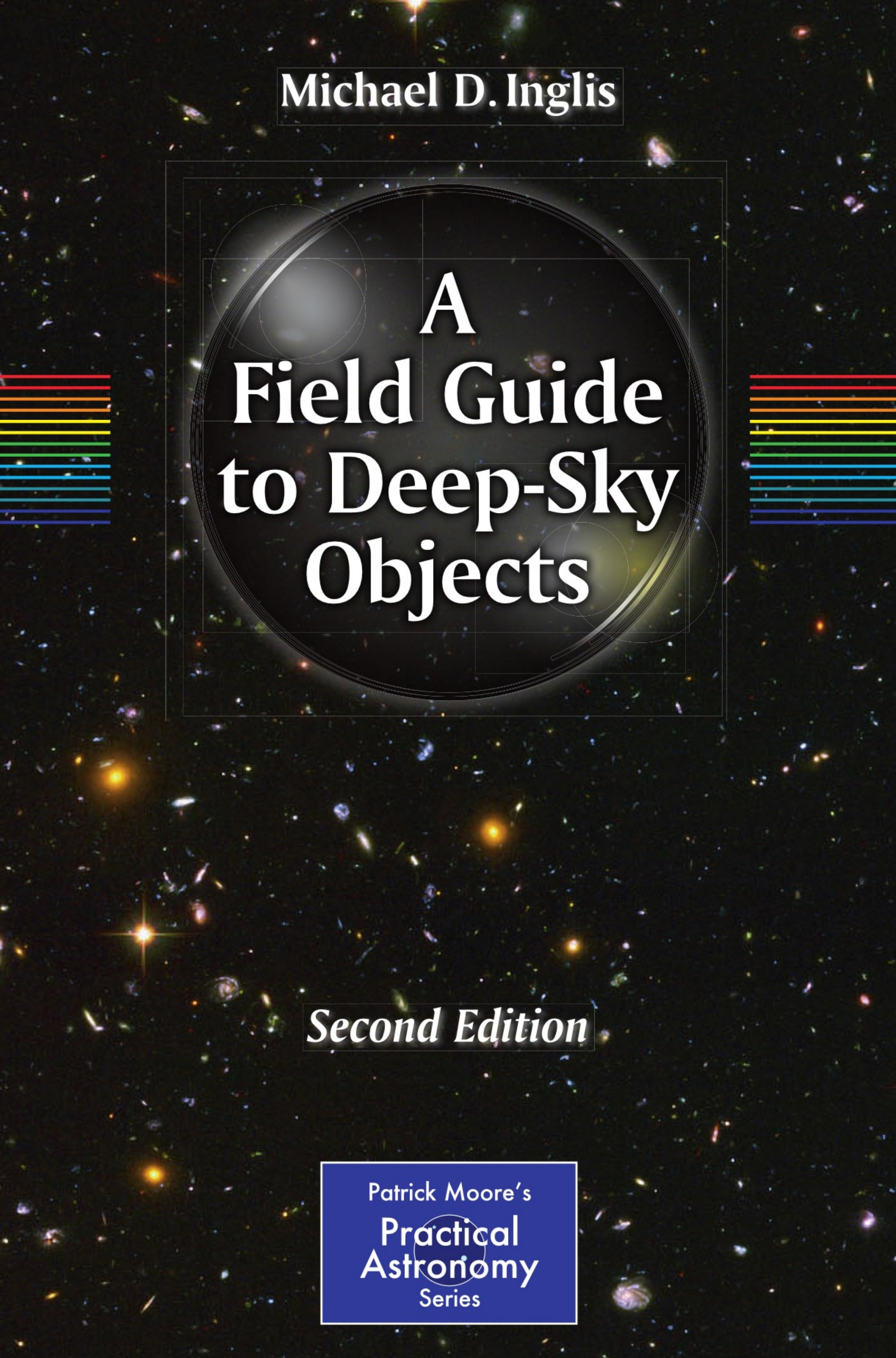
Michael D. Inglis

A Field Guide to Deep-Sky Objects

Second Edition



Patrick Moore's Practical Astronomy Series

Patrick Moore's Practical Astronomy Series

For further volumes:
http://www.springer.com/series/3192

A Field Guide to Deep-Sky Objects

Second Edition

Michael D. Inglis

Springer

Michael D. Inglis
Suffolk County Community College
Selden, NY, USA
inglism@sunysuffolk.edu

ISSN 1431-9756
ISBN 978-1-4614-1265-6 e-ISBN 978-1-4614-1266-3
DOI 10.1007/978-1-4614-1266-3
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011938479

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

for
Arfur

Preface

Second Edition

I was only knee-high to a tripod when, on a fateful night in April 1957, the first episode of the BBC television series, "The Sky at Night," presented by Patrick Moore, was broadcast on British TV. In the program he mentioned that the comet Arend-Roland was visible to the naked eye, and my father decided that this was something I ought to see. I don't actually remember seeing the comet, but I do recall being carried out in my father's arms, under a pitch-black sky in South Wales. From that moment on my life's purpose and direction were mapped out for me: I wanted to learn about the stars. So it is only right and proper that I begin this preface by thanking Patrick for providing the inspiration and desire (as he has also done for countless other people) to become, eventually, an astronomer.

The initial idea for a book of this type had been with me for many years, but it was only after meeting John Watson – of Springer-publishing – at the London Astrofest that I finally could begin work. John's knowledge of publishing, editing and indeed astronomy was of incalculable worth during the writing of the first edition. It is easy to have a mind full of ideas, but to actually get these onto paper in a coherent manner so that they are understandable by everyone and not only those with astrophysics PhDs has been achieved only with the steady hand of John guiding me.

Special mention must also be given to Maury Solomon, at Springer New York, who suggested writing a second edition of the book, who is a good friend and knows all there is to know about scientific publishing. She is also a very patient person, especially when dealing with astronomers when deadlines are long past.

I began my journey into astronomy as an amateur, and to this day, it remains a very important part of my life. The number of amateur astronomers I have met is enormous, and some of these meetings have developed into deep friendships. I refer, of course, to those two erstwhile members of the South Bayfordbury Astronomical Society, Mike Hurrell and Don Tinkler. The observing sessions I have had with these characters are some of the most unique and unforgettable observing experiences of my life (I am still in therapy), and to this day I cannot recall them without breaking out into a smile, and more often than not, hysterical laughter. Their outlook on astronomy is enviable, as they just enjoy the subject for what it is, amazing and beautiful, a viewpoint that is often overlooked by focusing too much on the science of astrophysics and the obsession with the latest observing aids and equipment.

During my apprenticeship as a professional astronomer I have been fortunate enough to meet many wonderful people, not necessarily involved in astronomy but rather as colleagues working at the same university. Between them they managed to keep me sane, by listening to me complain about the injustice of life in general, buying me beer (an excellent source of contentment) and just being there. They remain to this day my dearest friends and are indeed part of my extended family. Firstly I want to thank my dear friend, Karen Milstein, whose smile made life a happier time, and whose compassion and understanding when, sometimes, I complained bitterly about life, was a source of strength and comfort. I also want to thank, Bill Worthington, Peter Harris and Stuart Young.

Since moving to the New World, I have been fortunate enough to meet many people, both teachers and students, whose desire to learn about the universe and then pass this knowledge on to others matched my own. They make the often-bureaucratic nature of academia bearable. Thank you, Sean Tvelia, Matt Pappas, Tom Breedon, Gerry Schnall, and Dana D'Ambrosia.

However, all that I have achieved as an astronomer would have been for naught if it weren't for the astronomers at the University of Hertfordshire. Their knowledge of the way the universe works, and how to impart this knowledge to a student, is astounding. In my opinion they are the finest educators I have ever met. That they had the patience to teach me is something I still wonder about, as I remember only too well the number of mistakes and errors I made. But they took it all in good spirit and with humor, and to be associated with them is something that I look upon with humility. I would like to take this opportunity to acknowledge publicly the debt I owe these people: Iain Nicolson, Jim Hough, Alan McCall and the late great Lou Marsh.

It is also important that I single out and mention Professor Chris Kitchin, who was both Head of Physics and Astronomy, and Director of the University of Hertfordshire Observatory at Bayfordbury, and Bob Forrest, who was its principal technical officer. Their depth of knowledge about all matters astronomical, theoretical and observational is without parallel, and to be allowed to use the amazing variety of superb telescopes at the observatory was definitely a privilege afforded to few. Chris's knowledge of astronomy and astrophysics is very wide-ranging and impressive, and he has been my mentor in all that I have done. If it hadn't been for

Chris, I would have never found out how much I like to teach astronomy, and I have learned from him many of the techniques that make teaching a pleasure and not a chore. Bob is an astute observer and I learned most of my observational skills at his side. He is also a patient and long-suffering man (especially where I am involved), as on many occasions when I could not get the telescopes to work (the declination control just came off in my hand, Bob, honest!), Bob would wander over, twiddle a control so that the object sprang magically into view, then walk away, shaking his head and sighing deeply. Suffice to say that I owe both these astronomers a lot!

Writing a book is, strangely enough, just like observing. They are both, more often than not, solitary pastimes, and occur during the night hours. However, I have not been alone during either of these times, as I have had the music of the American Steve Roach as a companion. His musical tone poems are wonderful and inspiring, and it can truly be said that he has created the music of the spheres.

Finally, I have to thank those people who are closest to me, and whose presence makes life tolerable. Firstly, I want to say a few words about my brother Bob. It is true to say that without his help, I would have never become an astronomer. He also enjoys a pint of beer as much as I do, which is an excellent measure of someone's character. (Can I buy you a pint Bob, and we'll call everything quits?) I also want to thank Mam and Dad. My father, who bought me my first astronomical telescope, always encouraged me to seek out my dream of becoming an astronomer, and the memory I have of showing him the rings of Saturn in the telescope, and his subsequent true and real joy, is something I will treasure forever. My mother, who has been with me all the way, with unconditional love, food parcels and clean socks, and has also been there for me during those times when not everything was going according to plan.

To everyone I have mentioned, thank you all!

Long Island, NY Mike Inglis

Contents

About the Author

Michael Inglis is a professional astronomer with a Ph.D. in Astrophysics from the University of Hertfordshire, UK. He has worked at the University of Hertfordshire, Warwick University (UK), Princeton University (United States), and currently is an Associate Professor of Astronomy for the Earth & Space Sciences Department at Suffolk County Community College (part of the State University of New York, SUNY). He has done research in nebulae morphology, active galactic nuclei, and cosmic rays and has authored several refereed papers. He has also had many popular articles published in the magazines *Sky & Telescope* and *Astronomy Now* and written several books for Springer, including *An Observer's Guide to Stellar Evolution*, (2002); *Astronomy of the Milky Way*, Vols I & II (2004); *Astrophysics Is Easy* (2007). He currently serves as the series editor of the Springer *Astronomy Observing Guides.*

Chapter 1

Some Background

It's a beautiful, crisp and clear winter's night. The seeing is perfect, light pollution is minimal, and you're equipped with high-quality binoculars or a telescope. Eager to pursue your passion for astronomy, you have decided that tonight you'll look at a whole range of interesting objects – beginning with a beautiful colored double star, or perhaps a triple star system. Then once you've become dark-adapted you'll try for a glimpse of a few star clusters and then onto a couple of spiral galaxies.

Easier said than done!

Even when planning well ahead, you still have to find out what is visible at this particular time of year. Putting together an evening's observing program means that you have to know which double stars, galaxies and clusters are the best ones to observe. Star atlases – on paper or on the computer – give you the references and the positions, but often won't indicate how easy (or not) your selected objects are to see, or even if they are visible at all on the dates you wish to observe them!

If it's a spur-of-the-moment decision, you may not have time to plan your observing in advance. In that case, when you get outside, not only will you have to carry your binoculars (or telescope) but also several books, catalogs and manuals. You'll need all these to discover which objects you are going to look at and where they are, and you'll probably spend an inordinate amount of time trying to find the positions and descriptions of the stars and galaxies you wish to see from several different books, and what should have been a glorious time scanning the sky has instead become a trying one, leaving you with seriously dampened enthusiasm.

Amateur astronomy shouldn't be like that.

How much easier it would be if you had a guide to the night sky that not only provided you with a catalog of each type of object you wanted to see, but also arranged those objects in such a way as to make it easy to locate them by their

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_1,

classification, ease of observing, and the date you observe. How much more useful than a list of objects made according to the constellation they appear in!

I couldn't find such a book, so I set out to write one myself.

My purpose is twofold: first to provide an introduction to the thousands upon thousands of objects within reach of the amateur astronomer, and second to help develop a lifelong interest in what is without a doubt the most beautiful, exciting and thought-provoking field of science.[1]

The notion of providing a means of finding an object by the type of object it is, and by the date you are observing it on (rather than by its position in the sky and what constellation it lies in) came partly from my own experiences as an amateur astronomer, when I spent many nights trying to find objects I had read about or seen pictures of, but partly also through my work as a professional astronomer teaching astronomy to undergraduates, where the time taken in locating a particular class of star, cluster, nebula or galaxy was often longer than the time I had been allocated to teach for!

As well as listing objects according to their type, I have also grouped them into three broad sub-categories according to how easy it is to see them – "easy," "moderate," and "difficult." This helps observers to improve their skills in viewing different classes of object. For a given night, you can just work through the list in order. Start with the easy objects, then just work your way down to hard. The best way to get better at observational astronomy is to look at progressively more challenging objects.

Most of the easy objects are very simple to find and can be seen in binoculars and small telescopes and perhaps even the naked eye. Those classified as moderate objects may be a bit fainter and smaller, needing a little more skill to observe properly. The difficult objects could be faint and located in sparsely populated regions of the sky and/or may need larger-aperture telescopes.

Locating and observing these objects in the order set down should also help you hone your observing skills.

The Many Types of Objects

The number of objects that could be observed throughout a year, which could include interesting stars, clusters, nebulae and galaxies, is immense. Equipped with even a small pair of binoculars, you could easily spend a lifetime looking at (or for) these objects. Because this book is limited in size and cannot run to several volumes, this means a certain amount of judicious pruning has had to take place.

[1]There are hardly any photographs in the book. That was a deliberate decision. The reason is that more often than not the photos give a completely false impression as to what can be seen through a telescope. I am seeking to give a true and accurate description of what can be observed. What you can actually see depends on your experience as an observer, weather conditions, and of course upon the kind of instrument you have available to observe through.

We've therefore limited, in most cases, the number and type of objects to those visible by most amateurs equipped with small[2] (up to 8-in, 200 mm) telescopes and binoculars. The categories are:

1. Stars (bright, colored, double, triple, quadruple, multiple)
2. The spectral sequence
3. Star clusters
4. Globular clusters
5. Nebulae (emission, dark, reflection, planetary, supernova remnants)
6. Galaxies (spiral, elliptical, irregular), galaxy clusters
7. Several miscellaneous but interesting objects
8. Naked-eye objects

In some instances (like supernova remnants) there may only be a few objects described, even though many exist; some have been excluded simply because they are too difficult. Readers who own large-aperture telescopes will find all of the listed objects easily; there are many other catalogs and handbooks that will satisfy a craving for smaller and fainter objects!

Whenever possible, some objects are included may not be so familiar to the amateur astronomer, along with some that are often described in specialist books and magazine articles, but usually get left out of general books like this one.

Telescope and Observing Essentials

You may think that a section on observing the night sky is redundant. What is there to observing but just going outside with a pair of binoculars and getting on with it? Well, there are in fact several important topics that not only explain what limits the amount and type of observing that can be done but also help you to understand how to achieve more when you go outside, and thus become a better and more confident observer.

Although most readers may already be familiar with the use of a telescope, it wouldn't harm even experienced amateurs to read the following sections. Give it a shot – there may be a few things you don't know!

Binoculars or Telescopes?

Once upon a time, all astronomy books would recommend that the first piece of equipment you ought to buy was a pair of binoculars, because this would allow you

[2] In several sections a few objects that can only be seen by using very large aperture telescopes have been added, say, 30 cm and larger, just for fun.

to get a feel for the night sky and so introduce you to the constellations and objects that lie therein. For many years this advice was correct. But now, with the advent of small telescopes of scarcely more than 80-mm (3-in) aperture or thereabouts, equipped with superb optics, equatorial mounts, electric drives and computer databases of several thousand objects, this advice may no longer be entirely appropriate.

Furthermore, astronomy is now such a glamorous science, with incredible telescopic images regularly seen in daily newspapers and on television and the Internet, that today's amateur often wants to go outside and find these objects immediately and not bother with the slow and steady method of learning patiently over several months the shapes and contents of the constellations. And why not? There's plenty of room in the world for every sort of amateur astronomer.

It may be that the deciding factor on choosing optical equipment is now the cost. If money is no object, then by all means buy a mid-aperture telescope – a 200 mm (8-in) reflector, say, or a 75 mm (3-in) refractor. However, in every case, the quality of the optics must not be compromised. Whether you are buying binoculars or a telescope, always try to make sure that the optical system is of the highest quality.

How do you find out if what you are buying is of good quality, as there are, unfortunately, many pieces of astronomical equipment now available that are, to be blunt, far from appropriate? The answer is to make sure that you buy any and all of the equipment from a reputable supplier. Advertisements for these companies can often be seen in astronomy magazines, and generally, the people who run them are usually amateur astronomers themselves and will give you the best advice available, particularly if the company is large and well known.

It might be a good idea to have both a pair of binoculars *and* a small-aperture telescope. The binoculars can be used for scanning the night sky, to locate bright objects, and to sweep across the star fields of the Milky Way. The telescope can be used for more detailed work on individual objects.

To find the piece of equipment you are most comfortable with, check out your local astronomical society and attend their meetings.[3] They are usually great fun, and their members will have both binoculars and telescopes; more often than not, one member at least will have a large-aperture telescope. Members will be only too happy to give you good advice and help in your decision, and allow you the opportunity to try out the different pieces of equipment.

Whatever you decide, whether it be a pair of good binoculars or a small telescope, or even a large computer-driven telescope, don't just rush out and buy it. Try, wherever possible, to use a similar piece of equipment before you buy one. This way, if you find that you cannot justify the purchase of a telescope because you feel you are not ready to progress to that size of aperture just yet, then all well and good. You not only will have saved yourself a considerable sum of money but also will probably have changed what may have been just a passing interest in astronomy into a lifelong passion.

---

[3] A list of useful addresses can be found under "Organizations" in Appendix A of this book.

Most of the readers of this book will have some background knowledge on certain aspects of amateur astronomy, even if only a fleeting acquaintance. Nevertheless it is worthwhile mentioning a few topics that everyone who wishes to be an accomplished observer should be familiar with (even if some of them may appear trivial). These topics are:

- Magnification
- Resolution
- Limiting Magnitude
- Field of View
- Atmospheric Effects
  - Transparency
  - Seeing
  - Light Pollution
- Dark Adaption and Averted Vision
- Clothing
- Recording Observations

Magnification

Most of us have heard a story like this. Someone decides to "take up astronomy" and spends a lot of money on buying a telescope. It has superb optics, computer control, and comes with three eyepieces. A bright supernova has been reported as visible in the faint galaxy M33 in Triangulum, and the person rushes out into the evening, sets up the telescope and using the highest magnification tells the computer to GOTO M33. Nothing is visible. Not a glimmer. The telescope ends up being sent back, and the owner is irate.

Well, maybe that's just a *little* bit of an exaggeration. Most of you are already familiar with the night sky and have had some experience observing with binoculars or telescopes, so that the topic of magnification is not new to you. But who among us has not been so eager to try out some new piece of equipment, or view an exciting object, that we rush out and try to observe with an inappropriate magnification, only to be disappointed when the image doesn't live up to our expectations?[4] The purpose of this section is to explain how magnification works, and when best to use a certain magnification for a particular object, when circumstances warrant it.

The topic of magnification can be a confusing one for newcomers to amateur astronomy. What is the best time to use high magnification, or low? Why doesn't higher magnification split close doubles? Why do some extended objects seem to get fainter at higher magnification, while others seem to get brighter with low magnification? This section will help clarify these and other points.

[4] I plead guilty!

A full description of the physical process of magnification is beyond the scope of this book, but a few details are appropriate.[5]

The magnification of a telescope (or binoculars) is given by a simple formula: the focal length of the objective lens (or mirror), f_o, divided by the focal length of the eyepiece, f_e. This is usually written as;

$$M = \frac{f_o}{f_e}$$

An example will be useful here;

A telescope with a mirror of focal length 200 cm, used with an eyepiece of focal length 5 cm, gives a magnification of 200/5 = 40; thus the magnification of the telescope using this eyepiece is 40 times, sometimes written as 40×. In this way, a selection of eyepieces of differing focal lengths provides several different magnifications.

It usually comes as a surprise to newcomers to learn that there is a minimum magnification that can be usefully used. This is sometimes quoted as $M \geq 1.7D$, where D is the diameter of the telescope in cm. What this really means is that there is a minimum magnification at which all of the light from the telescope passes into your eye. If you use a lower magnification some of the light is wasted as it is spread out over an area larger than the pupil of your eye.

Another example. If you have a telescope of diameter 20 cm, then the minimum magnification is $1.7 \times 20 = 34$. Thus, using the eyepiece from the example above will give a magnification of 40×, which is appropriate for this optical system.

It comes as less of a surprise that there is also a limit to the *highest* useful magnification that can be employed. In the past, advertisements for telescopes would quote ridiculously high values for magnifications, often several hundred times. While it is true to say that these magnifications are in theory possible, in practice they are, in a word, useless.

Although there is no hard-and-fast rule for the limit of highest magnification, a good rule of thumb is that the highest power, on average, should be from about 10*D* to 20*D*, where *D* is the diameter of the primary mirror (or lens) in centimeters. For a 20-cm telescope this would result in magnification from 200× to 400×. Such high magnifications are, however, rarely used, as they suffer from the following drawbacks:

- A smaller field of view.[6]
- A decrease in brightness of extended or non-stellar objects.
- An exaggeration of atmospheric defects.
- An exaggeration of any tremors or defects in the mount or drive system.

[5] A list of several books that deal with the subject in more detail can be found in Appendix A of this book.

[6] See later.

Usually, most amateurs have a minimum of three eyepieces that provide a good range of magnifications. These are:

Low power, 2*D* to 3*D* – this shows the largest amount of sky.
Medium power, 5*D* to 8*D* – used for more general observations.
High power, 10*D* to 20*D* – useful for double star work.

The usual approach is always to observe with the lowest-power eyepiece, and then move on to other higher powers provided the conditions are right. On some very rare nights when the observing conditions are perfect you will be able to use very high powers, and the amount of detail that reveals itself will be staggering. But such nights are few and far between, and you will be the best judge of what eyepieces to use. It all comes down to experience, and gradually over time you will acquire a knowledge of the characteristics not only of the objects you observe but also of the limitations and potential of your telescope and eyepieces.

Most people who are not familiar with observing would expect an object like a nebula to be brighter when viewed through a telescope than when seen with the naked eye. It's usually a surprise that this is not the case.[7]

Basically, because of light losses and other effects, the brightness of a nebula – or any other extended deep-sky object – are fainter when seen through the telescope than if viewed by the naked eye! But what a telescope does is increase the apparent size of a nebula from an inappreciable to appreciable extent. And the background sky appears darker through a telescope than when seen with the naked eye. Too high a magnification, however, spreads the light out to such an extent as to make any detailed observation suspect.

Finally in this section on magnification, it should be mentioned that there is a minimum magnification that is needed, if you are to resolve all the detail that your telescope is capable of achieving. Although the section on resolution comes later,[8] it seems appropriate to mention this aspect here.

It's probably easiest to discuss this point by using an example. Take for instance a close double star. You know from the telescope's handbook (or you may have calculated for yourself) that the resolution of your telescope has a certain value. You see in the section on double stars in this book that your telescope is capable of splitting these stars. However, when you observe them, instead of seeing two separate and distinct stars, you see instead just one star, or maybe an elongated blur. This may be because the magnification is too low; although the double star should be resolvable by the objective lens (or mirror), the two components will not be observed as individual stars unless a high magnification is used in order to bring them above the resolving threshold of the human eye (about 2–3 min of arc).

Ignoring for the moment atmospheric effects and other considerations which limit resolution, this magnification is given a value anywhere from 10 to 16 times

[7] Note that this discussion does not apply to point sources, i.e., stars!

[8] See the section in this chapter on the resolution of a telescope.

the telescope's aperture in centimeters. A ballpark number is 13 times the aperture in centimeters. Thus, to split very close double stars and to resolve detail close to your resolution limit, you need not only superb optics, good weather, and so on, but also, on occasion, a high magnification.

Remember, however, that you can never increase the resolution by increasing magnification ad infinitum. As you will see in the next section, the resolution of your binoculars or telescope is constrained both by the size of the primary mirror or lens and by the physical nature of light itself.

Resolution

The topic of resolution is extremely theoretical, and a full description of the theory would be better suited to an undergraduate textbook in astrophysics.[9] Not surprisingly, it is also confusing for many amateur astronomers (and even a few professional astronomers), as more often than not, there are few books specifically written for the amateur that describe the Rayleigh resolution, the Dawes limit, the resolving power, the Airy disc, and so on. With this in mind we will not bother to explain where the theory and formulas come from but just write them down without explanation as to their derivation.

Let's begin our foray into the area of telescopic resolution by starting with some simple theory. You might expect that stars that appear as incredibly small points of light to the naked eye because of their immense distance from us would, when magnified, still appear as small points of light – but observation tells us otherwise. The image of a star, when at the focus of a telescope, appears as a finite – although very small – disc of light. This is called the *Airy disc*. In fact, the Airy disc represents about 83% of the star's light. The remaining 17% can often be seen as faint diffraction rings around the star's image.

This is the first counter-intuitive result: no matter how big a telescope you have, how perfect the optics, or how high a magnification you use, not all of the star's light goes into making the central image. This is a consequence of the wave nature of light.

The normally accepted definition of the theoretical resolution of a telescope is given by what is called the *Rayleigh criterion*, denoted by α and given by the formula;

$$\alpha = 1.22\frac{\lambda}{D}(\text{radians})$$

where λ is the wavelength of light and *D* is the diameter in meters of the lens or mirror. However, the unit of measurement for this definition is the radian – one that strikes terror into most people!

[9] For those with a theoretical mind, a list of astrophysics texts is in the appendices of this book.

If we assume however that the wavelength of light, λ, is about 500 nm,[10] a perfectly acceptable value when using the telescope for optical observations, a more user-friendly formula giving an answer in arcseconds[11] can be obtained:

$$r = \frac{0.122}{D}(\text{arc sec})$$

where r is the angular resolution in arc seconds and D is the diameter in meters of the objective lens or mirror.

There's another definition of the highest resolution of a telescope to be found in the literature, and this is the *Dawes limit*. This one isn't derived from any theory but is an empirical criterion, the result of a series of observations made with telescopes of various apertures. The resolution in arc seconds for the Dawes criterion is given by the formula

$$r_D = \frac{0.116}{D}(\text{arc sec})$$

where D is the diameter of the objective lens or mirror in meters.

Both these resolution criteria are useful in that they can give a useful measure for the capabilities of your telescope, but be warned, in practice the performance of the telescope may be different from both the Rayleigh and Dawes criteria. The reasons for this are:

1. The visual acuity of the observer.
2. Both criteria only apply strictly for objects that are both of the same brightness. The bigger the difference in brightness, the greater is the discrepancy between what is expected and what is actually seen.[12]
3. The criteria have been calculated for a light wavelength of 500 nm, and thus it follows that a pair of bluish stars can be resolved at a smaller separation than a pair of reddish stars.
4. The type of telescope you use has can also change the resolution. A reflecting telescope has about 5% greater resolution than a refractor of the same aperture, owing to diffraction effects at the support and flat in a Newtonian telescope.
5. Atmospheric turbulence, or scintillation, usually always stops you from achieving the expected resolutions.

It may seem to you that no matter what the calculated or expected resolution of your own telescope, you will never achieve it, or even know what it is actually capable of resolving! Take heart, though – there *is* a way to discover what your

[10] A nanometer is one billionth of a meter.

[11] A degree can de sub-divided into 60 arc minutes. Each arcminute can be further sub-divided into 60 arcseconds.

[12] You may be forgiven in thinking that fainter stars would be easier to resolve than brighter ones, but this is not borne out from experience. In addition, bright double stars are found to be more difficult to resolve as they tend to "dazzle" and thus reduce the performance of the eye.

telescope is actually capable of, namely by observing a number of double stars whose separations are known.

By undertaking this series of observations, you will be able to determine the performance of your telescope under various conditions, and thus determine the resolution. Of course, the above list of conditions will have to be taken into account, but at least you will know how your telescope behaves, and thus will know what objects cannot be seen, and, more importantly, those which can.

Limiting Magnitude

Having decided what magnifications to use with your telescope, and the resolution you can expect to get, we now turn our attention to the topic of *limiting magnitude*, m_L, or *light grasp*. This determines what is the faintest object you can detect with a given telescope.

Once again, different books give different explanations and formulas, thus confusing the issue, and we should not forget that several factors similar to those listed in the previous section will determine what you can see. And then there is the issue of whether continuous visibility is needed, or whether a fleeting glance can be considered as detection – an important point for the variable star observer, who needs to make a definite magnitude determination,[13] as opposed to a glancing determination of magnitude.

The important point here is that the bigger the aperture, the greater the amount of light collected, and thus the fainter the objects detected. For example, a telescope with a 5-cm aperture has half the light grasp of a 7.5-cm one, which in turn has just over half the light grasp of a 10-cm telescope. In fact, the theoretical value for light grasp is given by the simple formula

$$\frac{D^2}{P^2}$$

where D is the diameter of the objective lens or mirror and P is the diameter of the eye's pupil.

In order to determine the limiting magnitude, a series of observations were carried out several years ago on the faint stars in the Pleiades star cluster, with telescopes of different apertures, and an empirical formula determined. This is

$$m_L = 7.71 + 5 \log D$$

and represents the expected performance of typical observers under normal conditions.

[13] Magnitudes will be discussed later in this chapter.

Table 1.1 Resolutions & limiting magnitudes for different apertures

D (cm)	5.0	6.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
r (arcsec)	2.77	2.3	1.85	1.38	1.11	0.92	0.79	0.69	0.65	0.55
r_D (arcsec)	2.32	1.9	1.54	1.16	0.93	0.77	0.66	0.58	0.52	0.46
m_L	11.2	11.5	12.1	12.7	13.2	13.6	13.9	14.2	14.5	14.7

Sometimes, when conditions permit, it may be possible to improve your visual limiting magnitude by using a higher magnification, because this reduces the total amount of light from the sky background.

Again, it is worth stressing that factors such as observing skill, atmospheric conditions, the magnification used and even the physiological structure of an observer's eyes (we're all different!) can and does influence the limiting magnitude observed, and any figures quoted are approximate.[14]

Table 1.1 gives the Rayleigh resolution, r, Dawes resolution, $r_{D,}$ and limiting magnitude, m_L for those telescope apertures most commonly used by amateurs.

Field of View

The field of view of binoculars and telescopes is an important topic. Field of view defines how much of the sky you see through your equipment and can vary from 30° to 80°, depending on the type of eyepiece you use.

The field of view of a telescope (FOV) is given by

$$FOV = \frac{FOV \text{ of eyepiece}}{\text{Magnification}}$$

This equation shows that when the magnification increases, the size of the amount of sky visible decreases. This is why it is so important to center any object you view in eyepiece before switching to higher magnifications, especially with faint and small objects such as, say, planetary nebulae. If you don't do this and the object is off-center, switching to a higher magnification will result in your losing

[14]Many popular astronomy books will tell you that the faintest, or limiting magnitude, for the naked eye is around sixth magnitude. This may well be true for those of us who live in an urban location. But the truth of the matter is that from exceptionally dark sites with a complete absence of light pollution, magnitudes as faint as eight can be seen. This will come as a surprise to many amateurs. Furthermore, when eyes are fully dark-adapted, the technique of averted vision will allow you to see with the naked eye up to three magnitudes fainter! But before you rush outside to test these claims, remember that to see really faint objects, either with the naked eye or telescopically, several factors mentioned in the text will need to be taken into consideration, with light pollution as the biggest evil.

the object, and a frustrating time can ensue as you try to find it again. Always center objects in the eyepiece initially.[15]

Of course, in order to use the above formula, one needs to know, or determine, the field of view of an eyepiece. Fortunately, this is very easy. Locate a star that lies on or very close to the celestial equator – α Aquari and δ Orionis are good examples – and set up the telescope so that the star will pass through the center of the field of view. Now, using any fine controls you may have, adjust the telescope in order to position the star at the extreme edge of the field of view. Turn off any motor drives and measure the time t it takes for the star to drift across the field of view. This should take several minutes and seconds, depending on the eyepiece used. Then multiply this time by 15, to determine the apparent field diameter of the eyepiece, conveniently also in minutes and seconds – but minutes and seconds of arc, rather than of time.

If you have to use a star that does not lie on or close to the celestial equator, then the formula $15t \cos \delta$, where δ is the declination of the star, can be used to find the apparent field diameter of the eyepiece in minutes and seconds of arc.

All of the previous sections have dealt with parameters that are defined by the optics of the system you are using. Let's now look at a factor that is beyond the control of most of us – the atmosphere.

Atmospheric Effects

No matter what sort of equipment you have, whether it is a pair of binoculars, a small telescope, or a large-aperture "light-bucket," all equipped with superb optics and a rock-solid mount, there is one element that can reduce us all to equals, and this is the atmosphere we live in. Of course, we have to breathe, but it really is the bane of astronomers the world over! There are three things to discuss – transparency, seeing and light pollution.[16]

Transparency

The term *transparency* is used to define the clarity of the atmosphere, an important factor when taking long-exposure photographs or measurements. It is dependent on the altitude of your observing site, and there are several components which contribute to the transparency: clouds, fog, mist, smoke and particles suspended in the air. Such is the effect of these components that even under what may be considered

[15] With some observations it may be necessary to off-center the object in order to locate fainter and more elusive structure within an object. This is good and proper observing technique, but center it first, then move off.

[16] I have included light pollution under this heading since, without an atmosphere, there wouldn't be any light pollution!

perfect conditions, a star always appears nearly three magnitudes dimmer at the horizon than it would at the zenith.

Other factors can also affect transparency. Living near built-up areas and even aurora in the upper atmosphere can dim the stars.

Seeing

Seeing is something everyone is familiar with if they trouble to look, for the twinkling of the stars is dependent upon the condition of the atmosphere – whether the air is steady or turbulent. Seeing affects the quality of the telescopic image in that it can cause the image in the telescope to dance about, or deform the image, or even do both simultaneously.

The twinkling, or scintillation, comes about when the temperature of the air changes, altering the air's refractive index and hence causing the image to flicker. Surely everyone has noticed the scintillation that Sirius exhibits when it is close to the horizon on cold winter nights? It twinkles in all the colors of the rainbow as different wavelengths are dispersed by the atmospheric turbulence!

Seeing can be also be divided into two components, sometimes referred to as "high" and "low" seeing. High seeing is due to air currents found at altitudes of 1,000 m and more, and causes the movement of an image in the field of view as mentioned above. Low seeing, as you might expect, depends on local conditions near ground level and also within a dome or telescope; for example, warm air trapped inside a dome or telescope tube causes the air to become unsteady.[17]

Telescopes with different apertures are affected in different ways. One with a large aperture "sees" a larger cross-section of turbulent air and so may produce a more deformed image than a smaller-aperture one.

Light Pollution

It is a sad reflection on our times that nearly all amateur astronomers are familiar with, and complain of, light pollution. It has grown alarmingly over the past few decades, and although steps are being made to reduce it, it marches ever onward.

The cause of the problem is predominantly street lighting, shining up into the sky and being scattered and reflected throughout the atmosphere. This glow of diffuse light is instantly recognizable as the orange radiance seen over most of the horizon and extending quite high into the sky. From urban sites, it severely limits what can be seen, particularly of the fainter nebulae and galaxies.

[17] A surprising result is that when the transparency is poor, the seeing can be good. For example, if the there is a slight haze in the air, as on autumn evenings, the atmosphere will be still, and this is often a good time for planetary observation. Similarly, when the transparency is good, and the stars appear as bright sharp points, the seeing can be at its worst. These nights, however, are perfect for observations of nebulae and galaxies.

The good news is that most of the brighter objects talked about in this book can be seen from a town location.

There are two practical solutions to the problem of light pollution: (1) use filters to block it out,[18] and/or (2) make your observations from a dark location. The first may be of little use to the binocular observer but should be a weapon in the arsenal of every telescope user, while the second may be impractical for casual observers or those of us with big telescopes or permanently located observatories.

However, observing from a dark sight is a truly awe-inspiring experience. The experience of being unable to discern the constellations because of the plethora of stars visible is breathtaking, as is being able to see most of the Messier objects in Sagittarius with the naked eye! If you ever have the opportunity to observe from a really dark location, then take it![19] It also makes sense to observe after it has rained, as rain removes some of the dust and larger pollutant particles in the air, thus reducing the scattering of street light.

The three atmospheric variables mentioned above – transparency, seeing, and light pollution – all have an influence on what can be observed, and thus you should always record them. Any classification you use will always be of a subjective nature, and writing "poor" as a description of the conditions will not usually provide much information, at least for other people. Several observing scales have been introduced, and the one most widely used is the Antoniadi scale. It was originally intended for lunar and planetary work, but is just as applicable for other objects. You can write it down in "shorthand" like this:

1. Perfect seeing, no movement whatsoever.
2. Moments of calm lasting several seconds, with some slight undulation.
3. Moderate seeing, accompanied with large air tremors.
4. Poor seeing, accompanied by constant air tremors.
5. Bad seeing, preventing any worthwhile observing to be made.

That's enough about seeing. Now let's turn our attention to two matters that will allow you, when you have mastered them, to observe faint objects – *dark adaption* and *averted vision*.

Dark Adaption and Averted Vision

The eye is a very complicated optical device. It uses a simple lens to focus light onto the retina, and changes focus by altering the geometry of the lens itself.

[18] A discussion on light pollution filters can be found in the appendices.

[19] Note that the term "dark sky" refers to a sky that is clear, free of light pollution, and transparent – not one that is very black. In fact, contrary to popular belief, the more light that is seen from stellar objects, the brighter the sky will appear to be. From exceptionally "dark" sites, the light from the stars, Milky Way, zodiacal light, galaxies, and so on., will all combine to brighten the night sky. With such a "dark sky" objects with very faint magnitudes can be observed.

The retina – the light-sensitive inside back surface of the eye – is composed of two sorts of photosensitive cell, *rods* and *cones.* These cells are packed closely together, stacked rather like the pile in a carpet. The cones are responsible for the perception of color and for our excellent daytime color vision; they also enable us to see fine detail. The rods, on the other hand, are sensitive to very low levels of illumination (and also to movement) but produce a low-resolution image and do not discriminate different colors. These different photosensitive cells are mixed together in the retina, but the concentration of each type is not even – there are many more rods toward the edge of the retina, and more cones near the eye's optical axis. Right in the center of the retina is a small area called the *fovea centralis*, where there are no rods at all and the cones are packed extremely densely. This area is about 600 μm[20] in diameter, and is the part of the retina that provides the highest resolution of detail; however, the absence of rods makes it relatively insensitive to light.

The eye has three mechanisms for regulating the amount of light reaching the retina. Short-term and fairly small variations are dealt with by the iris, which opens and closes to adjust the size of the eye's aperture. There is also a safety system (rather like that on the Hubble Space Telescope) that rapidly closes our eyelids if the light is too bright. The third mechanism is chemical in nature and varies the sensitivity of the retina itself, like using fast or slow film in a camera. It is this chemical mechanism that causes the most dramatic change in the eye's sensitivity to light.

When you leave a brightly lit room and go outside and observe you can only see a few stars, but after a period of time, which can be as short as 10 min, it becomes apparent that more stars are becoming visible. In fact, after a period of about 15 min, the eye is six times more sensitive to low light levels than it was immediately after leaving a lit room. This is the process of *dark adaption*. If you spend even longer in the dark – at least 30 min – then the rod cells, located, you will remember, mostly nearer the edge of the retina, can become nearly *one thousand* times more sensitive.

That's why it really is very important to allow time for your eye to become adapted to the darkness before you start to observe. Try to make sure that no bright light can interfere with your observing (as this will destroy your dark adaption, and you will have to wait another 30 min before you begin observing again). Such is the sensitivity of the eye that even bright red light can affect your adaption, so a dull red light should be used. Indeed, some experienced observers place a thick black cloth over their heads before beginning observations (and yes, it may look silly, but it works really well!) to totally exclude even the minutest trace of light. It's worth thinking about keeping your eyes dark adapted and allowing the needed time – it really does work, as faint objects will be much easier to locate.

A possible problem can arise for double star observers because of the eye's response to differing levels of illumination. The cones, which are responsible for

[20] A μm is one millionth of a meter, often called a micron.

color vision, peak at about 550 nm, that is, in the yellow-green region of the spectrum, while the rods peak at about 510 nm, the green region of the spectrum. This shift in sensitivity is called the *Purkinje effect* and may result in an observer underestimating the magnitude of a bright and hot star when comparing it with a cool, fainter one. This is also the reason why moonlight appears bluer than sunlight.

When you look directly at an object, you are using the fovea centralis, because it is in the optical center of the retina, and probably some of the surrounding area of the retina in which there are relatively few rod cells. The human eye has evolved to provide us with high-resolution vision in daylight, along with low-resolution but sensitive night vision, particularly at the periphery – for daytime hunting and night-time avoidance of predators!

Observers can consciously make use of the sensitive rod cells to look at faint objects. This is the technique of using averted vision. It may go against all your experience, but don't look directly at the object. Instead, look to one side of it, shifting your gaze from one side of the object to the other. This works surprisingly well, and much more detail becomes apparent than you would expect.

It works best with very faint objects, of course, and should be the principal method of observation of such objects.[21]

Clothing

This may seem a strange topic to include, but, as experienced observers know only too well, if you are not kept reasonably warm while you observe then in only a very short time you will be far too cold to even make any pretence of observation. Basically, common sense should prevail, and even if you don't actually wear any thick clothing to begin with, it should be available as the temperature drops. Nothing spoils a clear night's observing more than having cold hands and feet.

Those of us familiar with the climate of northern Europe know that even in early and late summer, when the days may be warm and sometimes hot, the nights can be quite chilly. So to be sensible, take gloves and a hat (a very important piece of apparel), have a thick coat to hand, and wear thick shoes. Shoes with thick insulating soles – such as air-sprung sports shoes – are good. During winter nights, when the skies can be glorious, the temperature can easily fall way below freezing, and warm clothing is a necessity. It also helps if you can keep out of any wind, as this will soon sap any heat from you. Several layers of loose clothing are preferable to one thick layer, as they trap pockets of air that are then warmed by your body heat.

[21] There is another phenomenon that is applicable to observing, namely the Troxler phenomenon, which basically means that any image that remains on the same area of the retina for any amount of time will be ignored by the brain and seem to disappear. Thus, when observing, move your eyes about. The inverse is true as well, in that you should rest your eyes from time to time.

One last piece of advice in this section is to know when it's time to stop observing! This is usually when your teeth are chattering and your body is shaking from the cold.[22] This is the time to go indoors and have a hot drink, looking back in your mind over the incredible sights you have seen earlier that evening.

Recording Observations

This is a subject that, for some unknown reason, is often ignored by many amateur astronomers. If you are just casually observing, sweeping the sky at leisure, then recording your observations may indeed be superfluous, but once you start to search out and observe specific objects, like the stars, nebulae and galaxies found within this book, then note-taking should become second nature, if only to make a checklist of the items you have seen.

Basically, you should record the object viewed, the time of the observation,[23] the telescope used (with eyepiece and magnification), the seeing and transparency, and maybe a brief description of the object and a sketch. These notes can then, if needs be, be copied into more formal notes later, preferably the next day. (Your initial notes should always be made at the telescope, so as to keep as accurate a record as possible.) Some observers use a separate book or notepad for each type of object observed. A pocket dictation machine can be a quick and easy substitute for the notebook (apart from the sketch!). Whatever method you use, keeping a record will help you keep track of your observations and will help you to become a better observer.

The Science of Astronomy

This book was written for non-professional astronomers who want to observe the night sky, and doesn't deal in any great depth with the physics and mathematics of the subject – that is, astrophysics. There are plenty of books available that do that.

But it is inevitable that throughout this book, terms will arise that need defining, such as magnitude, light-years, right ascension and declination, and later, the spectral sequence,[24] galaxy classification, and so on and so forth. Therefore we will explain some of these terms, even if you are already familiar with them. These are:

- Angular measurements
- Date and time
- Coordinate astronomy

[22] Believe it or not, many observers, myself included, have reached this stage on several occasions, not wanting to waste a minute of a clear night!

[23] A discussion of the time coordinates used in astronomy is found later in this chapter.

[24] The descriptions of the spectral sequence and galaxy classification are given later in the book.

- Distances in astronomy
- Magnitudes
- Star maps

Angular Measurements

In some areas of astronomical observing it is useful to be able to estimate angular distances by eye alone.

From the horizon to the point directly above your head – the zenith – is 90°. If you look due south and scan the horizon going from south to west, continuing to the north, then east and back to south, you will have traversed 360°. The angular diameter of the Moon and also of the Sun is 0.5°. Other distances that may be useful are:

δ–ε Orionis	1.25°
α–λ Aquilae	2°
δ–ζ Orionis	3°
α–β Canis Majoris	4°
α–β Ursae Majoris	5°
α–δ Ursae Majoris	10°

Further approximate distances are:

The width of the nail of your index finger at arm's length	1°
The width of your clenched fist held at arm's length	8°
The span of your open hand held at arm's length	18°

Date and Time

We are all familiar with the passing of time – day and night, autumn following summer, family birthdays, and so on. But in astronomy accurate measurements rely on the accurate determination of the time of the observation. Not surprisingly, there are many time systems used, but we shall limit ourselves to only a few.

