sky this month is impressive: home to Camelopardalis and its neighbours Auriga, Taurus, Gemini, Orion, Lepus and Canis Major.

In December, weather permitting, it will be possible to get out and observe early, making fatigue less of a problem. Those of us managing to get outside out by 9 p.m. will find that Andromeda and Pegasus have lots to offer. Anyone braving the small hours of the night and its cold draughts will find the bowl of Virgo putting in an appearance – recompense if ever there was.

Compulsory Viewing

Binoculars and smaller telescopes:	M36, M37, M42
Moderate telescopes:	M78, M42, NGC1931
Larger telescopes and CCDs:	IC434, IC405, B33

So Much to See

The major problem with December's constellations is that, when it comes to selecting something to observe, we are spoilt for choice. Let's start in Auriga. Toward the border with Taurus, south of Capella, and within a few degrees of the 5th magnitude star phi Aurigae lies a relatively close grouping of four open clusters: **M36*****, **NGC1907*****, **M38***** and **M37*****. The first three are all close to phi whilst M37 is slightly further away to the southeast, toward Gemini. If you have a taste for open clusters then this is a wonderful region in which to spend some time. Of the four, M37 is probably the most striking telescopically. It's a tightly packed collection of several hundred stars, ranging from about 8th to 15th magnitude (giving the cluster an integrated magnitude of 6), that should be resolvable with even the smallest of instruments. It is probably best located by finding the mid-point between theta and upsilon Aurigae and from there sweeping south about 5°. With a width of 20′ it should be difficult to miss in a scope with a 45′ field of view. It bears frequent revisiting.

M38 is just over 1° north (and a little west) of phi and is also easily located by sweeping. During the sweep to M38 you will first encounter the somewhat fainter NGC1907. Separated by only 30′, M38 and NGC1907 should both be visible in the same low-power eyepiece, allowing comparison. Both are sparse compared to M37. NGC1907, the more distant and smaller of the two, will prove a challenge for smaller scopes, as its brightest star is 11th magnitude. M38 is probably the least attractive of the three Messier clusters here, being bigger and looser than the others. But at 7th magnitude, it's still a nice find, containing several interesting chains of stars. It would probably be appreciated much more were it not in such grand company. When viewed through binoculars, M38 appears at the northeastern end of a large oval of stars.

M36 is a very attractive sight in any scope. At around 25′ across and with far fewer stars than M37, it might sound unremarkable. Fortunately, however, many of its members are quite bright, combining to give an integrated magnitude of 6. This makes the cluster bright and not difficult to find, even when there is a faint haze in the sky. About midway between phi Aurigae and M36 is the nebula **NGC1931****, which may appeal more to users of medium-sized and larger apertures. Databases record this object as a cluster with nebulosity, but it looks more like a small elongated nebulosity, about 2′ across, within which are embedded 4 or 5 stars, all brighter than 15th magnitude. It makes the poorer Messier clusters, such as M29, look positively cluttered. With a little effort NGC1931 can be