When you are making notes at the telescope, there is a standard way to record the date and time, usually in units of increasing accuracy, for example:

2020 February 2d 2 h 22 m 2.4 s
or
2020 February 2.204

A time system that is often seen, but little understood, is the *Julian date, JD.* This is the number of days that have elapsed since midday at Greenwich on 4713BC January 1. The reason for such a strange date is that it doesn't rely on any secular calendar, and to find any astronomical events we may wish to look at that may have happened in the past. For example, the past return of comets have positive dates. To calculate a Julian date is rather longwinded, and the interested reader is referred to any of the textbooks mentioned in the appendices of this book.[25]

The *apparent solar day* is the interval between two successive transits of the Sun. It is a measure of the motion of the Sun across the sky. However, as Earth's orbit is elliptical, this interval changes slightly throughout the year, and so the *mean solar day* is also used. This is the time interval between two successive transits of the mean Sun, which is thus equal to the mean value of the apparent solar day. The mean solar day is the time interval we are all used to in day-to-day timekeeping.

Greenwich Mean Time, GMT, is the mean solar time at the longitude of Greenwich, England, starting from midnight. It is also known (more correctly) as *Universal Time,* UT. All astronomical observations should be quoted in UT, even though this may need some recalculating if you don't live near the Greenwich meridian. There are many ways to determine the UT, but the easiest is probably to use some sort of planetarium software that can easily determine the UT at your location (in addition to several hundred other parameters as well!).

Coordinate Astronomy

Throughout this book you will see that all the objects listed have definite coordinates, namely *right ascension,* RA, *and declination,* Dec. These allow you to locate, with the use of star maps, the position of any celestial body.[26] Because the vast majority of astronomical objects observed in the universe are so faint that to locate them by visual techniques is impossible,[27] a coordinate system – rather like a map reference – was devised. The RA and Dec (as they are usually referred to) are the terrestrial equivalents of longitude and latitude. The system may initially look complicated, but once mastered it is extremely useful, and indeed indispensable.

Any book on basic astronomy will explain the details of the system, so here we are just highlighting the more important topics.

Basically, try to visualize the stars placed on the surface of a sphere, with the observer at its center. This is the "celestial sphere." Now imagine Earth's equator and North and South Pole projected onto this celestial sphere. We call these the "celestial equator" and "celestial north and south poles."

[25] The modified Julian date, MJD, is the number of days that have elapsed since Greenwich Midnight 1989 June 7.75.

[26] There are several other coordinate systems in use in astronomy – horizontal, ecliptic, galactic, heliocentric – and descriptions of them can be found in most astronomy textbooks.

[27] Nearly all the objects in this book are visible to the naked eye, or in binoculars or small telescopes.

The RA is measured east of the equivalent of the Greenwich meridian and is described not in degrees but in hours, minutes and seconds, with the Greenwich meridian at 0^h. Declination is a measurement above and below the celestial equator: above (north of) the celestial equator is preceded by a plus sign (+), and below (south of) with a negative sign (−). The units of declination are in degrees (°), minutes (′) and seconds (″). Using these coordinates, the position of any object may be located in the sky.

Finding a given object in the sky can sometimes be a problem, even when you know the RA and Dec. There are several possible approaches. A detailed knowledge of the night sky is something that is to be built up over time, and so eventually you will have an idea of where the object should be, but this background information isn't likely to be acquired overnight!

A popular technique is *star-hopping*. You begin by locating the position of the object on a star map, and then you try to see if there are any bright stars nearby that you can use as signposts to the fainter object, moving the telescope from one to another until you finally have your target in your field of view. This is actually quite a good way of finding double stars, nebulae and galaxies, which may reside in unfamiliar parts of the sky.

But even this technique has its limitations, especially with the very faint objects and those that lie in parts of the sky where there are few bright stars. In such cases the next alternative is to use *setting circles,* which should be on the telescope. Many people find using setting circles difficult, yet spending a few minutes aligning them can allow you to locate many faint and hitherto unobserved objects. In order to use setting circles correctly, the telescope needs to be equatorially mounted and polar-aligned. A telescope that is equatorially mounted has its polar axis pointing to the north celestial pole (NCP) and its declination axis at right angles to it. This is illustrated in the diagram that follows.

The advantage of such a mounting is that once an object is located within the field of view, it is necessary only to move the telescope in right ascension in order to track it across the sky as Earth rotates. Most amateur astronomers use portable telescopes, and it is imperative that if you have one of these you correctly align the polar axis so that it points towards the NCP. Different telescope manufacturers recommend different methods of doing this. Most involve at least a degree of trial and error (Fig. 1.1).

For short-term visual observing, it is perfectly acceptable to try to align the axis on Polaris, the Pole Star. In most cases this suffices to track an object; however, after a few hours it will be necessary to realign the telescope. Some telescopes are equipped with a small polar alignment finder scope as part of the main telescope body or mounting, which allows you to set up the axis such that it is correctly positioned.

Having aligned the telescope, you can now begin to use the setting circles. Do it like this.

First find a bright star, for example Vega (α Lyrae), and center this in the telescope. You need to know the RA and Dec of Vega; they are $18^h\ 35.9^m$: 38° 47′.

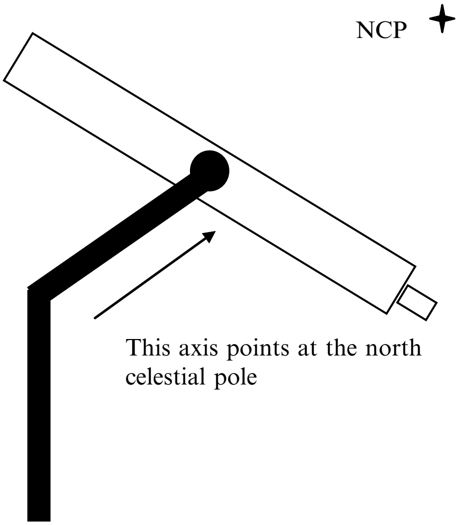


Fig. 1.1 An equatorially mounted telescope with its polar axis pointing to the north celestial pole, *NCP*

A book (including this one!), a chart or planetarium software will give you the figures you need.

Now align the setting circles so that the RA and Dec are at the coordinates of (in this case) Vega. The telescope having been aligned for Vega, it will now be set up for locating any other object.[28] It may seem a cumbersome procedure, but it will, rest assured, be a great advantage.

Finally, there are computer-controlled "go-to" telescopes. These have recently achieved affordable prices and great popularity. It is true to say that they have revolutionized amateur astronomy. Along with motor drives on both the RA and Dec axes, they also come equipped with a database of at least several thousand stars, nebulae, galaxies and the planets. All you have to do to find an object is key in its reference number (or RA and Dec coordinates), and the telescope will automatically slew to the desired position.

These are fantastic telescopes because they allow you to spend much more time observing an object, instead of trying to find it! They open up the field of deep-sky observing like no other product.

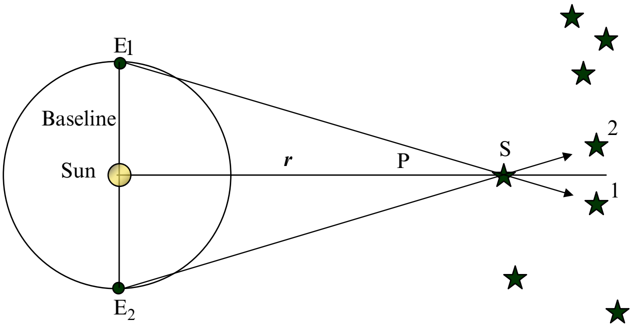
[28]It is important to remember that the setting circles will be accurate only if the telescope is equatorially mounted. This means that the Dec axis points to the north (or south) celestial pole. Several telescopes that have an alt-azimuth mount have a "wedge," which allows you to tilt the telescope so that it is correctly mounted.

Distances in Astronomy

The best-known unit of astronomical distance is the *light year*. Simply put, it is the distance that electromagnetic radiation travels in a vacuum in 1 year. As light travels at a speed of 300,000 kilometers per second (kms^{-1}), the distance it travels in 1 year is 9,460,000,000,000 km, which is close enough to call it 10 trillion kilometers! Light year is often abbreviated to l.y.

The next most commonly used distance unit is the *parsec*. This is the distance at which a star would have an annual parallax of 1 s of arc, hence the term parallax second. The parallax is the angular measurement that is observed from Earth when an object (a star or nebula) is seen from two different locations in Earth's orbit, usually 6 months apart. It appears to shift its position with respect to more distant background stars, and an object that appears to shift by 1 s of arc will lie at a distance of 3.2616 l.y.

The following diagram should help; *r* is the distance, in this case one parsec, and *P* is the parallax, of 1 arcsec.



The Star, S, when observed from Earth at E_1, is in the direction of background star 1. Six months later, when star S is observed from Earth at E_2, S is in the direction of background star 2. This apparent change in direction results from being observed at the two ends of the baseline, which is 2 AU long.

Another unit of distance sometimes used is the a*stronomical unit,* AU, which is the mean distance between Earth and Sun and is 149,597,870 km. Note that one light year is nearly 63,200 AU.

Magnitudes

The first thing that strikes even a casual observer is that the stars are of differing brightness. Some are faint, some are bright, and a few are very bright; this brightness is called the *apparent magnitude* of a star. The apparent part means this is how bright a star apparently looks, irrespective of its actual energy output or whether it is close to us or distant.

The origins of this brightness system are historical, when all the stars seen with the naked eye were classified into one of six magnitudes, with the brightest being called a "star of the first magnitude," the faintest a "star of the sixth magnitude." Since then the magnitude scale has been extended to include negative numbers for the brightest stars and decimal numbers used between magnitudes, along with a more precise measurement of the visual brightness of the stars. Sirius has a magnitude of −1.44, while Regulus has a magnitude of +1.36. Magnitude is usually abbreviated to *m*. The odd thing here to note is that the brighter the star, the smaller the numerical value of its magnitude, terminology that astronomers are happy with but the rest of the world dislikes intensely.

Because we shall be using the magnitude system from this point on for every single object under discussion, it's worthwhile looking at it in greater detail.

A difference between two objects of one magnitude means that the object is about 2.512 times brighter (or fainter) than the other. Thus a first-magnitude object (magnitude $m=1$) is 2.512 times brighter than a second-magnitude object ($m=2$). This definition means that a first-magnitude star is brighter than a sixth-magnitude star by the factor 2.512 raised to the power of 5. That is a hundredfold difference in brightness.

The naked-eye limit of what you can see is about magnitude 5, in urban or suburban skies. Experienced observers report seeing stars and deep-sky objects as faint as magnitude 8 under exceptional conditions and locations, and these are the subject of a later chapter.

However, the magnitude brightness scale doesn't tell us whether a star is bright because it is close to us, or whether a star is faint because it's small or because it's distant. All that this classification tells us is the *apparent magnitude* of the object – that is, the brightness of an object as observed visually, with the naked eye or with a telescope.

A more precise classification is the *absolute magnitude*, *M*, of an object. This is defined as the brightness an object would have at a distance of 10 pc from us. It's an arbitrary distance, deriving from the parallax technique of distance determination discussed earlier. Nevertheless, it does quantify the brightness of objects in a more rigorous way. For example, Rigel has as an absolute magnitude of −6.7, and one of the faintest stars known, Van Biesbroeck's Star, has a value of +18.6.

Of course, the above all assumes that we are looking at objects in the visible part of the spectrum. It shouldn't come as any surprise to know that there are several further definitions of magnitude that rely on the brightness of an object when observed at a different wavelength, or waveband, the most common being the U, B and V wavebands, corresponding to the wavelengths 350, 410 and 550 nm, respectively.

There is also a magnitude system based on photographic plates: the *photographic magnitude*, m_{pg}, and the *photovisual magnitude*, m_{pv}. Finally, there is the *bolometric magnitude*, m_{BOL}, which is the measure of all the radiation emitted from the object.[29]

[29] It is interesting to reflect that *no* magnitudes are in fact a true representation of the brightness of an object, because every object will be dimmed by the presence of interstellar dust. All magnitude determinations therefore have to be corrected for the presence of dust lying between us and the object. It is dust that stops us from observing the center of our galaxy.

From this point forward, wherever you see a reference to the "magnitude" of an object, it is referring to its apparent magnitude, unless stated otherwise.

Star Maps

The night sky can be a confusing place, even to a naked-eye observer, and through binoculars or a telescope even more so, with its myriad stars, clusters, nebulae and galaxies. To make sense out of this apparent confusion, there is one item that should rank alongside a telescope and few decent eyepieces as an essential piece of equipment, and that's a star atlas.

Throughout this book you'll find several star maps, to help you to locate the constellations and the objects within them. These maps are very simple and are meant to be signposts to their approximate location of the objects in the sky; they are not meant to be detailed charts and should not be treated as such.

With this in mind, it cannot be stressed too highly the importance in getting a detailed star map, as this allows you to plot the location of the objects listed in this book and subsequently help you find them. An example of a good pocket-sized star atlas is *The Observer's Sky Atlas*, by E. Karkoschka; this book is, incidentally, a perfect companion to this volume. Various other star atlases are available[30] that show objects down to much fainter magnitudes and should be in the library of any serious observer.

A recent addition to the amateur astronomer's arsenal is the planetarium, or computerized star atlas. There are numerous computer programs that will plot a virtual night sky, for whatever time and location you desire. They range in sophistication from very simple "star atlas" types, showing just the basic constellations and objects contained therein, to the more detailed "ephemeris" type, which have stars and other celestial objects such as galaxies and nebulae, often down to a magnitude of 12 and even fainter. Several of them also possess the ability to guide and control various commercially made telescopes.

And Finally…

Having read this first chapter, you should now have some idea of what's in store for you, and be at least theoretically familiar with the techniques that will allow you to become a competent observer. Before you rush outside, let's just finish with a few words of prudence.

Success in astronomy, like any hobby or pastime (or lifelong devotion!), gets greater with time. The longer you spend observing, the better you will become.

[30] These atlases are listed in Appendix B of this book.

It won't be too long before you are familiar with most of the objects in this book and know how to locate them without recourse to a star map. You will also, it is hoped, glean some background information as to the origin and structure of these fascinating and beautiful objects. Remember that success in seeing all the objects that you observe – or try to observe – will depend on many things: the seeing, the time of year, the instruments used, and even your state of health!

Don't be despondent if you can't find an object the first time around.[31] It may be beyond your capabilities, at that particular time, to see it. Just record the fact of your non-observation, and move onto something new. You'll be able to go back to the elusive object another day, or month. It will still be there. Take your time. You don't need to rush through your observations. Try spending a long time on each object you observe. In the case of extended objects (nebulae, galaxies and star clusters) it is sometimes very instructive and fascinating (and often breathtaking) to let an object drift into the telescope's field of view. You'll be surprised at how much more detail you will seem to notice.

Finally, although this book includes many of the famous objects, if your favorite was omitted, we apologize! To include everybody's favorite would be a nice idea, but an impossible task.

Astronomy is a remarkable and exhilarating science, in which amateur astronomers can participate.

We live in exciting times. Above all else – enjoy yourself!

[31]It is often useful to be able to determine the night sky's observing conditions (light pollution, haze, cloud cover, transparency) before starting an observing session, so as to determine what type of objects will be visible and even allow you to decide whether observing is viable at all. A good way to do this is to use a familiar constellation, which should be observable every night of the year, and estimate what stars in the constellation are visible. If only the brighter stars are visible, then this would limit you to only bright stellar objects, while if the fainter stars in the constellation can be seen, then conditions may be ideal to seek out the more elusive, and faint objects. A favorite constellation used by many amateurs for just such a technique is Ursa Minor, the Little Bear. If, once outside, you can see υUMi (mag 5.2) from an urban site, then the night is ideal for deep-sky observing. However, if υ UMi is not visible, then the sky conditions are not favorable for any serious deep-sky observing, but casual constellation observing may be possible. If the stars δ, ε and ζUMi, located in the "handle" of the Little Bear, are not visible (magnitudes 4.3, 4.2 and 4.3 respectively) then do not bother observing at all, but go back indoors and read this book.

Chapter 2

The Stars

This chapter deals with those objects that are easily the most familiar to us all, whether astronomers or not – the stars. Stars are the first things you notice in the sky as soon as you step out on a clear night, and for most of us they are usually the initial target of any observing session, whether it be to align the telescope or judge the seeing conditions.

You may be forgiven in thinking that one star looks very like another, and to a casual observer this may well be true, whereas experienced amateurs will know that the stars differ from each other in many fascinating ways and are a rich source for study. This chapter looks at the brightest and nearest stars, along with double, triple and even quadruple star groupings. Also included are examples of the different spectral classification types of stars. There's even a section devoted to colored stars!

But before we start looking at the stars themselves, it is important that we cover some basic astrophysics, and it will be basic! From this point on, we will be mentioning such topics as luminosity, spectral classification, and so on, so let's begin by explaining in detail what is meant. It is no use, and indeed pointless, if certain details about a star are given without an explanation of what is meant by the information.

Starlight

When you go out into the evening, the only immediate difference you notice between the stars is their brightness, or magnitude. Yet most amateur astronomers are aware that some stars are called white dwarfs, while others are red giants.

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_2,

Some are old stars, while there are a few that are relatively young. How were these things discovered? Furthermore, even to the untrained naked eye a few stars have a perceptible color – Betelgeuse (α Orionis)[1] is most definitely red, Capella (α Aurigae) is yellow, and Vega (α Lyrae) is steely blue. What causes stars to have such different colors, and why aren't all the stars visibly multicolored?

Well, stars can be classified into various groups, and these groups relate to the stars' temperature, size and color. In fact, the classification is so exact that in certain cases star masses and sizes can also be determined.

The history of stellar classification is a fascinating study in itself, but is not really important to us here. We will just explain the basic principles and how these are related to the stars that you observe. But before we go any further, it's probably worth discussing just what a star is!

A star is an immense ball of gas.[2]

It is as simple, or as complex, as that, whichever way you wish to look at it. Owing to its very large mass, and its concomitant strong gravitational field, conditions in the center of the ball of gas are such that the temperature can be about 10 million Kelvin. At this temperature the process of nuclear fusion occurs – and a star is born!

The gases composing the star are hydrogen, the most common element in the universe, along with some helium and then some other elements.[3] By and large, most stars are nearly all hydrogen (~75%),[4] with just a few percent helium (~24%), and very small amounts of everything else (~1%). As the star ages, it uses up more and more hydrogen in order to keep the nuclear reactions going. A by-product of this reaction is helium. Thus, as time passes, the amount of hydrogen decreases and the amount of helium increases. If conditions are right (these include a higher temperature and a large mass) then the helium itself will start to undergo nuclear fusion at the core of the star. This in turn will produce, as a by-product of the reaction,

[1] To explain how stars are named would take a book in itself. Suffice to say that many of the brighter stars were given Arabic names, for example, Betelgeuse, Rigel, and so on, for the simple reason that they were originally named by the ancient Arabian astronomers. The name in brackets signifies a star's listing in order of brightness in that particular constellation. Thus α Orionis (Betelgeuse) is the brightest star in the constellation Orion, β Orionios (Rigel), the second brightest, and so on and so forth. When all the letters of the Greek alphabet are used up, numbers are then given to the stars; thus: 1 Orionis, 2, Orionis and so on. The use of the Greek alphabet for referencing stars is called the Bayer classification system, while using a number is the Flamsteed system.

[2] In fact, the gas in a star is more properly called a plasma. A plasma is a collection of electrons and ions – atoms that have had electrons stripped from them.

[3] Astronomers call every element other than hydrogen and helium, metals. It's odd, I agree, but don't worry about it – just accept it.

[4] These percentages will of course change slightly as the star ages and uses up its store of hydrogen, thus increasing the amount of helium, and other elements.

the element carbon, and again, if conditions are suitable, this too will start to begin nuclear fusion and produce more energy.

Note that each step requires a higher temperature to begin the nuclear reactions, and if a star does not have the conditions necessary to provide this high temperature then further reactions will not occur. Thus the "burning" of hydrogen and helium is the power source for nearly all the stars you can see, and the mass of the star determines how fast, and how far, the reaction will proceed.

To determine the classification of stars one needs a spectroscope. This is an instrument that utilizes either a prism or a diffraction grating to analyze the light. You'll be aware that white light is in fact a mixture of many different colors, or wavelengths, so it's safe to assume that the light from a star is also a mixture of colors. Indeed it is, but usually with an added component. Using a spectroscope mounted at the eyepiece end of the telescope,[5] light from the star can be collected and analyzed. The end result is something called a spectrum.

Basically, a spectrum is a map of the light coming from the star. It consists of all of the light from the star, spread out according to wavelength (color) so that the different amounts of light at different wavelengths can be measured. Red stars have a lot of light at the red end of the spectrum, while blue stars have a correspondingly larger amount at the blue end. However, the important point here is that in addition to this light, there will be a series of dark lines superimposed upon this rainbow-like array of colors. These are called *absorption lines* and are formed in the atmosphere of the star. In a few rare cases, there are also bright lines, called *emission lines*. These lines, although comparatively rare in stars, are very important in nebulae.[6] The origins of the absorption lines are due to the differing amounts of elements in the cooler atmosphere of the stars absorbing the light at very specific wavelengths (recall that it was mentioned earlier that in addition to hydrogen and helium, there are also the other elements, or metals, present, although in minute quantities).

The factor that determines whether an absorption line will occur is the temperature of the atmosphere of a star. A hot star will have different absorption lines from a cool star – the classification of a star is determined by examining its spectrum and measuring aspects of the absorption lines. Thus the observational classification of a star is determined primarily by the temperature of the atmosphere and not the core temperature. The structure of the absorption lines themselves can also be examined, and this gives further information on pressure, rotation and even whether a companion star is present.

[5] Some spectroscopes place the prism or grating in front of the telescope, and thus the light from *every* star in the field of view is analysed simultaneously. This is called an *objective spectroscope*. The drawback is the considerable loss of detail about the stars, but does allow initial measurements to be made.

[6] See Chap. 4 for a discussion about the processes that make nebulæ shine.

Star Classification

Having seen how stars are distinguished by their spectra (and thus temperature), let's now think about the spectral type. For historical reasons a star's classification is designated by a capital letter; thus, in order of *decreasing* temperature, you have:

O B A F G K M[7]

The sequence goes from hot blue stars types O and A to cool red stars K and M. In addition there are rare and hot stars called *Wolf-Rayet* stars, class WC and WN, exploding stars Q, and peculiar stars, P. Furthermore, the spectral types themselves are divided into ten spectral classes beginning with 0, 1, 2, 3 and so on up to 9. A class A1 star is thus hotter than a class A8 star, which in turn is hotter than a class F0 star. Further prefixes and suffixes can be used to illustrate additional features:

A star with emission lines (also called f in some O-type stars)	e
Metallic lines	m
A peculiar spectrum	p
A variable spectrum	v
A star with a blue or red shift in the line (for example P-Cygni stars)	q

And so forth. For historical reasons, the spectra of the hotter star types O, A and B are sometimes referred to as *early-type* stars, while the cooler ones, K, M, C and S, are *later-type*. Also, F and G stars are *intermediate-type* stars.

Finally, a star can also be additionally classified by its *luminosity,* which is related to the star's intrinsic brightness, with the following system:

Hypergiants	O
Supergiants[8]	I
Bright giants	II
Giants	III
Subgiants	IV
Main sequence (dwarfs)	V
Subdwarfs	VI
White dwarfs	VII

[7] The full classification system is somewhat more complex (naturally!). It runs something like this; O B A F G M L T Y R N S. The L stars are dwarf stars, The T stars are brown dwarfs while the Y stars are sub-brown dwarfs. As of the time of writing, no Y objects have yet been discovered! The star types R, N and S actually overlap class M, and so R and N have been reclassified as C-type stars, the C standing for carbon stars. Complicated, isn't it!

[8] These can be further subclassified into Ia and Ib, with Ia the brighter.

It's evident that astronomers use a complex and seemingly confusing system! In fact several classes of spectral type are no longer in use, and the luminosity classification is also open to confusion. It will not surprise you to know that there is even disagreement among astronomers as to whether, for example, a star labeled F9 should be reclassified as G0. Nevertheless, it is the system used and so will be adhered to here. Examples of classification are:

α Boötes (Arcturus)	K2IIIp
β Orionis (Rigel)	B8Ia
α Aurigae (Capella)	G8 III
P Cygni	B1Iapeq
Sun	G2V

Let's recap what has just been discussed. You will recall that the classification was based on the detection of absorption lines, which in turn depend on the temperature of the star's atmosphere. Thus, the classification relies on the detection of certain elements in a star, giving rise to a temperature determination for that star.[9] The classification can be summarized best by Table 2.1.

Having now briefly discussed the various stellar parameters and classifications, let's begin our exploration of the night sky.

Table 2.1 Star spectral classification

Spectral-Type	Absorption lines	Temperature	Color	Notes
O	Ionized helium (HeII)	35,000 K+	Blue-white	Massive, short-lived
B	Neutral helium first appearance of hydrogen	20,000 K	Blue-white	Massive and luminous
A	Hydrogen lines singly ionized metals	10,000 K	White	Up to 100 times more luminous than Sun
F	Ionized calcium (CaII), weak hydrogen	7,000 K	Yellow-white	
G	CaII prominent, very weak hydrogen	6,000 K	Yellow	Sun is G-type
K	Neutral metals, faint hydrogen, hydrocarbon bands	4,000–4,700 K	Orange	
M	Molecular bands, titanium oxide (TiO)	2,500–3,000 K	Red	Most prolific stars in galaxy

[9] It usual for only the classes O, A, B, F, G, K and M to be listed. The other classes are used and defined as and when they are needed.

The Brightest Stars

This section describes in detail the 20 brightest stars in the sky, as seen with the naked eye. Some stars, for instance Alpha Centauri, will be visible only from the southern hemisphere, while others can be observed only from a northerly location. The stars are listed in Table 2.2, going from the brightest to the faintest, but, as you will see from the detailed descriptions, the stars (and all other objects mentioned in the book) are cataloged in such a way as to allow you to observe objects at different times of the year, from January to December. All the stars in this section are easily visible with the naked eye, even from the most heavily light-polluted areas.

Throughout the rest of the book we'll use the following nomenclature: first is the common or popular name for the object (if it has one), followed by its scientific

Table 2.2 The 20 brightest stars in the sky

	Star	Apparent magnitude (m)	Constellation
1	Sirius	-1.46_v[a,b,c]	Canis Major
2	Canopus	-0.72_v	Carina
3	Alpha Centauri A	−0.01	Centaurus
4	Arcturus	-0.04_v	Boötes
5	Vega	0.03_v	Lyra
6	Capella	0.08_v	Auriga
7	Rigel	0.12_v	Orion
8	Procyon	0.34	Canis Minor
9	Achernar	0.50_v	Eradinus
10	Betelgeuse	0.58_v	Orion
11	Hadar	0.60_v	Centaurus
12	Altair	0.77_v	Aquila
13	Acrux	0.8	Crux
14	Aldebaran	0.85	Taurus
15	Spica	1.04_v	Virgo
16	Antares	1.09_v	Scorpius
17	Pollux	1.15	Gemini
18	Formalhaut	1.16	Piscis Austrinus
19	Deneb	1.25	Cygnus
20	Mimosa	1.30	Crux

[a] Many stars are variable so the value for the apparent magnitude will change. Any variable will have the suffix v, and the value given will be the mean value.
[b] The data for the magnitude is from the SIMBAD database.
[c] In some instances the star will actually be a double or triple star system. The magnitude quoted is for the complete system and not an individual star.

designation. The next item is its position in right ascension and declination, and the final term is the date of transit at midnight (at Greenwich[10]) – this is the time when the object is at its highest in the sky[11] and so will be the best time to observe.[12]

The next line will then present information pertinent to the type of object. Thus, if it is a star, it will give its magnitudes, stellar classification and distance in light-years. If a double star is being described, then information about both components will be given, if a star cluster, its size, and so on. The positions quoted are for epoch 2000.0 and the source of data is the Hipparcos Catalogue or the SIMBAD database.

Some objects will be *circumpolar*, that is, they never set below the horizon, and thus are observable on every night of the year (weather permitting). However, this is a double-edged sword because it also means that at certain times of the year the object, be it a star, nebula or galaxy, will be so close to the horizon that it would be a waste of time trying to observe it. Use your own judgement to decide. In later sections, circumpolar[13] objects will be indicated by the symbol ©, which will be placed after the ease-of-observation designation. So for the brightest stars it will look something like this:

Popular name	Scientific designation	RA	Dec.	Date of midnight transit
Apparent magnitude	Absolute magnitude[14]	Stellar classification		Distance

You will also notice that the listings present data in two forms. If an object is at its best time to observe, i.e., the month during which it transits, then a full description will be given; however, usually lots of other similar objects will also be visible, but they may not be at their best position to be observed. In that instance, a brief reference to the month at which the object will transit is given and thus be at an acceptable position to be observed.

[10] There will be several instances when an object is not visible from northern latitudes. In such cases the transit time will be for an observer at 0° latitude and longitude.

[11] It will be due south for northern observers and due north for southern observers.

[12] Any object can of course be observed earlier or later than this date. Remember that a star or any astronomical object (except the Moon!) rises about 4 min earlier each night, nearly ½ h each week, and thus about 2 h a month. To observe any object earlier than its transit date, you will have to get up in (or stay up to) the early hours of the morning. To observe a star later than the transit date will mean looking for the object earlier in the evening. As an example, Sirius transits on January 1 at midnight, but will transit on December 1 at about 2.00 a.m., and at around 4.00 a.m. on November 1. Similarly, it will transit on February 1 at approximately 10.00 p.m., and on March 1 at about 8.00 p.m.

[13] The circumpolar objects will be those that are visible from around a latitude of 40° North.

[14] The absolute magnitude (M) is the apparent magnitude (m) an object would have if it were 10 pc distant. One parsec is 3.26 light-years.

There is one caveat however. There are several disparate lists of the 20 brightest stars that can be found on the Internet and in various books. What with new measuring techniques and observations, these lists are always being corrected and stars being added and removed. This list is as accurate as can be for summer 2010. It will change!

January

Sirius	α Canis Majoris	$06^h\ 45.1^m$	−16° 43′	January 1
-1.46_v[15]m	1.45 M	A1 V		8.58

Also known as the Dog Star, this is the brightest star in the night sky. It is the closest bright star visible from a latitude of 40°N, with a parallax of 0.3792″. When observed from northerly latitudes, it is justly famous for the exotic range of colors it exhibits owing to the effects of the atmosphere. It also has a close companion star known as the Pup, which is a white dwarf star, the first ever to be discovered. Sirius is a dazzling sight in a telescope.

Procyon	α Canis Minoris	$07^h\ 39.3^m$	+05° 13′	January 15
0.34 m	2.68 M	F5 IV		11.41

The eighth brightest star in the sky, notable for the fact that it has, like nearby Sirius, a companion star that is a white dwarf. However, unlike Sirius, the dwarf star is not easily visible in small amateur telescopes, having a magnitude of 10.8 and a mean separation of 5 arcsec.

Pollux	β Geminorum	$07^h\ 45.3^m$	+28° 02′	January 16
1.15 m	1.09 M	K0 IIIvar		33.72

The 17th brightest star is the brighter star of the two in Gemini, the other being, of course, Castor. It is also, however, the less interesting. It has a ruddier color than its brother, and thus is the bigger star.

See also:

Star	Magnitude	Month
Rigel	0.12	December
Capella	0.08	December
Betelgeuse	0.58	December
Canopus	−0.72	December

[15] Denotes that the star, and thus the magnitude, is variable.

February

See:

Star	Magnitude	Month
Sirius	–1.46	January
Procyon	0.34	January
Pollux	1.15	January
Acrux	0.8	March

March

Acrux	α Crucis	$12^h\ 26.6^m$	–63° 06′	March 29
0.8[16]m	–4.19 M	B0.5 IV + B1 V		321

The 13th brightest star in the sky, it is a double star, components about $4^1/_2''$ apart. Both stars are around the same magnitude, 1.4 for α^1 and 1.9 for α^2. The colors of the stars are white and blue-white, respectively.

See also:

Star	Magnitude	Month
Mimosa	1.3	April
Spica	1.04	April
Hadar	0.64	April
Arcturus	–0.04	April

April

Mimosa	β Crucis	$12^h\ 47.7^m$	–59° 41′	April 3
1.30_vm	–3.92 M	B0.5 III		352

The 20th brightest and penultimate star in our list lies too far south for northern observers. It occurs in the same field as the Jewel Box cluster and is a pulsating variable with a very small change in brightness.

Spica	α Virginis	$13^h\ 25.2^m$	–11° 10′	April 13
1.04_vm	–3.55 M	B1 V		262

[16] This is the value for the combined magnitudes of the double-star system.

The 15th brightest star, and a fascinating one at that. It is a large spectroscopic binary with the companion star lying very close to it and thus eclipsing it slightly. Spica is also a pulsating variable star, though the variability and the pulsations are not visible with amateur equipment.

Hadar	β Centauri	$14^h\ 03.8^m$	−60° 22′	April 22
0.60_vm	−5.45 M	B1 III		525

The 11th brightest star in the sky, and unknown to northern observers because of its low latitude, lying as it does only $4^1/_2$° from α Centauri. It has a luminosity that is an astonishing 10,000 times that of the Sun. A definitely white star, it has a companion of magnitude 4.1, but it is a difficult double to split as the companion is only 1.28 arcsec from the primary.

Arcturus	α Boötis	$14^h\ 15.6^m$	+19° 11′	April 25
-0.04_vm	−0.10 M	K2 IIIp		36.7

The fourth brightest star in the sky, and the brightest star north of the celestial equator. It has a lovely orange color. Notable for its peculiar motion through space, Arcturus, unlike most stars, is not traveling in the plane of the Milky Way, but is instead circling the galactic center in an orbit that is highly inclined. Calculations predict that it will swoop past the Solar System in several thousand years' time, moving towards the constellation Virgo. Some astronomers believe that in as little as half a million years Arcturus will have disappeared from naked-eye visibility. At present it is about 100 times more luminous than the Sun.

See also:

Star	Magnitude	Month
Acrux	0.8	March
Rigel Kentaurus	−0.01	May
Antares	1.09	May

May

Rigel Kentaurus	α Centauri	$14^h\ 39.6^m$	−60° 50′	May 1
−0.01 m[17]	4.07 M	G2 V+K1 V		4.39

The third brightest star in the sky, this is in fact part of a triple system, with the two brightest components contributing most of the light. The system contains the closest star to the Sun, Proxima Centauri. The group also has a very large proper motion (its apparent motion in relation to the background). Unfortunately, it is too far south

[17] This is the value for the combined magnitudes of the double-star system.

to be seen by any northern observer. Some observers have claimed that the star is visible in the daylight with any aperture.

Antares	α Scorpii	16^h 29.4^m	−26° 26′	May 29
1.09_vm	−5.28 M	M1 Ib+B2.5 V		604

The 16th brightest star in the sky, this is a red giant, with a luminosity 6,000 times that of the Sun and a diameter hundreds of times bigger than the Sun's. But what makes this star especially worthy is the vivid color contrast that is seen between it and its companion star, often described as vivid green when seen with the red of Antares. The companion has a magnitude of 5.4, with a PA of 273°, lying 2.6″ away.

See also:

Star	Magnitude	Month
Mimosa	1.3	April
Spica	1.04	April
Hadar	0.64	April
Arcturus	−0.04	April

June

See also:

Star	Magnitude	Month
Rigel Kentaurus	−0.01	May
Antares	1.09	May
Vega	0.03	July
Altair	0.77	July

July

Vega	α Lyrae	18^h 36.9^m	+38° 47′	July 1
0.03_vm	0.58 M	A0 V		25.3

The fifth brightest star, familiar to northern observers, located high in the summer sky. Although similar to Sirius in composition and size, it is three times as distant, and thus appears fainter. Often described as having a steely blue color, it was one of the first stars observed to have a disc of dust surrounding it – a possible proto-solar system in formation. Vega was the Pole Star some 12,000 years ago and will be again in a further 12,000 years.

Altair	α Aquilae	19*h* 50.8*m*	+08° 52′	July 19
0.77_vm	2.20 M	A7 IV – V		16.77

The 12th brightest star, this has the honor of being the fastest-spinning of the bright stars, completing one revolution in approximately $6^1/_2$ h. Such a high speed deforms the star into what is called a flattened ellipsoid, and it is believed that because of this amazing property the star may have an equatorial diameter twice that of its polar diameter. The star's color has been reported as completely white, although some observers see a hint of yellow.

See also:

Star	Magnitude	Month
Deneb	1.25	August

August

Deneb	α Cygni	20^h 41.4^m	+45° 17′	August 1
1.25_vm	−8.73 M	A2 Ia		3228

The 19th brightest star is very familiar to observers in the northern hemisphere. This pale-blue supergiant has recently been recognized as the prototype of a class of non-radially pulsating variable stars. Although the magnitude change is very small, the time scale is from days to weeks. It is believed that the luminosity of Deneb is some 60,000 times that of the Sun, with a diameter 60 times greater.

See also:

Star	Magnitude	Month
Vega	0.03	July
Altair	0.77	July
Formalhaut	1.16	September

September

Formalhaut	α Pisces Austrini	22^h 57.6^m	−29° 37′	September 5
1.16 m	1.74 M	A3 V		25.07

The 18th brightest star is a white one, which often appears reddish to northern observers owing to the effect of the atmosphere. It lies in a barren area of the sky and is remarkable only for the fact that a star close to it, which is not bound gravitationally yet lies at the same distance from Earth, is moving through space in a manner and direction similar to Formalhaut's. It has been suggested that the two stars are remnants of a star cluster or star association that has long since dispersed. This companion(?) star is an orange 6.5-magnitude object about 2° south of Formalhaut.

See also:

Star	Magnitude	Month
Deneb	1.25	August
Achernar	0.50	October

October

Achernar	α Eridani	$01^h\ 37.7^m$	−57° 14′	October 15
0.50_vm	−2.77 M	B3 Vpe		144

The ninth brightest star in the sky lies too far south for northern observers, at the southernmost end of the constellation. Among the bright stars it is one of the very few that has the designation "p" in its stellar classification, indicating that it is a "peculiar" star.

See also:

Star	Magnitude	Month
Formalhaut	1.16	September
Aldebaran	0.85	November

November

Aldebaran	α Tauri	$04^h\ 35.9^m$	+16° 31′	November 29
0.85 m	−0.63 M	K5 III		65.11

The 14th brightest star, apparently located in the star cluster called the Hyades. However, it is not physically in the cluster, lying as it does twice as close as the cluster members. This pale-orange star is around 120 times more luminous than the Sun. It is also a double star, but a very difficult one to separate owing to the extreme faintness of the companion. The companion star, a red dwarf star, magnitude 13.4, lies at a PA of 34° at a distance of 121.7″.

See also:

Star	Magnitude	Month
Formalhaut	1.16	September
Rigel	0.12	December
Capella	0.08	December
Betelgeuse	0.58	December
Canopus	−0.72	December

December

Rigel	β Orionis	05^h 14.5^m	−08° 12′	December 9
$-0.12_v m$	−6.69 M	B8 Iac		773

The seventh-brightest star in the sky, Rigel is in fact brighter than α Orionis. This supergiant star is one of the most luminous stars in our part of the galaxy, almost 560,000 times more luminous than our Sun but at a greater distance than any other nearby bright star. Often described as bluish in color, it is a truly tremendous star, with about 50 times the mass of the Sun and around 50 times the diameter. It has a close bluish companion at a PA of 202°, apparent magnitude 6.8, at a distance of 9 arcsec, which should be visible with a 15 cm telescope, or one even smaller under excellent observing conditions.

Capella	α Aurigae	05^h 16.7^m	+46° 00′	December 10
$0.08_v m$	−0.48 M	G5 IIIe		42

The sixth brightest star in the sky. High in the sky in winter, it has a definite yellow color, reminiscent of the Sun's own hue. It is in fact a spectroscopic double and is thus not split in a telescope; however, it has a fainter tenth magnitude star about 12 arcsec to the southeast, at a PA of 137°. This is a red dwarf star, which in turn is itself a double (only visible in larger telescopes). Thus, Capella is in fact a quadruple system.

Betelgeuse	α Orionis	05^h 55.2^m	+07° 24′	December 20
$0.58_v m$	−5.14 M	M2 Iab		427

The tenth brightest star in the sky, and a favorite among observers, this orange-red star is a giant variable, with an irregular period. Recent observations by the Hubble Space Telescope have shown that it has features on its surface that are similar to sunspots, but much larger, covering perhaps a tenth of the surface. It also has a companion star, which may be responsible for the non-spherical shape it exhibits. Although a giant star, it has a very low density and a mass only 20 times greater than the Sun's, which together mean that the density is in fact about 0.000000005 that of the Sun! A lovely sight in a telescope of any aperture; subtle color changes have been reported as the star goes through its variability cycle.

Canopus	α Carinae	06^h 24^m	−52° 42′	December 27
$-0.72_v m$	−5.53 M	F0 Ib		313

The second brightest star in the sky, although its position makes it very difficult to observe for northern latitudes. An intrinsically brilliant star, it is some 30 times larger than the Sun, and over 1,000 times more luminous. Its parallax is 0.0104″.

See also:

Star	Magnitude	Month
Sirius	−1.46	January
Procyon	0.34	January
Pollux	1.15	January
Aldebaran	0.85	November

The Nearest Stars

Let's now look at the nearest stars to us. The layout of this section is similar to that above. Also, several of the stars will be the same and in such a case, the information will not be duplicated, but a note will direct you to the relevant section. An important caveat is that the nearest stars to us will not necessarily be the brightest, and so some of the stars listed will be very faint and will need a correspondingly larger aperture telescope in order to be visible.

There is also an additional observing parameter, which gives an indication of the ease of observability – easy, moderate or difficult.[18]

Easy objects are within naked-eye limit, or just beyond it, and so will be relatively easy to locate.

Moderate objects include those beyond naked-eye visibility, or may be hard to detect from an urban location, thus needing a somewhat more careful approach to find and observe.

Difficult objects require very dark skies, or may lie in a sparse area of the sky, and will definitely need a telescope of moderate to large aperture.

With this information, you will not only be able to go out on any clear evening and find many different types of objects, but over time, you will improve your observing skills as you locate the fainter and thus more difficult objects.

An interesting point to note is that when you compare the 20 brightest stars with the 20 nearest stars, you will be surprised. Common sense would lead you to believe that there would be some sort of parity between the two lists. Far from it!

The brightest stars are mostly giants and supergiants (a topic we will cover later), and thus are bright due to the vast amount of energy they emit. However the nearest stars consist of red dwarfs, white dwarfs, K-type stars and G-type stars (the same spectral class as the Sun), and thus are low luminosity objects. The night sky would be very different if the closest stars were of the giant and supergiant variety! (Table 2.3).

[18]This parameter is used throughout the book but will be modified to take into account the different types of objects observed.

Table 2.3 The 20 nearest stars in the sky

	Star	Distance (l.y.)	Constellation
1	Sun	–	–
2	Proxima Centauri[a]	4.24	Centaurus
3	Barnard's Star	5.96	Ophiuchus
4	Wolf 359	7.78	Leo
5	Lalande 21185	8.29	Ursa Major
6	Sirius	8.58	Canis Major
7	UV Ceti	8.72	Cetus
8	Ross 154	9.68	Sagittarius
9	Ross 248	10.32	Andromeda
10	Epsilon Eridani	10.52	Eradinus
11	Lacaille 9352	10.74	Piscis Austrinus
12	Ross 128	10.92	Virgo
13	EZ Aquarii	11.27	Aquarius
14	Procyon	11.40	Canis Minor
15	61 Cygni	11.40	Cygnus
16	Struve 2398	11.53	Drace
17	Groombridge 34	11.62	Andromeda
18	Epsilon Indi	11.82	Indus
19	DX Cancri	11.83	Cancer
20	Tau Ceti	11.89	Cetus

[a] This also includes the group of stars Alpha Centauri A and B.

January

The Sun			January–December
–26.78 m	4.82 M	G2 V	

The closest star to Earth and the object without which no life would have evolved on Earth. It is visible every day, throughout the year, unless you happen to live in the UK or another cloudy climate.

Sirius	α Canis Majoris	06^h 45.1^m	–16° 43′	January 1
–1.46 m/+8.44 m	1.42 M/11.34 M	A1 V/DA2	8.58	Easy

The sixth closest star is also the brightest star in the night sky. It has a companion star, a white dwarf, that can be seen under excellent conditions and when its distance from the primary is at its greatest. For further details see the earlier section in this chapter on the brightest stars.

Procyon	α Canis Minoris	$07^h\ 39.3^m$	+05° 13′	January 15
0.38 m/10.7 m	2.66 M/12.98 M	F5 IV/DA	11.40	Easy

The 14th nearest star is a very easy object to observe as well as being the eighth brightest star in the sky. It is notable for the fact that it has, like nearby Sirius, a companion star that is a white dwarf. However, unlike Sirius, the dwarf star is not easily visible in small amateur telescopes, having a magnitude of 10.8 and a mean separation of only 5 arcsec.

See also:

Star	Distance	Month
Lalande 21185	8.29	March
Wolf 359	7.78	March
Ross 128	10.92	March
Epsilon Eridani	10.52	November

February

See:

Star	Distance	Month
Sirius	8.58	January
Procyon	11.40	January
Lalande 21185	8.29	March
Wolf 359	7.78	March
Ross 128	10.92	March

March

Lalande 21185	HD 95735	$11^h\ 03.3^m$	+35° 58′	March 8
7.47 m	10.44 M	M2 V	8.29	Moderate

The fifth closest star is a red dwarf star and has the eighth largest known proper motion[19] of 4.84 arcsec per year. Measurements indicate that it may have an unseen companion of very low mass.

Wolf 359	CN Leonis	$10^h\ 56.5^m$	+07° 01′	March 6
13.44_vm	16.55 M	M6.5 Ve	7.78	Difficult

[19] Proper motion is the angular change in the star's position over time, as seen from the Sun.

The fourth closest star, a red dwarf, is an extremely faint object and thus difficult to observe. It is one of the least luminous stars that can be seen. Like Barnard's Star it, too, is a flare[20] star, with a proper motion of 4.7 arcsec per year.

Ross 128	FI Virginis	11^h 47.6^m	+00° 48′	March 19
11.13_vm	13.51 M	M4.5 V	10.92	Difficult

The 12th nearest star is once again a red dwarf star and correspondingly difficult to observe.

See also:

Star	Distance	Month
Sirius	8.58	January
Procyon	11.40	January
Epsilon Eridani	10.52	November
Proxima Centauri	4.14	April

April

Proxima Centauri	V645 Cen	14^h 29.7^m	−62° 41′	April 29
11.09_vm	15.53 M	M5 Ve	4.24	Difficult

The second closest star to Earth but the closest star to the Solar System. It is a very faint red dwarf star and also another flare star, with frequent bursts having a maximum amplitude difference of around one magnitude.

See also:

Star	Distance	Month
Lalande 21185	8.29	March
Wolf 359	7.78	March
Ross 128	10.92	March
Barnard's Star	5.96	June

May

See:

Star	Distance	Month
Proxima Centauri	4.24	April
Barnard's Star	5.96	June

[20] A flare star is a star that undergoes unpredictable and often spectacular increases in brightness lasting for just a few minutes.

June

Barnard's Star	Gilese 699	17^h 57.8^m	+4° 38′	June 21
9.53 m	13.22 M	M4.0 V	5.96	Moderate

The third closest star is a red dwarf. It also has the largest proper motion of any star: 10.3 arcsec per year. Thus it would take about 150 years for the star to move the distance equivalent to the Moon's diameter across the sky. Barnard's Star is believed to be one of the oldest stars in the Milky Way, and in 1998 a stellar flare was thought to have occurred on the star. Due to the unpredictability of flares, this makes the star a perfect target for observers.

See also:

Star	Distance	Month
Proxima Centauri	4.24	April
Epsilon Indi	11.82	July
Ross 154	9.68	July
Epsilon Indi	11.82	July
Struve	11.53	July

July

Struve 2398	HD 173740	18^h 42.7^m	+59° 37′	July 2
8.9 m	11.16 M	M3	11.53	Moderate ©

The 17th closest star is one-half of one of the closest double stars to the Solar System. Both stars are red dwarfs, flare stars and a source of X-rays.

Ross 154	V1216 Sagittarii	18^h 49.8^m	–23° 50′	July 4
10.43 m	13.07 M	M3.5 Ve	9.68	Difficult

The eighth closest star is, like so many of its peers, a red dwarf star. It is a UV Ceti-type flare star, having an average time between major flares of around 2 days. Typically, the star will increase by three to four magnitudes during a flare. But note that the star is much too faint to be viewed with the unaided eye and requires at least a 65 mm telescope aperture and ideal conditions.

Epsilon Indi	HD 209100	22^h 03.3^m	–56° 47′	July 7
4.69 m	6.89 M	K5Ve	11.82	Easy

The 18th closest star is only visible to southern observers, but what makes it especially interesting is that it is believed to have two brown dwarf[21] companion stars. In addition, the star has the third highest proper motion of any star visible to the unaided eye (after Groombridge 1830 and 61 Cygni) and the ninth highest overall.

See also:

Star	Distance	Month
Barnard's Star	5.96	June
61 Cygni	11.40	August
EZ Aquarii	11.27	August

August

61Cygni A/B	Bessel's Star	21^h 06.9^m	+38° 45′	August 8
5.21/6.03$_v$m	7.49/8.31 M	K5 V/K7 V	11.40	Easy/moderate

The 14th nearest star is a famous double, the stars separated by 30.3 arcsec at a PA of 150°. Both stars are dwarfs and have a nice orange color. This was the first star to have its distance measured successfully by F. W. Bessel in 1838 using the technique of parallax.

EZ Aquarii	L789-6	22^h 38.5^m	−15° 19′	August 31
12.32 m	15.64 M	M5 Ve	11.27	Difficult

The 13th nearest star is actually part of a triple-star system, and of course, a red dwarf star, difficult to observe. The A and B components are X-ray emitters, while the C component is itself a spectroscopic binary.[22]

See also:

Star	Distance	Month
Struve 2398	11.53	July
Ross 154	9.68	July
Epsilon Indi	11.82	July
Lacaille 9352	10.74	September
GX Andromedae	11.62	September
Ross 248	10.32	September

[21] Brown dwarfs are sub-stellar objects that are too low in mass to sustain stable hydrogen fusion.

[22] A binary system that can only be detected by measuring the effect of the Doppler shift on its spectral lines.

September

Lacaille 9352	HD 217987	23^h 05.5^m	–35° 52′	September 7
7.34 m	9.75 M	K2 V	10.74	Moderate

The 11th nearest star is a red dwarf, with the fourth fastest proper motion of any known star. It traverses a distance of nearly 7 arcsec a year, and thus would take about 1,000 years to cover the angular distance of the full Moon, which is half a degree. It was the first red dwarf star to have its angular diameter measured.

GX Andromedae	Groombridge 34	00^h 18.2^m	+44° 01′	September 25
8.08$_v$m	10.32 M	M1 V	11.62	Moderate

The 17th closest star to the Solar System and the 20th closest to Earth, this is half of a noted red dwarf binary system. The primary is in itself a spectroscopic binary.

Ross 248	HH Andromedae	23^h 41.6^m	+44° 10′	September 16
12.29$_v$m	14.79 M	M5 Ve	10.32	Moderate

The ninth closest star to the Solar System is a red dwarf star and a difficult object to observe. An interesting fact: the *Voyager 2* spacecraft is traveling on a path headed roughly in the direction of this star and is expected to come within 1.76 light-years (0.54 pc) of the star in 40,176 years.

See also:

Star	Distance	Month
61 Cygni	11.40	August
EZ Aquarii	11.27	August
UV Ceti	8.73	October

October

UV Ceti	L726-8	01^h 38.8^m	–17° 57′	October 16
12.54$_v$m/12 99$_v$m	15.40 M/15.85 M	M5.5Ve/M6 Ve	8.73	Difficult

The seventh closest star is a red dwarf system and is a very difficult but not impossible object to observe. The UV prefix indicates that the two components are flare stars, and the fainter is referred to in older texts as “Luyten’s Flare Star,” after its discoverer, W. J. Luyten, who first observed it in 1949.

See also:

Star	Distance	Month
Lacaille 9352	10.74	September
GX Andromedae	11.62	September
Ross 248	10.32	September
Epsilon Eridani	10.52	November

November

Epsilon Eridani	HD 22049	03^h 32.9^m	–.09° 27′	November 13
3.73 m	6.19 M	K2 V	10.52	Easy

The tenth closest star is a naked-eye object (it is the third closest star visible to the naked eye), which some observers describe as having a yellow color, while others say it is more orange. The star is believed to the closest system that has a planet in orbit, and maybe even two. Furthermore, there is evidence that Epilson Eridani has two asteroid belts made of rocky and metallic debris left over from the early stages of planetary formation, similar to our Solar System's, and even and a broad outer ring of icy objects similar to our Kuiper Belt. All in all a very interesting star!

See also:

Star	Distance	Month
Lacaille 9352	10.74	September
GX Andromedae	11.62	September
Ross 248	10.32	September
UV Ceti	8.73	October

December

See:

Star	Distance	Month
Epsilon Eridani	10.52	November
Sirius	8.58	January
Procyon	11.40	January

The Spectral Sequence

This section will look at examples of the spectral classification of stars as discussed earlier. Even though most amateurs observe the stars without paying too much attention to their astrophysical classification, it is always a fascinating project to be able to search out and observe examples of various classes. After all, it is a system that is used by all astronomers in the world, and to be able to understand, albeit at an introductory level, how the system is applied will give you an added level of enjoyment to your observing sessions.

Several stars and their spectral classes have already been mentioned in describing the bright stars, but to cover them again serves no positive use, therefore we have tried to include stars which may not be familiar to you (But remember that all the stars you can see, either with the naked eye or binoculars or telescopes are classified in this manner, and so there is no limit, literally, to the number of stars you could observe and classify).

A point to note: Not every class is represented, as some are not used and other representative stars may be too faint and thus beyond the scope of small telescopes.[23] Also, the stars have been listed as before, by date, with those transiting at midnight having a full listing, followed by those that are in the sky, but maybe at a less than favorable position. In this way, you should be able to observe several of the classes at any given time of the year. Finally, the constellation in which the star resides is also given.[24]

January

Aludra	η CMa	$07^h\ 24.1^m$	–29° 18′	January 11
2.45 m	7.51 M	B5 I	Canis Major	Easy

A highly luminous supergiant, with an estimated luminosity of 50,000 times that of the Sun.[25]

Castor	α Geminorum	$07^h\ 34.6^m$	+31° 53′	January 14
1.43 m	0.94 M	A1 V	Gemini	Easy

[23]The values for the apparent and absolute magnitudes are taken from the Hipparchos catalog, and in nearly every star listed the values differ from those previously published (pre-Hipparchos). It is an interesting exercise to compare the old and new values, as sometimes there is a considerable difference.

[24]Note that the stars are listed in order of spectral classification.

[25]A wonderful month! A lot of stars are visible for this section.

This is part of the famous multiple-star system and fainter brother to Pollux. The visual magnitude stated is the result of combining the magnitudes of the two brighter components of the system, 1.9 and 2.9 (See also Sirius.).[26]

Velorum b	HD 74180	08^h 40.6^m	−46° 39′	January 30
3.84 m	−6.07 M	F3 Ia	Vela	Easy

This star, part of a double system, is unremarkable visually, except that its luminosity has been calculated to be that of 180,000 Suns. Due to its southerly position, it cannot be seen by northern observers, alas. Recent research suggests it may be part of the Pismis 6 star cluster and even a lower-range member of the class hypergiant,[27] a star of immense mass and luminosity.

γ^2 Vel	HD 68273	08^h 09.5^m	−47° 20′	January 23
1.99_vm	0.05 M	WC 8	Vela	Easy

The brightest and closest of all Wolf-Rayet stars, believed to be precursors to the formation of planetary nebulae. Extremely luminous, Wolf-Rayets have luminosities that may reach 100,000 times that of the Sun and temperatures in excess of 50,000 K. γ^2 Vel is an easy double, with colors of white and greenish-white.

See also:

Star	Class	Month
θ Orionis C	O7 V	December
15 Monocerotis	O7 Ve	December
Plaskett's Star	O8 I	December
i Orionis	O9 III	December
Murzim	B1 II	December
λ Canis Majotris	B4 IV	December
Alhena	A0 IV	December
β Aurigae	A2 V	December
2 Monocerotis	A6	December
Canopus	F0 I	December
111 Tauri	F8 V	December
Algeiba	G7 III	February
β Leo Minoris	G8 III	February
ν^2 Canis Majoris	K1 III	December

February

Regulas	α Leonis	10^h 08.3^m	+11° 58′	February 19
1.36 m	−0.52 M	B7 V	Leo	Easy

[26]Denotes a similar class star.

[27]If it were to be found a hypergiant, its classification would change to F3 0a.

Alpha Leonis is the handle of the Lion's sickle. It's an easy double star with an eighth-magnitude companion 3′ away, color orange-red. The companion is itself a double, but visible only in large instruments.

Algeiba	γ^2Leo	10^h 19.9^m	+19° 50′	February 25
3.64 m	0.72 M	G7 III	Leo	Easy

A famous double; most observers report orange-yellowish colors, but some see the G7 star as greenish.

β LMi	HD 90537	10^h 27.8^m	+36° 42′	February 27
4.20 m	0.9 M	G8 III	Leo Minor	Easy

A constellation in which there is no star given the classification α, β LMi has the misfortune of not even being the brightest star in the constellation; that honor goes to 46 LMi.

See also:

Star	Class	Month
Aludra	B5 I	January
Castor	A1 V	January
Denebola	A3 V	March
Delta Leonis	A4 V	March
Velorum b	F3 I	January
β Vir	F8 V	March
Gacrux	M4 III	March
γ^2 Vel	WC 8	January

March

Denebola	β Leonis	11^h 49.1^m	+14° 34′	March 19
2.14 $_v$m	1.92 M	A3 V	Leo	Easy

Several companion stars are visible in a variety of instruments. The star has only recently been designated a variable.

Zozma	δ Leonis	11^h 14.1^m	+20° 31′	March 10
2.56 m	1.32 M	A4 V	Leo	Easy

This star lies at a distance of 80 light-years, with a luminosity of 50 Suns.

β Virginis	HD 102870	11^h 50.7^m	+01° 46′	March 20
3.59 m	3.40 M	F8 V	Virgo	Easy

A close star at 34 light-years, only three times as luminous as the Sun.

Gacrux	γ^A Crucis	12^h 31.2^m	−57° 07′	March 30
1.59 m	−0.56 M	M4 III	Crux	Easy

The top star of the Southern Cross, this is a giant star. γ^A and γ^B do not form a true binary, as they are apparently moving in different directions.

See also:

Star	Class	Month
Regulas	B7 V	February
Gamma Centauri	A1 IV	April
Algeiba	G7 III	February
β LMi	G8 III	February
θ Apodis	M6.5 III	April

April

Gamma Centauri	γ Cen	12^h 41.5^m	−48° 58′	April 2
2.17 m	−0.6 M	A1 IV	Centaurus	Easy

Binary star with both members being almost identical (see Vega).

Zeta Virginis	ζVir	13^h 34.7^m	−00° 36′	April 15
3.38 m	1.62 M	A3 V	Virgo	Easy

A nice white star, also called Heze, only 30 times as luminous as the Sun and lying at a distance of 92 light-years.

θ Apodis	HD 122250	14^h 05.3^m	−76° 48′	April 23
5.69_vm	−0.67 M	M6.5 III	Apus	Easy

A reddish-tinted star that stands out nicely, in contrast to its background of faint stars. This is a semi-regular variable with a period of 119 days and a range of fifth to nearly eighth magnitude. The titanium bands are now at their strongest.

See also:

Star	Class	Month
Zubeneschamali	B8 V	May
β Leonis	A3 V	March
δ Leonis	A4 V	March
γ Herculis	A9 III	May
Zubenelgenubi	F4 IV	May
β Virginis	F8 V	March
Kornephorus	G8 III	May
ν^1 Boö	K5 III	May
Antares	M1 I	May
Gacrux	M4 III	March

May

Zubeneschamali	β Libris	$15^h\ 17.0^m$	−09° 23′	May 11
2.61 m	−0.84 M	B8 V	Libra	Easy

A mysterious star for two reasons. Historical records state that it was much brighter than it is seen today, while observers of the past 100 years have declared that it is greenish or pale emerald in color. Observe for yourself and decide if it is one of the rare green-colored stars!

Gamma Herculis	γ Her	$16^h\ 21.8^m$	+19° 09′	May 27
3.74 m	−0.15 M	A9 III	Hercules	Easy

An optical double star system lying at a distance of 144 light-years and with a luminosity of 46 Suns.

Zubenelgenubi	α^1 Lib	$14^h\ 50.7^m$	−15° 60′	May 4
5.15 m	3.28 M	F4 IV	Libra	Easy

An easily resolvable double star, α^1 is also a spectroscopic binary. The colors are a nice faint yellow and pale blue.

Kornephorus	βHer	$16^h\ 30.2^m$	+21° 29′	May 29
2.78 m	−0.50 M	G8 III	Hercules	Easy

A spectroscopic binary star, it lies at a distance of 100 light-years and is some 60 times as luminous as the Sun (See also Capella).

ν^1 Boö	HD 138481	$15^h\ 30.9^m$	+40° 50′	May 14
5.04 m	−2.10 M	K5 III	Boötes	Easy

The star lies at a distance of 385 light-years and has a luminosity of 104 Suns (See also Aldebaran).

Antares	α Scopi	16^h 29.4^m	−26° 26′	May 29
1.06_vm	−5.28 M	M1 I	Scorpio	Easy

A gloriously colored star of fiery red (or, as some astronomers of the last century observed, saffron-rose), it contrasts nicely with its fainter green companion, a giant star measured to be some 600 times the diameter of our Sun (See also Betelgeuse.).

See also:

Star	Class	Month
Eta Sagitai	B9.5 III	June
Nu Draconis[1]	Am	June
Gamma Centauri	A1 IV	April
Zeta Virginis	A3 V	April
Ras Alhague	A5 III	June
Ras Algethi[1]	G5 III	June
Ras Algethi[2]	M5 II	June
θ Apodis	M6.5 III	April

June

Eta Sagitai	ε Sgr	18^h 24.2^m	−34° 23′	June 27
1.79 m	−1.44 M	B9.5 III	Sagittarius	Easy

A brilliant orange star lying at a distance of 125 light-years with a luminosity of 250 Suns.

Nu Draconis[1]	ν^1Dra	17^h 32.2^m	+55° 11′	June 14
4.89 m	2.48 M	Am	Draco	Easy

A classic double star system easily visible in binoculars or small telescopes. Both stars are nearly identical in magnitude and stellar class and have a lovely white color.

Sarin	δ Her	17^h 15.0^m	+24° 50′	June 10
3.12 m	1.21 M	A3 IV	Hercules	Easy

A fine example of an optical double star. What is astonishing about these stars is the range of colors ascribed to them. They have been called greenish and pale violet, green and ashy white, pale yellow and bluish-green, white and azure, and finally pale yellow and ruddy purple! Spectral class indicates that the stars should be yellow and orange; what colors do you see?

Ras Alhague	α Oph	$17^h\ 34.9^m$	+12° 34′	June 15
2.08 m	1.30 M	A5 III	Ophiuchus	Easy

This is an interesting star for several reasons. It shows the same motions through space as several other stars in the so-called Ursa Major Group (see Chap. 7). It also shows interstellar absorption lines in its spectrum. Finally, measurements show an oscillation, or wobble, in its proper motion, which would indicate an unseen companion star (See β Triangulum).

Ras Algethi	α^2 Her	$17^h\ 14.7^m$	+14° 23′	June 10
5.37 m	0.03 M	G5 III	Hercules	Easy

A beautiful double star, with colors of ruddy orange and blue-green. The spectral class refers to the primary of α^2 Her, which is a spectroscopic double and thus visually inseparable with any telescope.

Ras Algethi	α^1 Her	$17^h\ 14.6^m$	+14° 23′	June 10
3.03_v m	−2.32 M	M5 II	Hercules	Easy

A fine double-star system, this M5 semi-regular star is an orange supergiant, in contrast to its companion, a blue-green giant. However, it must be pointed out here that it can be resolved only with a telescope and not binoculars, as the two stars are less than 5″ apart. The changes in brightness are attributed to actual physical changes to the star, as it increases and then decreases in diameter.

See also:

Star	Class	Month
Zubeneschamali	B8 V	May
γ Herculis	A9 II	May
Albaldah	F3 III	July
Zubenelgenubi	F4 IV	May
Kornephorus	G8 III	May
ν^1 Boö	K5 III	May
Antares	M1 I	May

July

Albaldah	π Sagittarii	$19^h\ 09.8^m$	−21° 01′	July 9
2.88 m	−2.77 M	F2 III	Sagittarius	Easy

An easily visible star that is in fact a triple-star system. However, the components can only be resolved by the largest amateur telescopes (See also β^2 Sagittarii).

See also:

Star	Class	Month
Eta Sagitai	B9.5 III	June
Nu Draconis[1]	Am	June
Deneb	A2 I	August
Sarin	A3 IV	June
Ras Alhague	A5 III	June
Alderamin	A7 IV	August
Sadal Suud	G0 I	August
Sadal Melik	G2 I	August
Ras Algethi	G5 III	June
Gienah	K0 III	August
Enif	K2 I	August
Ras Algethi	M5 II	June

August

Deneb	α Cygni	$20^h\ 41.3^m$	+45° 17′	August 1
1.25_vm	−8.73[28]M	A2 I	Cygnus	Easy

The faintest star of the famous "Summer Triangle," the others being Altair and Vega. This is a rare supergiant star with a definite pale blue color. It is also the prototype of a class of pulsating variable stars.

Alderamin	α Cephei	$21^h\ 18.6^m$	+62° 35′	August 11
2.45 m	1.58 M	A7 IV	Cepheus	Easy ©

This is a rapidly rotating star resulting in the spectral lines becoming broad and less clear. It also has the dubious distinction of becoming the Pole Star in 7500A.D. (See also Altair).

Sadal Suud	β Aquarii	$21^h\ 31.6^m$	−05° 34′	August 14
2.91 m	−3.46 M	G0 Ib	Aquarius	Easy

A giant star, and a close twin to α Aqr. It lies at a distance of 610 light-years and is 2,200 times more luminous than the Sun. The name means "luck of lucks."

Sadal Melik	α Aquarii	$22^h\ 05.8^m$	−00° 19′	August 23
2.95 m	−3.88 M	G2 Ib	Aquarius	Easy

[28] This value is in question. The data is awaiting reassessment.

Although it has the same spectral class and surface temperature of the Sun, α Aqr is a giant star, whereas the Sun is a main sequence star (See also Sun, Alpha Centauri A).

Gienah	ε Cygni	20^h 46.2^m	^{s} +33° 58′	August 2
2.48 m	0.76 M	K0 III	Cygnus	Easy

Marking the eastern arm of the Northern Cross, the star is a spectroscopic binary. In the K-class stars the metallic lines seen in the spectrum are now becoming more prominent than the hydrogen lines.

Enif	ε Pegasi	21^h 44.2^m	+09° 52′	August 17
2.40_vm	−4.19 M	K2 Ib	Pegasus	Easy

This star lies at a distance of 740 light-years with a luminosity 7,450 times that of the Sun. The two faint stars in the same field of view have been mistakenly classified as companions, but analysis has now shown them to be stars in the line of sight. Epsilon Pegasi is a type LC "slow irregular variable" star that varies from +0.7 to +3.5 in magnitude.

See also:

Star	Class	Month
Algenib	B2 V	September
Albaldah	F3 III	July
Scheat	M2 II	September

September

Algenib	γ Pegasi	00^h 13.2^m	+15° 11′	September 24
2.83_vm	−2.22 M	B2 IV	Pegasus	Easy

A member of the type β Cephei variable star. It is the southeastern corner star of the famed square of Pegasus.

Scheat	βPegasi	23^h 03.8^m	+28° 045	September 6
2.44_vm	−1.49 M	M2 II	Pegasus	Easy

Marking the northwestern corner of the Square of Pegasus, this is a red, slow, irregular variable star of the type LB, its brightness varying from magnitude +2.31 to +2.74. It is noted for having been one of the first stars to have its diameter measured by the technique of interferometry, at 0.015″. Being variable, its size oscillates, to a maximum diameter of about 95 Suns.

See also:

Star	Class	Month
Gamma Cas	B0 IV	October
Achernar	B3 V	October
Deneb	A2 I	August
Alderamin	A7 IV	August
Polaris	F7 I	October
Sadal Suud	G0 I	August
Sadal Melik	G2 I	August
ξ^1 Cet	G8 II	October
βCet	G9.5 III	October
Gienah	K0 III	August
Hamal	K2 III	October
Almach	K3 III	October
Mirach	M0 III	October
Mira	M5	October
Mira minimum	M9	October

October

Gamma Cassiopeiae	γ Cas	00^h 56.7^m	+60° 43′	October 5
2.15_vm	−4.22 M	B0 IV	Cassiopeia	Easy

A peculiar but also very interesting star. It has bright emission lines in its spectrum, indicating that it ejects material in periodic outbursts and is thus classed as an eruptive variable (it being the prototype of the class). Also, research indicates that it is a rapidly spinning star bulging outward along the equator. Thus, when combined with its high luminosity, the result is a tremendous mass loss that forms a disk around the star. The resulting emissions and observed brightness variations are apparently caused by this disk. It is a spectroscopic binary with an orbital period of about 204 days and an eccentricity alternately reported as 0.26 and "near zero." The mass of the companion is believed to be about that of the Sun. Furthermore, it is also an optical double, with a faint 11th magnitude companion, B, about 2 arcsec distant and a further, fainter, optical companion C. Finally, it is the middle star of the familiar W-shape of Cassiopeia.

Achernar	α Eridani	01^h 37.7^m	−57° 14′	October 15
0.50_vm	−2.77 M	B3 Vpe	Eradinus	Easy

A hot and blue star. It lies so far south that it can never be seen from the UK and most of the United States but is perfectly placed for southern observers. What makes this an exceptional star is that it is one of the least spherically shaped stars in the Milky Way. Due to its extremely high rotation rate, its equatorial diameter is about 50% greater than its polar diameter!

Polaris	α UMi	$02^h\ 31.8^m$	+89° 16′	October 29
1.97_vm	−3.64 M	F7 Ib	Ursa Minor	Easy ©

An interesting and famous star, even though it is only the 49th brightest star in the sky. It is a Cepheid variable type I (although it used to be classified as a type II – the W Virginis class); it will be closest to the celestial pole in 2102, and is a binary star (the companion reported as being pale bluish), being a good test for small telescopes.

ξ^1 Ceti	HD 15318	$02^h\ 12.0^m$	+08° 51′	October 24
4.36 m	−0.87 M	G8 II	Cetus	Easy

A star with an interesting background. Although about 550 times as luminous as the Sun, various measurements place it at 130, 175 and 640 light-years distant!

β Ceti	Diphda	$00^h\ 43.6^m$	−17° 59′	October 2
2.04 m	−0.31 M	G9.5 III	Cetus	Easy

The star lies at a distance of 60 light-years with a luminosity of 42 Suns. Oddly, although classified as β, indicating it is second in brightness, it is in fact brighter than α Ceti.

Hamal	α Ari	$02^h\ 07.2^m$	+23° 28′	October 23
2.01 m	0.48 M	K2 III	Aries	Easy

This star lies at a distance of 63 light-years with a luminosity 90 times that of the Sun (See also Arcturus.).

Almach	γ^1 Andromedae	$02^h\ 03.9^m$	+42° 20′	October 22
2.26 m	−2.86 M	K3 III	Andromeda	Easy

A famous and beautiful binary star. The colors are gold and blue, although some observers see orange and greenish-blue. Nevertheless, the fainter companion is hot enough to truly show a blue color. It is also a binary in its own right but not observable in amateur instruments.

Mirach	β Andromedae	$01^h\ 09.7^m$	+35° 37′	October 8
2.07_vm	−1.86 M	M0 III	Andromeda	Easy

With this stellar class, the bands of titanium oxide are strengthening. This red giant star is suspected of being slightly variable, like so many other stars of the same type. In the field of view is the galaxy NGC 404 at magnitude 12, a good test for large telescopes.

Mira	o Ceti	$02^h\ 19.3^m$	–02° 59′	October 26
2.00_vm	–3.54 M	M5	Cetus	Easy

An important star, and maybe the first variable star ever observed. Written records certainly exist as far back as 1596. The prototype of a long-period pulsating variable, it ranges from third to tenth magnitude over a period of 332 days and is an ideal star for the first-time variable star observer. It has the dubious distinction of being the brightest periodic variable that is not visible to the naked eye for part of its cycle (with the exception of the even stranger Eta Carinae!).

Mira minimum	o Ceti	$02^h\ 19.3^m$	–02° 59′	October 26
10.1_vm	–0.5 M	M9	Cetus	Difficult

At minimum, the star is a deeper red color, but of course fainter. It now has a lower temperature of 1,900 K. The period, however, is subject to irregularities, as is its magnitude. At maximum it can reach first magnitude – similar to Aldebaran!

See also:

Star	Class	Month
Algenib	B2 V	September
Electra	B6 III	November
Atlas	B8 III	November
Algenib	F5 I	November
Scheat	M2 II	September
Menkar	M2 III	November
Eta Persei	M3 I	November

November

Electra	17 Tauri	$03^h\ 44.9^m$	+24° 07′	November 16
3.71 m	–1.56 M	B6 IIIe	Taurus	Easy

Located within the Pleiades star cluster. A breathtaking and spectacular view when seen through binoculars, the cluster is a highlight of the night sky (See also Taygeta [19 Tau] and Merope [23 Tau] in the Pleiades cluster.). Electra is classified as a Be star, which is a B-type star having prominent emission lines of hydrogen in its spectrum.

Atlas	27 Tauri	$03^h\ 49.2^m$	–24° 03′	November 18
3.62 m	–2.55 M	B8 III	Taurus	Easy

A lovely blue star (See also Maia [20 Tau], Asterope [21 Tau] and Pleione [28 Tau] in the Pleiades.).

Algenib	α Per	03^h 24.3^m	+49° 52′	November 11
1.79 m	–4.5 M	F5 Ib	Perseus	Easy

The star lies within Melotte 20, a loosely bound stellar association, also known as the Perseus OB-3, or the Alpha Persei Association. About 75 stars with magnitudes down to ten are contained within the group. All are stellar infants, only 50 million years old, lying 550 light-years away. The metallic lines now increase through the F class, especially the H and K lines of ionized calcium. Has been described as having a pale yellow hue (See also Procyon).

Menkar	α Ceti	03^h 02.3^m	+0.4° 05′	November 6
2.54_vm	−1.61 M	M2 III	Cetus	Easy

An orange-colored giant star, which contrasts nicely with a fainter blue star (93 Ceti nearly at due north) that can be seen in the same field of view with small telescopes at low power.

Eta Persei	η Per	02^h 50.7^m	+55° 54′	November
3.77 m	–4.28 M	M3 I	Perseus	Easy

The yellowish star in an easily resolved double-star system. The color contrasts nicely with its blue companion.

See also:

Star	Class	Month
15 Monocerotis	O7 Ve	December
Plaskett's Star	O8 I	December
Iota Orionis	O9 III	December
Gamma Cas	B0 IV	October
λ CMa	B4 IV	December
El Nath	B7 III	December
Alhena	A0 IV	December
Beta Aurigae	A2 V	December
2 Mon	A6	December
Polaris	F7 I	October
111 Tau	F8 V	December
ξ^1 Cet	G8 II	October
βCet	G9.5 III	October
ν^2 CMa	K1 III	December
Mira	M5	October
Mira minimum	M9	October

December

15 Monocerotis	S Mon	06^h 40.9^m	+09° 54′	December 31
4.66_vm	–2.3 M	O7 Ve	Monoceris	Easy

Both a visual binary and a variable star, it is located in the star cluster NGC 2264, which in turn is encased in a diffuse nebula. About 1° south is the famous Cone Nebula, visible only in the largest amateur telescopes under perfect conditions.

Plaskett's Star	V640Mon	06^h 37.4^m	+06° 08′	December 30
6.05 m	–3.54 M	O8 I	Monoceros	Easy

This is actually composed of two stars, a spectroscopic binary system, with an estimated mass of around 110 Suns, making it one of the most massive binaries known. It can be located just east of 13 Monocerotis and may be a member of NGC 2244, which in turn is part of the famous Rosette Cluster.

Iota Orionis	ι Ori	05^h 35.4^m	–05° 55′	December 15
2.75 m	–5.30 M	O9 III	Orion	Easy

The brightest star in the sword of Orion is in fact a fine triple-star system, with reported colors of white, blue and red.

Murzim	β CMa	06^h 22.7^m	–17° 57′	December 27
1.98_vm	–3.96 M	B1 II	Canis Major	Easy

This is the prototype of a class of variable star now classified as β Cepheid stars, which are pulsating variables. The magnitude variation is too small to be observed visually (See also Spica and Beta Centauri in previous sections). An interesting aside: Murzim is located near the far end of the Local Bubble – a cavity in the local interstellar medium – through which our Solar System is traveling.

λ CMa	HD 45813	06^h 28.2^m	–32° 35′	December 28
4.47 m	–1.01 M	B4 IV	Canis Major	Easy

A nice bluish-white star.

El Nath	β Tauri	05^h 26.3^m	+28° 36′	December 12
1.65 m	–1.37 M	B7 III	Taurus	Easy

Located on the border of Auriga, it is sometimes mistakenly called γ Aurigae. It lies at a distance of 160 light-years.

Alhena	γGem	$06^h\ 37.7^m$	+16° 23′	December 30
1.93 m	–0.60 M	A0 IV	Gemini	Easy

This star is relatively close at about 58 light-years, with a luminosity of 160 Suns.

Beta Aurigae	β Aur	$05^h\ 59.5^m$	+44° 57′	December 21
1.90_vm	–0.10 M	A2 V	Auriga	Easy

This is a good example of the Algol-type of variable star, which is due to stars eclipsing each other. A spectral class A2 signifies that the hydrogen lines are now at their strongest.

2 Mon	HD 40536	$05^h\ 59.1^m$	–09° 33′	December 21
5.01 m	0.02 M	A6	Monoceros	Easy

The star lies at a distance of over 1,900 light-years, with a luminosity of 5,000 Suns.

Canopus	α Car	$06^h\ 23.9^m$	–52° 41′	December 27
–0.72 m	–5.53 M	F0 Ia	Carina	Easy

The second brightest star in the sky. Its color is often reported as orange or yellow, as it is usually seen lying low in the sky and is thus apt to be affected by the atmosphere. Its true color is white.

111 Tau	HD 35296	$05^h\ 24.4^m$	+17° 23′	December 12
5.00 m	4.17 M	F8 V	Taurus	Easy

A close star at 52 light-years, it is only two times as luminous as the Sun.

ν^2 CMa	HD 47205	$06^h\ 36.7^m$	–19° 15′	December 30
3.95 m	2.46 M	K1 III	Canis Major	Easy

This star lies at a distance of 60 light-years with a luminosity seven times that of the Sun.

See also:

Star	Class	Month
Electra	B6 III	November
Atlas	B8 III	November
Castor	A1 V	January
Algenib	F5 I	November
γ^2 Vel	WC 8	January

Red Stars

This section will deal with the topic of colored stars. It may seem to a casual observer that stars are not strongly colored, at least to the naked eye, and only the very brightest stars show any perceptible color. Betelgeuse, for example, can be seen to be red, and Capella, yellow, while Vega is blue and Aldebaran has an orange tint. But beyond that, most stars seem to be an overall white. To the naked eye, this is certainly the case, and it is only with some kind of optical equipment that the full range of star color becomes apparent.

But what is meant by the color of a star? A scientific description of a star's color is one that is based on the stellar classification, which in turn is dependent upon the chemical composition and temperature of a star. A term commonly used by astronomers is the *color index*, determined by observing a star through two filters, the B and the V filters, corresponding to wavelengths of 440 and 550 nm, respectively, and measuring its brightness. Subtracting the two values obtained gives B – V, the color index. Usually, a blue star will have a color index that is negative, i.e., –0.3; orange-red stars could have a value greater than 0.0, and upwards to about 3.00 and even greater for very red stars (M6 and greater).[29] But as this is an observationally based book, the scientific description will not generally apply.

From a purely observational viewpoint, the most important factor that determines what the color of a star is, is you – the observer! It is simply a matter of both physiological and psychological influences. What one observer describes as a blue star another may describe as a white star, or one may see an orange star, while another observes the same star as being yellow. It may even be that you will observe a star to have a different color when using different telescopes or magnifications, and atmospheric conditions will certainly have a role to play. The important thing to remember is that whatever color you observe a star to have, then that is the color you should record.[30]

As mentioned previously, red, yellow, orange and blue stars are fairly common, but are there stars that have, say, a purple tint, or blue, or violet, crimson, lemon, and the ever elusive green color? The answer is yes, but with the caveat that it depends on how you describe the color. A glance at astronomy books from the last century and beginning of the twentieth century will show you that star color was a hot topic, and descriptions such as amethyst (purple), cinerous (wood-ash tint),

[29] Note that in this section the magnitude quoted is the Hipparcos value, while the B-V value and the magnitude ranges have been taken from other sources. Also, it can be difficult to ascertain a correct value for B-V as the light can be reddened by interstellar dust.

[30] An interesting experiment is to observe a colored star first through one eye, then the other. You may be surprised by the result!

jacinth (pellucid orange), and smalt (deep blue), to name but a few, were used frequently. Indeed, the British Astronomical Association even had a section devoted to star colors. But today, observing and cataloging star color is just a pleasant pastime. Nevertheless, under good seeing conditions, with a dark sky, the keen-eyed observer will be able to see gloriously tinted colors from the deepest red to steeliest blue, with a plethora of colors in between.

It is worth noting that several distinctly colored stars occur as part of a multiple star system. The reason for this may be that although the color is difficult to see in an individual star, it may appear more intense when seen together with a contrasting color. Thus, the section on double and triple stars will catalog many beautifully colored systems. For instance, the fainter of the two stars in η *Cassiopeiae* has a distinct purple tint, while in γ Andromedae and α Herculis, the fainter stars are most definitely green.

Many of the strongly colored stars have already been described in the previous section, and thus will not be repeated here, and other stars will be described in the sections on double and triple stars. However, there is a star color upon which most observers agree – the red stars, and to that end, the following list will catalog the most famous and brightest of this type of star. All are classified as N- or R-type stars, as well as a few C-type stars. The N and R classification signifies that although the temperature may be of the same order as M-type stars, these stars show different chemical compositions, while the C-type stars are the carbon stars mentioned earlier. Some of these stars are intensely red and have a deeper color than even Betelgeuse and Arcturus!

The same listing system is used as before, with the addition of the color Index, B-V.

January

See:

Star	Color index	Month
Hind’s Crimson Star	3.4	December
W Orionis	3.33	December
X Cancri	2.97	February

February

X Cancri	HD 76221	$08^h\ 55.4^m$	+17° 14′	February 3
6.12_vm	B-V:2.97	C6		Moderate

An extremely orange star, this semi-regular variable star, classification SRB, has a period of 180–195 days and has been observed to range in magnitude from 5.6 to 7.5.

See also:

Star	Color index	Month
Hind's Crimson Star	3.4	December
W Orionis	3.33	December
X Cancri	2.97	February
V Hydrae	4.5	March

March

V Hydrae	Lalande 16	$10^h\ 51.6^m$	−21° 15′	March 5
7.0_vm	B-V:4.5	C9		Easy

This star, another classic long-period variable, has a period of about 533 days and varies in brightness between 6 and 12 m. It also has a second periodicity of 18 years. One of the rare carbon stars that is visible in amateur instruments, its color has been described as a 'magnificent copper red.' Note however it is difficult to observe owing to its large magnitude range.

See also:

Star	Color index	Month
La Superba (Chapter 7)	2.9	April
RY Draconis	3.3	April
X Cancri	2.97	February

April

RY Draconis	HD 112559	$12^h\ 56.3^m$	+66° 00′	April 5
6.9_vm	B-V:3.3	C7		Easy ©

A red giant variable star, class SRB, with a poorly understood periodicity (believed to be 200 days) and a magnitude range of 6.0–8.0 m. The star has a lovely red color, although some reports suggest it has more of an orange-red color.

See also:

Star	Color index	Month
V Hydrae	4.5	March

May

See:

Star	Color index	Month
La Superba (Chapter 7)	2.9	April
RY Dra	3.3	April
V Pavonis	2.45	June
T Lyrae	3.7?	June

June

V Pavonis	HD 160435	17^h 43.3^m	−57° 43′	June 17
6.65_vm	B-V:2.45	C5		Easy ©

A red giant variable star, class SRB, varying in brightness from 6.3 to 8.2 m, over a period of 225.4 days. It also has a secondary period of about 3,735 days. It exhibits a glorious deep-red color.

T Lyrae	SAO 67087	18^h 32.3^m	+37° 00′	June 29
7.57_vm	B-V:3.7?	C8		Moderate

An extremely red-colored star, this is another with an irregular period and has a magnitude range 7.5–9.3. Its color index poses somewhat of a problem, often quoted as having a value ranging from 3.7 to 5.16, making it a *very* red star.

See also:

Star	Color index	Month
V Aquilae	5.46	July
RS Cygni	3.3	July

July

V Aquilae	HD 177336	19^h 04.4^m	−05° 41′	July 8
7.5_vm	B-V:5.46	C5		Easy

A semi-regular variable star with a period of about 350 days, varying in magnitude from 6.6 to 8.1 m. It has a very deep red color.

RS Cygni	HD 192443	20^h 13.3^m	+38° 44′	July 25
8.1_vm	B-V:3.3	C5		Easy

A red giant star with a persistent periodicity, class SRA; it has a period of 417.39 days, with a magnitude range of 6.5–9.5 m. A strange star as where the light curve can vary appreciably, the maxima sometimes doubles. Another deeply red-colored star.

See also:

Star	Colorindex	Month
V Pavonis	2.45	June
T Lyrae	3.7?	June
S Cephei	4.85	August
Garnet Star (Chapter 7)	2.26	August

August

S Cephei	HD 206362	$21^h\ 35.2^m$	+78° 37′	August 15
7.49_vm	B-V:4.85	C6		Moderate/difficult©

A moderately difficult star to observe, owing to its magnitude range of between 7 and 12 magnitudes, it nevertheless has a very high color index, making it one of the reddest stars in the sky.

See also:

Star	Color index	Month
V Aquilae	5.46	July
RS Cygni	3.3	July
19 Piscium	2.5	September

September

19 Piscium	TX Psc	$23^h\ 46.4^m$	+03° 29′	September 17
4.95_vm	B-V:2.5	C5		Easy

A slow, irregular-period variable star. Classification LB, with a magnitude range of 4.8–5.2 m. The color is an orange-red, best seen in small instruments.

See also:

Star	Color index	Month
Garnet Star (Chapter 7)	2.3	August
S Cephei	4.85	August
R Sculptoris	1.4	October

October

R Sculptoris	HD 8879	$01^h\ 26.9^m$	−32° 33′	October 13
5.79_vm	B-V:1.4	C6		Easy

A semi-regular-period variable star, with a period of between 140 and 146 days. It varies in brightness from 5.0 to 6.5.

See also:

Star	Color index	Month
19 Piscium	2.5	September
U Camelopardalis	4.1	November

November

U Camelopardalis	$03^h\ 41.8^m$	+62° 39′	November 16
8.3_vm	B-V:4.1	N5	Moderate ©

A semi-regular variable star, period 412 days with a magnitude range of 7.7–9.5 m. It has a very deep-red color.

See also:

Star	Color index	Month
R Sculptoris	1.4	October
Hind's Crimson Star	3.4	December
W Orionis	3.33	December

December

Hind's Crimson Star	R Leporis	$04^h\ 59.6^m$	−14° 48′	December 5
7.71_vm	B-V:3.4	C7		Easy

The star, a classic long-period variable. Period about 432 days, varies in brightness between 6.0 and 9.7 m. At maximum brightness it displays the famous ruddy color that gives it its name. Discovered in 1845 by J. R. Hind with a color described as "intense smoky red," many amateurs regard this to be the reddest star.

W Orionis	HD 32736	$05^h\ 0.4^m$	+01° 11′	December 7
6.3_vm	B-V:3.33	N5		Easy

A red giant variable star, classification SRB, with a period of 212 days although a secondary period of 2,450 days is believed to occur. Varies in magnitude from 5.5 to 7.7. A deep-red star seen in the often-regarded best season to observe – winter!

See also:

Star	Color index	Month
U Camelopardalis	4.1	November

Double Stars

Having started our observation of the night sky by looking at single stars, we are able to use the skills developed so far to observe objects that not only display a wonderful array of colors but also allow precise measurements to be made, namely, double-star systems. The study of double stars is one that has a great pedigree. It was, and in fact still is, an area of astronomy where the observer can make useful detailed observations, and as mentioned previously many double stars present a glittering range of colors.

Double stars are stars that can appear to be just a single star to the naked eye, but on observation with either binoculars or telescopes they resolve itself into two stars. Indeed, some apparently single stars turn out to be several stars and present a marvelous challenge and observing delight to the amateur.

An accurate classification of double stars is quite complex, and lies really in the realm of astrophysics, but a brief description is warranted here.

There are, roughly speaking, five main types of double-star systems[31]:

1. *Optical Doubles,* which appear as double stars due to them lying in the same line of sight as seen from Earth, but it may well be that the two stars are separated in space by a vast distance and are not gravitationally bound.
2. *Spectroscopic Binaries*, where the components in the system cannot be resolved visually, the double component only being fully understood when the spectra is analyzed.
3. *Eclipsing Binaries,* such as Algol (β Persei), where one star moves during its orbit in front of its companion, thus brightening and dimming the light observed over a well-defined period of time.
4. *Astrometric Binaries*, such as Sirius (α Canis Majoris), where the companion star may only be detected by its influence on the motion of the primary star.
5. *Visual Binaries*, such as Mizar (ζ Ursae Majoris) and Alcor (80 Ursae Majoris),[32] where both components, gravitationally bound to each other, are resolvable in optical equipment and, using the example given here, with the naked eye.

[31] The last four types represent gravitationally bound systems.

[32] It used to be thought that the system was not a true binary; however, in 2009, research indicated that in fact Alcor is actually two stars, gravitationally bound with Mizar, and as Mizar is itself a quadruple system we now have an amazing sextuplet system of stars!

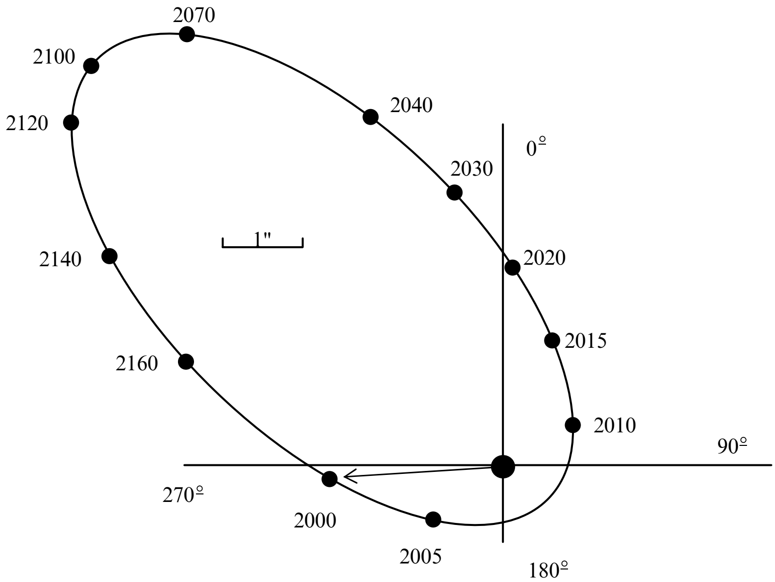


Fig. 2.1 γ Virgins

However, as this book is concerned with objects that can be observed visually, we will concentrate on double stars that can be resolved with either the naked eye or by using some sort of optical equipment such as binoculars or small telescopes.