Figure 19.2 The region of M42 around the Trapezium. © Jeff MacQuarrie

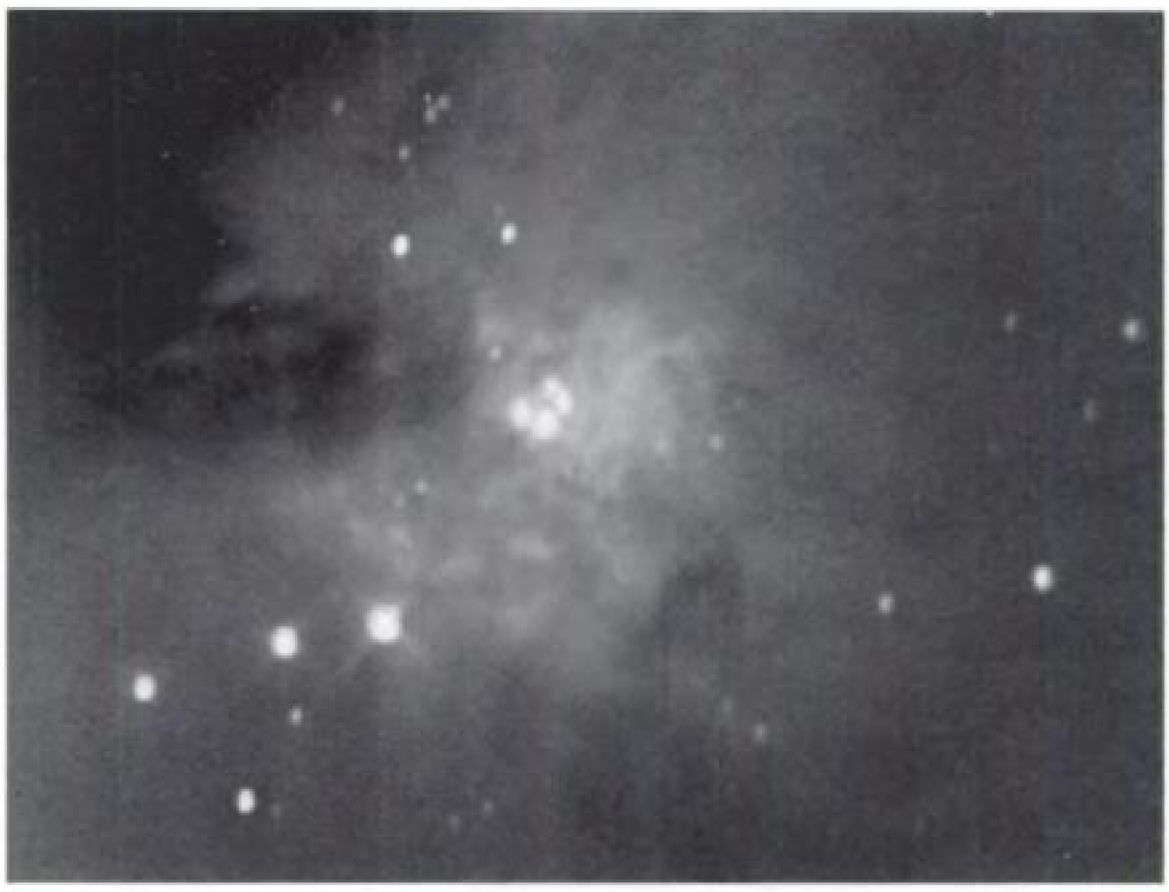


Figure 19.3 The Orion Nebula. Difficult to draw. Beautiful to see. © Adrian Catterall

are good at detecting movement. If you've never tried it, have a go next time it's clear. On particularly fine nights, look out for faint stars in the nebula and subtle details in the outer regions. Remember that this is one of the brightest coloured nebulae. What colour can you see?

Orion's multiple star system the Trapezium is attractive to observe, but poses a problem for CCD users trying to image M42. To prevent the Trapezium stars from saturating the detector, exposure times must not exceed a few seconds. Many such exposures must then be stacked to improve the signal-to-noise ratio in fainter regions of the image. Photography, and CCDs with anti-blooming gates (which prevent bright objects saturating the CCD) do not suffer from this problem so badly. Whatever you use to record M42, no one will have any trouble spotting the dark nebula that forms the mouth shape on its northern edge - probably the most easily spotted dark nebula that there is. While looking at M42, be sure to try out any filters that you have O-III, hydrogen-beta, anti-pollution - anything.

Figure 19.4 M42 as seen with binoculars. © Grant Privett

Each will provide a different view, making the nebula even more interesting.

Travelling north from M42 and M43 by just 30′ brings us to a star very appropriately named 42 Orionis. This, and its immediate neighbours, are surrounded by the faint glow from the gas and dust cloud **NGC1977****. This is a roughly oval patch, approximately 40′ × 30′ in size. It has a much lower surface brightness than M42, and so may elude many smaller scopes. Deep photos show NGC1977 and the nearby, still fainter and smaller **NGC1973***, as strikingly blue; M42 and M43 are predominantly red. These colours can only be seen in images, however; they are well below visual detection. Photographs should also show the still fainter form of NGC1975 close by. Some texts give these objects as 9th magnitude and others rather vaguely just say "faint". See what you think.

Moving a few degrees east and north of M42 to the region of zeta Orionis, keen-sighted users of big telescopes will find the long, thin emission nebula **IC434*** extending directly southwards for almost 30′. IC434 is hard to see, requiring at least an unfiltered 200 mm reflector. The reason it is so well known is that part of its hydrogen glow is obscured by a darker foreground cloud of gas and dust called **B33***. The silhouette of the

Figure 19.5 42 Orionis and the beautiful NGC1977. © Wil Milan

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