Some terminology must now be introduced that is specific to double star observation:

- The *primary*[33] star is the brighter of the two stars.
- The *secondary* star is the fainter of the two stars, although in some texts it may be called the companion, and both terms will appear in this book.
- The *separation* is the angular distance between the two stars usually given in seconds of arc (″) and measured from the brighter star to the fainter.
- The *position angle* (PA), a somewhat more difficult concept to understand. This is the relative position of one star, usually the secondary, with respect to the primary, and is measured in degrees, with 0° at due north, 90° at due east, 180° due south, 270° at due west, and back to 0°.

To illustrate the above concepts, an example would be useful here. Using Fig. 2.1, the double star γ Virginis, with components of magnitude 3.5 and 3.5, has a separation of 1.8″ (arcseconds), at a PA of 267° (epoch 2000.0). Note that the secondary star is the one always placed somewhere on the orbit, the primary star is at the

[33]This terminology is employed regardless of how massive either star is, or whether the primary is in fact the less luminous of the two in reality, but just appears brighter because it is closer.

Table 2.4 Selected double stars

Star		RA	Dec	m1	m2	PA °	Sep ″	Aperture cm
ζ CMa[a]	Zeta Ursa Majoris	$13^h 23^m 55.5^s$	+54° 55′ 31″	2.5	3.9	152	709	Naked eye
ε Lyr[b]	Epsilon Lyrae	$18^h 44^m 20.3^s$	+39° 40′ 12″	4.7	4.6	350	207.7	Naked eye
ο Cep	Omicron Cephei	$23^h 18^m 37.4^s$	+68° 06′ 42″	5.0	7.3	223	2.8	5
ζ Aqr	Zeta Aquarii	$22^h 28^m 49.6^s$	−00° 01′ 13″	4.4	4.6	192	2.1	5
ε Ari	Epsilon Arietis	$02^h 59^m 12.6^s$	+21° 20′ 25″	5.2	5.6	203	1.4	7.5
μ Lib	Mu Librae	$14^h 49^m 19.0^s$	−14° 08′ 56″	5.7	6.7	355	1.8	7.5
θ Aur	Theta Aurigae	$05^h 59^m 43.2^s$	+37° 12′ 45″	2.6	7.1	313	3.6	10
η Ori	Eta Orionis	$05^h 24^m 28.6^s$	−02° 23′ 49″	3.6	4.9	80	1.5	10
ζ Boo	Zeta Boötis	$14^h 41^m 08.8^s$	+13° 43′ 42″	4.5	4.6	300	0.8	15
ι Leo	Iota Leonis	$11^h 23^m 55.4^s$	+10° 31′ 45″	4.1	6.9	116	1.7	20
χ Aql	Chi Aquilae	$23^h 18^m 37.4^s$	+68° 06′ 42″	5.8	6.9	77	0.5	25

[a]Mizar and Alcor, probably the most famous visual double in the northern hemisphere.
[b]The "double-double," a good test for visual acuity.

center of the perpendicular lines, and that the separation and PA of any double star are constantly changing, and should be quoted for the year observed.

Some stars, where the period is very long, will have no appreciable change in PA for several years; others, however, will change from year to year. Many books that discuss double stars in detail will have similar diagrams for the stars listed; however, to present a similar facility here would entail a doubling of the book's size.[34]

It is worth mentioning again that although your optical equipment, including your eyes, should in theory be able to resolve many of the double listed here,[35] there are several factors that will constrain your observable resolution, i.e., the seeing, light pollution, dark adaption, etc., and your temperament. Thus, if you cannot initially resolve a double star, do not despair, but move onto another, and return to the one in question at another date. Also recall that the colors ascribed to the star will not necessarily be the color you see. They are just indicators of the general color, and in fact, as you will see from the text, many observers will, and can, disagree on a star's color.

Included is a brief list of several stars that can help to determine the resolution of both yourself and your binoculars/telescope.[36] All the positions quoted are for the primary star (Table 2.4).

[34]Several of the books listed in the appendices will have the double star orbits drawn, which will significantly aid you in determining which star is which.

[35]There are literally thousands of double-, triple- and multiple-star systems in the sky, all within reach of the amateur astronomer, and the list that follows is but a taste of what awaits the observer.

[36]Note that the position angle and separation are quoted for epoch 2000.0. With double stars that have small periods, these figures will change appreciably.

In the lists that follow, the same information set up is used as before, with the addition of the Position Angle (PA) and Separation (Sep).

January

φ Aurigae	HD 48682	06^h 46.7^m	+43° 35′	January 2
5.3, 8.3 m	PA 31°| Sep. 36.2″			Easy[37]

A pair of yellow and blue stars set against a backdrop of faint stars.

π Canis Majoris	HD 51199	06^h 55.6^m	–20° 08′	January 4
4.7, 9.7 m	PA 18°| Sep. 11.6″			Easy

A pale yellow primary and bluish secondary.

h 3945[38]	HD 56577	07^h 16.1^m	–23° 19′	January 9
4.8, 6.1 m	PA 55°| Sep. 26.6″			Easy

A wonderful dark orange and blue double-star system. The colors have also been described as gold and blue.

Struve 1149	Σ1149	07^h 49.5^m	+03° 13′	January 18
7.9, 9.6 m	PA 41°| Sep. 21.7″			Easy

A lovely double-star system with a yellow primary and blue secondary.

38 Geminorum	ADS 5559[39]	06^h 54.6^m	+13° 11′	January 4
4.7, 7.7 m	PA 145°| Sep. 7.1″			Moderate

Easily split using small telescopes, yellow and blue. Note that some observers see the secondary as purple.

μ Canis Majoris	ADS 5605	06^h 56.1^m	–14° 03′	January 4
5.3, 8.6 m	PA 340°| Sep. 3.0″			Moderate

[37]The terms "easy, moderate and difficult" have a slightly different meaning to that used previously. In the present context it refers to the ability to split the double and not just its ease of being observed, although this will also be a significant factor in the use of the definition.

[38]This signifies that it is the 3,945th star in the John Herschel catalog.

[39]The ADS number is the number given in the *New General Catalogue of Double Stars*, which covers as far south as –30°.

Two stars of differing brightness that nevertheless present a glorious double of orange and blue.

κ Geminorum	ADS 6321	07^h 44.4^m	+24° 24′	January 16
3.6, 8.1 m	PA 240°| Sep. 7.1″			Moderate

A bright orange-yellow primary with a fainter blue secondary.

ϕ^2 Cancri	ADS 6815	08^h 26.8^m	+26° 56′	January 27
6.3, 6.3 m	PA 218°|Sep. 5.1″			Moderate

A superb pair of white stars.

See also:

Star	PA|Sep	Month
11 & 12 Cml	8°| 108.5″	December
S473	305°| 20.6″	December
La 1	123°| 11.0″	December
γ Leporis	350°| 96.3″	December
41 Aurigae	356°| 7.7″	December
15 Geminorum	204°| 25.1″	December
ν^1 Canis Majoris	262°| 17.5″	December
ω Aurigae	359°| 5.4″	December
h3750	282°| 4.2″	December
κ Leporis	358°| 2.6″	December
UV Aurigae	4°| 3.4″	December
θ Aurigae	313°| 3.6″	December
ι^1 Cancri	307°| 30.5″	February
6 Leonis	75°| 37.4″	February
ο Leonis	44°| 85.4″	February
38 Lyncis	229°| 2.7″	February
γ Leonis	125°| 4.4″	February

February

ι^1 Cancri	ADS 6988	08^h 46.7^m	+28° 46′	February 1
4.0, 6.6 m	PA 307°| Sep. 30.5″			Easy

Spectacular! A gold primary with a blue secondary. Can be split with as low a magnification as 12× but is a challenge for binoculars.

6 Leonis	ADS 7416	09^h 32.0^m	+09° 43′	February 12
5.2, 8.2 m	PA 75°| Sep. 37.4″			Easy

A stunning gold and blue double-star system.

o Leonis	ADS 7480	09^h 41.2^m	+09° 54′	February 15
3.5, 9.5 m	PA 44°| Sep. 85.4″			Easy

A nice double of yellow and blue stars that are easy to resolve.

38 Lyncis	ADS 7292	09^h 18.8^m	+36° 48′	February 9
3.9, 6.3 m	PA 229°| Sep. 2.7″			Moderate

This is a nice pair of stars, where the primary is white, while some observers describe the secondary as rust-colored.

γ Leonis	ADS 7724	10^h 20.0^m	+19° 51′	February 25
2.5, 3.6 m	PA 125°| Sep. 4.4″			Easy/Moderate

A fine pairing of yellow stars, one deep and the other paler. Easy to find as it is the brightest star in the curve of the sickle of Leo (See also Regulus).

See also:

Star	PA/Sep	Month
φ^5 Aurigae	31°| 36.2″	January
π Canis Majoris	18°| 11.6″	January
h 3945	55°| 26.6″	January
Struve 1149	41°| 21.7″	January
38 Geminorum	145°| 7.1″	January
μ Canis Majoris	340°| 3.0″	January
κ Geminorum	240°| 7.1″	January
ϕ^2 Cancri	218°| 5.1″	January
N Hydrae	210°| 9.2″	March
δ Corvi	214°| 24.2″	March
35 Sextantis	240°| 6.8″	March
2 CVn	260°| 11.4″	March
γ Crt	96°| 5.2″	March
ξ Ursae Majoris	273°| 1.8″	March
ι Leonis	116°| 1.7″	March

March

N Hydrae	17 Crt	11^h 32.3^m	−29° 16′	March 15
5.8, 5.9 m	PA 210°| Sep. 9.2″			Easy

This is an easy double to resolve with a small telescope, consisting of unequally bright yellow stars.

δ Corvi	ADS 8572	12^h 29.9^m	−16° 31′	March 30
3.0, 9.2 m	PA 214°| Sep. 24.2″			Easy

A superb double-star system consisting of a bright white primary and fainter pale blue secondary. First observed in 1823.

35 Sextantis	ADS 7902	10^h 43.3^m	+04° 45′	March 3
6.3, 7.4 m	PA 240°| Sep. 6.8″			Easy/moderate

Easily resolved by small telescope, a fine system of orange and yellowish stars.

2 CVn	ADS 8489	12^h 16.1^m	+40° 40′	March 26
5.8, 8.1 m	PA 260°| Sep. 11.4″			Easy/moderate

An easy double for small telescopes, with a yellow primary and pale blue secondary.

γ Crt	ADS 8153	11^h 24.9^m	−17° 41′	March 13
4.1, 9.6 m	PA 96°| Sep. 5.2″			Moderate

An unequally bright double consisting of a white primary and blue secondary.

ξ Ursae Majoris	ADS 8119	11^h 18.2^m	+31° 32′	March 12
4.3, 4.8 m	PA 273°| Sep. 1.8″			v. difficult

Discovered by William Herschel in 1780, this is a close pair of pale yellow stars. It also has the distinction of being the first binary system to have its orbit calculated by Savary in 1828. Both components are also spectroscopic binaries.

ι Leonis	ADS 8148	11^h 23.9^m	+10° 32′	March 13
4.0, 6.7 m	PA 116°| Sep. 1.7″			v. difficult

A difficult double star to resolve owing to its small angular separation. However, it is widening now (E 2000.0), and so will get easier to split. The components are yellow and white.

See also:

Star	PA/Sep	Month
ι^1 Cancri	307°| 30.5″	February
6 Leonis	75°| 37.4″	February
o Leonis	44°| 85.4″	February
38 Lyncis	229°| 2.7″	February
γ Leonis	125°| 4.4″	February
α CVn	229°| 19.4″	April
κ Boötis	236°| 13.4″	April
ε Boötis	339°| 2.8″″	April
84 Virginis	229°| 2.9″	April
γ Virginis	259°| 1.5″	April

April

α CVn	ADS 8706	12^h 56.0^m	+38° 19′	April 5
2.9, 5.5 m	PA 229°| Sep. 19.4″			Easy

Also known as Cor Caroli, the stars of this system are separated by a distance equivalent to five Solar System widths – 770 astronomical units! The two stars are yellowish in small instruments; however, with large aperture, subtle tints become apparent and have been called flushed white and pale lilac or pale yellow and fawn!

κ Boötis	ADS 9173	14^h 13.5^m	+51° 47′	April 25
4.6, 6.6 m	PA 236°| Sep. 13.4″			Easy ©

A nice double for small telescopes, where the primary is white, although some observers see yellow, and the secondary is blue. The primary is also a variable.

ε Boötis	ADS 9372	13^h 45.0^m	+27° 04′	April 18
2.5, 4.9 m	PA 339°| Sep. 2.8″			Moderate

A wonderful contrast of gold and green stars that has also been reported to be yellow and blue. However, it is difficult with apertures of around 7.5 cm, and even a challenge for beginners with apertures of 15.0 cm. With small telescopes a high power is needed to resolve them. Also known as Mirak.

84 Virginis	ADS 9000	13^h 43.1^m	+03° 32′	April 17
5.5, 7.9 m	PA 229°| Sep. 2.9″			Difficult

A high magnification will split this system into vivid orange and pale yellow stars.

γ Virginis	ADS 8630	12^h 41.7^m	−01° 27′	April 2
3.5, 3.5 m	PA 259°| Sep. 1.5″			v. difficult

A very difficult double to resolve owing to the small separation, which will decrease even further until soon they will be 0.9″ apart, and so to all intents and purposes appear single. It is, however, a nice pair of pale yellow stars.

See also:

Star	PA/Sep	Month
N Hydrae	210°| 9.2″	March
δ Corvi	214°| 24.2″	March
35 Sextantis	240°| 6.8″	March
2 CVn	260°| 11.4″	March
γ Crt	96°| 5.2″	March
ξ Ursae Majoris	273°| 1.8″	March
ι Leonis	116°| 1.7″	March
ι^1Librae	314°| 231.0″	May
54 Hydrae	126°| 8.6″	May
ι^1 Librae	111°| 57.8″	May
ν^1 Corona Borealis	165°| 364.4″	May
β Scorpii	21°| 13.6″	May
OΣ 300	261°| 15.3″	May
ξ Corona Borealis	305°| 6.3″	May
ρ Ophiuchi	344°| 3.1″	May
λ Ophiuchi	29°| 1.4″	May
ν Scorpii	03°| 0.9″	May
ν Scorpii	51°| 2.3″	May

May

α Librae	h186	14^h 50.9^m	−16° 02′	May 4
2.8, 5.2 m	PA 314°| Sep. 231.0″			v. easy

This can be seen with binoculars as a widely separated pair of white and yellow stars. The primary is itself a spectroscopic binary.

54 Hydrae	ADS 9375	14^h 46.0^m	−25° 27′	May 3
5.1, 7.1 m	PA 126°| Sep. 8.6″			Easy

An easy double of yellowish stars with the primary a pale yellow, while the secondary is a stronger yellow.

ι^1 Librae	ADS 9532	15^h 12.2^m	−19° 47′	May 10
4.5, 9.4 m	PA 111°| Sep. 57.8″			easy

A rather nice system of white and red stars. There is a much fainter third star, magnitude 11.1, that is sometimes described as having a purplish color. However, this is only 1.9″ away from the primary and exceedingly difficult to detect.

ν^1 Corona Borealis	$15^h\ 22.4^m$	+33° 48′	May 12
5.4, 5.3 m	PA 165°| Sep. 364.4″		Easy

A nice binocular pair of orange stars.

β Scorpii	ADS 9913	$16^h\ 05.4^m$	−19° 48′	May 23
2.6, 4.9 m	PA 21°| Sep. 13.6″			Easy

A good double for small apertures of around 5.0 cm, this has a brilliant blue-white primary with a paler blue secondary. The primary is itself a binary.

OΣ 300	ADS 9740	$15^h\ 40.2^m$	+12° 03′	May 17
6.4, 9.5 m	PA 261°| Sep. 15.3″			Easy/moderate

Located within the faint and often overlooked constellation Serpens Caput. This is a nice system consisting of yellow and blue stars.

ξ Corona Borealis	ADS 9737	$15^h\ 39.4^m$	+36° 38′	May 17
5.1, 6.0 m	PA 305°| Sep. 6.3″			Moderate

These two stars contrast each other nicely with definite blue and green colors.

ρ Ophiuchi	ADS 10049	$16^h\ 25.6^m$	−23° 27′	May 28
5.3, 6.0 m	PA 344°| Sep. 3.1″			Moderate

A medium-sized telescope of at least 10.0 cm aperture along with a high magnification is needed to resolve this pair of blue stars.

λ Ophiuchi	ADS 10087	$16^h\ 30.9^m$	+01° 59′	May 30
4.1, 5.2 m	PA 29°| Sep. 1.4″			Difficult

A nice pairing of white and pale lemon stars. Can be used as a test for small telescopes.

ν Scorpii	ADS 9951	$16^h\ 12.0^m$	−19° 28′	May 25
4.3, 6.8 m	PA 03°| Sep. 0.9″			v. difficult
6.4, 7.8 m	PA 51°| Sep. 2.3″			Easy

Another system of double-double stars. The main white pair will appear as two discs in contact, but only under near-perfect conditions; the easier pair are nice yellowish stars. The two components appear as magnitude 4.2 and 6.1, separation 41.1″, and with a PA of 337° (See Antares.).

See also:

Star	PA/Sep	Month
α CVn	229°| 19.4″	April
κ Boötis	236°| 13.4″	April
ε Boötis	339°| 2.8″	April
84 Virginis	229°| 2.9″	April
γ Virginis	259°| 1.5″	April
ο Ophiuchi	355°| 10.3″	June
56 Herculis	93°| 18.1″	June
21 Sagittarii	289°| 1.8″	June
α Herculis	104°| 4.6″	June

June

ο Ophiuchi	ADS 10442	17^h 18.0^m	−24° 17′	June 11
5.4, 6.9 m	PA 355°| Sep. 10.3″			Easy

Located in a field of bright stars, this double makes a nice contrast of orange and yellow.

56 Herculis	ADS 10259	16^h 55.0^m	+25° 44′	June 5
6.1, 10.6 m	PA 93°| Sep. 18.1″			Easy/moderate

The primary is a semi-regular variable star, type M, with a magnitude change of 3.1–3.9 and a period of 90 days. It is a wonderful double, with an orange primary and a greenish secondary.

21 Sagittarii	ADS 1325	18^h 25.3^m	−20° 32′	June 28
4.9, 7.4 m	PA 289°| Sep. 1.8″			Moderate

A rigorous test for small telescopes, and even a challenge for medium apertures, this is a nice contrast of orange and blue stars. Some observers report the secondary as greenish.

α Herculis	ADS 10418	17^h 14.6^m	+14° 23′	June 10
3.5_v, 5.4_vm	PA 104°| Sep. 4.6″			Difficult

A lovely color contrast double: orange and bluish green. The primary star is itself variable, while the secondary is an unresolvable double.

See also:

Star	PA/Sep	Month
α Librae	314°| 231.0″	May
54 Hydrae	126°| 8.6″	May
ι^1 Librae	111°| 57.8″	May
ν^1 Corona Borealis	165°| 364.4″	May
β Scorpii	21°| 13.6″	May
OΣ 300	261°| 15.3″	May
ζ Corona Borealis	305°| 6.3″	May
ρ Ophiuchi	344°| 3.1″	May
λ Ophiuchi	29°| 1.4″	May
ν Scorpii	03°| 0.9″	May
ν Scorpii	51°| 2.3″	May
ρ Capricornin	150°| 247.6″	July
ζ Lyrae	150°| 43.7″	July
β Lyrae	149°| 45.7″	July
11 Aquilae	286°| 17.5″	July
β Cygni	54°| 34.4″	July
H N 84	302°| 28.2″	July
σ Capricornin	179°| 55.9″	July
ε Lyrae^1 (Chapter 7)	357°| 2.6″	July
ε Lyrae^2 (Chapter 7)	94°| 2.3″	July
HN 119	142°| 7.8″	July
OΣ 394	294°| 11.0″	July
23 Aquilae	05°| 3.1″	July
δ Cygni	221°| 2.5″	July
β441 (Vulpecula)	66°| 5.9″	July

July

ρ Capricornin	ADS 13887	20^h 28.9^m	−17° 49′	July 29
5.0, 6.7 m	PA 150°| Sep. 247.6″			v. easy

Easily seen in binoculars. This attractive pair of stars are colored yellow and purplish.

ζ Lyrae	ADS 11639	18^h 44.8^m	+37° 36′	July 3
4.3, 5.9 m	PA 150°| Sep. 43.7″			Easy

An easy pair of yellowish stars.

β Lyrae	ADS 11745	18^h 50.1^m	+33° 22′	July 4
3.4_v, 8.6 m	PA 149°| Sep. 45.7″			Easy

This pair of white stars is a challenging double for binoculars. β^1 is also an eclipsing binary. A fascinating situation occurs owing to the gravitational effects of the components of β^1. The stars are distorted from their spherical shapes into ellipsoids.

11 Aquilae	Σ2424	18^h 59.1^m	+13° 37′	July 6
5.2, 8.7 m	PA 286°| Sep. 17.5″			Easy

An optical double with a nice color contrast – yellow and blue.

β Cygni	ADS 12540	19^h 30.7^m	+27° 58′	July 14
3.1, 5.1 m	PA 54°| Sep. 34.4″			Easy

Thought by many to be the finest double in the skies, Albireo is a golden-yellow primary and lovely blue secondary against the backdrop of the myriad fainter stars of the Milky Way. Easy to locate at the foot of the Northern Cross, the colors can be made to appear even more spectacular if you slightly defocus the images. Wonderful!

H N 84	ADS 12750	19^h 39.4^m	+16° 34′	July 16
6.5, 8.9 m	PA 302°| Sep. 28.2″			Easy

Located in the constellation of Sagitta, this is a fine double of orange and blue.

σ Capricornin	ADS 13675	20^h 19.4^m	−19° 07′	July 27
5.5, 9.0 m	PA 179°| Sep. 55.9″			Easy

An easy system to resolve although the primary is considerably brighter than the secondary. The stars are a yellow and a pale blue in color.

HN 119	ADS 12506	19^h 29.9^m	−26° 59′	July 14
5.6, 8.6 m	PA 142°| Sep. 7.8″			Easy/moderate

Known as far back as 1821, this is a nice double of orange and blue stars.

OΣ394	ADS 13240	20^h 00.2^m	+36° 25′	July 22
7.1, 9.9 m	PA 294°| Sep. 11.0″			Easy/moderate

A delightful system consisting of an orange primary and a blue secondary.

23 Aquilae	Σ2492	19^h 18.5^m	+1° 05′	July 11
5.3, 9.3 m	PA 5°| Sep. 3.1″			Moderate

A very close pair, but a lovely deep yellow and greenish-blue double system.

δ Cygni	ADS 12880	$19^h\ 45.0^m$	+45° 08′	July 18
2.9, 6.3 m	PA 221°| Sep. 2.5″			Difficult

Contrasting reports of this system's colors abound: a blue-white or greenish-white primary, and a blue-white or bluish secondary. A test for telescopes of 10.0–15.0 cm, and exceptional seeing is needed.

β441 (Vulpecula)	ADS 13648	$20^h\ 17.5^m$	+29° 09′	July 26
6.2, 10.7 m	PA 66°| Sep. 5.9″			Difficult

Also known as Burnham 441, this is a nice contrasting pair of yellow and blue stars.

See also:

Star	PA/Sep	Month
ο Ophiuchi	355°| 10.3″	June
56 Herculis	93°| 18.1″	June
21 Sagittarii	289°| 1.8″	June
α Herculis	104°| 4.6″	June
61 Cygni	150°| 30.3″	August
β Cephei	249°| 13.3″	August
Σ2894Lac	194°| 15.6″	August
94 Aquarii	350°| 12.7″	August
Aquarius	184°| 17.6″	August
γ Delphini	268°| 9.6″	August
12 Aquarii	192°| 2.8″	August
29 Aquarii	244°| 3.7″	August
41 Aquarii	114°| 5.0″	August
ξ Aquarii	192°| 2.1″	August

August

61 Cygni	ADS 14636	$21^h\ 06.9^m$	+38° 45′	August 8
5.2, 6.0 m	PA 150°| Sep. 30.3″			Easy

Best seen with binoculars (but sometimes a challenge if conditions are poor) that seem to emphasize the vibrant colors of these stars, both orange-red. This system is famous for being the first to have its distance measured by the technique of parallax. The German astronomer Friedrich Bessel determined its distance to be 10.3 light-years; modern measurements give a figure of 11.36. Also has an unseen third component, which has the mass of eight Jupiters. Has a very large proper motion.[40]

[40]Motion across the sky.

β Cephei	ADS 15032	21^h 28.7^m	+70° 34′	August 13
3.2, 7.9 m	PA 249°| Sep. 13.3″			Easy ©

Also known as Alfirk, it is a cepheid variable. The system is a nice white and blue double. Using a large-aperture telescope, the secondary takes on a definite green tint.

Σ2894Lac	ADS 15828	22^h 18.9^m	+37° 46′	August 26
6.1, 8.3 m	PA 194°| Sep. 15.6″			Easy

A nice system of yellow and blue stars in the constellation Lacerta.

94 Aquarii	HD 219834	22^h 19.1^m	−13° 28′	August 26
5.3, 7.3 m	PA 350°| Sep. 12.7″			Easy

A lovely double, yellowish red and pale green.

Aquarius	Σ2838	21^h 54.7^m	−03° 18′	August 20
6.3, 9.1 m	PA 184°| Sep. 17.6″			Easy/Moderate

A yellow and bluish pair of stars with a background of many faint stars.

γ Delphini	ADS 14279	20^h 46.7^m	+16° 07′	August 3
4.3, 5.5 m	PA 268°| Sep. 9.6″			Easy/Moderate

Easily resolved with a small telescope, this is a beautiful double with a yellow primary and a rare green secondary.

12 Aquarii	Σ2745	21^h 04.1^m	−05° 49′	August 7
5.9, 7.3 m	PA 192°| Sep. 2.8″			Moderate

A close pair of pale blue and yellow stars.

29 Aquarii	S 802[41]	22^h 02.4^m	−16° 58′	August 22
7.2, 7.4 m	PA 244°| Sep. 3.7″			Moderate

A high power is needed to split this pair of white stars.

41 Aquarii	ADS 15753	22^h 14.3^m	−21° 04′	August 25
7.1, 7.1 m	PA 114°| Sep. 5.0″			Moderate

[41] This signifies that it is the 802nd star in the John South catalog.

A lovely double system consisting of contrasting gold and blue stars.

ξ Aquarii	ADS 15971	22^h 28.8^m	−00° 01′	August 28
4.3, 4.5 m	PA 192°| Sep. 2.1″			Moderate

Good conditions and optics are needed to be able to split this double star, which is white and white. This is the central star of the Water Jar asterism in Aquarius.

See also:

Star	PA/Sep	Month
ρ Capricorni	150°| 247.6″	July
ζ Lyrae	150°| 43.7″	July
β Lyrae	149°| 45.7″	July
11 Aquilae	286°| 17.5″	July
β Cygni	54°| 34.4″	July
H N 84	302°| 28.2″	July
σ Capricorni	179°| 55.9″	July
HN 119	142°| 7.8″	July
OΣ394	294°| 11.0″	July
23 Aquilae	05°| 3.1″	July
δ Cygni	221°| 2.5″	July
β441 (Vulpecula)	66°| 5.9″	July
τ^1 Aquarii	121°| 23.7″	September
Herschel 975	243°| 51.0″	September
42 Piscium	324°| 28.5″	September
51 Piscium	83°| 27.5″	September
57 Pegasi	198°| 32.6″	September
107 Aquarii	136°| 6.6″	September
σ Cassiopeiae	326°| 3.0″	September
Struve 3050	335°| 1.7″	September
Groombridge 34	62°| 40.0″	September

September

τ^1 Aquarii	ADS 16268	22^h 47.7^m	−14° 03′	September 2
5.8, 9.0 m	PA 121°| Sep. 23.7″			Easy

A double that exhibits many colors to different observers; yellowish and orange, blue-white and greenish, white and yellow, white and pale red. What do you see?

Herschel 975	h975	22^h 55.7^m	+36° 21′	September 4
5.6, 9.5 m	PA 243°| Sep. 51.0″			Easy

A system with a large magnitude difference. A white primary and pale blue secondary. Located in the constellation Lacerta.

42 Piscium	00^h 22.4^m	+13° 29′	September 26
6.2, 10.1 m	PA 324°| Sep. 28.5″		Easy

An easy double-star system to split comprised of an orange primary and blue secondary.

51 Piscium	00^h 32.4^m	+06° 57′	September 29
5.7, 9.5 m	PA 83°| Sep. 27.5″		Easy

A wonderful double-star system with a bluish-white primary and greenish secondary.

57 Pegasi	HD 218634	23^h 09.5^m	+08° 41′	September 8
5.1, 9.7 m	PA 198°| Sep. 32.6″			Easy/moderate

A lovely system that is easily resolved in small telescopes. It consists of an orange primary and bluish secondary.

107 Aquarii	H II 24	23^h 46.0^m	−18° 41′	September 17
5.7, 6.7 m	PA 136°| Sep. 6.6″			Easy/moderate

A close double with colors of pale yellow and a definite bluish white.

σ Cassiopeiae	ADS 17140	23^h 59.0^m	+55° 45′	September 20
5.0, 7.1 m	PA 326°| Sep. 3.0″			Moderate ©

Located within a nice star field, a bluish and yellow system. Has also been described as green and blue.

Struve 3050	Σ3050	23^h 59.5^m	+33° 43′	September 20
6.6, 6.6 m	PA 335°| Sep. 1.7″			Moderate

A very close double that shows the two yellow stars almost touching.

Groombridge 34	ADS 246	00^h 17.9^m	+44° 00′	September 25
8.2, 10.6 m	PA 62°|Sep. 40.0″			Moderate/difficult

A red dwarf binary system, with a large proper motion that could easily be plotted over several years. Discovered in 1860.

See also:

Star	PA/Sep	Month
61 Cygni	150°| 30.3″	August
β Cephei	249°| 13.3″	August
Σ2894Lac	194°| 15.6″	August
94 Aquarii	350°| 12.7″	August
Aquarius	184°| 17.6″	August
γDelphini	268°| 9.6″	August
12 Aquarii	192°| 2.8″	August
29 Aquarii	244°| 3.7″	August
41 Aquarii	114°| 5.0″	August
ξ Aquarii	192°| 2.1″	August
η Cassiopeiae	317°| 12.9″	October
26 Ceti	253°| 16.0″	October
γ Arietis	0°| 7.8″	October
λ Arietis	46°| 37.4″	October
66 Ceti	234°| 16.5″	October
α Ursae Minoris	218°| 18.4″	October
33 Arietis	0°| 28.6″	October
ι Trianguli	71°| 3.9″	October
84 Ceti	310°| 4.0″	October
36 Andromedae	313°| 0.9″	October
ε Trianguli	118°| 3.9″	October

October

η Cassiopeiae	ADS 671	00^h 49.1^m	+57° 49′	October 3
3.4, 7.5 m	PA 317°| Sep. 12.9″			Easy ©

Discovered by William Herschel in 1779. Another system that has different colors being reported. The primary has been described as gold, yellow and topaz, while the secondary has been called orange, red and purple. Has an apparently near-circular orbit.

26 Ceti	Σ84	01^h 03.8^m	+01° 22′	October 7
6.2, 8.6 m	PA 253°| Sep. 16.0″			Easy

A nice system, reported as yellow and lilac.

γ Arietis	ADS 1507	01^h 53.5^m	+19° 18′	October 19
4.8, 4.8 m	PA 0°| Sep. 7.8″			Easy

Discovered by Robert Hooke in 1664 this is a lovely pair of equally bright bluish white stars.

λ Arietis	ADS 1563	$01^h\ 57.9^m$	+23° 35′	October 20
4.9, 7.7 m	PA 46°| Sep. 37.4″			Easy

An easy pair to split in binoculars with colors of pale yellow and pale blue.

66 Ceti	ADS 1703	$02^h\ 12.8^m$	−02° 24′	October 24
5.7, 7.5 m	PA 234°| Sep. 16.5″			Easy

With small aperture, the colors are yellow and blue, but with large aperture, they are reported to be topaz and violet!

α Ursae Minoris	ADS 1477	$02^h\ 31.8^m$	+89° 16′	October 29
2.0, 8.2 m	PA 218°| Sep. 18.4″			Easy ©

Possibly the most famous star in the entire sky, Polaris, or the Pole Star, is located less than a degree from the celestial pole, and is a nice double consisting of a yellowish primary and a faint whitish-blue secondary. The primary is also a Population II[42] Cepheid variable, and a spectroscopic binary. Although claims have been made to the effect that the system can be resolved in an aperture as small as 4.0 cm, at least 6.0 cm will be required to split it clearly.

33 Arietis	HD 16628	$02^h\ 40.7^m$	+27° 04′	October 31
5.5, 8.4 m	PA 0°| Sep. 28.6″			Easy

An easy pair to split consisting of pale yellow and pale blue stars.

55 Piscium	ADS 558	$00^h\ 39.9^m$	+21° 26′	October 1
5.4, 8.7 m	PA 194°| Sep. 6.5″			Moderate

A lovely system with a vivid yellow primary and blue secondary.

1 Arietis	ADS 1457	$01^h\ 50.1^m$	+22° 17′	October 18
6.2, 7.2 m	PA 166°| Sep. 2.8″			Moderate

A nice system consisting of yellow and faint blue stars. Could be used as a test for a 5.0 cm telescope.

ι Trianguli	ADS 1697	$02^h\ 12.4^m$	+30° 18′	October 24
5.3, 6.9 m	PA 71°| Sep. 3.9″			Moderate

[42] See Chap. 3 for a discussion of Population I and II stars.

A nice yellow and blue system. First observed by Herschel in 1781, both stars are themselves spectroscopic binaries.

84 Ceti	Σ295	$02^h\ 41.2^m$	–00° 42′	October 31
5.8, 9.0 m	PA 310°| Sep. 4.0″			Moderate

A lovely double-star system, consisting of a yellow primary and reddish secondary.

36 Andromedae	ADS 755	$00^h\ 55.0^m$	+23° 38′	October 4
6.0, 6.4 m	PA 313°| Sep. 0.9″			Difficult

This pair of brilliant yellow stars is a test for large amateur telescopes. Discovered by F. Struve in 1836.

ε Trianguli	HD 12471	$02^h\ 03.0^m$	+33° 17′	October 22
5.4, 11.4 m	PA 118°| Sep. 3.9″			Difficult

This is a difficult double because of the large magnitude difference. It consists of a blue white primary and white secondary.

See also:

Star	PA/Sep	Month
τ^1 Aquarii	121°| 23.7″	September
Herschel 975	243°| 51.0″	September
42 Piscium	324°| 28.5″	September
51 Piscium	83°| 27.5″	September
57 Pegasi	198°| 32.6″	September
107 Aquarii	136°| 6.6″	September
σ Cassiopeiae	326°| 3.0″	September
Struve 3050	335°| 1.7″	September
Groombridge 34	62°| 40.0″	September
η Persei	300°| 28.3″	November
Struve 390	159°| 14.8″	November
φTauri	250°| 52.1″	November
θ Persei	305°| 20.0″	November
o^2 Eradini	104°| 83″	November
30 Tauri	59°| 9.0″	November
32 Eridani	347°| 6.8″	November
39 Eridani	146°| 6.4″	November
ε Arietis	208°| 1.5″	November
47 Tauri	351°| 1.1″	November

November

η Persei	ADS 2157	$02^h\ 50.7^m$	+55° 54′	November 3
3.8, 8.5 m	PA 300°| Sep. 28.3″			Easy©

Seek this one out as it has a gold primary and blue secondary. Magnificent!

Struve 390	Σ390	$03^h\ 30.0^m$	+55° 27′	November 13
5.1, 9.5 m	PA 159°| Sep. 14.8″			Easy©

Two stars of very different brightness; the primary is white, but the secondary is a lovely purple color.

φTauri	ADS 3137	$04^h\ 20.4^m$	+27° 21′	November 26
5.0, 8.4 m	PA 250°| Sep. 52.1″			Easy

Easily seen in binoculars. Bright yellow primary and blue secondary.

θ Persei	HD 16895	$02^h\ 44.2^m$	+49° 14′	November 1
4.1, 9.9 m	PA 305°| Sep. 20.0″			Easy/moderate

A nice system with a bright yellow primary and blue secondary.

o^2 Eradini	ADS 3093	$04^h\ 15.2^m$	–07° 39′	November 24
4.4, 9.5 m	PA 104°| Sep. 83″			Easy/moderate

Now for a challenge to split with binoculars. What makes this system so interesting is that the secondary is the brightest white dwarf star visible from Earth.

30 Tauri	HD 23793	$03^h\ 48.3^m$	+11° 09′	November 17
5.1, 10.2 m	PA 59°| Sep. 9.0″			Moderate

An interesting system lying in a star field, comprising a bluish-white and reddish double. Observers have reported the primary as green and pale yellow, and the secondary as purple.

32 Eridani	HD24555	$03^h\ 54.3^m$	–02° 57′	November 19
4.8, 6.1 m	PA 347°| Sep. 6.8″			Moderate

A yellow and white double-star system, with colors that have also been described as yellow and blue, and topaz and bright green.

39 Eridani	HD 26846	$04^h\ 14.4^m$	–10° 15′	November 24
5.0, 8.0 m	PA 146°| Sep. 6.4″			Moderate

Situated in a star field, consisting of a nice orange and white double-star system.

ε Arietis	ADS 2257	02^h 59.2^m +21° 20′	November 5
5.2, 5.5 m	PA 208°| Sep. 1.5″		Difficult

A test of the optics of your telescope. Both white stars are nearly equally bright. Test for 7.5 cm.

47 Tauri	HD 26722	04^h 13.9^m	+09° 16′	November 24
4.9, 7.4 m	PA 351°| Sep. 1.1″			v. difficult

A high magnification is needed to split this system, where both stars appear yellow.

See also:

Star	PA/Sep	Month
η Cassiopeiae	317°| 12.9″	October
26 Ceti	253°| 16.0″	October
γ Arietis	0°| 7.8″	October
λ Arietis	46°| 37.4″	October
66 Ceti	234°| 16.5″	October
α Ursae Minoris	218°| 18.4″	October
33 Arietis	0°| 28.6″	October
ι Trianguli	71°| 3.9″	October
84 Ceti	310°| 4.0″	October
36 Andromedae	313°| 0.9″	October
ε Trianguli	118°| 3.9″	October
11 & 12 Cml	8°| 108.5″	December
S473	305°| 20.6″	December
La 1	123°| 11.0″	December
γ Leporis	350°| 96.3″	December
41 Aurigae	356°| 7.7″	December
15 Geminorum	204°| 25.1″	December
ν^1 Canis Majoris	262°| 17.5″	December
ω Aurigae	359°| 5.4″	December
h3750	282°| 4.2″	December
γ Leporis	358°| 2.6″	December
UV Aurigae	4°| 3.4″	December
θ Aurigae	313°| 3.6″	December

December

11 & 12 Camelopardalis		05^h 06.1^m	+58° 58′	December 7
5.4, 6.5 m	PA 8°| Sep. 108.5″			Easy ©

Easily spotted in binoculars, this is a pair of white and deep yellow stars.

S473	ADS 3883	05^h 17.1^m	−15° 13	December 10
6.7, 8.7 m	PA 305°| Sep. 20.6″			Easy

A system that is suitable for small telescopes with a white primary and blue secondary.

La 1	ADS 4260	05^h 39.7^m	−20° 26′	December 16
6.9, 7.9 m	PA 123°| Sep. 11.0″			Easy

Now for a rare treat, a system consisting of white and purple stars!

γ Leporis	ADS 4334	05^h 44.5^m	−22° 27′	December 17
3.7, 6.3 m	PA 350°| Sep. 96.3″			Easy

A glorious system that is easy to resolve for even the smallest telescope. Bright yellow and pale tinted orange. Test for 7.5 cm.

41 Aurigae	ADS 4773	06^h 11.6^m	+48° 43′	December 24
6.3, 7.0 m	PA 356°| Sep. 7.7″			Easy

A nice white and bluish-white double-star system.

15 Geminorum	h 70	06^h 27.8^m	+20° 47′	December 28
6.6, 8.0 m	PA 204°| Sep. 25.1″			Easy

A double-star system of yellow and blue stars.

ν^1 Canis Majoris	ADS 5253	06^h 36.7^m	−18° 40′	December 30
5.8, 8.5 m	PA 262°| Sep. 17.5″			Easy

An easily resolved pair of yellow stars.

ω Aurigae	ADS 3572	04^h 59.3^m	+37° 53′	December 5
5.0, 8.0 m	PA 359°| Sep. 5.4″			Moderate

Stars appear white and blue in small telescopes but have shown subtle tints in larger instruments.

h3750	ADS 3930	05^h 20.4^m	−21° 14′	December 11
4.7, 8.4 m	PA 282°| Sep. 4.2″			Moderate

A lovely yellow and blue star system that has been described as “most beautiful.”

κ Leporis	ADS 3800	05^h 13.2^m	−12° 56′	December 9
4.5, 7.4 m	PA 358°| Sep. 2.6″			v. difficult

A pair of white stars that will require the best conditions and optics in order to be resolved.

UV Aurigae	05^h 21.8^m	+32° 31′	December 11
7–10.6, 11.5 m	PA 4°| Sep. 3.4″		v. difficult

This is a difficult object to locate owing to its variable nature. It is a carbon star, coupled with a B-type giant star. But persevere and you will be rewarded by a lovely combination of orange and blue stars.

θ Aurigae	ADS 4566	05^h 59.7^m	+37° 13′	December 21
2.6, 7.1 m	PA 313°| Sep. 3.6″			v. difficult

With small telescopes, excellent seeing conditions and superb optics are required to see these two bluish-white stars. The spectrum shows strong lines of silicon. Would be a good test for a 10 cm telescope.

See also:

Star	PA/Sep	Month
η Persei	300°| 28.3″	November
Struve 390	159°| 14.8″	November
φ Tauri	250°| 52.1″	November
θ Persei	305°| 20.0″	November
o^2 Eradini	104°| 83″	November
30 Tauri	59°| 9.0″	November
32 Eridani	347°| 6.8″	November
39 Eridani	146°| 6.4″	November
ε Arietis	208°| 1.5″	November
47 Tauri	351°| 1.1″	November
φ^5 Aurigae	31°| 36.2″	January
μ Canis Majoris	18°| 11.6″	January
h 3945	55°| 26.6″	January
Struve 1149	41°| 21.7″	January
38 Geminorum	145°| 7.1″	January
μ Canis Majoris	340°| 3.0″	January
κ Geminorum	240°| 7.1″	January
ϕ^2 Cancri	218°| 5.1″	January

Other Multiple Star Systems

Double stars are not the only type of multiple-star system. There exist many beautiful triple and even quadruple stars within reach of modest telescopes. A few of these are presented in the following lists. The same nomenclature applies as in the double-star section.

January

17 Canis Majoris	ADS 5585	06^h 55.0 ^{m}	−20° 24′	January 4
5.8, 9.3, 9.0 m	PA 147°| Sep. 44.4″			Easy

A nice triple system. Wonderful color contrasts of white and orange-red stars.

Burnham 324	ADS 5498	06^h 49.7^m	−24° 05′	January 2
6.3, 7.6, 8.6 m	PA 206°| Sep. 1.8″			Easy/moderate

A nice multiple-star system in the constellation of Canis Major, consisting of many white and blue stars.

Struve 1245	ADS 6886	08^h 35.8^m	+06° 37′	January 29
6.0, 7.2, 10.7, 12.2, 8.8 m	PA 25°| Sep. 10.3″			Easy/moderate/difficult

A lovely multiple-star system in the constellation Cancer. The triple aspect is seen in small telescopes. Yellow, pale yellow and white stars. Depending on the telescope used, you will see a double-, triple- or multiple-star system!

τ Canis Majoris	ADS 5977	07^h 18.7 ^{m}	−24° 57′	January 10
4.4, 10.5, 11.2 m	PA 90°| Sep. 80.2″			Difficult

Wonderful! This triple is within the open cluster NGC 2362, and so its yellow and blue components are set against a glorious backdrop of faint stars.

See also:

Star	PA/Sep	Month
Struve 1369	148°| 24.7″	February
β Camelopardalis	208°| 80.8″	December
Trapezium	241°| 13.4″	December
σ Orionis	238°| 11.4″	December
ε Monocerotis	27°| 13.4″	December
β Monocerotis	132°| 7.3″	December

(continued)

Star	PA/Sep	Month
14 Aurigae	352°| 14.6″	December
OΣ 147	73°| 43.2″	December
Struve 939	106°| 30.2″	December
ξ Orionis	165°| 2.3″	December
ι Orionis	141°| 11.3″	December
η Orionis	80°| 1.5″	December
λ Orionis	43°| 4.4″	December

February

Struve 1369	ADS 7438	09^h 35.4^m	-+39° 57′	February 13
7.9, 8.0, 8.7 m	PA 148°| Sep. 24.7″			Easy

Located in the constellation Lynx, this is an easily resolved system of yellow stars, along with faint white stars.

See also:

Star	PA/Sep	Month
17 Canis Majoris	147°| 44.4″	January
Burnham 324	206°| 1.8″	January
Struve 1245	25°| 10.3″	January
τ Canis Majoris	90°| 80.2″	January
Struve 1604	89°| 9.9″	March

March

Struve 1604	ADS 8440	12^h 09.5^m	−11° 51′	March 24
6.8, 8.5, 9.1 m	PA 89°| Sep. 9.9″			Moderate

Another rare but lovely triple-star system that forms an equilateral triangle. Lies in the constellation Corvus.

See also:

Star	PA/Sep	Month
Struve 1369	148°| 24.7″	February
Burnham 800	106°| 6.8″	April
35 Comae Berenices	182°| 1.2″	April
ι Boötis	33°| 38.5″	April

April

Burnham 800	β800[43]	$13^h\ 16.9^m$	+17° 01′	April 10
6.6, 9.7, 10.4 m	PA 106°| Sep. 6.8″			Moderate

In the constellation of Coma Berenices lies this lovely triple-star system of orange, pale red and white stars.

35 Comae Berenices	ADS 8695	$12^h\ 53.3^m$	+21° 14′	April 5
5.1, 7.2, 9.1 m	PA 182°| Sep. 1.2″			Difficult

A fine triple-star system, consisting of one yellow and two of the very rare purple-colored stars.

ι Boötis	ADS 9198	$14^h\ 16.2^m$	+51° 22′	April 26
4.9, 7.5, 12.6 m	PA 33°| Sep. 38.5″			Difficult©

A nice triple-star system, although difficult to see in small instruments. The brighter members are yellow- and blue-colored stars.

See also:

Star	PA/Sep	Month
Struve 1604	89°| 9.9″	March
16 & 17 Draconis	194°| 90.3″	May
5 Serpentis	36°| 11.2″	May
β Serpentis	265°| 30.6″	May
μ Boötis	8°| 2.3″	May
ξ Scorpii	61°| 0.5″	May
σ Coronae Borealis	236°| 7.1″	May
λ Ophiuchi	30°| 1.5″	May

May

16 & 17 Draconis	ADS 10129	$16^h\ 36.2^m$	+52° 55′	May 31
5.4, 5.5, 6.4 m	PA 194°| Sep. 90.3″			Easy©

An easily split triple-star system. The two main stars can be seen in binoculars. However, the third star will require a small telescope in order to be seen. Consists of three white stars.

[43] This signifies that it is the 800th object in the S. W. Burnham catalog.

5 Serpentis	ADS 9584	15*h* 19.3*m*	+01° 46′	May 12
5.1, 10.1, 9.1 m	PA 36°| Sep. 11.2″			Moderate

A triple system of unequally bright stars, which always seems to enhance color contrast. It consists of a pair of yellow and red stars with a faint white companion.

β Serpentis	Σ1970	15^h 46.2^m	+15° 25′	May 18
3.7, 9.9, 10.7 m	PA 265°| Sep. 30.6″			Moderate

A nice system for small telescopes. The stars are colored lemon, blue and white.

μ Boötis	ADS 9626	15^h 24.5^m	+37° 23′	May 13
4.3, 7.0, 7.6 m	PA 8°| Sep. 2.3″			Difficult

A nice triple-star system of close stars consisting of a pale yellow primary and pale yellow and orange companions. Discovered by G. Struve in 1835.

ξ Scorpii	Σ 1998	16^h 04.4^m	−11° 22′	May 23
4.8, 5.1, 7.3 m	PA 61°| Sep. 0.5″			Difficult

A triple-star system that is a test for medium aperture telescopes. Consists of two yellow stars and a fainter blue companion, although reports describe the primary as golden in color.

σ Coronae Borealis	ADS 9979	16^h 14.7^m	+33° 52′	May 26
5.6, 6.6, 13.1, 10.6 m	PA 236°| Sep. 7.1″			Difficult

A quadruple-star system. The two main stars are easily seen, colored pale and deep yellow, although some observers report that the color contrast is slight. The remaining two companion stars, however, are very faint.

λ Ophiuchi	ADS 10087	16^h 30.9^m	+01° 59′	May 30
4.2, 5.2, 11.1, 9.5 m	PA 30°| Sep. 1.5″			Difficult

A nice though difficult quadruple-star system. The white and yellow primaries are a good test for small telescopes.

See also:

Star	PA/Sep	Month
Burnham 800	106°| 6.8″	April
35 Comae Berenices	182°| 1.2″	April
ι Boötis	33°| 38.5″	April
μ Herculis	247°| 33.8″	June
Struve 2306	221°| 10.2″	June

June

μ Herculis	ADS 10786	17^h 46.5^m	+27° 43′	June 18
3.4, 10.1 m	PA 247°| Sep. 33.8″			Moderate

A triple-star system consisting of a yellow primary star and two faint red dwarf stars. Discovered by William Herschel in 1781.

Struve 2306	Σ2306	18^h 22.2^m	−15° 05′	June 27
7.9, 8.6, 9.0 m	PA 221°| Sep. 10.2″			Moderate

Located in the constellation Scutum, this is a wonderful triple-star system of delicately colored stars. Observers have reported the primary as gold or copper-colored and the secondary as cobalt blue or blue. The blue secondary will need a high magnification in order to split it.

See also:

Star	PA/Sep	Month
16 & 17 Draconis	194°| 90.3″	May
5 Serpentis	36°| 11.2″	May
β Serpentis	265°| 30.6″	May
μ Boötis	8°| 2.3″	May
ξ Scorpii	61°| 0.5″	May
σ Coronae Borealis	236°| 7.1″	May
λ Ophiuchi	30°| 1.5″	May
Struve 2445	263°| 12.6″	July
β Capricorni	267°| 205.3″	July
α Lyrae	173°| 62.8″	July
54 Sagittarii	38°| 274″	July

July

Struve 2445	Σ 2445	19^h 04.6^m	+23° 20′	July 8
7.2, 8.9, 8.9 m	PA 263°| Sep. 12.6″			Easy

Located in the constellation Vulpecula, this is a nice triple for small telescopes or binoculars. Blue stars and white ones.

β Capricorni	Σ 152	20^h 21.0^m	−14° 47′	July 27
3.4, 6.2, 9.0 m	PA 267°| Sep. 205.3″			Easy

A fine triple-star system that can be easily resolved by binoculars. It has a nice color contrast of a yellow primary with blue and pale yellow secondaries.

α Lyrae	ADS 11510	18^h 36.9^m	+38° 47′	July 1
0.0, 9.5, 11.0, 9.5 m	PA 173°| Sep. 62.8″			Moderate

A very famous star, Vega is the brightest in the summer sky, and has a wonderful steely blue-white color. The star has many faint companions that are not physically associated. It was the first star to be photographed (1850), and recent measurements of infrared radiation from it indicate proto-planetary material surrounding the star that imply a solar system in formation.

54 Sagittarii	ADS 12767	19^h 40.7^m	−16° 18′	July 17
5.4, 11.9, 8.9 m	PA 38°| Sep. 274″			Moderate

A wonderfully colored triple-star system, with a yellow-orangish primary, a pale blue secondary and pale yellow companion.

See also:

Star	PA/Sep	Month
μ Herculis	247°| 33.8″	June
Struve 2306	221°| 10.2″	June
ε Equulei	70°| 10.7″	August

August

ε Equulei	ADS 14499	20^h 59.1^m	+04° 18′	August 6
6.0, 6.3, 7.1 m	PA 70°| Sep. 10.7″			Difficult

This is a very difficult triple-star system to resolve. The two brightest members are very close at the moment, and will remain so for quite some time, and so it will appear as an elongated blob, even under high magnification. The third member of the system is blue, in contrast to the yellow of the main stars.

See also:

Star	PA/Sep	Month
Struve 2445	263°| 12.6″	July
β Capricornin	267°| 205.3″	July
α Lyrae	173°| 62.8″	July
54 Sagittarii	38°| 274″	July

September

See:

Star	PA/Sep	Month
ε Equulei	70°| 10.7″	August
ι Cassiopeiae	230°| 2.5″	October

October

ι Cassiopeiae	ADS 1860	02^h 29.1 ^{m}	+67° 24′	October 28
4.6, 6.9, 8.4 m	PA 230°| Sep. 2.5″			Difficult©

Thought by many to be one of the loveliest triple-star systems in the entire sky. A brilliant yellowish-white primary with bluish companions. The primary is also a variable of the Alpha Canum Venaticorum type, with a magnitude range of only 0.03.

See also:	*PA/Sep*	*Month*
γ Ceti	294°| 2.8″	November
o^2 Eridani	347°| 7.6″	November

November

γ Ceti	ADS 2080	02^h 43.3 ^{m}	+03° 14′	November 1
3.5, 7.3, 10.1 m	PA 294°| Sep. 2.8″			Moderate

In medium-aperture telescopes (between 20.0 and about 25 cm) this triple appears as a lovely white, yellow and faint red system, although the latter has been called tawny or dusky!

o^2 Eridani	ADS 3093	04^h 15.2 ^{m}	–07° 39′	November 24
4.4, 9.4, 11.2 m	PA 347°| Sep. 7.6″			Moderate/difficult

A triple-star system consisting of a creamy yellowish star along with pale blue companions. What is exceptional about the two fainter companions is that they are a white dwarf and a red dwarf. The white dwarf is the brightest visible from Earth, with a mass equal to that of the Sun, although only 17,000 miles across. The red dwarf has a mass only one-fifth that of Earth.

See also:

Star	PA/Sep	Month
ι Cassiopeiae	230°| 2.5″	October
Trapezium	241°| 13.4″	December
σ Orionis	238°| 11.4″	December
ε Monocerotis	27°| 13.4″	December
β Monocerotis	132°| 7.3″	December
14 Aurigae	352°| 14.6″	December
ΟΣ 147	73°| 43.2″	December
Struve 939	106°| 30.2″	December
ζ Orionis	165°| 2.3″	December
ι Orionis	141°| 11.3″	December
η Orionis	80°| 1.5″	December
λ Orionis	43°| 4.4″	December

December

β Camelopardalis	HD 31910	$05^h\ 03.4^m$	+60° 27′	December 6
4.0, 8.6, 11.2 m	PA 208°| Sep. 80.8″			Easy ©

This is a nice triple system of yellow and blue stars. What makes this system so memorable is that it is seen against the dark nebula of the Milky Way.

Trapezium	θ Orionis	$05^h\ 35.3^m$	–05° 23′	December 14
5.1, 6.7 m	PA 241°| Sep. 13.4″			Easy
6.7, 7.9 m				

Probably the most famous multiple-star system in the sky and always a test for small telescopes. The four stars that make up the famous quadrilateral are set among the wispy embrace of the Orion Nebula, M42, one of the most magnificent sites in any telescope. Very young stars recently formed from the material in the nebula, and so should all appear bright white, but the nebula itself probably affects the light that is observed, so the stars appear as off-white, delicately tinted yellowish and bluish. Other observers have reported the colors as pale white, faint lilac, garnet and reddish! It is believed that these four stars contribute nearly all the radiation that makes the Orion Nebula glow. Well worth spending an entire evening just observing this region. A glorious sight! (See the relevant entry in Chapter 7).

σ Orionis	ADS 4241	$05^h\ 38.7^m$	–02° 36′	December 15
4.0, 10.3, 7.5, 6.5 m	PA 238°| Sep. 11.4″			Easy

A multiple-star system of white and bluish stars.

ε Monocerotis	ADS 5012	06^h 23.8^m	+04° 36′	December 27
4.5, 6.5, 5.6 m	PA 27°| Sep. 13.4″			Easy

A lovely triple system of pale yellow stars, along with a very faintly tinted blue companion. Set against the star fields of the Milky Way.

β Monocerotis	ADS 5107	06^h 28.8^m	–07° 02′	December 28
4.7, 5.2, 6.1 m	PA 132°| Sep. 7.3″			Easy

A magnificent triple star first discovered in 1781 by Herschel. All the stars are a lovely steely blue-white in color. What makes this system so unique is that all the stars are very nearly equal in brightness.

14 Aurigae	ADS 3824	05^h 15.4^m	+32° 31′	December 9
5.1, 11.1, 7.4 m	PA 352°| Sep. 14.6″			Easy/moderate

A nice system visible in all sizes of telescopes consisting of yellow, blue and white stars.

OΣ 147	ADS 5188	06^h 34.3^m	+38° 05′	December 29
6.6, 10, 10.6 m	PA 73°| Sep. 43.2″			Moderate

Located in the constellation Auriga, this is a wonderful triple star system forming a triangle of yellow and blue stars.

Struve 939	Σ 939	06^h 35.9^m	+05° 19′	December 30
8.3, 9.2, 9.4 m	PA 106°| Sep. 30.2″			Moderate

A fascinating but rare triple system with all its members forming a nearly perfect equilateral triangle.

ξ Orionis	ADS 4263	05^h 40.8^m	–01° 57′	December 16
1.9, 4.0, 9.9 m	PA 165°| Sep. 2.3″			Moderate

A nice triple system of blue, white and very pale red stars. Located among and near several bright and dark nebulae.

ι Orionis	ADS 4193	05^h 35.4^m	–05° 55′	December 15
2.8, 7.3, 11.1 m	PA 141°| Sep. 11.3″			Moderate/difficult

A nice color-contrasted triple system that is also a test for small telescopes. The stars are colored white with delicately tinted blue and red companions.

η Orionis	ADS 4002	05^h 24.5^m	–02° 24′	December 12
3.6, 5.0, 10.1 m	PA 80°| Sep. 1.5″			Difficult

Also known as Dawes 5, this is a wonderful system. Even under high magnification, the two brighter members will appear as two white discs in contact. η Orionis is also a spectroscopic binary.

λ Orionis	ADS 4179	05^h 31.1^m	+09° 56′	December 13
3.5, 5.6, 11.1, 11.1 m	PA 43°| Sep. 4.4″			Difficult

A nice quadruple-star system consisting of white and blue stars. Various observers have reported them as yellowish and purple and pale white and violet.

See also:

Star	PA/Sep	Month
17 Canis Majoris	147°| 44.4″	January
Burnham 324	206°| 1.8″	January
Struve 1245	25°| 10.3″	January
τ Canis Majoris	90°| 80.2″	January
γ Ceti	294°| 2.8″	November
o^2Eridani	347°| 7.6″	November

Chapter 3

Star Clusters

Having looked at stars as individual objects, let's now turn our attention to groups of stars, or *star clusters*.

There is such a plethora of star clusters available for observation that they provide a rich and diverse selection of observing targets whether one is using the naked eye, binoculars or telescopes. Some clusters may have only a few members (these are the *open clusters*), while others may contain several thousand stars – or, in some cases, even a million – as is the case for many so-called *globular clusters*. Many display a jewel-box array of colors, while others may contain only steely blue stars or brilliant white ones. Some types of clusters contain only very young stars, perhaps only a few million years old, whereas other kinds will contain stars that are very old, perhaps several billion years old.

The clusters selected here are only a representative few of the hundreds that are available to the amateur astronomer.

As usual, a few words on origin, evolution and structure are appropriate before the objects are described.

Open Star Clusters

A casual glance at the night sky may lead you into believing that stars are solitary, isolated objects, but in fact no star is born in isolation. The process of star birth takes place in immense interstellar clouds of dust and gas that, depending upon the cloud's size, can give rise to anything from a few dozen to many thousands of new, and young, stars. Over time, however, this stellar nursery of young stars will gradually disperse. Theory predicts that massive stars have much shorter life spans than

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_3,

smaller, less massive ones, such that the more massive stars do not live long enough to escape their birthplace, whereas a smaller star, say, of solar mass in size, will in most cases easily migrate from its stellar birthplace.

It's worth noting, in relation to stars of mass about equal to that of the Sun, that where there may be several thousand of these objects, the combined gravitational attraction of so many stars may slow down the dispersion of the group. It really depends on the star-density and mass of the particular cluster. So we can infer that the most dense or closely packed clusters, containing solar mass-sized stars, will be the ones that contain the oldest population of stars, while the most scattered clusters will have the youngest stellar population.

Open clusters, or *galactic clusters*, as they are also called, are collections of young stars, containing anything from maybe a dozen members to thousands. A few of them, for example, Messier 11 in Scutum, contains an impressive number of stars, equaling that of globular clusters, while others seem little more than a faint grouping set against the background star field.

Such is the variety of open clusters that they come in all shapes and sizes. Several are over a degree in size, and their full impact can only be appreciated by using binoculars, as a telescope has too narrow a field of view. An example of such a large cluster is Messier 44 in Cancer. Then there are tiny clusters, seemingly nothing more than compact multiple stars, as is the case with IC 4996 in Cygnus. In some cases all the members of the cluster are equally bright, such as Caldwell 71 in Puppis, but there are others that consist of only a few bright members accompanied by several fainter companions, as is the case of Messier 29 in Cygnus. The stars that make up an open cluster are called *Population I* stars, which are metal-rich and usually to be found in or near the spiral arms of the galaxy.

The size of a cluster can vary from a few dozen light-years across, as in the case of NGC 255 in Cassiopeia, to about 70 light-years across, as in either component of Caldwell 14, the Perseus Double Cluster.

The reason for the varied and disparate appearances of open clusters is the circumstances of their births. It is the interstellar cloud that determines both the number and type of stars that are born within it. Factors such as the size, density, turbulence, temperature, and magnetic field all play a role as the deciding parameters in star birth. In the case of *giant molecular clouds* (GMCs) the conditions can give rise to both O- and B-type giant stars along with solar-type dwarf stars, whereas in *small molecular clouds* (SMCs) many solar-type stars will be formed, with very few, if any at all, of the luminous 0- and B-type stars. An example of an SMC is the Taurus Dark Cloud, which lies just beyond the Pleiades.

An interesting aspect of open clusters is their distribution in the night sky. You may be forgiven in thinking that they are randomly distributed across the sky, but sky surveys show that although well over a thousand clusters have been discovered, only a few are observed to be at distances greater than 25° above or below the galactic equator. Some parts of the sky are very rich in clusters – Cassiopeia, and Puppis, for example – and this is due to the absence of dust lying along these lines of sight, allowing us to see across the spiral plane of our galaxy. Many of the clusters mentioned actually lie in different spiral arms, and so as you observe them you are actually looking at different parts of the spiral structure of our galaxy. An amazing thought!

It was mentioned earlier that stars are not born in isolation. However, this does not mean that they are all born simultaneously. The more massive a star the faster it contracts and becomes stable, with the result that some clusters have a few bright young O- and B- main sequence stars, while at the same time contain low-mass members that may still be in the process of gravitational contraction, for example the star cluster at the center of the Lagoon Nebula. In a few cases, the star production can be at a very early stage, with only a few stars visible, the majority of protostars, as they are called, still in the process of contraction and hidden within the interstellar cloud.

A perfect example of such a process is the open cluster within Messier 42, the Orion Nebula. The stars within the cluster called the Trapezium are the brightest, youngest and most massive stars in what will eventually become a large cluster containing many A-, F- and G-type stars. However, the majority are blanketed by dust and gas clouds and are only detectable by their infrared radiation.

As time passes, the dust and gas surrounding a new cluster will be blown away by the radiation from the O-type stars, resulting in the cluster becoming visible in its entirety, such as in the case of the young cluster Caldwell 76 in Scorpius.

Once a cluster has formed it will remain more or less unchanged for at least a few million years, but over time changes within the cluster occur, with two processes responsible. The evolution of open clusters depends on both the initial stellar content of the group and the ever-pervasive pull of gravity. If a cluster contains O-, B- and A-type stars, then these stars will eventually become supernovae, leaving the cluster with slower evolving, less massive and less luminous members of type G, K and M stars. A famous example of such a cluster is Caldwell 94, the Jewel Box in Crux, which is a highlight of the southern sky, although, alas, unobservable to northern hemisphere observers. However, these too will become supernovae, with the result that the most luminous members of a cluster will, one by one, disappear over time. This doesn't necessarily mean the demise of a cluster, especially those that have many tens or hundreds of members. But some, which consist of only a few bright stars, will seem to meld into the background star field.

However, even those clusters that have survived the demise of their brighter members will eventually begin to feel the effect of a force that pervades everywhere – the galaxy's gravitational field. As time passes the cluster will be affected by the influence of other clusters and the interstellar medium itself, as well as the tidal force of the galaxy. The cumulative effect of all these encounters will result in some of the less massive members of the cluster acquiring enough velocity to escape from it. Thus, given enough time, a cluster will fade and disperse. (Take heart, as this isn't likely to happen in the near future so that you would notice. The Hyades star cluster, even after having lost most of its O- and B-type stars, is still with us, after 600 million years!).

For the amateur, observing open clusters is a very rewarding experience, as they offer a variety of views from naked eye to telescopic. Happily, many of them are best viewed by binoculars, especially the larger clusters that are of an appreciable angular size. Furthermore, nearly all have double or triple stars within the cluster, and so regardless of magnification there is always something of interest to be seen.

From the preceding chapter you will know that color in observed stars is best seen when contrasted with a companion or companions. Thus an open cluster presents a perfect opportunity for observing star colors. Many clusters, such as the ever and rightly popular Pleiades, are all a lovely steely blue color. On the other hand, Caldwell 10 in Cassiopeia has contrasting bluish stars along with a nice orange star. Other clusters have a solitary yellowish or ruddy orange star along with fainter white ones, such as Messier 6 in Scorpius. An often striking characteristic of open clusters is the apparent chains of stars that seemingly arc across apparently empty voids, as in Messier 41 in Canis Major.

Another word for a very small, loose group of stars is an *asterism*. In some cases there may only be five to six stars within the group.

Because open clusters display such a wealth of characteristics, different parameters are assigned to a cluster that describe its shape and content. For instance, a designation called the *Trumpler type* is often used. It is a three-part designation that describes the cluster's degree of concentration, that is, from a packed cluster to one that is evenly distributed, the range in brightness of the stars within the cluster, and finally the richness of the cluster, from poor (less than 50 stars) to rich (more than 100). The full classification is:

Trumpler classification for star clusters	
Concentration	
I	Detached – strong concentration of stars towards the center
II	Detached – weak concentration of stars towards the center
III	Detached – no concentration of stars towards the center
IV	Poor detachment from background star field
Range of Brightness	
1	Small range
2	Moderate range
3	Large range
Richness of Cluster	
p	Poor (with less than 50 stars)
m	Moderate (with 50–100 stars)
r	Rich (with more than 100 stars)
n	Cluster within nebulosity

Actually, in truth, this designation is of limited use, as some clusters that appear very rich when seen in good binoculars are disappointing when viewed using a telescope. Additionally, the use of high magnification and large aperture will often make a poor cluster appear very rich. However, for completeness, we are using the designation as a rough guide as to what you can expect to see under perfect conditions with perfect optics, and so on.

Two further points need to be mentioned that can often cause problems: the magnitude and size of the cluster. The quoted apparent magnitude of a cluster may be the result of only a few bright stars, but it can also be the result of a large number of faint stars. Therefore, do not be surprised if a low magnitude cluster appears faint in the eyepiece. Also, the diameter of a cluster is often misleading, as in most cases it has been calculated from photographic plates, which, as experienced amateurs will know, bear little resemblance to what is seen at the eyepiece.

Although magnitudes and diameters may be quoted in the text, do treat them with a certain amount of caution.

You may notice that a few star clusters seem to be missing from the lists. There is a reason for this. In this new edition, a new chapter has been included, "Naked-Eye Deep-Sky Objects." This new chapter will deal with, among other things, star clusters that can (hopefully) be seen with the naked eye. So for instance, the Pleiades will be mentioned in the new chapter, and not this one. But telescope users should take heart, as the descriptions of the naked-eye objects will also include binocular and telescopic information as and when appropriate.

In the descriptions given below, the first line lists the name, the position and the approximate midnight transit time, the second line the visual magnitude (this is the combined magnitude of all stars in cluster), object size in arcminutes (⊕), the approximate number of stars in the cluster (bear in mind that the number of stars seen will depend on magnification and aperture and will increase when large apertures are used; thus the number quoted is an estimate using modest aperture), the Trumpler designation and the level of difficulty (based on the magnitude, size and ease of finding the cluster).

Once again you will notice that the listings present data in two forms. If a cluster is at its best time to observe, i.e., the month during which it transits, then a full description will be given. Lots of other clusters may also be visible, but they may not be at their best position to be observed. In that instance, a brief reference to the month at which the cluster will transit is given and thus be at an acceptable position to be observed.

January

–	NGC 2301	$06^h\ 51.8^m$	+00° 28′	January 3
6.0 m	⊕ 12′	70	I 3 m	Easy

Superb! A very striking cluster. In binoculars, a north-south chain of eighth- and ninth-magnitude stars is revealed, marked at its midway point by a faint haze of unresolvable stars. With large aperture, there is a colorful trio of red, gold and blue stars at the cluster's center.

Collinder 121	–	$06^h\ 54.2^m$	–24° 38′	January 3
2.6 m	⊕ 50′	20	III 3 p	Easy

A very large cluster, but one that is difficult to locate because of the plethora of stars in the background. At the northern border of the cluster is *O* Canis Majoris. Best seen with large binoculars or low-power telescopes.

Herschel 34	NGC 2353	07^h 14.6^m	−10° 18′	January 9
7.1 m	⊕ 20′	30	II 2 p	Easy

A cluster of stars best seen in a telescope. It includes many orange sixth-magnitude stars.

Caldwell 58	NGC 2360	07^h 17.8^m	−15° 37′	January 9
7.2 m	⊕ 12′	80	II 2 m	Easy

A beautiful open cluster, irregularly shaped and very rich. There are many faint stars, however, so the cluster needs moderate-aperture telescopes for these to be resolved, although it will appear as a faint blur in binoculars. This is believed to be an old cluster with an estimated age of around 1.3 billion years.

Caldwell 64	NGC 2362	07^h 18.8^m	−24° 57′	January 10
4.1 m	⊕ 8′	60	I 3 p n	Easy

A very nice cluster, tightly packed and easily seen. With small binoculars the glare from t CMa tends to overwhelm the majority of stars, although it is itself is a nice star, with two bluish companion stars (recent research indicates that the star is a quadruple system). But the cluster becomes truly impressive with telescopic apertures; the bigger the aperture, the more stunning the vista. It is believed to be very young – only a couple of million years old – and thus has the distinction of being the youngest cluster in our galaxy. Contains O- and B-type giant stars.

Messier 48	NGC 2548	08^h 13.8^m	−05° 48′	January 24
5.8 m	⊕ 55′	80	I 3 r	Easy

Located in a rather empty part of the constellation Hydra, this is believed to be the missing Messier object. It is a nice cluster in both binoculars and small telescopes. In the former, about a dozen stars are seen, with a pleasing triangular asterism at its center, while the latter will show a rather nice but large group of about 50 stars. Many amateurs often find the cluster difficult to locate for the reason mentioned above, but also for the fact that within a few degrees of M48 is another nameless, but brighter, cluster of stars that is often mistakenly identified as M48. Some observers claim that this nameless group of stars is in fact the correct missing Messier object, and not the one that now bears the name.

Caldwell 54	NGC 2506	08^h 00.2^m	−10° 47′	January 20
7.6 m	⊕ 7′	100	I 2 r	Medium

A nice, rich and concentrated cluster best seen with a telescope, but one that is often overlooked owing to its faintness even though it is just visible in binoculars. Includes many 11th- and 12th-magnitude stars. It is a very old cluster, around 2 billion years, and contains several blue stragglers. These are old stars that nevertheless have the spectrum signatures of young stars. This paradox was solved when research indicated that the younger-looking stars were the result of a merger of two older stars.

Herschel 21	NGC 2266	$06^h\ 43.2^m$	+26° 58′	January 1
9.5 m	⊕ 6′	50	II 2 m	Difficult

A pleasant cluster though difficult to locate, consisting of over 50 stars tightly compressed.

See also:

Cluster	Designation[1]	Month
Herschel 33	II 2 m	December
Collinder 464	II 2 m	December
Collinder 69	II 3 p n	December
Collinder 73	III 2 p n	December
Collinder 38	I 3 p n	December
Caldwell 50	–	December
Collinder 112	IV 3 p	December
Herschel 59	III 1 p	December
Collinder 81	II 3 r	December
Herschel 61	III 2 p	December
Herschel 68	II 1 p	December
Herschel 13	III 3 m	December
Messier 67	II 2 m	February

February

Messier 67	NGC 2682	$08^h\ 50.4^m$	+11° 49′	February 2
6.9 m	⊕ 30′	200	II 2 m	Difficult

Often overlooked owing to its proximity to M44, it is nevertheless very pleasing. However, the stars it is composed of are faint ones, so in binoculars it will be unresolved and seen as a faint misty glow. At a distance of 2,500 light-years, it is believed to be very old, possibly 9 billion years, and thus has had time to move from the galactic plane, the usual abode of open clusters, to a distance of about 1,600 light-years off the plane.

[1]This is the Trumpler designation discussed earlier in the chapter.

See also:

Cluster	Designation	Month
NGC 2301	I 3 m	January
Collinder 121	III 3 p	January
Messier 50 (see Chapter 7)	II 3 m	January
Herschel 34	II 2 p	January
Caldwell 58	II 2 m	January
Caldwell 64	I 3 p n	January
Messier 48	I 3 r	January
Caldwell 54	I 2 r	January
Herschel 21	II 2 m	January
Upgren 1	IV 2 p	March

March

Upgren 1	–	12^h 35.0^m	+36° 18′	March 31
6.6 m	⊕ 10′	10	IV 2 p	Easy

Almost unknown to amateurs, this is a fairly inconspicuous cluster of about ten stars. Binoculars show about seven of these. Although it has been shown to be a cluster, it appears to many observers as nothing more than an asterism.

See also:

Cluster	Designation	Month
Messier 67	II 2 m	February

April

See:

Cluster	Designation	Month
Upgren 1	I 3 r	March
Caldwell 75	I 3 r	May

May

Caldwell 75	NGC 6124	16^h 25.6^m	–40° 40′	May 28
5.8 m	⊕ 29′	75	I 3 r	Easy

A very nice, rich cluster, suitable for large binoculars and small telescopes. There is a chain of stars at its southern edge, and a tightly grouped collection of five bright stars at its center. It also contains several nice star chains and a few red-tinted stars. It is relatively close, at a distance of around 1,500 light-years.

See also:

Cluster	Designation	Month
Caldwell 76	I 3 p	June
Trumpler 24	IV 2 p n	June
IC 4665	III 2 m	June
Messier 23	II 2 r	June
Messier 21	I 3 r	June
Messier 16	II 3 m n	June
Messier 18	II 3 p n	June
Herschel 72	III 2 m	June
Collinder 309	I 2 r	June
Trumpler 26	II 1 m	June
Trumpler 26	II 1 m	June
Herschel 7	I 2 r n	June

June

Caldwell 76	NGC 6231	16^h 54.0^m	–41° 48′	June 5
2.6 m	⊕ 14′	100	I 3 p	Easy

A superb cluster located in an awe-inspiring region of the sky. Brighter by 2.5 magnitudes than its northern cousins, the Double Cluster in Perseus. This cluster is full of spectacular stars – very hot and luminous O-type and B0-type giants and supergiants, a couple of Wolf-Rayet stars, and ξ^{-1} Scorpii, which is a B1.5 Ia extreme supergiant star with a luminosity nearly 280,000 times that of the Sun! The cluster is thought to be a member of the stellar association Sco OB1, with an estimated age of 3 million years. A wonderful object in binoculars and telescopes, the cluster contains many blue, orange and yellow stars. It lies between μ^{1+2} Scorpii and ξ^{-1} Scorpii, an area rich in spectacular views. A good cluster to test the technique of averted vision, where many more stars will jump into view. Observe and enjoy.

Trumpler 24	Harvard 12	16^h 57.0^m	–40° 40′	June 5
8.6 m	⊕ 60′	100	IV 2 p n	Easy

A loose and scattered cluster, set against the backdrop of the Milky Way. It is, along with nearby Collinder 316, the core of the Scorpius OB1 stellar association.[2]

Messier 23	NGC 6494	17^h 56.8^m	–19° 01′	June 20
5.5 m	⊕ 27′	100	II 2 r	Easy

Often overlooked because it lies in an area studded with celestial showpieces, this is a wonderful cluster that is equally impressive seen in telescopes or binoculars, but the latter will only show a few of the brighter stars shining against a misty glow of fainter stars. Full of double stars and star chains.

Messier 21	NGC 6531	18^h 04.6^m	–22° 30′	June 22
5.9 m	⊕ 14′	60	I 3 r	Easy

An outstanding cluster for small telescopes and binoculars. A compact, symmetrical cluster of bright stars with a nice double system of ninth and tenth magnitude located at its center. Very close to the Triffid Nebula. In the cluster is the grouping called Webb's Cross, which consists of several stars of sixth and seventh magnitude arranged in a cross. Several amateurs report that some stars within the cluster show definite tints of blue, red and yellow. Can you see them?

A fine large cluster easily seen with binoculars. About 7,000 light-years away,

Messier 16	NGC 6611	18^h 18.8^m	–13° 47′	June 26
6.0 m	⊕ 22′	50	II 3 m n	Easy

Located in the Sagittarius-Carina spiral arm of the galaxy, its hot O-type stars provide the energy for the Eagle Nebula, within which the cluster is embedded. A very young cluster of only 800,000 years, with a few at 50,000 years old.

Messier 18	NGC 6613	18^h 19.9^m	–17° 08′	June 26
6.9 m	⊕ 10′	30	II 3 p n	Easy

A small and unremarkable Messier object, and perhaps the most often ignored, this little cluster, containing many ninth-magnitude stars, is still worth observing. Best seen with binoculars or low-power telescopes. A double star is located within the cluster.

[2]Stellar associations are discussed in the naked-eye deep-sky chapter.

Herschel 72	NGC 6633	$18^h\ 27.7^m$	+06° 34′	June 28
4.6 m	⊕ 27′	25	III 2 m	Easy

Bordering on naked-eye visibility, although reports are hard to come by, this bright, large but loose cluster is perfect for binoculars and small telescopes. The stars are a lovely bluish-white set against the faint glow of the unresolved members. At the northern periphery of the cluster is a small but nice triple-star system.

Herschel 7	NGC 6520	$18^h\ 03.4^m$	–27° 54′	June 22
7.5 m	⊕ 7′	30	I 2 r n	Difficult

This cluster, although fairly bright, is situated within the Great Sagittarius Star Cloud, and thus makes positive identification difficult. It contains about three dozen faint stars and locating it is a good test of an observer's skill.

See also:

Cluster	Designation	Month
Caldwell 75	I 3 r	May
Stock 1	III 2 m	July
Collinder 413	II 2 p n	July
Caldwell 37	III 2 p	July
Messier 29	I 2 m n	July
Herschel 8	III 2 r	July
Messier 26	I 2 m	July
Messier 11	I 2 r	July
Collinder 392	III 2 m	July
NGC 6755	II 2 r	July
Collinder 402	IV 3 p	July
Collinder 403	I 1 r	July
Harvard 20	IV 2 p	July
NGC 6791	I 2 r	July
NGC 6939	I 1 m	July

July

Stock 1	–	$19^h\ 35.8^m$	+25° 13′	July 16
5.3 m	⊕ 60′	40	III 2 m	Easy

An enormous cluster best seen in binoculars, although it is difficult to estimate where the cluster ends and the background stars begin.

Collinder 413	NGC 6871	$20^h\ 05.9^m$	+35° 47′	July 23
5.2 m	⊕ 20′	30	II 2 p n	Easy

A nice cluster that is easily seen in small telescopes. It appears as a enhancement of the background Milky Way. Binoculars will show several stars of seventh to ninth magnitude surrounded by fainter members.

Caldwell 37	NGC 6885	$20^h\ 12.0^m$	+26° 29′	July 25
5.9 m	⊕ 7′	25	III 2 p	Easy

An irregular cluster containing many 9th- to 13th-magnitude stars. One of a number of objects that apparently remain unknown to many amateur astronomers. Visible in binoculars as a hazy blur, it is located next to (within?) the cluster NGC 6882 and thus is not easily delineated. An old cluster with an estimated age of around 1 billion years, with recent measurements by Hipparchos placing it at a distance of 1,140 light-years.

Messier 29	NGC 6913	$20^h\ 23.9^m$	+38° 32′	July 28
6.6 m	⊕ 7′	80	I 2 m n	Easy

A very small cluster and one of only two Messier objects in Cygnus. It contains only about a dozen stars visible with small instruments, and even then benefits from a low magnification. However, studies show that it contains many more bright B0-type giant stars, which are obscured by dust. Without this, the cluster would be a very spectacular object.

Herschel 8	NGC 6940	$20^h\ 34.6^m$	+28° 18′	July 30
6.3 m	⊕ 32′	75	III 2 r	Easy

A beautiful cluster, which although visible in binoculars, is best appreciated with a telescope. It contains the semi-variable star FG Vulpeculae near its center that has a nice reddish-orange tint.

Messier 26	NGC 6694	$18^h\ 45.2^m$	–09° 24′	July 3
8.0 m	⊕ 14′	30	I 2 m	Medium

This is a small but rich cluster containing 11th- and 12th-magnitude stars, set against a haze of unresolved stars. This makes it unsuitable for binoculars, as it will be only a hazy small patch of light, and so apertures of 10 cm and more will be needed to appreciate it in any detail.

Messier 11	NGC 6705	$18^h\ 51.1^m$	–06° 16′	July 4
5.8 m	⊕ 13′	200	I 2 r	Medium

Also known as the Wild Duck Cluster, this is a gem of an object. Although it is visible with binoculars as a small, tightly compact group, reminiscent of a globular cluster, they do not do it justice. With telescopes, however, its full majesty becomes apparent. Containing many hundreds of stars, it is a very impressive cluster. It takes high magnification well, where many more of its 700 members become visible. At the top of the cluster is a glorious pale yellow tinted star. The well-known British amateur astronomer Michael Hurrell called this "one of the most impressive and beautiful celestial objects in the entire sky."

Collinder 392	NGC 6709	18^h 51.5^m	+10° 21′	July 4
6.7 m	⊕ 13′	45	III 2 m	Medium

A difficult object to locate for binoculars, as it will be unresolvable. Nevertheless this presents a good challenge for you to hone your observing skill. For small telescopes it presents a nice, rich cluster.

–	NGC 6755	19^h 07.8^m	+04° 14′	July 8
7.5 m	⊕ 15′	100	II 2 r	Medium

An easily found cluster in small telescopes, standing out from the background star field.

Collinder 402	NGC 6811	19^h 36.9^m	+46° 23′	July 16
6.8 m	⊕ 21′	65	IV 3 p	Medium

One of many clusters in Cygnus, this is a coarse open cluster of many tenth magnitude and fainter stars. The cluster has caught the attention of many amateurs, as it has been described as looking like a "smoke ring." The stars resemble the ring, while the interior is very dark. Apparently, the feature is easier to see with a small telescope than with a large one.

Collinder 403	NGC 6819	19^h 41.3^m	+40° 11′	July 17
7.3 m	⊕ 10′	100	I 1 r	Medium

A rich cluster located within, and contrasting with, the Milky Way. Contains many 11th-magnitude stars and thus is an observing challenge. The cluster is very old at over 3 billion years.

Harvard 20	–	19^h 53.1^m	+18° 20′	July 20
7.7 m	⊕ 10′	20	IV 2 p	Medium

A somewhat difficult binocular object, as the stars are of 12th and 13th magnitude and spread out without any noticeable concentration. The two nineth-magnitude members are easily spotted, however.

–	NGC 6791	19^h 20.7^m	+37° 51′	July 12
9.5 m	⊕ 15′	250	I 2 r	Difficult

A rich cluster of faint stars. It contains many faint 11th-magnitude stars and so poses an observing challenge.

–	NGC 6939	20^h 31.4^m	+60° 38′	July 30
7.8 m	⊕ 7.0′	50	I 1 m	Difficult ©

A moderately bright and small cluster, unresolvable in binoculars. A challenge as the brightest member is only of 11.9 magnitude. In telescopes of aperture 10 cm, it will appear as a small hazy spot with just a few very faint stars resolved.

See also:

Cluster	Designation	Month
Caldwell 76	I 3 p	June
Trumpler 24	IV 2 p n	June
IC 4665	III 2 m	June
Messier 23	II 2 r	June
Messier 21	I 3 r	June
Messier 16	II 3 m n	June
Messier 18	II 3 p n	June
Herschel 72	III 2 m	June
Collinder 309	I 2 r	June
Trumpler 26	II 1 m	June
Trumpler 26	II 1 m	June
Herschel 7	I 2 r n	June
Messier 73	IV 1 p	August
Messier 39	III 2 m	August
Caldwell 16	IV 2 p	August
IC 1396	II m n	August
Collinder 445	II 1 p	August

August

Messier 73	NGC 6994	20^h 59.0^m	−12° 38′	August 6
8.9 m	⊕ 2.8′	4	IV 1 p	Easy

Something of an enigma. It shouldn't really be classified as an open cluster, as it consists of only four stars! Perhaps originally cataloged when Messier was having a bad day. Still nice, though. A small grouping of stars like this is often called an asterism. There is considerable debate as to whether the stars are related to each other, or are the result of a chance alignment. One line of research suggests M73 is a "Possible Open Cluster Remnant (POCR)," whereas later work suggests otherwise.

Messier 39	NGC 7092	21^h 32.2^m	+48° 26′	August 14
4.6 m	⊕ 31′	30	III 2 m	Easy ©

A nice cluster in binoculars, it lies at a distance of 840 light-years. About two dozen stars are visible, ranging from seventh to ninth magnitude. What makes this cluster so distinctive is the lovely color of the stars – steely blue – and the fact that it is nearly perfectly symmetrical, having a triangular shape. There is also a nice double star at the center of the cluster.

Caldwell 16	NGC 7243	22^h 15.3^m	+49° 53′	August 25
6.4 m	⊕ 21′	40	IV 2 p	Easy ©

Set against the backdrop of the Milky Way, this large, irregular cluster nevertheless stands out quite well. Several of the stars are visible in binoculars, but the remainder blur in the background star field. A nice object in an otherwise empty part of the sky – if you overlook the fact that it is located within the Milky Way!

–	IC 1396	21^h 39.1^m	+57° 30′	August 16
3.7 m	⊕ 50′	40	II m n	Medium

Although a telescope of at least 20 cm is needed to really appreciate this cluster, it is nevertheless worth searching out. It lies south of Herschel's Garnet Star and is rich but compressed. What makes this so special, however, is that it is cocooned within a very large and bright nebula.

Collinder 445	IC 1434	22^h 10.5^m	+52° 50′	August 24
9.0 m	⊕ 7′	70	II 1 p	Difficult ©

Located within the Milky Way, this is a large but irregular cluster of over 70 stars of tenth magnitude and fainter. Try using a high magnification of, say, 150–200×, and also use averted vision. These two factors will almost certainly improve this cluster's observability.

See also:

Cluster	Designation	Month
Stock 1	III 2 m	July
Collinder 413	II 2 p n	July
Caldwell 37	III 2 p	July
Messier 29	I 2 m n	July
Herschel 8	III 2 r	July
Messier 26	I 2 m	July
Messier 11	I 2 r	July
Collinder 392	III 2 m	July.
NGC 6755	II 2 r	July
Collinder 402	IV 3 p	July
Collinder 403	I 1 r	July
Harvard 20	IV 2 p	July
NGC 6791	I 2 r	July

(continued)

Cluster	Designation	Month
NGC 6939	I 1 m	July
Messier 52	I 2 r	September
Blanco 1	III 2 m	September
Herschel 78	IV 2 p	September
Herschel 69	IV 1 p	September
King 14	III 2 p	September
King 12	I 2 p	September
Herschel 35	II 2 p	September

September

Messier 52	NGC 7654	23^h 24.2^m	+61° 35′	September 11
6.9 m	⊕ 12′	100	I 2 r	Easy ©

A small, rich and fairly bright cluster. One of the densest north of the celestial equator. Several stars are visible in binoculars, but telescopic apertures are needed to fully appreciate this cluster. It is one of the few clusters that show a distinct color. Many observers report a faint blue tint to the group, and this along with a fine topaz-colored (blue) star and several nice yellow and blue stars make it a very nice object to observe. Apparently, it has a star density of the order of 50 stars per cubic parsec!

Blanco 1	–	00^h 04.3^m	−29° 56′	September 22
4.5 m	⊕ 90′	30	III 2 m	Easy

Located close to the south galactic pole, this is an ill-defined and very large cluster. Easily visible in binoculars.

Herschel 78	NGC 129	00^h 29.9^m	+60° 14′	September 28
6.5 m	⊕ 21′	30	IV 2 p	Easy ©

A bright, open cluster. Irregularly scattered and uncompressed, making it difficult to distinguish from the background. Up to a dozen stars can be seen with binoculars, but many more are visible under telescopic aperture. Under good observing conditions and using averted vision, the unresolved background stars of the cluster can be seen as a faint glow.

Herschel 69	NGC 7686	23^h 30.2^m	+49° 08′	September 13
5.6 m	⊕ 14′	20	IV 1 p	Medium ©

A sparse and widely dispersed cluster containing many 10th- and 11th-magnitude stars. Best seen with large-aperture telescopes.

King 14	–	$00^h\ 31.9^m$	+63° 10′	September 28
8.5 m	⊕ 7′	20	III 2 p	Medium ©

Often overlooked, this cluster is a faint but rich object. With a 10-cm aperture telescope, several stars can be resolved set against a faint glow.

King 12	–	$23^h\ 53.0^m$	+61° 58′	September 19
9.0 m	⊕ 2′	15	I 2 p	Difficult

A very faint cluster containing many 10th-, 11th- and 12th-magnitude stars. A challenge to deep-sky observers.

Herschel 35	NGC 136	$00^h\ 31.5^m$	+61° 32′	September 28
– m	⊕ 1.2′	20	II 2 p	Difficult

A very small cluster looking like a tiny sprinkling of diamond dust. Although it can be observed with a 15-cm telescope, it needs a very large aperture of at least 20 cm to be fully resolvable.

See also:

Cluster	Designation	Month
Messier 73	IV 1 p	August
Messier 39	III 2 m	August
Caldwell 16	IV 2 p	August
IC 1396	II m n	August
Collinder 445	II 1 p	August
Caldwell 13	I 3 r	October
Collinder 33	III 1 m	October
Stock 2	III 1 m	October
Caldwell 14 (see Chapter 7)	I 3 r	October
Herschel 64	III 2 p	October
Messier 103	III 2 p	October
Trumpler 1	I 3 p	October
Herschel 49	I 3 p	October

October

Caldwell 13	NGC 457	$01^h\ 19.1^m$	+58° 20	October 11
6.4 m	⊕ 13′	80	I 3 r	Easy ©

This is a wonderful cluster and can be considered one of the finest in Cassiopeia. Easily seen in binoculars as two southward-arcing chains of stars, surrounded by many fainter components. The gorgeous blue and yellow double φ Cass and a lovely red star, HD 7902, lie within the cluster. Located at a distance of about 8,000 light-years, this young cluster is located within the Perseus spiral arm of our galaxy.

Collinder 33	NGC 752	01^h 57.8^m	+37° 41′	October 20
5.7 m	⊕ 45′	77	III 1 m	Easy

Best seen in binoculars, or even at low powers in a telescope, this is a large, loosely structured group of stars containing many chains and double stars. Lies about 5° south-southwest of γ Andromedae. Often underrated by observing guides, it is worth seeking out. It is a cluster of intermediate age.

Stock 2		02^h 15.0^m	+59° 16′	October 25
4.4 m	⊕ 60′	50	III 1 m	Easy ©

Another often passed-over cluster! Wonderful in binoculars and small telescopes it lies 2° north of its more famous cousin, the Double Cluster. At nearly a degree across it contains over 50, 8th magnitude and fainter stars. Well worth seeking out.

Herschel 64	NGC 381	01^h 08.3^m	+61° 35′	October 8
9.3 m	⊕ 6′	50	III 2 p	Medium ©

A faint cluster, but rich and compressed. Can be resolved with an aperture of 10 cm, but with medium aperture, of say, 20–25 cm, over 60 stars of 12th and 13th magnitude become visible.

Messier 103	NGC 581	01^h 33.2^m	+60° 42′	October 14
7.4 m	⊕ 6′	25	III 2 p	Difficult ©

A nice, rich cluster of stars, which is resolvable in small binoculars. Using progressively larger apertures, more and more of the cluster will be revealed (as with most clusters). It has a distinct fan shape, and the star at the top of the fan is Struve 131, a double star with colors reported as pale yellow and blue. Close by is also a rather nice, pale, red-tinted star. The cluster is the last object in Messier's original catalog.

Trumpler 1	Collinder 15	01^h 35.7^m	+61° 17′	October 15
8.1 m	⊕ 4.5′	20	I 3 p	Difficult ©

Even with a telescope of 12 cm aperture, this small and tightly compressed cluster will be a challenge.

Herschel 49	NGC 637	01^h 42.9^m	+64° 00′	October 17
8.2 m	⊕ 3.5′	20	I 3 p	Difficult ©

A faint and very condensed cluster. About ten stars can be seen with a telescope of at least 10 cm aperture, but many more will remain unresolved.

See also:

Cluster	Designation	Month
Messier 52	I 2 r	September
Blanco 1	III 2 m	September
Herschel 78	IV 2 p	September
Herschel 69	IV 1 p	September
King 14	III 2 p	September
King 12	I 2 p	September
Herschel 35	II 2 p	September
Messier 34 (see Chapter 7)	II 3 m	November
Stock 23	III 3 p n	November

November

Stock 23	–	$03^h\ 16.3^m$	+60° 02′	November 9
5.6 m	⊕ 18′	25	III 3 p n	Easy ©

A little known cluster on the border of Camelopardalis-Cassiopeia. Binoculars reveal several stars, best viewed in medium-aperture telescopes. It is bright and large but spread out.

See also:

Cluster	Designation	Month
Caldwell 13	I 3 r	October
Collinder 33	III 1 m	October
Stock 2	III 1 m	October
Caldwell 14 (see Chapter 7)	I 3 r	October
Herschel 64	III 2 p	October
Messier 103	III 2 p	October
Trumpler 1	I 3 p	October
Herschel 49	I 3 p	October
Herschel 33	II 2 m	December
Collinder 464	II 2 m	December
Collinder 69	II 3 p n	December
Collinder 73	III 2 p n	December
Collinder 38	I 3 p n	December
Herschel 59	III 1 p	December
Collinder 81	II 3 r	December
Herschel 68	II 1 p	December
Herschel 61	III 2 p	December
Herschel 13	III 3 m	December

December

Herschel 33	NGC 1857	05^h 20.2^m	+39° 21′	December 11
7.0 m	⊕ 6′	35	II 2 m	Easy

A very rich cluster containing several small chains of stars with starless voids located within and around it. The brightest member of the cluster is a nice orange-tinted star, but its glare can overpower the many fainter stars. Some observers try to occult the bright star so that it is obscured, thus allowing the fainter stars to be observed.

Collinder 464		05^h 22.0^m	+73° 00′	December 11
4.2 m	⊕ 120′	50	II 2 m	Easy ©

A large, very rich, irregular open cluster, with the distinction that it is best seen in binoculars, as viewing it in a telescope will dissipate the cluster. Contains many fifth-, sixth- and seventh-magnitude stars.

Collinder 69	–	05^h 35.1^m	+09° 56′	December 14
2.8 m	⊕ 65′	20	II 3 p n	Easy

Perfect for binoculars. This cluster surrounds the third-magnitude stars l Orionis, and includes φ^{-1} and φ^{-2} Orionis, both fourth magnitude. Encircling the cluster is the very faint emission nebula, Sharpless 2–264, only visible using averted vision and an OIII filter with extremely dark skies.

Collinder 73	NGC 1981	05^h 35.2^m	–04° 26′	December 14
4.6 m	⊕ 25′	20	III 2 p n	Easy

A nice, bright, coarse cluster, lying about 1° north of M42. Around eight or nine stars can be seen in binoculars, while the remaining stars are a hazy background glow. In moderate telescopes, the most striking feature is two parallel rows of stars.

Collinder 38	NGC 2169	06^h 08.4^m	+13° 57′	December 23
5.9 m	⊕ 6′	30	I 3 p n	Easy

This is a small but bright cluster. Some observers find it hard to believe that this scattering of stars has been classified as a cluster. Easily visible in binoculars, the stars appear to range in magnitude from about 8–10. Also, binoculars will show the four brightest members to be surrounded by faint nebulosity – sometimes!

Herschel 59	NGC 1664	$04^h\ 51.1^m$	+43° 42′	December 3
7.6 m	⊕ 13′	25	III 1 p	Medium

A nice bright cluster, but loosely structured and best seen with an aperture of 20 cm. Appears as an enrichment of the background Milky Way star field. There is a seventh-magnitude star within the cluster, but it is not a true member, and the glare from the star can sometimes make observation of the cluster difficult. Increasing the aperture will progressively show more stars.

Collinder 81	NGC 2158	$06^h\ 07.5^m$	+24° 06′	December 23
8.6 m	⊕ 5′	70	II 3 r	Medium

Lying at a distance of 160,000 light-years, this is one of the most distant clusters visible using small telescopes, and lies at the edge of the galaxy. It needs a 20 cm telescope to be resolved, and even then only a few stars will be visible against a background glow. It is a very tight, compact grouping of stars, and something of an astronomical problem. Some astronomers class it as an intermediate object lying between an open cluster and a globular cluster, and it is believed to be about 800 million years old, making it very old as open clusters go.

Herschel 68	NGC 2126	$06^h\ 03.0^m$	+49° 54′	December 22
10.2 m	⊕ 6′	40	II 1 p	Difficult ©

Has been described as diamond dust on black velvet. A very faint but nice cluster, although it can prove a challenge to find.

Herschel 61	NGC 1778	0	$5^h\ 08.1^m$	+37° 03′	December 8
7.7 m	⊕ 6′		30	III 2 p	Difficult

Although a fairly bright cluster, it is so sparse and spread out that it will require some careful observation to be located.

Herschel 13	NGC 2204	$06^h\ 15.7^m$	−18° 39′	December 25
8.6 m	⊕ 13′	80	III 3 m	Difficult

A difficult cluster to locate and observe, composed of many faint stars but with a nice orange star at its northern limit.

See also:

Cluster	Designation	Month
Messier 34	II 3 m	November
Stock 23	III 3 p n	November
NGC 2301	I 3 m	January
Collinder 121	III 3 p	January
Messier 50 (see Chapter 7)	II 3 m	January
Herschel 34	II 2 p	January
Caldwell 58	II 2 m	January
Caldwell 64	I 3 p n	January
Messier 48	I 3 r	January
Caldwell 54	I 2 r	January
Herschel 21	II 2 m	January

Globular Clusters

Having covered one type of star cluster – the open or galactic cluster – we now turn our attention to a very different type.

Recall that open clusters are groups of stars that are usually young, have an appreciable angular size and may have a few hundred components. Globular clusters, as they are known, are clusters that are very old, are compact and may contain up to a half a million stars, in some cases even more.[3]

The stars that make up a globular cluster are called Population II stars. These are metal-poor stars and are usually to be found in a spherical distribution around the galactic center at a radius of about 200 light-years. Furthermore, the number of globular clusters increases significantly the closer one gets to the galactic center. This means constellations that are located in a direction towards the galactic bulge have a high concentration of globular clusters within them, such as Sagittarius and Scorpius. Thus, the spring and summer are by far the most favorable times for viewing these elusive objects.

The origin and evolution of a globular cluster is very different from that of an open or galactic cluster. All the stars in a globular cluster are old, with the result that any star earlier than class G- or F-type will have left the main sequence and either be moving toward the red giant stage of its life, or, for the O- and B- type stars will have long ago evolved to the supernova phase and beyond, leaving behind a neutron star or even perhaps a black hole! In fact, new star formation[4] no longer takes place within any globular clusters in our galaxy, and these clusters are

[3]The very largest, for example, Omega Centuari, are now believed to be the dense cores of satellite galaxies that have been consumed by the Milky Way – galactic cannibalization, as it is called!

[4]The possibility that new stars can be formed from merging old stars does not count!

believed to be the oldest structures formed in our galaxy.[5] It may well be that the youngest of the globular clusters is still far older than the oldest open cluster. The origin of the globular clusters is a topic of fierce debate, and research with the current models predict that the globular clusters may have been formed within the proto-galaxy clouds that went to make up our galaxy.

There are about 150–158[6] globular clusters in our galaxy ranging in size from 60 to 150 light-years in diameter. They all lie at vast distances from the Sun, are about 60,000 light-years from the galactic plane, and are located in what is termed the halo of the galaxy. The nearest globular clusters, for example, Caldwell 86 in Ara, lies at a distance of over 6,000 light-years, and thus the clusters are difficult objects for small telescopes. That is not to say they can't be seen; rather, it means that any structure within the cluster will be difficult to observe with small aperture telescopes. Even the brightest and biggest globular will need apertures of at least 15 cm for individual stars to be resolved. However, if large aperture telescopes are used, then these objects are truly magnificent. Some globular clusters have dense concentrations towards their center while others may appear as compact open clusters. In some cases, it is difficult to say where the globular cluster peters out and the background stars begin.

As in the case of open clusters, there exists a classification system, the Shapley-Sawyer concentration class, where Class I globular clusters are the most star-dense, while Class XII is the least star-dense. The ability of an amateur to resolve the stars in a globular actually depends on how condensed the cluster actually is, and so the scheme will be used in the descriptions, but it is only really useful for those amateurs who have large aperture instruments. Nevertheless, the observation of these clusters that are among the oldest objects visible can provide you with breathtaking, seemingly three-dimensional aspects, and at the same time, increase and develop your observing skills.

The details listed are of the same order as in open clusters, with the omission of star numbers, and the replacement of Trumpler type with the Shapley-Sawyer concentration class.

January

Caldwell 25	NGC 2419	07^h 38.1^m	+38° 53′	January 15
9,06 m	⊕ 4.1′		II	Difficult

Also known as the Intergalactic Wanderer. A difficult object to resolve with any detail; even large telescopes of aperture 40 cm will be unable to resolve any stellar detail.

[5] There now exists the interesting scenario that there are in fact two types, or populations, of globular clusters. Named after their discoverer, the Dutch astronomer Pieter Oosterhoff, Type II clusters differ from Type I in that they are actually captured clusters from satellite galaxies and could be older than Type I clusters.

[6] Depending on which research paper you read!

It has been reported as observed with an 10 cm telescope under perfect conditions, but will appear as just a faint, hazy dot. It lies at the vast distance of 300,000 light-years, further even than the Magellanic Clouds, because it has a space velocity in excess of the velocity needed to escape from the gravitational pull of our galaxy. One of the five most luminous clusters in the Milky Way, it has been suggested that it is in fact of extragalactic origin and maybe the remains of a small galaxy, captured and subsequently disrupted by the Milky Way.

See also:

Cluster	Designation	Month
Messier 79	V	December

February

See:

Cluster	Designation	Month
Caldwell 25	II	January
NGC 4147	VI	March

March

–	NGC 4147	$12^h\ 10.1^m$	+18° 33′	March 25
10.2 m	⊕ 4′		VI	Difficult

This is a faint cluster, hazy in appearance with a star-like core. A challenge for telescopic observers. Several variable stars are also located within the cluster.

See also:

Cluster	Designation	Month
Messier 68	X	April
Caldwell 80	VIII	April
Messier 53	V	April
Herschel 9	XII	April
Herschel 7	XI	April

April

Messier 68	NGC 4590	12^h 39.5^m	−26° 45′	April 1
7.8 m	⊕ 12′		X	Easy

Appearing only as a small, hazy patch in binoculars, this is a nice cluster in telescopes, with an uneven core and faint halo. Under low magnification, some faint structure or mottling can be glimpsed which under medium to high magnification resolves itself as a myriad assembly of stars. A definite challenge to naked-eye observers, where perfect seeing will be needed. Use averted vision and make sure that your eyes are well and truly dark-adapted.

Caldwell 80	NGC 5139	13^h 26.8^m	−47° 29′	April 13
3.5 m	⊕ 36′		VIII	Easy

Also known as Omega Centauri. A fabulous cluster and one of the showpieces of the night sky. Visible to the naked eye as a clearly seen, hazy patch of light. A stunning sight in binoculars, and a jaw-dropping spectacle in telescopes.[7] Words do not do it justice, so we won't even attempt to describe it but will leave it up to you to search out this wonderful object. It contains over a million stars, and some sources put it at having nearly ten million. It is about 15,800 light-years away. Recent research has suggested that the cluster is in fact the central core of a dwarf galaxy that was disrupted by the Milky Way.

Messier 53	NGC 5024	13^h 12.9^m	+18° 10′	April 9
7.6 m	⊕ 12′		V	Medium

An often ignored globular cluster, which is a shame as it is a nice object. Contains about 100,000 stars, none of which are resolved in binoculars, through which it will appear as a faint hazy patch with a brighter center, located in a star field. Telescopes show a nice symmetrical glow with a concentrated core. Some observers report a colored hue to the cluster – what do you see? It stands up nicely to magnification and indeed is a lovely sight in telescopes of aperture 10 cm and greater. It lies at a distance of around 60,000 light-years away from the center of the Milky Way.

Herschel 9	NGC 5466	14^h 05.5^m	+28° 32′	April 23
9.0 m	⊕ 11′		XII	Medium

[7] Alas, this wonderful globular cluster is not visible from the UK, or northern parts of the United States, but it is still included here as it is truly an amazing object to observe, and should you have the chance to see it, then do so.

A challenge for binoculars, and even when located will appear as a faint hazy and small glow. In telescopes the cluster has a resolvable core.

Herschel 7	NGC 5053	13^h 16.4^m	+17° 42′	April 10
10.9 m	⊕ 10′		XI	Difficult

A very faint and loose cluster containing only 3,500 stars, it lies very close to Messier 53, and both can be glimpsed using a low power. This is one of those clusters that is very impressive when seen through a large-aperture telescope. Its position in space is also unique, in that it lies about 50,000 light-years above the galactic plane.

See also:

Cluster	Designation	Month
NGC 4147	VI	March
Messier 80	II	May
Messier 4	IX	May
Messier 107	X	May
Caldwell 66	VII	May
Herschel 19	XI	May

May

Messier 80	NGC 6093	16^h 17.0^m	−22° 59′	May 26
7.9 m	⊕ 10.0′		II	Easy

Readily detectable in binoculars as a tiny, glowing hazy patch set in a stunning star field, it has a distinctly noticeable brighter core. Telescopes will be needed to resolve its 14th-magnitude stellar core. One of the few globular clusters to have been the origin of a nova, T Scorpii, when it flared to prominence in 1860, then disappeared back into obscurity within 3 months.

Messier 4	NGC 6121	16^h 23.6^m	−26° 32′	May 28
5.8 m	⊕ 26.3′		IX	Easy

A superb object, presenting a spectacle in all optical instruments, but it does lie very close to the star Antares, so that the glare of the latter may prove a problem in the detection with small aperture telescopes. High-power binoculars will even resolve several stars. Telescopes of all apertures show detail and structure within the cluster, and the use of high magnification will prove beneficial; but what is more noticeable is the bright lane of stars that runs through the cluster's center. Thought to be the closest globular to Earth at 7,200 light-years (although NGC 6397 in Ara may be closer), and about 12.2 billion years old. Research has discovered many white dwarf stars in the cluster, believed to be among the oldest known, and one in particular is a binary star with a pulsar companion, PSR B1620-26, and a planet orbiting it with a mass of 2.5 times that of Jupiter.

Messier 107	NGC 6171	$16^h\ 32.5^m$	−13° 03′	May 30
8.85 m	⊕ 13′		X	Medium

Often missed by amateurs owing to its faintness, it is nevertheless a pleasant cluster with a mottled disc and brighter core. Not visible with the naked eye, it nevertheless presents a pleasing aspect when medium to high magnification is used. What makes this inconspicuous globular important, however, is that it is one of the very few that seem to be affected by the presence of interstellar dust. Deep imaging has revealed several obscured areas within the cluster, possibly due to dust grains lying between us. This isn't such a surprise, as the globular is located over the hub of the galaxy in Scorpius.

Caldwell 66	NGC 5694	$14^h\ 39.6^m$	−26° 32′	May 1
10.9 m	⊕ 3.6′		VII	Difficult

A faint cluster that has a bright core but an unresolved halo in telescopes of less than 30 cm. An unremarkable object, which you will probably not visit more than once! It is a difficult cluster to locate, especially from the UK. Precise setting circles on your telescope (or of course even a computerized system) will help significantly in finding it. It is actually located on the far side of our galaxy, at around 110,000 light-years from the Solar System. Research suggests that the cluster may have attained a velocity that will allow it to escape from the gravitational pull of the galaxy.

Herschel 19	NGC 5897	$15^h\ 17.4^m$	−21° 01′	May 11
8.6 m	⊕ 12.5′		XI	Difficult

A very difficult cluster to locate in binoculars owing to its low surface brightness. Even with a telescope, it is not an easy object to observe.

See also:

Cluster	Designation	Month
Messier 68	X	April
Caldwell 80	VIII	April
Messier 53	V	April
Herschel 9	XII	April
Herschel 7	XI	April
Messier 12	IX	June
Messier 62	IV	June
Messier 19	VIII	June

(continued)

Cluster	Designation	Month
Messier 9	VII	June
Messier 92 (see Chapter 7)	IV	June
Messier 14	VIII	June
Herschel 147	VI	June
Herschel 49	VI	June
Herschel 12	XI	June
Messier 28	IV	June
Messier 69	V	June
Herschel 50	IV	June
Herschel 200	V	June

June

Messier 12	NGC 6218	16^h 47.2^m	−01° 57′	June 3
7.68 m	⊕ 16.0′		IX	Easy

A small cluster that will be a challenge to naked-eye observers. In telescopes of aperture 20 cm and more, this cluster is very impressive, with many stars being resolved against the fainter background of unresolved members. It also contains many faint-colored stars that show up well with telescopes of aperture 10 cm and greater. It is nearly the twin of Messier 10, which is within 3° southeast. A recent study has shown that it has a small number of low mass stars, and it has been suggested that many stars may have been stripped from it by the gravitational influence of the Milky Way.

Messier 62	NGC 6266	17^h 01.2^m	−30° 07′	June 6
6.5 m	⊕ 14′		IV	Easy

A very nice cluster, visible in binoculars as a small hazy patch of light set in a wonderful star field. Owing to its irregular shape, it bears a cometary appearance, which is apparent even in small telescopes. Has a very interesting structure where concentric rings of stars have been reported by several observers, along with a colored sheen to its center, described as both pale red and yellow!

Messier 19	NGC 6273	17^h 02.6^m	−26° 16′	June 7
6.8 m	⊕ 17′		VIII	Easy

A splendid albeit faint cluster when viewed through a telescope, it nevertheless can be glimpsed with binoculars, where its egg shape is very apparent. Although a challenge to resolve, it is nevertheless a colorful object, reported as having both faint orange and faint blue stars, while the overall color of the cluster is a creamy white. Some amateurs also claim that a few faint dark patches mottle the cluster; perhaps this is interstellar dust between us and it.

Messier 9	NGC 6333	17^h 19.2^m	–18° 31′	June 11
7.7 m	⊕ 12.0′		VII	Easy

Visible in binoculars, this is a small cluster with a bright core. The cluster is one of the nearest to the center of our galaxy and is in a region conspicuous for its dark nebulae, including Barnard 64; it may be that the entire region is swathed in interstellar dust, which gives rise to the cluster's dim appearance. It lies about 26,000 light-years away.

Messier 14	NGC 6402	17^h 37.6^m	–03° 15′	June 16
7.6 m	⊕ 11.7′		VIII	Medium

Located in an empty part of the sky, this is brighter and larger than is usual for a globular. Though visible only in binoculars as a small patch of light, and not resolved even in a small telescope (<15 cm), it is nevertheless worth searching for. It shows a delicate structure with a lot of detail, much of which will be obscured if seen from an urban location. It has a pale yellow tint, and some observers report seeing a definite stellar core, which has a striking orange color. But this feature is seen only with telescopes of aperture 15 cm and greater and using a high magnification.

Herschel 147	NGC 6304	17^h 14.5^m	–29° 28′	June 18
8.4 m	⊕ 6.9′		VI	Medium

This is a small but bright cluster with only a few resolvable stars near its edge. Nevertheless it will be a challenge to locate with binoculars.

Herschel 49[8]	NGC 6522	18^h 03.6^m	–30° 02′	June 22
8.6 m	⊕ 5.6′		VI	Medium

With telescopes of aperture 20 cm this cluster will appear with a bright core but an unresolved halo. A difficult object to locate with binoculars.

Herschel 12	NGC 6553	18^h 09.3^m	–25° 54′	June 24
8.1 m	⊕ 8.1′		XI	Medium

Not easily visible in binoculars (although it would prove an observational challenge to locate), this is a fairly evenly bright cluster, with no perceptible increase towards the core.

[8]Located within the constellation Sagittarius are a plethora of globular clusters; only the brightest are discussed here.

Messier 28	NGC 6626	18^h 24.5^m	−24° 52′	June 27
6.8 m	⊕ 11.2′		IV	Medium

Only seen as a small patch of faint light in binoculars, this is an impressive cluster in telescopes. With an aperture of 15 cm it shows a bright core with a few resolvable stars at the halo's rim. With a larger aperture the cluster becomes increasingly resolvable and presents a spectacular sight. It lies at a distance of about 22,000 light-years. Well worth seeking out for large-aperture telescope owners, as it is a lost gem.

Messier 69	NGC 6637	18^h 31.4^m	−32° 21′	June 29
7.6 m	⊕ 7.1′		V	Medium

Visible as just a hazy spot in binoculars, this appears with a nearly star-like core in telescopes. Large aperture will be needed to resolve any detail and will show the myriad dark patches located within the cluster.

Herschel 50	NGC 6229	16^h 47.0^m	+47° 32′	June 3
9.4 m	⊕ 4.5′		IV	Difficult

A difficult object to locate, and even with 20 cm telescopes will appear unresolved. Large-aperture telescopes, however, will show structure and detail within the cluster.

Herschel 200	NGC 6528	18^h 04.8^m	−30° 03′	June 22
9.5 m	⊕ 3.7′		V	Difficult

Even in large telescope of aperture 35 cm this cluster is unresolved. It will just appear as a faint glow with a slightly brighter center. A good challenge for large-aperture telescopes.

See also:

Cluster	Designation	Month
Messier 80	II	May
Messier 4	IX	May
Messier 107	X	May
Caldwell 66	VII	May
Herschel 19	XI	May
Messier 55 (see Chapter 7)	XI	July
Messier 70	V	July
Messier 54	III	July
NGC 6760	IX	July
Messier 56	X	July
Messier 71	X	July
Messier 75	I	July
Caldwell 47	VIII	July

July

Messier 70	NGC 6681	18^h 42.2^m	−32° 18′	July 2
8.0 m	⊕ 7.8′		V	Medium

A faint binocular object that is a twin of M69. Best viewed with a large aperture, as with a small telescope, it is often mistaken for a galaxy. It lies at a distance of 35,000 light-years.

Messier 54	NGC 6715	18^h 55.1^m	−30° 29′	July 5
7.6 m	⊕ 9.1′		III	Medium

With telescopic apertures smaller than 35 cm the cluster remains unresolved and will show only a larger view similar to that seen in binoculars – a faint hazy patch of light. It has a colorful aspect – a pale blue outer region and pale yellow inner core. Recent research has found that the cluster was originally related to the Sagittarius dwarf galaxy, but that the gravitational attraction of our galaxy has pulled the globular from its parent. Among the globular clusters in the Messier catalog it is one of the densest as well as being the most distant.

–	NGC 6760	19^h 11.2^m	+01° 02′	July 9
9.1 m	⊕ 6.5′		IX	Medium

A faint, symmetrical cluster with a just perceptible brighter core. High-power binoculars should be able to locate this cluster, and even with a small telescope it should present no problems. But a knowledge of the use of setting circles would be useful, as would a computer-controlled telescope.

Messier 56	NGC 6779	19^h 16.6^m	+30° 11′	July 11
8.3 m	⊕ 7′		X	Medium

It is situated in a rich star field and in small instruments will appear as a hazy patch with a brighter core. It has often been likened to a comet in its appearance. Resolution of the cluster will need at least a 20 cm aperture telescope, and increasing magnification will show further detail.

Messier 71	NGC 6838	19^h 53.8^m	+18° 47′	July 20
8.2 m	⊕ 7.2′		X	Medium

A rich and compressed cluster that only shows a very faint glow in binoculars. Located in a glittering star field. Up until recently there was some debate as to whether this was a globular or open cluster. The consensus now is that it is a very young globular cluster, only 13,000 light-years away. What makes this globular so nice is that the central stars can be resolved all the way to the core, which is rare among globular clusters.

Messier 75	NGC 6864	20^h 06.1^m	−21° 55′	July 23
8.5 m	⊕ 6′		I	Medium

A difficult object to locate with binoculars as it is so small and faint. Even then it will only appear as a hazy spot (like so many others). Will show a bright core and a few resolved stars in the halo with 25 cm aperture telescopes. One of the most distant globulars in Messier's catalog, at 60,000 light-years.

Caldwell 47	NGC 6934	20^h 34.2^m	+07° 24′	July 30
8.9 m	⊕ 5.9′		VIII	Medium

A difficult object for binoculars, appearing as a tiny patch of light. Just resolvable, with 10 cm aperture telescopes, as a small, bright, round cluster, with a brighter and condensed center. Some observers report that the use of averted vision aids in seeing some faint structure within the cluster. It has many blue straggler stars and was one of the first objects to be imaged by the Gemini North Telescope, which resolved its core.

See also:

Cluster	Designation	Month
Messier 12	IX	June
Messier 62	IV	June
Messier 19	VIII	June
Messier 9	VII	June
Messier 92 (see Chapter 7)	IV	June
Messier 14	VIII	June
Herschel 147	VI	June
Herschel 49	VI	June
Herschel 12	XI	June
Messier 28	IV	June
Messier 69	V	June
Herschel 50	IV	June
Herschel 200	V	June
Messier 15 (see Chapter 7)	IV	August
Messier 2 (see Chapter 7)	II	August
Messier 30	V	August
Messier 72	IX	August
Caldwell 42	I	August
Palomar 12	XII	August

August

Messier 30	NGC 7099	21^h 40.4^m	−23° 11′	August 16
7.2 m	⊕ 12′		V	Easy

In binoculars this will appear simply as a tiny, round, hazy patch of light, and even telescopes of aperture 20–25 cm will show just a bright, asymmetrical core with an unresolved halo. At its periphery are several looping arcs of stars.

Messier 72	NGC 6981	20^h 53.5^m	−12° 32′	August 4
9.3 m	⊕ 6.6′		IX	Medium

At a distance of about 53,000 light-years, this is faintest globular cluster cataloged by Messier. In binoculars it will appear as just a tiny, hazy point of light, but in telescopes of aperture 20 cm and larger its true nature becomes apparent. The use of averted vision may help you to see any detail within the cluster.

Caldwell 42	NGC 7006	21^h 01.5^m	+16° 11′	August 6
10.6 m	⊕ 2.8′		I	Medium

Another very distant cluster, at 185,000 light-years from the Solar System. In telescopes it appears as a small unresolved disc, not unlike a planetary nebula. However, even with large binoculars little will be seen unless averted vision is used. A very old cluster located far out in the galactic halo.

Palomar 12	–	21^h 46.5^m	−21° 14′	August 18
11.7 m		⊕ 3′	XII	Difficult

A challenge for amateurs who possess telescopes of aperture 20–25 cm. It will appear as a faint, small patch of nebulosity. Perfect seeing conditions will be needed.

See also:

Cluster	Designation	Month
Messier 55 (see Chapter 7)	XI	July
Messier 70	V	July
Messier 54	III	July
NGC 6760	IX	July
Messier 56	X	July
Messier 71	X	July
Messier 75	I	July
Caldwell 47	VIII	July

September

See:

Cluster	Designation	Month
Messier 15 (see Chapter 7)	IV	August
Messier 2 (see Chapter 7)	II	August
Messier 30	V	August
Messier 72	IX	August
Caldwell 42	I	August
Palomar 12	XII	August

October

Only a few objects are visible in October, and these are not very well placed. Refer to the August list for details.

November

See:

Cluster	Designation	Month
Messier 79	V	December

December

Messier 79	NGC 1904	$05^h\ 24.5^m$	−24° 33′	December 12
8.0 m	⊕ 9.6′		V	Medium

A fine cluster, best appreciated with a telescope because binoculars cannot resolve it. Small telescopes of, say, 10 cm aperture can resolve the core, but it will be a challenge because you will need a high magnification, dark skies and averted vision. A perfect test for you and your telescope optics. Telescopes of aperture 40 cm and more will resolve the core with no difficulty. Located at a distance of 41,000 light-years, it is the sole globular cluster for northern hemisphere observers in the winter. Like Messier 54, it is believed that Messier 79 is in fact a member of the Canis Major dwarf galaxy, currently undergoing a close encounter with the Milky Way – one that it is unlikely to survive!

See also:

Cluster	Designation	Month
Caldwell 25	II	January

Chapter 4

Nebulae

Of all the photographs in large-format "coffee table" astronomy books or posted on the Internet, those of nebulae are often the most spectacular. With their panoramas of glowing red, green and yellow colored gas clouds, and impenetrable blankets of black dust lanes, often intertwined and seemingly swirling around each other, they give a wonderfully vivid impression of the amazing mechanisms at work in the universe.

But nebulae are very disparate in nature, even though many of them have a rather similar appearance. They are associated with areas of star formation and can cover several aspects of a star's life, ending inevitably with the process of star death.

This chapter then concerns itself with these processes and will cover the four main types of nebulae – emission, reflecting, dark and planetary – as well as the very faint and rare supernova remnant.

However there is one caveat. As this book is a guide for amateur astronomers, and thus seeks to give a true and honest description of what can be seen, we begin by saying that the glorious pictures referred to in the first paragraph give a completely false impression of what one can see with the naked eye, or indeed with optical equipment. It is a fact that nebulae are very faint and elusive objects. Those wonderful images, which may have been obtained with the world's largest telescopes (including, more often than not, the Hubble Space Telescope), and using the most sophisticated imaging techniques, are long-exposure images made under perfect conditions, when there is sufficient time for the faint image to be built up, usually over several hours. The result is a bright and detailed picture.

The naked eye works in a different way from a photographic plate or CCD camera, and the image is seen "instantly" (like it is by a video camera). This is the reason we don't see images comparable to those in books. Also, add to this the fact

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_4,

that good observing conditions are crucial in order to observe nebulae (and the largest telescopes are located at the best possible places for seeing, including in Earth orbit); it then comes as no surprise that nebulae can often disappoint the inexperienced observer.

Having now completely dampened your spirits let us now say that there are many nebulae that can be seen with moderate instruments, and even several that can be glimpsed with the naked eye or binoculars. Indeed, many of the brighter or more distinctive nebulae can be easily recognized, and a few will even show faint traces or tints of subtle color.

As with most astronomical objects (except perhaps star clusters), the bigger the aperture, the more detail that will be seen, and telescopes of aperture 20 cm and greater will show hundreds of different objects: wispy emission nebulae, blue-green discs of planetary nebula, the barely discernible, breath-like reflecting nebulae, difficult and mysterious dark nebulae, and the rare and awe-inspiring supernovae remnants.

With the advent in recent years of the availability of specialized filters to improve visual contrast (once the province of professional astronomers), even more nebulae are now available to the amateur, and there are a handful that are among the most spectacular and beautiful objects in the night sky!

On crisp winter nights, or warm and still summer evenings, searching for and observing nebulae is a wonderful and rewarding pastime.

Emission Nebulae

This type of nebula is probably the easiest to observe, owing to its brightness and size. Emission nebulae are actually clouds of gas – mainly hydrogen, but there can be small amounts of oxygen and nitrogen present. Within the clouds are young and very hot O- and B-type stars that produce immense amounts of ultraviolet radiation. Usually, these very luminous stars are actually born within, and from, the clouds themselves, and so many emission nebulae are "stellar nurseries." Radiation from the stars typically causes the hydrogen gas to undergo a process called *fluorescence*, and this is responsible for the glow observed from the gas clouds. A full explanation requires a reasonable knowledge of astrophysics but here is a simplified explanation.[1]

The energy provided by ultraviolet radiation from the young and hot stars ionizes the hydrogen. Energy, in this case in the form of ultraviolet radiation, is absorbed by the atom and transferred to an electron that is sitting comfortably in what is called an energy level or orbital shell.[2] The electron, having gained extra

[1] A fuller explanation can be found in the author's book, *Astrophysics Is Easy! A Guide for the Amateur Astronomer,* published by Springer.

[2] Our simple model of an atom has a central nucleus with electrons orbiting around it, somewhat like planets orbiting a sun. Not all orbits are allowed by quantum mechanics: in order to move up to higher energy levels, electrons need very specific amounts of energy. Too much or too little and an electron will not move.

energy, will now leave the energy level it is in and in some instances actually break free from the atom. This process when an atom loses an electron is called *ionization*.

If electrons escape from their atoms, the hydrogen cloud will contain some hydrogen atoms without electrons and a corresponding number of free electrons. Eventually[3] the electrons recombine with the atoms, but an electron can't just settle down back to the state it originally had before it absorbed the extra energy – it has to lose the extra energy that the ultraviolet imparted. For this to happen, the electron moves down the atomic energy levels until it reaches its original level, losing energy as it goes.

In hydrogen (the most common gas in the nebula, you'll remember), an electron moving down from the third energy level to the second emits a photon of light at 656.3 nm. This is the origin of the famous "hydrogen alpha line," usually written as H-alpha. It is a lovely red color and is responsible for all the pink and red glowing gas clouds seen in the photographs referred to at the start of this chapter. Unfortunately the red glow is usually too weak to be seen at the eyepiece.

When electrons move down from other energy levels within the atom, other specific wavelengths of light are emitted. For instance, when an electron moves from the second level to the first, it emits a photon in the ultraviolet part of the spectrum – this particular wavelength is called the *Lyman alpha line* of hydrogen.

It is this process of atoms absorbing radiation to ionize a gas, with electrons subsequently cascading down the energy levels of an atom, that is responsible for nearly all the light we see from emission nebulae.

If a gas cloud is particularly dense and has a particularly luminous source of energy nearby, oxygen in it may be ionized, and the resulting recombination of the electron and atom produces the doubly ionized lines of oxygen, at wavelengths of 495.9 and 500.7 nm. These lines are a rich blue-green color, and under good seeing and with clean optics this color can be glimpsed in the Orion Nebula, M42.

Emission nebula are sometimes called HII regions, pronounced "aitch two." This astrophysical term refers to hydrogen that has lost one electron by ionization. The term HI, or "aitch one," refers to hydrogen that is unaffected by any radiation, that is, neutral hydrogen. The doubly ionized oxygen line mentioned above is termed OIII ("oh three"); the "doubly" means that two of the outermost electrons have been lost from the atom by ionization.[4]

Having covered why emission nebulae glow, we can now understand how they get their shape. This is dependent on several factors: the amount of radiation available, the density of the gas cloud, and the amount of gas available for ionization. In the case where there is a significant amount of radiation, coupled with a small and

[3]The time spent before recombining is very short, millionths of a second, but it also depends on how much radiation is present and the density of the gas cloud.

[4]In some astrophysical contexts, such as those defining what happens in the center of quasars, conditions exist that can give rise to materials such as Fe23. The amount of radiation is so phenomenal that the atom of iron (Fe) has been ionized to such an extent that it has lost 22 of its electrons!

low-density cloud, then most probably all of the cloud will be ionized, and thus the resulting HII region will be of an irregular shape – the shape of the entire cloud.

However, if the cloud of gas is large and dense, then the radiation can penetrate only a certain distance before it is used up – that is, there is only a fixed amount of radiation available for ionization. In this case, the HII region will be a sphere,[5] often surrounded by the remaining gas cloud, which is not fluorescing.[6] Many of the emission regions that are irregular in shape include M42, the Orion Nebula, M8, the Lagoon Nebula, and M17 in Sagittarius. Those that exhibit a circular shape, and thus are in fact spherical, are M20, the Trifid Nebula, and NGC 2237, the Rosette Nebula, to name only two.

After a suitable period of time, usually around several million years, the group of young O- and B-type stars located at the center of the nebulae will have produced so much radiation that they will have swept away the residual gas and dust clouds surrounding them, producing a "bubble" of clear space surrounding the cluster of stars. Several emission regions show this, for example, NGC 6276 and M78, which show the star cluster residing in a circular clear area within the larger emission nebula.

From an observational viewpoint, emission nebulae are generally faint and have a low surface brightness, making them not exactly difficult objects to observe but rather somewhat featureless and indistinct, though in a few instances the brighter nebulae do show distinct features. Thus it goes without saying that clean optics (for maximum contrast) and excellent seeing conditions should be priorities when observing these nebulae, and dark adaption and averted vision are required techniques.

You may notice that a few nebulae seem to be missing from the lists. There is a reason for this. In this new edition, a new chapter has been included, "Naked-Eye Deep-Sky Objects." This new chapter will deal with, among other things, nebulae that can (hopefully) be seen with the naked eye. So for instance, the Orion Nebula will be mentioned in the new chapter and not this one. But telescope users should take heart as the descriptions of the naked-eye objects will also include binocular and telescopic information as and when appropriate.

There exist several classification schemes for emission nebula, but only one is used here. It is a measure of the visibility of the nebula as seen on the photographic plates from the Palomar Observatory Sky Survey (POSS). The photographic brightness is assigned a value from 1 to 6; those nebulae rated at 1 are just barely detectable on the plate, while those quoted at a value of 6 are easily seen on photographic plates. In the context of this book, it is just the measure of the difficulty (or ease) of observation and is given the symbol •.

The size of an object is also given in arcseconds and is indicated by the symbol ⊕. Where a value of ⊕ is given as $x|y$, then the object is approximately x arcminutes

---

[5]This is often called the Stromgren sphere, named after the astronomer Bengt Stromgren, who did some pioneering work on HII regions.

[6]It may however still be glowing as it reflects, or scatters, the low-energy light, giving a bluish tinge. This is a reflection nebula. See later in this chapter for more details.

long by *y* arcminutes wide. However, as larger apertures will show more and more of the nebula, what is given may not be what you observe.

The magnitude is also given where appropriate,[7] but on those occasions where a magnitude is quoted, treat it with caution!

The remaining usual nomenclature applies.

January–February–March

Gum 4	NGC 2359	07^h 18.6^m	–13° 12′	January 10
–	• 2–5	⊕ 9|6′		Moderate

This nice object, also known as the Duck Nebula, or more recently, as Thor's Helmet, lies about 9° to the northeast of Sirius. This is a bright emission nebula easily seen in telescopes of aperture 20 cm. It consists of two patches of nebulosity, with the northern patch being the larger and less dense. Using an OIII filter will greatly improve the appearance of the emission nebula, showing the delicate filamentary nature. The shape of the nebula is due to the presence of the central star, which is a Wolf-Rayet star – an extremely hot giant thought to be in a brief, pre-supernova stage of evolution.

See also:

Nebulae	Size	Month
NGC 604	60|35′	October
NGC 1499	160|50′	November
Herschell 258	25|25′	November
NGC 1555	1|7′	November
Messier 43	20|15′	December
Caldwell 49	80|60′	December
Herschel 261	4|4′	December
NGC 2024	30|30	December
Caldwell 46	3.5|1.5′	December
IC 417	13|10′	December
Messier 20	20|20′	June
Messier 16	35|30′	June

[7] To determine the true visual magnitude of nebulae can be fraught with difficulties. Assigning a magnitude to a nebula (or any extended object, including galaxies) is performed thus; it is treated as if all the light from the object originates from a single point – the *integrated magnitude*. So an object that has, say, an integrated magnitude of 5 will not look as bright as a 5th magnitude star.

April–May–June

Messier 20	NGC 6514	18^h 02.3^m	–23° 02′	June 22
6.3 m (9.0 m)	• 1–5	⊕ 20|20′		Easy

Also known as the Trifid Nebula. This emission nebula, or HII region, can be glimpsed as a small hazy patch of nebulosity and in fact is difficult to locate on warm summer evenings unless the skies are very transparent. In fact, determining its magnitude presents something of a problem due to the presence of several bright stars located within the nebula. With aperture around 15 cm, the nebula is easy to see, along with its famous three dark lanes (classified as Barnard 85) that give it its name. They radiate outwards from the central object, an O8-type star that is the power source for the nebula. The northern nebulosity is in fact a reflection nebula, and thus harder to observe. In large telescopes the nebula is wonderful and repays long and careful observation

Messier 16	IC 4703	18^h 18.8^m	–13° 49′	June 26
6.4 m	• 1–5	⊕ 35|30′		Moderate

Messier 16 is in fact a star cluster, NGC 6611, but associated with it is the famous Eagle Nebula, also known as the Star Queen Nebula. Oddly, even though it is famous, it is not often observed visually. Although it can be glimpsed in binoculars, the cluster can appear as a hazy patch with the naked eye; telescopic observation is needed to see any detail. As is usual, the use of a filter enhances the visibility. The "Black Pillar" and associated nebulosity are difficult to see, even though they are portrayed in many beautiful photographs. (A prime example of astronomical imagery fooling the amateur into thinking that these justifiably impressive objects can easily be seen through a telescope.) Nevertheless it can be spotted by an astute observer under near-perfect conditions.

See also:

Nebulae	Size	Month
Gum 4	9|6′	January
Herschel III-144	1|1′	July
Caldwell 27	18′|13′	July
IC 5067-70	60|50′	August
Caldwell 19	12|12′	August
Caldwell 11	16|9′	September

July–August–September

–	IC 5067-70	20^h 50.8^m	+44° 21′	August 4
8.0 m	• 1–5	⊕ 60|50′		Easy

Also known as the Pelican Nebula. This nebula, lying close to the North America Nebula (see below), is easily glimpsed in binoculars as a triangular faint hazy patch of light. It can be seen best with averted vision and the use of light filters. The Pelican is an object of much study as it consists of both of star-forming regions and evolving gas clouds.

Herschel III-144	NGC 6857	$20^h\ 01.9^m$	+33° 31′	July 22
–	• 1	⊕ 1|1′		Difficult

This is a very faint and small emission nebula, which requires telescopes of at least 20 cm aperture. It could easily be mistaken for a planetary nebula.

Caldwell 27	NGC 6888	$20^h\ 12.0^m$	+38° 21′	July 25
7.2 m	• 1–5	⊕ 18′|13′		Difficult

Also known as the Crescent Nebula. Although visible in binoculars, a dark location and a light filter will make it much easier to find. With good conditions, the emission nebula will live up to its name, having an oval shape with a gap in the ring on its southeastern side. The nebula is known as a Stellar Wind Bubble and is the result of a fast-moving stellar wind from a Wolf-Rayet star that is sweeping up all the material that it had previously ejected during its red giant stage.

Caldwell 19	Sh2-125	$21^h\ 53.4^m$	+47° 16′	August 19
9.0 m (7.2 m)	• 3–5	⊕ 12|12′		Difficult

Also known as the Cocoon Nebula. This is a very difficult nebula to find and observe. It has a low surface brightness and appears as nothing more than a hazy amorphous glow surrounding a couple of ninth-magnitude stars. The dark nebula Barnard 168 (which the Cocoon lies at the end of) is surprisingly easy to find, and thus can act as a pointer to the more elusive emission nebula. The whole area is a vast stellar nursery, and recent infrared research indicates the presence of many new and proto-stars within the nebula itself. Located with the nebula is the star cluster IC 5146.

Caldwell 11	NGC 7635	$23^h\ 20.7^m$	+61° 12′	September 11
10 m	• 1–5	⊕ 16|9′		Difficult ©

Also known as the Bubble Nebula and Sharpless 162. This is a very faint and strange nebula to observe, even in telescopes of aperture 20 cm. The "Bubble" part, 3 × 3 arcminutes in size, is actually located in a larger emission nebula of around 16 × 9 arcminutes. The use of averted vision will help in its detection. An eighth-magnitude star within the emission nebula and a nearby seventh-magnitude star hinder in its detection owing to their combined glare. Research suggests that a strong stellar wind from a star pushes material out and in turn ionizes the "Bubble," also heating up a nearby molecular cloud. It really does bear a striking resemblance to a soap bubble. Located nearby is the classic star cluster M52, so anyone observing the cluster will also be observing the nebula!

See also:

Nebulae	Size	Month
Herschel III-144	1|1′	July
Caldwell 27	18′|13′	July
NGC 604	60|35′	October
Herschell 258	25|25′	November
NGC 1555	1|7′	November
Messier 43	20|15′	December
Caldwell 49	80|60′	December
Herschel 261	4|4′	December
NGC 2024	30|30′	December
Caldwell 46	3.5|1.5′	December
IC 417	13|10′	December

October–November–December

–	NGC 604	01^h 34.5^m	+30° 48′	October 14
14 m	• 3–5	⊕ 60|35′		Moderate

This may come as quite a surprise to many observers, but this is possibly the brightest emission nebula that can be glimpsed that is actually located in another galaxy. It resides in M33, in the constellation Triangulum. It appears as a faint hazy glow some 10′ northeast of M33's core. Owing to M33's low surface brightness (which often makes it a difficult object to find), the emission nebula may be visible while the galaxy isn't! It is estimated to be about 1,000 times bigger than the Orion Nebula.

Herschell 258	NGC 1491	04^h 03.4^m	+51° 19′	November 21
–	• 1–5	⊕ 25|25′		Difficult©

Another faint and elusive emission nebula, with a telescope of aperture 25 cm, it appears as a hazy fan-shaped glow. The use of filters enhances the emission nebula quite well.

Messier 43	NGC 1982	05^h 35.6^m	–05° 16′	December 15
9.0 m	• 1–5	⊕ 20|15′		Easy

Visible in binoculars, this emission nebula is part of the M42 complex, and some observers find it difficult to discriminate between them. Visible to the north of M42, and separated from it by about 7′**,** it takes magnification well and will show many intricate details. It is also known as De Mairan's Nebula, after its discoverer.

Caldwell 49	NGC 2237-39	06^h 32.3^m	+05° 03′	December 29
–	• 1–5	⊕ 80|60′		Easy

Also known as the Rosette Nebula. This giant emission nebula has the dubious reputation of being very difficult to observe. But this is wrong – on clear nights it can be seen with binoculars. It is over 1° in diameter (~ 1.3°) and thus covers an area of sky four times larger than a full Moon! With a large aperture and light filters the complexity of the nebula becomes readily apparent, and under perfect seeing conditions dark dust lanes can be glimpsed. The brightest parts of the emission nebula have their own NGC numbers: 2237, 2238, 2239 (2244 is a cluster embedded within it) and 2246. It is a young nebula, perhaps only half a million years old, and star formation may still be occurring within it. Images show the central area containing the star cluster NGC 2244, along with the "empty" cavity caused by the hot young stars blowing the dust and gas away. Also known as the Rosette Molecular Complex (RMC).

Herschel 261	NGC 1931	05^h 31.4^m	+34° 15′	December 14
10.1 m	• 1–5	⊕ 4|4′		Moderate

Visible in telescopes of aperture 20 cm, the emission nebula appears as a very small faint hazy patch surrounding a triangle of stars. Larger apertures will show a slight brightening of the emission nebula at its center. It can be likened to the Orion Nebula, as it has similar characteristics, except that it is much smaller, of course.

NGC 2024	Sh2-227	05^h 41.7^m	–01° 51.5′	December 16
–	• 2–5	⊕ 30|30′		Moderate

Sometimes known as the Flame Nebula, this observationally difficult object lies next to the famous star ζ (Zeta) Orioni (Altinak), which is unfortunate as the glare from the star makes observation difficult. It can however be glimpsed in binoculars as an unevenly shaped hazy and faint patch to the east of the star, providing the star is placed out of the field of view. With large telescopes and filters the emission nebula is a striking object and has a shape reminiscent of a maple leaf.

Caldwell 46	NGC 2261	06^h 39.2^m	+08° 44′	December 31
–	• 1–5	⊕ 3.5|1.5′ variable		Moderate

This is an odd object, and of quite a rare type as well in that it shows signs of variability. Also known as Hubble's Variable Nebula, it is easily seen in small telescopes of 10 cm as a small, comet-like nebula that surprisingly can be viewed from a suburban location. Larger apertures just amplify what is seen with little detail visible. What we are observing is the result of a very young and hot star clearing away the debris from which it was formed. The star R Monocerotis (buried within the nebula and thus invisible to us) emits material from its polar regions, and we see the north polar emissions, with the southern emission blocked from view by an accretion disc. The variability of the nebula, reported by Edwin Hubble in 1916, is due to a shadowing effect caused by clouds of dust drifting near the stars. It was also the first object to be officially photographed with the 200-inch Hale Telescope, on January 26, 1949.

–	IC 417	05^h 28.1^m	+34° 26′	December 13
–	• 2–5	⊕ 13|10′		Difficult

In order to observe this emission nebula the use of averted vision is required. It appears as a very faint ghostly haze with a few faint stars located within it. Filters are again useful with the emission nebula, as are perfect seeing conditions.

NGC 1555	Sh2-238	04^h 21.8^m	+19° 32′	November 26
–	• 2–5	⊕ 1|7′ variable		Very difficult

Also known as Hind's Variable Nebula, this famous but incredibly faint emission nebula is located to the west of the also famous star T Tauri, the prototype for a class of variable star. The nebula has been much brighter in the past but now is an exceedingly difficult object to locate. With large aperture, it will appear as a small faint hazy patch. When (and if!) located, it does bear higher magnification well. It may become brighter in the future, so it is well worth looking for in the hope that it makes an unexpected reappearance.

See also:

Nebulae	Size	Month
Messier 20	20|20′	June
Messier 16	35|30′	June
Herschel III-144	1|1′	July
Caldwell 27	18|103′	July

Reflection Nebulae

As the name suggests these are nebula that shine by reflecting light from stars located within a nebula, or, perhaps close by to a nebula, and just like the emission nebula, they are vast clouds of both gas and dust. We should note however that the term "dust" used throughout this book and in many other texts isn't the dust that we are all familiar with on Earth; it is something very different indeed.

In space, conditions exist that allow for the formation of very small particles (or grains) of graphite, metals, silicates and ices. They are roughly 0.0001 cm in size and usually spindle-shaped. All these grains are embedded within a much larger cloud of molecular hydrogen, and one of the characteristics of particles, or grains that are so small (in proportion to the wavelength of light), is their property of selectively scattering light of a particular wavelength. What this means is that if a beam of white light shines upon a cloud containing the grains, the blue light is scattered in all directions, a phenomena similar to that seen in Earth's sky, hence its color blue. This is the reason why reflection nebulae appear so blue on photographs; it is just the blue wavelengths of the light from (usually) hot blue stars nearby.

So, if we want to be scientifically correct (and we do), the nebula should be called scattering nebulae instead of reflection nebulae, but the name has stuck. An interesting property of the scattered light is that the scattering process itself polarizes the light, useful in the studies of grain composition and structure.

Several of the larger emission nebulae have reflection nebulae associated with them, especially around their periphery. The Trifid Nebula is a perfect example. The inner parts of the nebula are glowing with the tell-tale pink color, indicative of the ionization process responsible for the emission, whereas further out from the center, the edge material is definitely blue, thus signposting the scattering nature of the nebula. The constellations of Sagittarius and Orion abound in combined bright emission and faint reflection nebulae.

Visually, reflection nebulae are very faint objects having a low surface brightness; thus they are not easy targets. Most require large aperture telescopes with moderate magnification in order to be seen, but there are a few visible in binoculars and small telescopes. There is also considerable debate concerning one particular nebula that some amateurs claim can actually be glimpsed with the naked eye!

As is to be expected, excellent seeing conditions are necessary and very dark skies. A simple star map of the reflection nebulae is at the end of this section.

January–February–March–April

See:

Nebulae	Size	Month
NGC 1333	⊕ 9|7′	November
Merope Nebula	⊕ 30|30′	November
Caldwell 31	⊕ 37|19′	December
NGC 1973-75-77	⊕ 5|5′	December
NGC 1999	⊕ 2|2′	December
Messier 78	⊕ 8|6′	December
Caldwell 4	⊕ 18|18′	August

May–June–July–August

Caldwell 4	NGC 7023	21^h 01.6^m	+68° 10′	August 6
–	• 1–5	⊕ 18|18′		Easy ©

Though small, this is a very nice, easy to observe reflection nebula. It has a star of seventh magnitude at its center that can aid or hinder observation, depending on your inclination. However, what makes the reflection nebula easy to detect is its location; it is surrounded by a larger area of dark nebulosity, probably part of the same nebula complex. The contrast between the background stars, the dark nebula and the reflection nebula makes for a very interesting region.

September–October–November–December

NGC 1333	LBN 741[8]	03^h 29.3^m	+31° 25′	November 13
–	• 3–5	⊕ 9|7′		Moderate

This is a nice, easily seen reflection nebula and appears as an elongated hazy patch. Larger aperture telescopes will show some detail along with two fainter dark nebulae, Barnard 1 and 2, lying toward that north and south of the reflection nebula.

Merope Nebula	NGC 1435	03^h 46.10^m	+23° 46′	November 17
–	• 2–5	⊕ 30|30′		Moderate

Also known as Tempel's Nebula. This faint patch of reflection nebula is located within the most famous star cluster in the sky – the Pleiades. The nebula surrounds the star Merope, one of the brighter members of the cluster, and under perfect conditions it can be glimpsed with binoculars. It has even been seen with a finder telescope, that, admittedly, was fitted with a deep sky filter. It is a comet-shaped cloud described by W. Tempel in 1859 as resembling "a breath on a mirror." Several other members of the cluster are also enshrouded by nebulosity, but these require exceptionally clear nights, and, incidentally, clean optics, as even the slightest smear on, say, a pair of binoculars, will reduce the chances to nil. There is considerable debate ongoing about the visibility of this nebula, as seen with the naked eye! Rumors abound that it is visible under perfect conditions. This reflection nebula has apparently never been seen from an urban location in the UK. Perhaps, though, the news has just not reached anyone yet.

Caldwell 31	IC 405	05^h 16.2^m	+34° 16′	December 10
–	• 2–5	⊕ 37|19′		Difficult

Also known as the Flaming Star Nebula. This is a very difficult nebula to observe. It is actually several nebula, including IC 405, 410 and 417, plus the variable star AE Aurigae. Using narrowband filters are justified with this reflection nebula, as they will highlight the various components. Definitely a challenge for the observer.

[8]This signifies it is the 741st object in the Lynd's *Catalogue of Bright Nebulae.*

NGC 1973-75-77	Sh2-279	05^h 35.1^m	–04° 44′	December 14
7.0 m	• 1–5	⊕ 5|5′		Difficult

The location of these omission nebulae so close to M42 has meant that they are often neglected by observers, lying as they do between M42 on their south and the cluster NGC 1981 to their north. To make matters worse, the glare from the nearby stars 42 & 45 Orionis (4.7 and 5.3 magnitude resp.) tends to make observation difficult.

NGC 1999	LBN 979[9]	05^h 36.5^m	–06° 43′	December 15
–	• 1–5	⊕ 2|2′		Moderate

In telescopes of aperture 20 cm, this small but bright emission nebula resembles a planetary nebula, and even has a 10.5 magnitude star, V380 Orionis, in its central region. The nebula lies about 1° south of M42.

Messier 78	NGC 2068	05^h 45.4^m	00° 05′	December 17
8.0	• 1–5	⊕ 8|6′		Moderate

This is a bright but small emission nebula that can be glimpsed in binoculars. Some observers say it resembles a fan shape, whereas others liken it to a comet. There are two 10th-magnitude stars located within the nebula that can give the false impression of two cometary nuclei. With a large-aperture telescope and high magnification, some very faint detail can be glimpsed along the eastern edge of the nebulosity, but excellent seeing will be needed. It is part of a group of reflection nebulae with NGC 2064 about 7′ to the southwest and NGC 2067 6′ to the west-northwest.

See also:

Nebulae	Size	Month
NGC 1333	⊕ 9|7′	November
Merope Nebula	⊕ 30|30′	November
Caldwell 31	⊕ 37|19′	December
NGC 1973-75-77	⊕ 5|5′	December
NGC 1999	⊕ 2|2′	December
Messier 78	⊕ 8|6′	December

Dark Nebulae

Dark nebula, by their very nature, are different in one major respect from all other types of nebula – they do not shine. When you observe them, what you are seeing is not due to any light emitting process but rather is due to their light blocking ability.

[9] This signifies it is the 979th object in the Lynd's *Catalogue of Bright Nebulae*.

In fact, they are vast clouds of dust grains, of the same type as described in the section on reflection nebulae, seen against other nebulae or the star fields of the Milky Way. The nebulae appear dark because they are very effective at scattering all of the incident light, and this, coupled with their vast size, means hardly any reaches the naked eye. The process of scattering the light is so effective that, for instance, visible light emitted from the center of our galaxy is extinguished nearly 100% by the dust clouds between the center and us. This is the reason why it is still a mystery as to what the central region of the Milky Way looks like in visible light.

Don't be confused however by thinking that these clouds of dust grains are very dense objects. They are not. Most of the material in the cloud is molecular hydrogen (along with carbon monoxide, which is responsible for their radio emission), along with the dust grains, and thus the resulting density is low. There is also some evidence to suggest that the dust grains present in the clouds have different properties than those dust grains in the interstellar medium.

Many dark nebulae are actually interacting with their environs, as witnessed by the spectacular images of M16 in Serpens showing dust clouds containing dense regions, or globules, resisting the radiation pressure from close, hot young stars, with the result that many of the globules have long tails of material trailing from them. Another famous example is the Horsehead Nebula in Orion, also famous for its image of the radiation from the supergiant stars of Orion's Belt impacting on the dark clouds to either side of the Horsehead with the result that material is ionized and streaming from the surface of the cloud.

Most of the dark clouds listed herein have vastly different shapes, and this is due to several reasons:

- The cloud could have originally been spherical in shape, and thus present a circular image to us, but hot stars in its environment will have disrupted this by radiation pressure and stellar winds.
- Shock fronts from nearby supernovae can also have an effect.
- Gravitational effects from other clouds, stars and even that of the Milky Way itself.
- Magnetic fields may also have some limited effect.
- Many of the dark clouds are part of a much larger star-forming region; thus new stars will themselves influence and alter cloud shape.

The "opacity" of dark nebulae is a measure of how opaque the cloud is to light, and thus how dark it will appear, and is given the symbol ❒ so this gives us a rough classification system that can be used:

- A value of 1 for a dark nebulae would indicate that it only very slightly attenuates the starlight from the background Milky Way.
- A value of 6 would mean that the cloud is nearly black.

For amateur astronomers, observing dark nebulae can be a very frustrating pastime, but there are a few tips that can help. The best advice is to always use the lowest magnification possible. This will enhance the contrast between the dark nebulae and that of the background star field. If a high magnification is used, the contrast will be lost, and you will only see the area surrounding the dark nebula and not the nebula itself. Of course there are exceptions to this rule. A high magnification can be employed on many of the dark nebulae in Sagittarius, but try a low magnification first in order to locate the object, then proceed to higher magnifications. Dark skies are a must with these objects, as even a hint of light pollution will make their detection an impossible task.

A final point. You will see that most of the dark nebulae listed are to be found in the summer months, when the Milky Way is resplendent high in the night sky. There are a few nebulae that can be seen in the spring and winter, but not many.

January–February–March–April

See:

Nebulae	Size	Month
Barnard 33	⊕ 6|4′	December
Barnard 228	⊕ 240|20′	May
Barnard 78	⊕ 200|150′	June
Barnard 86	⊕ 6′	June
Barnard 87	⊕ 12′	June
Barnard 103	⊕ 40|15′	July
Barnard 110-1	⊕ 11′	July
Barnard 142-3	⊕ 45′	July
Barnard 145	⊕ 35|8′	July
Barnard 343	⊕ 13|6′	July
Barnard 352	⊕ 20|10′	August

May–June–July–August

Barnard 228	15^h 45.5^m	−34° 24′	May 18
❐ 6	⊕ 240|20′		Easy

This is a long band of dark nebula, easily spotted in binoculars. It lies halfway between Psi (ψ) and Chi (χ) Lupi. Best seen in low-power, large-aperture binoculars, as it stands out well against the rich background star field.

Barnard 78	LDN 42	17^h 33.0^m	−25° 35′	June 14
❐ 5	⊕ 200|150′			Easy

Also known as the Pipe Nebula (Bowl). Part of the same dark nebula as above, the bowl appears as a jagged formation, covering over 9°. The whole region is studded with dark nebula and is thought to be a part of the same complex as that which encompasses Rho (ρ) Ophiuchi and Antares, which are over 700 light-years away from it.

Barnard 86	LDN 93	18^h 03.0^m	–27° 53′	June 22
❐ 5	⊕ 6′			Easy

Also known as the Ink Spot. Located within the Great Sagittarius Star Cloud, this is a near-perfect example of a dark nebula, appearing as a completely opaque blot against the background stars.

Barnard 87, 65-7	LDN 1771	18^h 04.2^m	–32° 30′	June 22
❐ 4	⊕ 12′			Easy

Also known as the Parrot Nebula. Although not a very distinct nebula, it stands out because of its location within a stunning background of stars. Visible in binoculars as a small circular dark patch, it is best seen in small telescopes of around 10–15 cm.

Barnard 103	LDN 497	18^h 39.4^m	–06° 41′	July 1
❐ 6	⊕ 40|15′			Easy

Easily seen at the northeast edge of the famous Scutum Star Cloud. It is a curved dark line. Can be glimpsed in binoculars, but best seen at apertures of around 10–15 cm.

Barnard 110-1		18^h 50.1^m	–04° 48′	July 4
❐ 6	⊕ 11′			Easy

An easily seen complex of dark nebulae that can be seen in binoculars. The contrast between the background star clouds and the darkness of the nebulae is immediately seen.

Barnard 142 – 3		19^h 39.7^m	+10° 31′	July 17
❐ 6	⊕ 45′			Easy

This is an easily seen pair of dark nebulae, visible in binoculars. It appears as a cloud with two "horns" extending towards the west. The nebula contrasts very easily with the background Milky Way and so is a fine object. With a rich field telescope and large binoculars, the dark nebula actually appears to be floating against the star field.

Barnard 145		20^h 02.8^m	+37° 40′	July 22
❐ 4	⊕ 35|8′			Easy

Visible in binoculars, it is a triangular dust cloud that stands out well against the impressive star field. As it is not completely opaque to starlight, several faint stars can be seen shining through it.

Barnard 343		20^h 13.5^m	+40° 16′	July 25
❒ 5	⊕ 13|6′			Easy

Easily seen as a “hole” in the background Milky Way, this is a dark oval nebula, which although glimpsed in binoculars is at its best in telescopes.

Barnard 352		20^h 57.1^m	+45° 54′	August 5
❒ 5	⊕ 20|10′			Moderate

Visible in binoculars, this is part of the much more famous North America Nebula, though this dark part is located to the north. It is a well-defined triangular dark nebula.

See also:

Nebulae	Size	Month
Barnard 33	⊕ 6|4′	December

September–October–November–December

Barnard 33		05^h 40.9^m	−02° 28′	December 16
❒ 4	⊕ 6|4′			Difficult

Also known as the Horsehead Nebula. Often photographed but very rarely observed, this famous dark nebula is very difficult to see. It is a small dark nebula that appears in silhouette against the dim glow of the emission nebula IC 434. Both are very faint and will need perfect seeing conditions. Such is the elusiveness of this object that even telescopes of 40 cm are not guaranteed a view. Dark adaption and averted vision, along with the judicious use of filters, may result in its detection. Nevertheless, have a go!

See also:

Nebulae	Size	Month
Barnard 228	⊕ 240|20′	May
Barnard 78	⊕ 200|150′	June
Barnard 86	⊕ 6′	June
Barnard 87	⊕ 12′	June
Barnard 103	⊕ 40|15′	July
Barnard 110-1	⊕ 11′	July
Barnard 142-3	⊕ 45′	July
Barnard 145	⊕ 35|8′	July
Barnard 343	⊕ 13|6′	July
Barnard 352	⊕ 20|10′	August

Planetary Nebulae

Our next class of objects in the catalog of nebulae are known as planetary nebulae.[10] These often beautiful objects, are some of the most interesting in the sky, having a lot to offer the amateur, ranging across the whole of the observational spectrum. Some are easy to find in binoculars, others will require large aperture, patience, and even maybe specialized filters in order for them to be distinguished from the background star fields. Comprised of small shells of gas, once the atmosphere of stars, they come in a variety of shapes, sizes and brightness, with many having a hot central star (visible in amateur equipment) that is the power source, providing the energy responsible for the glowing shell of gas.

The origin of planetary nebulae are very different from those nebulae mentioned previously. In stars with approximately solar mass (and perhaps just a little more), a time will arrive when the nuclear reactions in the core have transmuted all the hydrogen and helium into oxygen and carbon. The star by this time is extremely old and will have become a red giant and a variable star[11] (designated a *pulsating variable*). However, the core never proceeds beyond carbon and oxygen in its nucleosynthesis because the temperature never increases to a sufficiently high enough temperature for these later reactions to occur. The outer layers of the star actually pulsate in and out and in fact the material achieves escape velocity and so is able to expand into the space surrounding the star. The outer layers, now puffed into space, are the planetary nebulae we observe.

Several nebulae have a multiple shell appearance, and this is thought due to the red giant experiencing several periods of pulsation where the material escapes from the star. The strong stellar winds, magnetic fields and possible discs of material encircling the equator of the star are also thought responsible for the many observed exotic shapes of the nebulae.

Planetary nebulae are only a fleeting feature in our galaxy, for after only a few tens of thousands of years, the nebula will have dissipated into interstellar space, and so no longer exist. However, this aspect of a star's evolution is apparently very common, and there are over 1,400 planetary nebulae in our part of the galaxy alone, with a total of about 3,000 known in the Milky Way.

Visually, the nebulae are one of the few deep sky objects that actually appear colored. Around 90% of their light comes from the doubly ionized oxygen line, OIII, at wavelengths 495.9 nm and 500.7 nm. This is a very characteristic blue-green color, and, it so happens, the color at which the dark-adapted eye is at its most

[10] The name "planetary nebula" was first applied to these objects by Herschel who thought that the nebula looked like Jupiter when seen in a telescope.

[11] For the full details about this process, you are referred to the many astrophysics texts mentioned in the appendices.

sensitive. Specialized light filters are also extremely useful for observing planetaries as they isolate the OIII light in particular, increasing the contrast between the nebula and the sky background, thus markedly improving the nebula's visibility.

Such is the variety of shape and size that there is something to offer all types of observer. Some planetaries are so tiny that even at high magnification, using large aperture telescopes, the nebula will still appear star-like. Others are much larger. For instance the Helix Nebula, Caldwell 63, is half the size of the full Moon, but can only be observed with low magnification, and perhaps only in binoculars, as any higher magnification will lower its contrast to such an extent that it will simply disappear from view. Many exhibit a bipolar shape, such as the Dumbbell Nebula, M27, in Vulpecula, while others show ring shapes, such as the ever popular M57 in Lyra.

An interesting aside is the possibility of observing the central stars of the nebulae. These are very small, sub-dwarf and dwarf stars. They are similar in temperature to main sequence stars of type O and B, but, as they are running down their nuclear reactions, or in some cases, no longer producing energy by nuclear reactions (on their way to becoming white dwarf stars, or maybe already there) they are becoming fainter and smaller. These two characteristics make observation very difficult. The brightest central star is possibly that of NGC 1514 in Taurus, at 9.4 magnitude, but the majority are at magnitude 10 or fainter.

There is a classification system called the *Vorontsoz-Vellyaminov* classification system, which can be used to describe the appearance of a planetary. Although it is of limited use, it will be included here.

The usual information is given for each object, with the addition of morphology class [⦿] and central star brightness [✷]. In addition, the magnitude quoted is the magnitude of the planetary nebula as if it were a point source. This last parameter can often be confusing, so even if a nebula has a quoted magnitude of, say, 8, it may be much fainter than this, and consequently, somewhat difficult to locate.

Planetary Nebulae Morphology Types

1. Starlike
2. A smooth disc-like appearance
   (a) Bright towards center
   (b) Uniform brightness
   (c) Possible, faint ring structure
3. Irregular disc-like appearance
   (a) Irregular brightness distribution
   (b) Possible, faint ring structure
4. Definite ring structure
5. Irregular shape
6. Unclassified shape
   (can be a combination of two classifications, i. e., 4+3 [ring and irregular disc])

January

Caldwell 39	NGC 2392	07^h 29.2^m	+20° 55′	January 12
9.1 m	⊕ 47 | 43″	⦿ 3b+3b	✷9.8	Easy

Also known as the Eskimo Nebula, this is a small but famous planetary nebula that can be seen as a pale blue dot in a telescope of 10 cm, although it can be glimpsed in binoculars as the apparent southern half of a double star. Higher magnification will resolve the central star and the beginnings of its characteristic "Eskimo" face, and with an aperture of 20 cm the blue disc becomes apparent. The shell, ring and halo structure will need apertures of 40 cm in order to become easily resolvable. Research indicates that we are seeing the planetary nebula pole-on, although this is by no means certain. Its distance is also in doubt, with values ranging from 1,600 to 7,500 light-years.

Herschel 64	NGC 2440	07^h 41.9^m	−18° 12.5′	January 16
9.4 m	⊕ 74 | 42″	⦿ 5+3	✷19	Moderate

With a telescope of aperture 25 cm, this bipolar planetary nebula will appear as an oval shaped disc of hazy light and may show a faint green tint. Large telescopes will show several distinct patched of light and dark area within the planetary nebula.

See also:

Nebulae	Size	Month
Caldwell 59	45 | 36″	February
Sharpless 2-290	980′	February
PK196-10.1	28 | 27″	December
PK221-12.1	28″	December

February

Caldwell 59	NGC 3242	10^h 24.8^m	−18° 38′	February 26
7.7 m	⊕ 45 | 36″	⦿ 4+3b	✷12.1	Easy

Also known as the Ghost of Jupiter, this is one of the brighter planetary nebula, and the brightest in the spring sky for northern observers. It is a fine sight in small telescopes and can be glimpsed in binoculars as a tiny blue disc, but with an aperture of 10 cm the blue color becomes more pronounced along with its disc, which is approximately the same size as that of Jupiter in a similar aperture. It is bright, but with a faint hazy edge, and in larger telescopes the disc becomes oval in appearance, with barely perceptible extensions to either side. Photographs (and keen-eyed observers who possess large telescopes) suggest the planetary nebula has a strong resemblance to a human eye. The central star has a reported temperature of about 100,000 K.

Sharpless 2-290	Abell 31	08^h 54.2^m	+08° 55′	February 3
12.0 m	⊕ 980′	⦿ 3a	✷15.5	Difficult

Although this is an extremely large planetary nebula, it is very difficult to locate. Thus this is one planetary nebula where the use of an appropriate light filter is required or it proves pointless to try to observe. However, with a filter, the giant circular shape of the planetary nebula becomes obvious.

See also:

Nebulae	Size	Month
Caldwell 39	47 | 43″	January
Herschel 64	74 | 42″	January
Messier 97	202 | 196″	March
PK123+34.1	18 | 18″	March

March

Messier 97	NGC 3587	11^h 14.8^m	+55° 01′	March 11
9.9 m	⊕ 202 | 196″	⦿ 3a	✷16	Moderate©

Also known as the Owl Nebula, this is one planetary nebula that is not visible in binoculars owing to its low surface brightness; apertures of at least 20 cm will be needed to glimpse the "eyes" of the nebula. At about 10 cm aperture, the planetary nebula will appear as a very pale blue tinted circular disc, although the topic of color in regard to this particular planetary nebula is in question. Larger aperture will show more detail, and the central star can be glimpsed if seeing conditions permit.

PK123+34.1	IC 3568	12^h 32.9^m	+82° 33′	March 30
10.6 m	⊕ 18 | 18″	⦿ 2 +2a	✷11.5	Difficult©

This is a planetary nebula that will appear almost star-like unless a high magnification is used. Indeed, it is often mistaken for a star, and thus overlooked. Telescopes of aperture 20 cm will show the disc, but larger apertures resolve the lovely blue-green color of the planetary nebula. The central star can be seen to be slightly off-center.

See also:

Nebulae	Size	Month
Caldwell 59	45 | 36″	February
Sharpless 2-290	980′	February

April

See:

Nebulae	Size	Month
Messier 97	202 | 196″	March
PK123+34.1	18 | 18″	March

May

See:

Nebulae	Size	Month
Caldwell 6	23 | 17″	June
Caldwell 69	83 | 24″	June
PK64+5.1	7.5″	June

June

Caldwell 6	NGC 6543	17^h 58.6^m	+66° 38′	June 21
8.1 m	⊕ 23 | 17″	⦿ 3a+2	✷11	Easy ©

Also known as the Cat's Eye Nebula, it can be seen as a bright oval object with a fine blue-green color. This is one of the planetary nebula that became famous after the Hubble Space Telescope published its image. It is visible in small telescopes of, say, an aperture of 10 cm, but a large telescope (20 cm) will show some faint structure, while to observe the central star requires a 40 cm aperture. The incredibly beautiful and complex structure is thought to be the result of a binary system, with the central star classified as a Wolf-Rayet-type star.

Caldwell 69	NGC 6302	17^h 13.7^m	–37° 06′	June 10
9.6 m	⊕ 83 | 24″	⦿ 6	✷21	Difficult

Also known as the Bug Nebula, this is visible in nearly all sizes of telescope; with a large aperture, a distinct brightening at the center will be seen, which many incorrectly assume is the central star but in fact it is just the bright central region. A dust lane runs across the planetary nebula and obscures the central star from view. It is a class of nebula called bipolar, which to some will resemble an extended butterfly. The star responsible for the nebula has a temperature of 380,000 K. Unfortunately the nebula is not visible from the UK.

PK64+5.1		19^h 34.8^m	+30° 31′	June 30
9.6 m	⊕ 7.5″	⦿ 4	✷10.0	Difficult

This is a very small planetary nebula, that even with apertures of 20 cm and greater will require a high magnification. What makes it even more difficult to locate is the multitude of stars in the background. However, a pointer to the planetary nebula is the star responsible for it – Campbell's Hydrogen Star, which has a lovely orange color.

See also:

Nebulae	Size	Month
Messier 57	86 | 62″	July
Caldwell 15	27 | 24″	July
Messier 27	8 | 5.7′	July
PK54-12.1	74 | 62″	July
PK33-2.1	9 | 7″	July
Herschel 743	1.9 | 1.8′	July
Herschel 16	42 | 35″	July

July

Messier 57	NGC 6720	18^h 53.6^m	+33° 02′	July 5
8.8 m	⊕ 86 | 62″	⦿ 4 +3	✷15.3	Easy

Also known as the Ring Nebula, and possibly the most famous of all planetary nebula, it is, surprisingly – and pleasantly – visible in binoculars. However, it will not be resolved into the famous "smoke-ring" shape seen so often in color photographs; it will, rather, resemble an out-of-focus star. It is just resolved in telescopes of about 10 cm aperture, and at 20 cm the classic smoke-ring shape becomes apparent. At high magnification (and larger aperture), the Ring Nebula is truly spectacular. The inner region will be seen to be faintly hazy, but large aperture, high magnification and perfect conditions will be needed to see the central star. Does the planetary nebula appear perfectly circular, or is it slightly oval?

Caldwell 15	NGC 6826	19^h 44.8^m	+50° 31′	July 18
8.8 m	⊕ 27 | 24″	⦿ 3a+2	✷11	Easy ©

Also known as the Blinking Planetary, this is a difficult planetary nebula to locate, but well worth the effort. The blinking effect is due solely to the physiological structure of the eye. If you stare at the central star long enough, the planetary nebula will fade from view. At this point should you move the eye away from the star, and the planetary nebula will "blink" back into view at the periphery of your vision. Visually, it is a nice blue-green disc, which will take high magnification well. Although not visible in amateur telescopes, the planetary nebula is made up of two components – an inner region consisting of a bright shell and two extensions (called *ansae*), and a halo that is delicate in structure with a bright shell.

Messier 27	NGC 6853	19^h 59.6^m	+22° 43′	July 22
7.1 m	⊕ 8 | 5.7′	⦿ 3+2	✷13.8	Easy

Also known as the Dumbbell Nebula, this famous planetary nebula can be seen in small binoculars as a box-shaped hazy patch, and many amateurs rate this as the sky's premier planetary nebula. In apertures of 20 cm, the classic dumbbell shape is apparent, with the brighter parts appearing as wedge shapes that spread out to the north and south of the planetary nebula's center. The central star can often be glimpsed at this aperture. Under perfect observing conditions, however, a faint glow can be seen in its outer parts. All in all this is a wonderful object.

PK54-12.1	NGC 6891	20^h 15.2^m	+12° 42′	July 26
10.5 m	⊕ 74 | 62″	⦿ 2a+2b	✷11.1	Easy

A pleasant planetary nebula that can be seen in apertures of 10 cm it will appear as a small but bright disc, that can look like a star in low magnification. Using larger apertures, the central star will become visible along with the color of the blue-green disc.

PK33-2.1	NGC 6741	19^h 02.6^m	–00° 27′	July 7
11.4 m	⊕ 9 | 7″	⦿ 4	✷17.5	Moderate

This is a small but nicely colored planetary nebula. A small-aperture telescope of about 20 cm is needed to resolve the planetary nebula into a disc, but it will show the blue-green color. Larger apertures will just make the image bright but with no increase in resolution of detail. In some sources it is now being referred to as the Phantom Streak nebula!

Herschel 743	NGC 6781	19^h 18.4^m	+06° 33′	July 11
11.4 m	⊕ 1.9 | 1.8′	⦿ 3b+3	✷15.0	Moderate

This is an easily located planetary nebula – large, circular and bright and under excellent seeing, using averted vision and with dark adaption, a darkening of its center will be revealed along with the fainter part of its northern periphery. Large-aperture instruments will show far more detail, including the halo. Alas, it is not visible in binoculars.

Herschel 16	NGC 6905	20^h 22.4^m	+20° 06′	July 27
11.1 m	⊕ 42 | 35″	⦿ 3 +3	✷14.0	Moderate

Also known as the Blue Flash Nebula. The true nature of this planetary nebula only becomes apparent at apertures of at least 20 cm, when the lovely blue color is seen. The color and brightness also increase towards its center, but with moderate apertures the central star can be seen only under good seeing conditions.

Using a larger aperture will show that the planetary nebula has a mottled, unevenly bright disc.

See also:

Nebulae	Size	Month
Caldwell 6	23 | 17″	June
Caldwell 69	83 | 24″	June
PK64+5.1	7.5″	June
Caldwell 55	44 | 23″	August
PK89+0.1	27 | 11″	August
Caldwell 63	880 | 720″	August

August

Caldwell 55	NGC 7009	21^h 04.2^m	−11° 22′	August 7
8.0 m	⊕ 44 | 23″	⦿ 4+6	✷12.78	Moderate

Also known as the Saturn Nebula. Although it can sometimes be glimpsed in small apertures, a telescope of at least 25 cm is needed to see the striking morphology of this planetary nebula that gives it its name. There are extensions, or ansae, on either side of the disc, along an east-west direction, that can be seen under perfect seeing. The disc is a nice blue-green, and the central star may be glimpsed, but a high magnification is also justified in this case. Recent theory predicts a companion to the central star, which may be the cause of the peculiar shape.

PK89+0.1	NGC 7026	21^h 06.3^m	+47° 51′	August 7
10.9 m	⊕ 27 | 11″	⦿ 3a	✷14.5	Moderate

A nicely colored bluish-green planetary nebula that has a slightly brighter center, this will appear stellar-like in binoculars, and so 20 cm aperture telescopes will be needed to resolve it into a disc.

Caldwell 63	NGC 7293	22^h 29.6^m	−20° 50′	August 29
7.3 m	⊕ 880 | 720″	⦿ 4+3	✷13.5	Difficult

Also known as the Helix Nebula. Believed to be one of the closest planetary nebulae to Earth, at about 700 light-years, it has an angular size of over ¼° – half that of the full Moon that would lead one to assume it is easy to observe. It is not, however, as it has a very low surface brightness and is thus notoriously difficult to locate. With binoculars, the planetary nebula appears as a ghostly image. With an aperture of 10 cm, low magnification is necessary and averted vision is useful in order to glimpse the central star. The use of an OIII filter will drastically improve the image.

See also:

Nebulae	Size	Month
Messier 57	86 | 62″	July
Caldwell 15	27 | 24″	July
Messier 27	8 | 5.7′	July
PK54-12.1	74 | 62″	July
PK33-2.1	9 | 7″	July
Herschel 743	1.9 | 1.8′	July
Herschel 16	42 | 35″	July
Caldwell 22	32 | 28″	September
Caldwell 2	38 | 35″	September

September

Caldwell 22	NGC 7662	23^h 25.9^m	+42° 33′	September 12
8.3 m	⊕ 32 | 28″	⦿ 4+3	✷13.2	Moderate

Also known as the Blue Snowball, this nice planetary nebula is easily located owing to its striking blue color, but note that it will only appear stellar-like in binoculars. In telescopes of 20 cm, the disc is seen, along with some ring structure. With larger aperture, subtle color variations appear – blue-green shading. Research indicates that the planetary nebula has a structure similar to that seen in the striking HST image of the Helix Nebula, showing fast low-ionization emission regions (FLIERS). These are clumps of above-average-density gas that was ejected from the central star before it formed the planetary nebula.

Caldwell 2	NGC 40	00^h 13.0^m	+72° 31′	September 24
12.3 m	⊕ 38 | 35″	⦿ 3b+3	✷11.6	Moderate©

This is a nice object that is often, strangely, overlooked. Appearing as a star in binoculars, it needs an aperture of at least 20 cm for its planetary nebula nature to become apparent. Bright and oval, it has even brighter regions at its western and eastern sections and has a lighter northern area, but this latter feature is seen only under perfect seeing conditions.

See also:

Nebulae	Size	Month
Caldwell 55	44 | 23″	August
PK89+0.1	27 | 11″	August
Caldwell 63	880 | 720″	August
Caldwell 56	4.6 | 4.1′	October
Messier 76	163 | 107″	October

October

Caldwell 56	NGC 246	00^h 47.0^m	−11° 53′	October 2
10.4 m	⊕ 4.6 | 4.1′	⦿ 3b	✷11	Moderate

This is a nice planetary nebula that is large and moderately bright, showing a distinct circular appearance, but an aperture of at least 20 cm is needed for its true nature to become apparent. With larger apertures the mottling appearance is easily seen, with bright and dark areas making up the characteristic shape of this planetary nebula. Its central star is very strange, believed to be one of the hottest stars known, with a temperature of at least 135,000 K. It is also thought to be a binary star system that may account for its peculiar shape.

Messier 76	NGC 650-1	01^h 42.4^m	+51° 34′	October 16
10.1 m	⊕ 163 | 107″	⦿ 3+6	✷15.9	Moderate©

Also known as the Little Dumbbell Nebula, this is a small planetary nebula that shows a definite non-symmetrical shape. In small telescopes of aperture 10 cm, and using averted vision, two distinct "nodes," or protuberances, can be seen. With apertures of around 30 cm, the planetary nebula will appear as two bright but small discs that are in contact. Even larger telescopes will show considerably more detail. When it was originally cataloged, it was believed to be two separate nebulae, and so both parts were assigned names, NGC 650 and NGC 651.

See also:

Nebulae	Size	Month
Caldwell 22	32 | 28″	September
Caldwell 2	38 | 35″	September
PK206-40.1	48 | 42″	November
PK220-53.1	11.0 | 7.5′	November
Herschel 53	56 | 48″	November

November

PK206-40.1	NGC 1535	04^h 14.2^m	−12° 44′	November 24
9.6 m	⊕ 48 | 42″	⦿ 4+2c	✷12.5	Easy

This is one of the few planetary nebulae that show a distinct circular appearance in small telescopes. With an aperture of 5 cm and magnification of at least 100×, a small hazy glow will be seen. Under higher apertures, the disc is resolved along with the nice blue color. Telescopes of 20 cm will easily resolve the subtle hazy outer ring structure, surrounding the bright bluish-green disc. The central star is easily seen at this aperture. A nice but not well-known planetary nebula.

PK220-53.1	NGC 1360	03^h 33.3^m	−25° 52′	November 14
9.4 m	⊕ 11.0 | 7.5′	⦿ 3	✷11.4	Moderate

This is one of those planetary nebulae that just gets better with larger apertures. Easily seen in telescopes of 20 cm, it will appear as a large, hazy, but faint patch, with a prominent central star. Using a filter improves its visibility. As bigger apertures are used, it becomes more impressive, showing an enormous oval disc. Often overlooked because it is very far south, it nevertheless merits more attention than it receives. This is a planetary nebula that owners of large telescopes should seek out and observe.

Herschel 53	NGC 1501	04^h 07.0^m	+60° 55′	November 22
11.5 m	⊕ 56 | 48″	⦿ 3	✷14.4	Moderate©

This has been called the Oyster Nebula. A very nice blue planetary nebula, easily seen in telescopes of 20 cm and glimpsed in apertures of 10 cm. With larger aperture, some structure can be observed, and many liken this planetary nebula to that of the Eskimo Nebula. The central star can be seen if a high enough magnification is used – 300×.

See also:

Nebulae	Size	Month
Caldwell 56	4.6 | 4.1′	October
Messier 76	163 | 107″	October
PK196-10.1	28 | 27″	December
PK221-12.1	28″	December

December

PK196-10.1	NGC 2022	05^h 42.1^m	+09° 05′	December 16
11.6 m	⊕ 28 | 27″	⦿ 4+2	✷15	Moderate

This is a very small, faint, bluish-gray planetary nebula, but can be glimpsed in telescopes of 20 cm. Using a larger aperture will resolve the disc appearance along with a pale greenish tint.

PK221-12.1	IC 2165	06^h 21.7^m	−12° 59′	December 26
10.5 m	⊕ 28″	⦿ 3b	✷15	Difficult

This is another planetary nebula that needs a high magnification in order to resolve its non-stellar properties. With aperture of 20 cm, the small, faintly blue disc can be seen, but using larger apertures will resolve the non-circular shape along with a slight brightening at its center.

See also:

Nebulae	Size	Month
PK206-40.1	48 | 42″	November
PK220-53.1	11.0 | 7.5′	November
Herschel 53	56 | 48″	November
Caldwell 39	47 | 43″	January
Herschel 64	74 | 42″	January

Supernova Remnants

The last class of objects in this chapter concerns those that, although few and far between from an observational viewpoint, represent the final and spectacularly explosive stage of a supergiant star's life – a supernova. The finer details that lead up to a supernova are far beyond the scope of this book, but a rough picture can be sketched. Basically,[12] massive stars will, as mentioned earlier in the book, eventually turn all the hydrogen in their core to helium and, with an accompanying increase in temperature, turn this helium into carbon, then oxygen. Providing that the temperature increase needed to allow nucleosynthesis to occur is available, then many elements in the Periodic Table, up to and including iron, will be produced.

The reactions are very complex, but the outcome of all this activity will be an increase in the stars size, along with higher core temperatures. However, up until iron, all of the reactions have been *exothermic*, that is, they produce energy and thus heat. This energy balances the tremendous gravitational force that otherwise would make the star collapse. The star is held in a state of equilibrium – the gravity balanced by the thermal pressure produced in the core. The reactions involving iron, however, become *endothermic* – they take in energy. Thus the delicate balancing act is disrupted, gravity wins the day, and the core collapses very rapidly, maybe in a matter of seconds. The net outcome of this dramatic implosion is for a wave of energy and neutrinos to hurl the outer layers of the star into space at phenomenal speeds, often in the region of 10,000 km s^{-1}. The increasing surface area of the star represents an increase in luminosity, and this is what we see as a supernova.

The supernova remnant (usually abbreviated to SNR) represents the debris of the explosion, the layers of the star that have been hurled into space and the remains of the core that will now be a neutron star or, in some cases involving the most massive

[12]This description is VERY basic. More details of the processes involved can be found in the author's book *Astrophysics Is Easy!*

stars, a black hole. From an observational viewpoint, however, we are only concerned with the parts that can be observed with amateur instruments – the shell of material flung out during the explosion. The visibility of the remnant actually depends on several factors, such as its age, whether there is an energy source to continue making it shine and the original type of supernova explosion.

As the remnant ages, its velocity will decrease, usually from 10,000 km s^{-1} to maybe 200 km s^{-1}. It will of course fade during this time. A few SNR's have a neutron star at their center that provides a replenishing source of energy to the far flung material. The classic archetypal SNR that demonstrates this process is the Crab Nebula, M1 in Taurus. The pearly, faint glow we observe is actually light produced by electrons traveling at velocities near the speed of light as they circle around immense magnetic fields; this light is called *synchrotron radiation*. Some SNR's glow as the speeding material impacts dust grains and atoms in interstellar space, while others emit radiation as a consequence of the tremendous kinetic energies of the exploding star material.

What this all means to an amateur astronomer is that, unfortunately, only a handful of SNR's are observable. The good news is that most of them can be glimpsed with binoculars.

January–February–March–April

See:

Nebulae	Size	Month
NGC 1909	⊕ 3′|1′	December
Messier 1	⊕ 6′|4′	December

May–June–July–August

Caldwell 34	NGC 6960	20^h 45.7^m	+30° 43′	August 2
7 m (Blue)	⊕ 70′|6′			Moderate

Also known as the Veil Nebula (western section). This is the western portion of the Great Cygnus Loop, which is the remnant of a supernova that occurred about 30,000 years ago. It is easy to locate because it is close to the star 52 Cygni, though the glare from this star makes it difficult to see. Dark skies are needed and a light filter makes a vast difference. Positioning the telescope so that 52 Cygni is out of the field of view also helps. The nebulosity we observe is the result of the shockwave from the supernova explosion impacting on the much denser interstellar medium. The actual remains of the star have not been detected.

Caldwell 33	NGC 6992-5	$20^h\ 56.4^m$	+31° 43′	August 5
7 m (Blue)	⊕ 60′|8′			Moderate

Also known as the Veil Nebula (eastern section). A spectacular object when viewed under good conditions. It is the only part of the Loop that can be seen in binoculars and has been described as looking like a fish-hook. It takes large aperture and high magnification well, and 40 cm telescopes will show the southern knot. Using such a telescope, it becomes apparent why the nebula has been the named the Filamentary Nebula, as lacy and delicate strands will be seen. However, there is a down side: it is notoriously difficult to find. Patience, clear skies and a good star atlas will help. This is a showpiece of the summer sky (when you have finally found it).

NGC 6974-79		$20^h\ 51.0^m$	+32° 09′	August 4
–	⊕ 7′|3′			Difficult

Also known as the Veil Nebula (central section). This part of the Great Cygnus Loop is difficult to see, but the use of light filters makes it easier to locate and observe. It appears as a triangular hazy patch of light. A very transparent sky is needed to glimpse this.

September–October–November–December

NGC 1909	IC 2118	$05^h\ 02^m$	–07° 54′	December 7
–	⊕ 3′|1′			Moderate

Also known as the Witch Head Nebula. This is a very faint patch of nebulosity that apparently is the last of a very old supernova remnant. It resembles a long ribbon of material that can be glimpsed with binoculars. It is glowing by reflecting the light of nearby Rigel. Very rarely mentioned in observing guides, it deserves serious attention because it is one of a very select club of observable supernova remnants.

Messier 1	NGC 1952	$05^h\ 34.5^m$	+22° 01′	December 14
8.5 m	⊕ 6′|4′			Easy

Also known as the Crab Nebula. This is probably the most famous supernova remnant in the sky; it can be glimpsed in binoculars as an oval light of plain appearance. With telescopes of aperture 20 cm it becomes a ghostly patch of gray light. Larger aperture will show some faint mottled structure. In all apertures (except very large – 40 cm) it will remain uniform in appearance. In 1968 the Crab Pulsar, an object that we now know as a rapidly rotating neutron star (that has also been optically detected) was discovered as the source of the energy responsible for the pearly glow observed. Oddly enough the Crab Nebula is a type of supernova remnant called a *plerion*, which, however, is far from common among supernova remnants.

Chapter 5

Galaxies

This chapter deals with those deep-sky objects that every amateur astronomer not only knows about but also has usually observed at least a handful of – galaxies.[1]

But it must be said at the outset that, for the majority of observers, galaxies remain faint and elusive objects, and it is probably true to say that only perhaps 15–20 of the brightest and most well known galaxies are ever observed by 99% of amateur astronomers. However, with the proper optical system and under optimum seeing conditions (and a copy of this book), many more are within reach of even small telescopes or binoculars. In fact, and this may come as a surprise, there are a few visible to the naked eye.

Galaxies are vast, immense collections of stars, gas and interstellar dust. They are the origin of all stars, because stars are not born outside galaxies. The total number of stars in any one galaxy varies considerably. In some giant galaxies, there may be a trillion (1×10^{12}) stars – a number that staggers the mind. In small dwarf galaxies, such as Leo I, there may be only a few hundred thousand. Galaxies also come in a variety of shapes and sizes, but most can be grouped into a few distinct classifications because when astronomers began studying the galaxies, the characteristic that immediately became apparent was their shape, or morphology.

[1]The Milky Way Galaxy is sometimes referred to as the "Galaxy," with a capital letter, whereas any other is simply a "galaxy." However, in this book we do not capitalize the word galaxy unless it is linked with the actual name of the galaxy, i.e., the Milky Way Galaxy.

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_5,

Broadly speaking, galaxies can be classified into three major categories:

1. *Spiral galaxies* appear as flat white discs with yellowish bulges at their centers. The flat disc regions are occupied by dust and cool gas, interspersed with hotter ionized gas, as is the case in the Milky Way. Their most obvious characteristic is their beautiful spiral arms. Both old and new stars are found in spirals.
2. *Elliptical galaxies* are somewhat redder,[2] more rounded in appearance, like a football. Compared with spiral galaxies, elliptical galaxies, or *ellipticals,* contain far less cool gas and dust, but very much more hot ionized gas. Old stars are far more numerous in ellipticals.
3. Those galaxies that appear neither disc-like nor rounded are classified as *Irregular galaxies*. Again, like spirals, old and new stars are found here, but current ideas suggest that irregulars are created from the merging of galaxies, which give rise to a sudden burst of star formation.

The classification system can be further subdivided and specialized to take account of, for example, the brightness of the nuclear region (the tight compact central region of the galaxy), the tightness of the spiral arms, etc.

Galaxy Structure

Before going any further we will describe in more detail the structure of a galaxy, as this will, albeit in a small way, provide some insight into why galaxies appear the way they do. The books mentioned in the appendix of this book will contain more detailed coverage of this topic, along with discussions on the origin and formation of galaxies.

Most spiral galaxies have a thin disc extending outward from a central bulge. The bulge merges smoothly into what is called the *halo*, which can extend to a radius in excess of 100,000 light-years. Both the bulge and halo make up what is called the *spheroidal component*. There are no clear boundaries as to what divides this component up into its constituent parts, but a ball-park figure, often used, is that stars within 10,000 light-years of the center can be considered to be bulge stars, whereas those outside this radius are members of the halo.

The disc component of a spiral galaxy cuts through both the halo and the bulge and can, in a large spiral galaxy such as the Milky Way, extend 50,000 light-years from the center. The disc contains a mixture of gas and dust, – the interstellar medium – but the amounts and proportions of the gas, whether atomic, ionized or molecular, will be different from galaxy to galaxy. Located within the disc are the spiral arms, made up of stars, both old and new, gas, and immense clouds of interstellar dust.

[2] Scientifically speaking, that is. To the naked eye, they will still look white (–ish).

It is the presence of the young and hot stars that make the spiral arms so distinct. In fact, old photographs often convey a false impression of the morphology of spirals, as they would often give the impression that stars are more numerous in the arms, and far fewer are in the inter-arm spaces. We now know this to be false. Between the arms are immense numbers of yellow, orange and red stars, but because of the techniques used in old-style photographs, only the hot blue and white stars were picked up on the photographic medium, i.e., those located in the spiral arms. New images taken with CCD cameras, especially those taken with the Hubble Space Telescope, show the disc and spiral arms in all their glory!

The stars contained within a spiral galaxy can also be classified depending on where they reside. Those that lie in the disc region are called *Population I* stars and are stars that are relatively young and born from the remains of previous generations of stars; those in the bulge region are old, red giant stars, called *Population II* stars. This is why photographs often show the spiral arms colored blue, owing to the Population I stars, with the bulge colored orange because of the Population II ones. The spiral arms may also be dotted with pink and red HII regions,[3] areas of star formation. Thus, new stars are usually formed in the spiral arms of galaxies, seldom in the bulge.

Some spiral galaxies exhibit a straight bar of stars that cuts across the center, with spiral arms curling away from the ends of the bars. Galaxies with these features are known as *barred spirals*. Then there are galaxies that possess discs but not spiral arms and are called *lenticular* galaxies, because they look lens-shaped when seen edge-on.

Current ideas suggest that 75% of the *largest* galaxies in the observable universe are apparently spiral or lenticular. Some spiral galaxies that can be found in a loose collection of other spirals – this is known as a *group* – spread over several million light-years. Our galaxy, the Milky Way, is a member of the Local Group.

Elliptical galaxies differ significantly from spirals in that they do not have a significant disc component and thus an elliptical has only the spheroidal component. The interstellar medium is also different from that in spirals; it is a mixture of low-density, hot, X-ray-emitting gas, with little cool gas or dust. Contrary to what you may read in some books, ellipticals do possess a little gas and dust, and some have a small gaseous disc at their center that is believed to be the remains of spiral galaxies that the elliptical consumed in an earlier merger of galaxies.

The stars in the spheroidal population of elliptical galaxies give a clue to possible star formation, if any. Such stars are orange and red, with an absence of blue stars, indicating that they are old, and that any such star formation occurred a long time ago.

Elliptical galaxies are often found in large clusters of galaxies, usually located near their center. They make up about 15% of the large galaxies found outside clusters, but about 50% of the large galaxies within a cluster. Very small galaxies,

[3] See Chap. 4 for a description of HII regions.

called *dwarf elliptical galaxies*, are often found accompanying large spiral ones. A perfect example of such an arrangement, and one that is visible to the amateur, is the Andromeda Galaxy, M31, which is a classic spiral galaxy, and its attendants, M32 and M110, both dwarf ellipticals.

Several galaxies can be observed to not belong to either the spiral or the elliptical galaxy category. These are irregular galaxies, and in fact more or less include all those galaxies that do not easily fall into the two previous classes. They include small galaxies such as the Magellanic Clouds, and those galaxies that are peculiar owing to tidal interactions. These systems of galaxies are usually white and dusty, as spirals are, though there the resemblance ends. Deep imaging has shown that the more distant galaxies are irregular, which indicates that this type of galaxy was more common when the universe was much younger.

Hubble Classification of Galaxies

The famous American astronomer Edwin Hubble was the first person to put the many disparate types of galaxies into some sort of order. The *Hubble Classification*, as it is now known, is used as a means of categorizing any galaxy. Further amendments were added later, particularly by the astronomer de Vaucouleurs.

Basically the classification is as follows:

An upper-case letter followed by either a number or a lower-case letter is assigned to the galaxy in question, and this identifies its morphology. For instance, in the case of an elliptical galaxy, the letter E is used followed by a number. The larger the number, the flatter the galaxy. An E0 galaxy is round, whereas an E7 galaxy is very elongated. There exists a subgroup for the ellipticals with the following nomenclature: D signifies a diffuse halo, c is a supergiant galaxy, and d represents a dwarf galaxy.

A spiral galaxy is assigned the letter S, but can also be assigned SA, to signify that it is an ordinary spiral, or SB, where the B indicates it has a bar. It is then followed by a lower-case letter: a, b, c or d.[4] Intermediate classes also exist, for example ab, bc, cd, dm and m. The lower-case letter a to d indicates the size of the bulge region, the dustiness of the disc, and the tightness of the spiral arms, while m denotes a stage where the spiral shape is barely discernible. A Sa galaxy will usually have a large bulge, with a modest amount of dust and tightly wound arms, whereas an Sd galaxy will have a small bulge and very loosely wound arms. An SBc galaxy, for instance, will have a bar and also a small bulge.

There is also a classification for galaxies intermediate between spirals and ellipticals, the Lenticular galaxies, classified as SO, while SAO is for those that are ordinary and SBO for those that are barred. In addition, for galaxies between type

[4]The ‘d’ classification is a quite rare and so the majority of galaxies listed in the book will only have classifications up to “c.” It is included here for completeness.

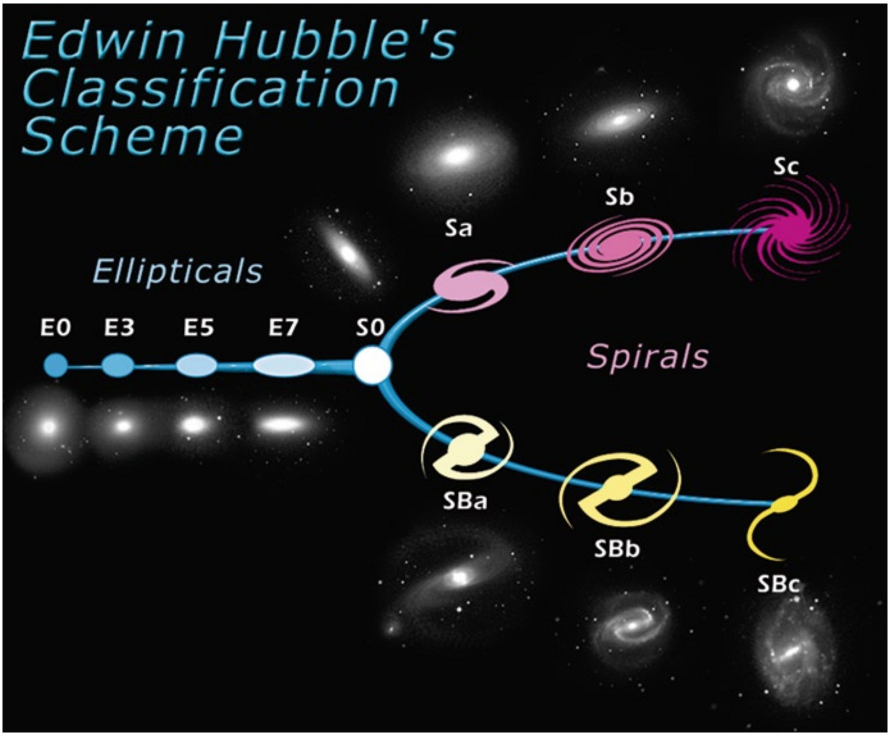


Fig. 5.1 Hubble's Tuning Fork diagram showing the main galaxy types (Courtesy of NASA & HST Heritage Project)

S and SB, there is the classification SAB. An outer ring can surround both lenticular and spiral galaxies, or perhaps the spiral arms will nearly close upon themselves, thus forming a pseudo-ring. These new features are classified as R and R′, respectively.

Finally, there are classifications for those galaxies that do not easily fall into any of the above three! These include Pec, for peculiar galaxies that may have a distorted form. Some galaxies have an irregular morphology and thus are classed as Irr. They can also be further classified as unstructured, IA, and barred, IB. Dwarf galaxies are classified as d. The difference between a galaxy classified as Pec and one classified as Irr can be very small, but it appears that a peculiar galaxy is one that may have suffered considerable tidal distortion due to the passage of another galaxy nearby.

The Hubble classification system can be represented by a diagram (Fig. 5.1) and is often referred to as the "Tuning Fork" diagram; note however, that the diagram, and the classification generally, do not represent an evolutionary sequence. Galaxies do not start as ellipticals and then progress to be spirals, though there is some evidence that the reverse is the true if one takes into account the apparently commonplace scenario of galaxies merging.

The classification system can be confusing (an understatement!), and the system and descriptions outlined above are by no means complete – there are further subdivisions to all the classes. But don't let that worry you – the complete system is only of relevance to those astrophysicists who study galaxies; to the observer, the important aspect is, more or less, whether the galaxy is a spiral (and if so, whether it is barred) or whether it is elliptical. In those few galaxies where the spiral or elliptical structure is very apparent, the subdivisions of, say, E1, E2 and Sa, Sb, SBa, etc., will be useful. Like most things in observational astronomy, it will all become easier with use.

There are some times when the classification system may be of no apparent use at all, namely when a galaxy is inclined to our line of sight. For instance, a galaxy such as M83, which is a nice spiral galaxy, is face-on to us, and thus the classic spiral shape is very apparent. However, a galaxy such as NGC 891, which is classified as a spiral, will just appear as a thin streak of light, because the galaxy is edge-on to us, and the spiral shape will not be visible. However, finding galaxies that present an edge-on or nearly edge-on perspective adds another element to the pleasure of locating and observing these faint objects.

Observing Galaxies

To the amateur astronomer, observing galaxies can present something of a dilemma. In astronomy magazines and books, you are presented with wonderful and spectacular images of galaxies, their spiral arms resplendent and multi-colored, speckled throughout with distinct pink HII regions. However, when you look at that same galaxy through your telescope, all you can see is a pale tiny blob!

It is true to say that in nearly every case, and from an urban location, any galaxy will be faint and indistinct. Only with medium and large telescopes and the darkest possible skies can any real structure be seen.

But take heart! Even with the naked eye, you will be astonished at what you can actually see with practice and from the right location. I recall that during a visit to the wilder parts of Turkey, on several occasions under utterly dark skies, I was able to see M31 in Andromeda and M33 in Triangulum in such amazing detail that even today the memory takes my breath away. Using just the naked eye, I was able to trace M31 to nearly 2½° across the sky, and M33 was a huge amorphous glow. Also, had I only known enough to look, I would have been able to see several other galaxies with the naked eye as well, but I was under the common misimpression that the naked-eye limit is about sixth magnitude, whereas I now know that, with extremely dark skies and light-adapted vision, magnitude 8 is more like the limit.

The purpose of this anecdote is to remind you that, in order to see faint galaxies and the detail therein, dark skies are indispensable. With such dark skies, and armed only with a pair of binoculars, many galaxies will be within reach. If you have a telescope that number increases dramatically.

As usual, dark skies, dark-adapted vision and averted vision will all help in tracking down and seeing galaxies. Clean optics will also greatly aid you in your observations. Dust and smears of grease will reduce by a surprising amount the light that reaches your eyes, and in particular will reduce the contrast.

Generally, those galaxies that have a brightness greater than 13th magnitude are usually visible in telescopes of aperture 15 cm, and those of aperture 30 cm will see down to about 14.5 magnitude. There will of course be galaxies that will have much brighter magnitudes than these and so will be visible in much smaller instruments. In some cases only the brightest part of a galaxy will be visible – perhaps its core (nuclear region), with the spiral part unobservable.

To be able to trace out the finer details of the spiral arms of galaxies, and to locate the bulge area, faint halo and HII regions, you will invariably require a large-aperture telescope. But if the purpose of your observing is just to locate these elusive objects, and to be amazed that the light that is entering your eye may have began its journey over 100 million years ago, then there are a plethora of galaxies awaiting your visit.[5] That is the real purpose of this chapter.

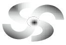
The usual nomenclature applies in the following descriptions, but with the following changes. Galaxies are *extended objects*, which means that they cover an appreciable part of the sky: in some cases a few degrees, in others only a few arc minutes. The light from the galaxy is therefore "spread out," and thus the quoted magnitude will be the magnitudes of the galaxy were it the "size" of a star; this magnitude is often termed the *integrated magnitude*. This often causes confusion, as a galaxy with, say, a magnitude of 8 will appear fainter than an eighth magnitude star, and so in some cases, where possible, the surface brightness of a galaxy will be given, thus giving you a better idea of what the overall magnitude of the galaxy will be. For instance, M64, the Black Eye Galaxy, magnitude of 8.5, has a surface brightness is 12.4. The surface brightness will be given in italics after the quoted magnitude, and to use the above example of M64 will appear like this: 8.5 m [*12.4 m*].

Following on from the previous paragraph, the designation "easy," "moderate" or "difficult" takes into account not only the brightness of the galaxy but also the area of the sky the galaxy spans. Thus, a galaxy may be bright, with – say – a magnitude of 8, which under normal circumstances would be visible in binoculars and designated as "easy"; but if it covers a significant amount of the sky (and thus its surface brightness is low, making it more difficult to observe) it is designated here as "moderate."

In addition, spiral galaxies can exhibit a variety of views, depending on their inclination to the Solar System. Some will appear face-on, others at a slight angle, and a few completely edge-on. As an indicator of inclination, the following symbols will be used.

---

[5]Of course, perhaps we don't have to mention that if you have a medium-to-large-aperture telescope, then the number of galaxies visible to you is vast, and the detail you will be able to see will astound you!

Face-on: 
Slight inclination: 
Edge-on: 

Furthermore, the Hubble classification of galaxies outlined earlier will also be used.

You may notice that a few galaxies seem to be missing from the lists. There is a reason for this. It is the new chapter that has been included, "Naked-Eye Deep-Sky Objects." This chapter will deal with, among other things, galaxies that can (hopefully) be seen with the naked-eye. So for instance, the Andromeda Galaxy will be mentioned in the new chapter, and not in this one. But telescope users should take heart as the descriptions of the naked-eye objects will also include binocular and telescopic information as and when appropriate.

Spiral Galaxies

January

Caldwell 7	NGC 2403	$07^h\ 36.9^m$	+65° 35′	January 14
8.5 m [*13.9 m*]	21.9′| 12.3′		SAB(s)cd	Easy ©

This is one of the brightest galaxies that was somehow left out of the Messier catalog and is often left out of an observer's schedule. In binoculars it appears as a large, oval hazy patch with a brighter central region. With averted vision, and an aperture of about 20 cm, faint hints of a spiral arm will become apparent. Larger apertures will of course present even further detail. It is not a member of the Local Group of galaxies[6] but believed to be a member of the M81-M82 group. It was the first galaxy outside the Local Group to have Cepheid[7] variable stars discovered within it, and the current estimate of its distance is 11.5 million light-years away.

See also:

Galaxy	Magnitude	Month
NGC 2683	SA(rs)b	February

[6]The Local Group is a cluster of several galaxies, including the Milky Way. It consists of M31, M33, M110, M32, the Large and Small Magellanic Clouds and about 25 other dwarf galaxies, including Leo I and II, And I and II, the Draco, Carina, Sextans and Phoenix dwarfs.

[7]Cepheid variables are used as standard candles for measuring distances to other extra-galactic objects.

February

–	NGC 2683	$08^h\ 52.7^m$	+33° 25′	February 3
9.6 m [*12.7 m*]	9.3′| 2.5′		SA(rs)b	Easy

Easily seen with binoculars, providing viewing conditions are at optimum. This cigar-shaped galaxy is inclined nearly edge-on to our line of sight. What is nice about it is the way that the nucleus clearly stands out from the thin disc. A fine sight in all sizes of optical equipment.

Caldwell 48	NGC 2775	$09^h\ 10.3^m$	+07° 02′	February 7
10.4 m [*13.1 m*]	4.3′| 3.3′		SA(R)ab	Moderate

A difficult object for binoculars, this galaxy really requires a telescope. With an aperture of about 20 cm, the galaxy will show itself as a large blob. Detail within the object is conspicuously absent, but a brighter core and fainter outer region can be resolved. The absence of detail (that is, spiral arm dust and gas) has been attributed to an early era of star formation, which used up all the material. The evidence for this was found in the galaxy's spectrum, which lacked emission lines, usually caused by star-forming regions in and around spiral arms.

See also:

Galaxy	Classification	Month
Caldwell 7	SAB(s)cd	January
Messier 96	SAB(rs)ab	March
Messier 65	SAB(rs)a	March
Messier 66	SA(s)b	March
Messier 106	SAB(s)bc	March
Messier 88	SA(rs)b	March
Caldwell 38	SA(s)bsp	March
Messier 90	SAB(rs)ab	March
Messier 98	SAB(s)ab	March
Messier 99	SA(s)c	March
Messier 61	SAB(rs)bc	March
Messier 100	SAB(s)bc	March
Caldwell 36	SAB(rs)cd	March
Caldwell 40	(R)SA(rs)	March
Caldwell 26	SA(s)cd:sp	March

March

Messier 96	NGC 3368	$10^h\ 46.8^m$	+11° 49′	March 3
9.3 m [*13.1 m*]	7.6′| 5.2′		SAB(rs)ab	Easy

This faint galaxy can be seen in binoculars as a faint hazy oval patch of light. But what you are observing is in fact just the bright central nucleus of the galaxy, as the spiral arms are too faint to be resolved. Telescopes will bring out further detail, and with good conditions the spiral arm features will be seen. There is some slight controversy over M96, as recent measurements of its distance place it at 38 million light-years away, which is 60% greater than the previous value. It forms a nice triangle with two other galaxies, M95 and M105, and as such is a member of the Leo I group of galaxies.

Messier 65	NGC 3623	11^h 18.9^m	+13° 05′	March 12
9.3 m [*12.7 m*]	9.8′| 2.9′		SAB(rs)a	Easy

Visible in binoculars, this is one-half of the most famous galaxy pair in the sky, after M81 and M82. Along with M66, it is a galaxy that shows up quite well with low-power optics where it appears as a nice oval patch of light, and with higher magnification both spiral arms and a dust lane can be glimpsed. However, it is difficult to observe, as the brightness of the sky background tends to meld in with the galaxy details. This presents a nice challenge for observers in an urban location.

Messier 66	NGC 3627	11^h 20.2^m	+12° 59′	March 12
9.0 m [*12.8 m*]	9.1′| 4.2′		SA(s)b	Easy

The other half of the galaxy duo mentioned above. This is bright galaxy, easily seen in binoculars, where its distinct elliptical shape and bright center can be resolved. With telescopes, the oval shape of the nucleus becomes apparent, and with higher magnification a spiral arm and dark patch can be seen. Large-aperture telescopes will show considerable detail consisting of dark and light patches.

Messier 106	NGC 4258	12^h 19.0^m	+47° 18′	March 27
8.7 m [*1,398 m*]	18.6′| 7.2′		SAB(s)bc	Easy

When seen in binoculars the galaxy appears as a large glow with a distinct elliptical shape. Large binoculars reveal the presence of the nucleus. With telescopes of small aperture (10 cm), and low magnification, the spiral arms become apparent, and with higher magnification further detail can be seen. It is a galaxy that takes large aperture and magnification well and will reveal a surprising amount of detail. The galaxy is nearly face-on to us, but a cloud of gas and dust surrounding the nucleus is apparently edge-on. Furthermore, there is evidence that a black hole resides at the core. This should come as no surprise, as current ideas suggest that nearly all galaxies have such beasts lurking at their centers!

Messier 88	NGC 4501	12^h 32.0^m	+14° 25′	March 30
9.7 m [*13.1 m*]	6.9′| 3.7′		SA(rs)b	Easy

A fine galaxy for binoculars, with a bright nucleus and a faint hazy glow surrounding it, caused by the spiral arms. What is a problem, however, is that the galaxy is located in a barren patch of the sky. With a telescope of medium aperture, say 20 cm, structure becomes visible. The spiral arms and nucleus can be seen, but use averted vision.

Caldwell 38	NGC 4565	12^h 36.3^m	+25° 59′	March 31
9.5 m [*13.2 m*]	15.8′| 2.1′		SA(s)bsp	Easy

This is a striking example of an edge-on galaxy. With small binoculars, the classic spindle shape can be seen set against the background stars, and with larger ones the central core region can be seen. Using a telescope of 15 cm, the lovely edge-on shape becomes even clearer, along with the star-like nucleus. The dust lane can be seen but will require apertures of at least 20 cm and more. A very massive galaxy and thought to be similar to the Milky Way, its dust lane the equivalent of our Great Rift.

Messier 90	NGC 4569	12^h 36.8^m	+13° 10′	March 31
9.6 m [*13.5 m*]	9.5′| 4.4′		SAB(rs)ab	Easy

This is one of the brighter galaxies in the Coma-Virgo Cluster[8] and an impressive sight in binoculars. If large binoculars are used and the conditions are right, the star-like nucleus and elliptical glow caused by the spiral arms can be seen. Telescopically, it is equally impressive, with its spiral arms and mottled nucleus resolvable. The galaxy is approaching us at 383 km/s, and it has been suggested that it may be in the process of escaping the cluster; some sources have speculated it may already have left the cluster and is now considerably closer to us.

Messier 98	NGC 4192	12^h 13.8^m	+ 14° 54′	March 25
10.0 m [*13.4 m*]	9.8′| 2.8′		SAB(s)ab	Moderate

[8]Sometimes the cluster is just referred to as the Virgo Cluster. For a description of the cluster, see the entry on M87.

This faint galaxy lies at the edge of the great Coma-Virgo Cluster, an area studded with galaxies, both faint and bright. It is a difficult object to locate and requires a small telescope of at least 10 cm aperture. It is highly inclined to us and has a very elongated shape. With excellent seeing conditions, a high power will show spectacular spiral arms and dust lanes, and under very rare conditions the entire halo can be seen to surround the galaxy. An excellent object to observe, but one that requires skill and patience in order to see any detail, especially from an urban location.

Messier 99	NGC 4254	$12^h\ 18.8^m$	+14° 25′	March 27
9.7 m [*13.0 m*]	5.4′| 4.7′		SA(s)c	Moderate

A difficult object for binoculars; its circular disc shape will need dark skies to be resolved. With a telescope of aperture 10 cm, the galaxy will remain a hazy round patch, but a small nucleus will be seen. Higher magnification with perhaps greater aperture will begin to show two spiral arms. However, M99 is one of those galaxies where the likelihood of capturing detail depends greatly on the seeing conditions. Try observing on a good night and then on an average night, and compare what you see. It lies at a distance of about 55 million light-years and is one of the galaxies within the Coma-Virgo Cluster.

Messier 61	NGC 4303	$12^h\ 21.9^m$	+04° 28′	March 28
9.6 m [*13.4 m*]	6.5′| 5.8′		SAB(rs)bc	Moderate

A difficult object to locate in binoculars, it will need dark skies and even then will resemble nothing more than a small faint circular patch of light. For small-telescope users, however, it is a delight, and although it is small and can be a problem to find, it is an ideal open-faced spiral galaxy. The use of averted vision is a must for this object, as only then will the nucleus and any spiral arm detail become apparent. A nice addition is the fact that the galaxy is located within the Coma-Virgo Cluster of galaxies, and when observing M61 you may notice several faint and indistinct glows in the same field of view, which are at the limit of your vision. These are probably unresolved galaxies!

Messier 100	NGC 4321	$12^h\ 22.9^m$	+15° 49′	March 28
9.7 m [*13.8 m*]	7.4′| 6.3′		SAB(s)bc	Moderate

Located very close to M99 (see above), this is a fainter and more elusive target. Although larger than M99 and half a magnitude brighter, it subsequently has a lower surface brightness. Thus excellent seeing conditions may be needed.

Telescopically, it will be seen as a brightish patch of hazy light, although some structure may be glimpsed with perfect seeing and high magnification. Research indicates that there has been a recent spate of star formation within M100, with its inner spiral arms rotating in an opposite direction to the spiral arms that lie further out.

Caldwell 36	NGC 4559	$12^h\ 35.9^m$	+27° 57′	March 31
9.8 m [*13.9 m*]	10.7′| 4.4′		SAB(rs)cd	Moderate

A member of the Coma-Virgo Cluster, this is often overlooked. Not really a binocular object, it is perfect for small telescopes. At about 20 cm aperture, the clearly seen oval shape will be resolved, along with a brightening of the nucleus. A just perceptible hint of further detail may be glimpsed. Large aperture shows considerably more detail.

Caldwell 40	NGC 3626	$11^h\ 20.1^m$	+18° 21′	March 12
10.6 m [*12.3 m*]	2.7′| 1.9′		(R)SA(rs)	Difficult

This galaxy is virtually unknown among amateurs. It lies close to several brighter Messier objects and is often mistaken for NGC 3607. Nevertheless, it is worth searching out. Visually it is a featureless oval patch of light, and apertures of at least 20 cm are needed to resolve the object. What makes it special, however, is that it is a *multispin* galaxy. This means the molecular and ionized gas is rotating around the galaxy in the opposite direction to that of its stars. The origin of this phenomenon is unknown, but one school of thought believes that the galaxy recently collided with another galaxy and assimilated a huge gas cloud with a mass of about one billion solar masses.

Caldwell 26	NGC 4244	$12^h\ 17.5^m$	+37° 48′	March 26
10.0 m [*13.6 m*]	16.6 | 1.9′		SA(s)cd:sp	Difficult

One of the most needle-like galaxies that can be seen with amateur instruments This edge-on galaxy really is exceedingly thin, and apertures of at least 20 cm will be need to locate and observe it. It has a faint but easily resolvable star-like nucleus, but detail within the galaxy itself is very rarely seen even with large apertures. It has a Hubble classification similar to that of M33, the Pinwheel Galaxy in Triangulum, and when such a galaxy is seen edge-on, the tiny nucleus and loose, open arms give it its indistinct appearance.

See also:

Galaxy	Classification	Month
NGC 2683	SA(rs)b	February
Caldwell 48	SA(R)ab	February
Messier 58	SAB(rs)b	April
Messier 104	SA(s)asp	April
Messier 94	(R)SA(r)ab	April
Messier 64	(R)SA(rs)ab	April
Caldwell 29	SAB(rs)bc	April
Messier 63	SA(rs)bc	April
Messier 51	SA(s)bcP	April
Messier 83	SAB(s)c	April
Caldwell 45	SAB(rs)bc	April
Messier 101/2	SAB(rs)cd	April

April

Messier 58	NGC 4579	12^h 37.7^m	+11° 49′	April 1
10.1 m [*13.5 m*]	5.9′| 4.7′		SAB(rs)b	Easy

Through binoculars this galaxy will appear as a faint, hazy patch of light with a barely discernible nucleus. You may also glimpse in the same field of view the galaxies M59 and M60. A telescope of about 10 cm aperture will show some structure in the halo, along with faint patches of light and dark. There are some reports that a 20 cm telescope will allow the bar connecting the spiral arms to the nucleus to be resolved. Can you see it? It has about the same mass as the Milky Way and is about 95,000 light-years in diameter.

Messier 104	NGC 4594	12^h 40.0^m	−11° 37′	April 1
7.9 m [*11.6 m*]	8.7′| 3.5′		SA(s)asp	Easy

Also known as the Sombrero Galaxy. This is an extragalactic treasure and a marvelous sight in almost all binoculars and telescopes. With small binoculars it will reveal itself as an oval disc, which increases in brightness toward the center. Using large binoculars will however reveal its true beauty. The dark dust lane that cuts across the galaxy readily becomes apparent. With a telescope even more detail is brought out. With a 10 cm aperture a bright core is seen, along with the long, spindle-like dust lane. With higher magnifications, the spiral arms stand out. Large apertures and higher magnifications will reveal a wealth of detail. It was the first galaxy other than the Milky Way to have its rotation determined. Glorious!

Messier 94	NGC 4736	12^h 50.9^m	+41° 07′	April 4
8.0 m [*12.9 m*]	11.2′| 9.1′		(R)SA(r)ab	Easy

This galaxy is visible in binoculars and will appear as a small circular hazy patch with a star-like nucleus. Telescopes will reveal some structure, possibly a faint spiral arm. Several observers have reported that a central ring can be seen near the core, which gives it an appearance very similar to M64, the Black Eye Galaxy (see entry below). A further elliptical ring has been reported outside the edge of the galaxy. Can you see it? Needless to say, exceptionally dark skies will be needed to observe this elusive feature.

Messier 64	NGC 4826	$12^h\ 56.7^m$	+21° 41′	April 5
8.4 m [*12.6 m*]	10.0′| 5.4′		(R)SA(rs)ab	Easy

Also known as the Black Eye Galaxy, this famous galaxy can be seen in small binoculars as an oval hazy patch with a slightly brighter center. The feature that gives the galaxy its name has been reported to be visible with large binoculars on very dark nights. Small telescopes show a very bright nucleus encased in a patch of glowing light. The "eye" is a vast dust lane, some 40,000 light-years in diameter. There is considerable debate as to whether the "eye" can be seen in small instruments. Some observers report that an aperture as small as 6 cm will resolve it, while others claim at least 20 cm is needed. What is agreed upon is that high magnification is necessary. There is also further controversy as to whether the nucleus is star-like or not. It may be that magnification plays an important role here. Observe it and see who you side with!

Caldwell 29	NGC 5005	$13^h\ 10.9^m$	+37° 03′	April 9
10.3 m [*13.2 m*]	6.3′| 3.0′		SAB(rs)bc	Easy

This galaxy is not a binocular object and with telescopes of about 15 cm aperture will reveal itself as an oval patch with a bright nucleus. The galaxy doesn't have any conspicuous spiral arms so that even with large-aperture telescopes further detail will be sparse, and only some slight irregularity in overall brightness will be resolved. Although it is similar to the Milky Way, what makes this galaxy special is that it is an active galaxy, of a class called a LINER (*L*ow *I*onization *N*uclear *E*mission-line *R*egion). In the center of the galaxy is some sort of mechanism that gives rise to both the observed spectral lines and a radio source. It may be due to massive stars called *warmers*, or an accretion disc around a black hole.

Messier 63	NGC 5055	$13^h\ 15.8^m$	+42° 02′	April 10
9.0 m [*13.8 m*]	12.6′| 7.2′		SA(rs)bc	Easy

Also known as the Sunflower Galaxy, this is a somewhat difficult object for binoculars, even though it has a fairly bright magnitude. In small binoculars it will just appear as a faint patch of light, but with large binoculars the classic oval shape will become apparent. In telescopes, it reveals a lot of detail, with many faint and detailed spiral arms. A very nice object for large-aperture instruments.

Messier 51	NGC 5194	$13^h\ 29.9^m$	+47° 12′	April 14
8.5 m [*13.1 m*]	11.2′| 6.9′		SA(s)bcP	Easy

Also known as the Whirlpool Galaxy, this famous galaxy is easily visible in binoculars and will appear as a small glowing patch with a bright, star-like nucleus. Many now believe that M51 is the finest example of a face-on spiral galaxy. But what makes it so special is the small, irregular class satellite galaxy NGC 5195 that is close to it. Deep photographs reveal that a bridge of material physically connects the galaxies. Unfortunately this satellite galaxy cannot be seen in most binoculars, and even in giant binoculars it would appear only as a slight bump on the side of M51. With small telescopes (10 cm) not a lot of detail is visible, just perhaps the slightest hint of spiral structure. With an aperture of 25 cm a lot more detail is resolved: spiral arms, structure within the arms, and dark patches. What is a matter of debate however is whether the bridge of material connecting M51 to NGC 5195 can be seen with small telescopes. Some observers claim it can be seen with a 10 cm aperture, others that at least 30 cm is needed. What everyone agrees upon is that absolute, perfect transparency is needed, as even the slightest haze or dust in the atmosphere will make observations much more difficult. An observing challenge – if ever I heard one!

Messier 83	NGC 5236	$13^h\ 37.0^m$	−29° 52′	April 16
7.8 m [*1302 m*]	14.4′| 13.1′		SAB(s)c	Easy

Often missed by observers, this is a nice galaxy located within the star fields of Hydra and is a showpiece for small telescopes. In binoculars it will appear as a hazy patch of light with a bright, star-like nucleus. With telescopes much more detail is seen, including spiral arms, dust lanes, bright knots and even detail within the nucleus itself. It is one of those objects that repay several observing sessions. Also, it ties with M81 as being one of the furthest objects that may be visible to the naked eye, at about 14.7 million light-years. As it is located so far south, there may be a problem locating it for observers living in the UK.

Caldwell 45	NGC 5248	$13^h\ 37.5^m$	+08° 53′	April 16
10.0 m [*13.5 m*]	6.2′| 4.5′		SAB(rs)bc	Moderate

Barely detectable in binoculars as a tiny patch of glowing light, but with telescopes of aperture 15 cm it will reveal itself as a bright nuclear region surrounded by a barely perceived haze, which is the spiral arms. In order to resolve the spiral structure a large aperture is needed, maybe 40 cm or more.

Messier 101/2[9]	NGC 5457	$14^h\ 03.2^m$	+54° 21′	April 22
7.5 m [*14.6 m*]	28.8′| 26.9′		SAB(rs)cd	Moderate ©

[9]M102 is now believed to be just a duplicate observation of M101.

A difficult object for binoculars because even though its integrated magnitude is high, it has a large surface area, and so the light is spread out, making its surface brightness very low. If glimpsed in binoculars it will appear as a very hazy and faint patch of light, and the nucleus can be seen if averted vision is used. Medium-to-large-aperture telescopes will however bring out a lot of detail. This is a fine face-on spiral galaxy, with two nice spiral arms and a bright star-like nucleus.

May

See:

Galaxy	Classification	Month
Messier 58	SAB(rs)b	April
Messier 104	SA(s)asp	April
Messier 94	(R)SA(r)ab	April
Messier 64	(R)SA(rs)ab	April
Caldwell 29	SAB(rs)bc	April
Messier 63	SA(rs)bc	April
Messier 51	SA(s)bcP	April
Messier 83	SAB(s)c	April
Caldwell 45	SAB(rs)bc	April
Messier 101/2	SAB(rs)cd	April

June

See:

Galaxy	Classification	Month
Caldwell 12	SAB(rs)cd	July

July

Caldwell 12	NGC 6946	20^h 34.9^m	+60° 09′	July 31
9.6 m [*14.1 m*]	11.5′| 9.8′		SAB(rs)cd	Moderate ©

A challenging galaxy to locate using binoculars, where it will appear, if at all, as a small round hazy patch of light with a barely perceptible increase at its center. What makes this galaxy difficult to locate and observe, even though it is close to us, is that it lies in the part of the sky near the plane of the Milky Way. This results in the light from the galaxy being dimmed by the intervening dust and stars.

With telescopes of 20 cm and a dark location, the faint outer halo can be glimpsed. In order to observe further detail such as spiral arms, a very dark location along with large aperture is needed. Research indicates that there is a hectic period of star formation occurring in its inner nuclear region. Such an outburst is termed a starburst.

See also:

Galaxy	Classification	Month
Caldwell 30	SA(s)bc	August

August

Caldwell 30	NGC 7331	22^h 37.1^m	+34° 25′	August 30
9.7 m [*13.5 m*]	10.5′| 3.7′		SA(s)bc	Easy

This is the brightest galaxy in the constellation Pegasus, and with binoculars it will appear as a faint patch of light that has a brighter core. Easily visible in a telescope of 20 cm, which will show its structure in a little more detail. Apparently this galaxy is similar to M31 but lies much further from us at a distance of 40 million light-years. There is also some debate as to whether it is linked with the famous Stephen's Quintet (see the section on groups and clusters of galaxies). Finally, in most spiral galaxies the central bulge typically co-rotates with the disk, but the bulge in Caldwell 30 is rotating in the opposite direction to the rest of the disk. As yet, no one knows how or why!

See also:

Galaxy	Classification	Month
Caldwell 12	SAB(rs)cd	July
Caldwell 43	SA(s)ab:sp	September

September

Caldwell 43	NGC 7814	00^h 03.2^m	+16° 08′	September 21
11.0 m [*13.6 m*]	5.5′| 2.3′		SA(s)ab:sp	Moderate

This is no binocular object but nevertheless a splendid sight, especially with larger aperture telescopes. It is a fine example of an edge-on galaxy and bears many similarities to its better-known cousin, M104. Easily seen in a telescope of aperture 20 cm, it does however provoke debate among amateurs as to whether its dust lane can be seen with small telescopes. Some profess to have seen it with 20 cm, while others claim that at least 40 cm is needed. Try observing with as high a power as it can take, as this may help you to resolve this dilemma.

See also:

Galaxy	Classification	Month
Caldwell 30	SA(s)bc	August
Caldwell 65	SAB(s)c	October
Caldwell 70	SA(s)d	October
Messier 33	SA(s)cd	October
Caldwell 62	SAB(s)	October
Messier 74	SA(s)c	October
Caldwell 23	SA(s)sp	October

October

Caldwell 65	NGC 253	$00^h\ 47.6^m$	−25° 17′	October 3
7.8 m [*13.3 m*]	27.5′| 6.8′		SAB(s)c	Easy

This is a wonderful object and is often referred to as the southern hemisphere's answer to the Andromeda Galaxy. Easily seen in binoculars as a long, spindle-shaped glow with a bright nucleus. Under absolutely perfect conditions, some structure can even be glimpsed with large binoculars. Its size makes it impressive, as it is about as long as the Moon is wide and around a third as thick. Any telescope will suffice to see this object, even as small as 6 cm. Larger apertures will reveal more detail, and with averted vision the spiral arms can be glimpsed. There are several reports that considerable mottling can be seen within the galaxy with a 15 cm telescope. It has the dubious honor of being one of the dustiest galaxies known, as well as one that is undergoing a period of frenetic star formation in its nuclear regions.

Caldwell 70	NGC 300	$00^h\ 54.9^m$	−37° 41′	October 4
8.3 m [*14.5 m*]	21.9′| 15.5′		SA(s)d	Easy

A difficult object to locate owing to its very low surface brightness, it will also present a considerable challenge to binocular observers. Nevertheless, once found it can be an impressive object. With a 20 cm aperture telescope, the nucleus is readily seen engulfed in the unresolved haze of the spiral arms. Larger telescopes will begin to resolve some further detail. It lies at the close distance of about 6 million light-years.

Caldwell 62	NGC 247	$00^h\ 47.1^m$	−20° 45′	October 2
9.2 m [*14.5 m*]	21.4′| 6.9′		SAB(s)	Moderate

This galaxy is barely discernible in large binoculars, where it can be glimpsed as an elongated hazy patch of light with a brighter nucleus. However, it is low down in the skies for UK observers, and so is often neglected. In larger-aperture telescopes, its mottled appearance becomes visible, along with the brighter, southern part of the galaxy. The northern aspect is much fainter and will require averted vision, along with clear skies. It was thought that the galaxy was a member of the Sculptor Group of galaxies, but recently doubts have arisen, as the most recent estimates of its distance put it at about 13.5 million light-years, which is twice the distance of the cluster.

Messier 74	NGC 628	$01^h\ 36.7^m$	+15° 47′	October 15
9.5 m [*14.3 m*]	10.5′| 9.5′		SA(s)c	Moderate

This is another object that proves frustrating to amateurs, as, with M33 above, it has low surface brightness. It can be glimpsed in binoculars but only under excellent conditions. It is also a paradox that the galaxy is often better glimpsed with small telescopes, even those of 5 cm aperture rather than, say, 10 cm. One way to find this elusive object is to locate the star Eta (η) Piscium and put it at the southern edge of your field of view. Then let the stars drift across, and within a few minutes M74 will enter the field. Of course, averted vision and excellent sky transparency will all help.

Caldwell 23	NGC 891	$02^h\ 22.6^m$	+42° 21′	October 27
10.0 m [*13.7 m*]	13.5′| 2.5′		SA(s)sp	Moderate

This is a fine example of an edge-on galaxy and is thought by many to be the finest. Just visible in binoculars as a hazy but distinct elongated smudge. But with a telescope of aperture 20 cm, its spindle shape is very apparent, and with a larger aperture the distinctive dust lane will be resolved.

See also:

Galaxy	Classification	Month
Caldwell 43	SA(s)ab:sp	September
Messier 77	(R)SA(rs)b	November
Caldwell 5	SAB(rs)cd	November

November

Messier 77	NGC 1068	$02^h\ 42.7^m$	–00° 01′	November 1
9.1 m [*13.0 m*]	7.1′| 6.0′		(R)SA(rs)b	Easy

This is a famous galaxy for several reasons.[10] In binoculars it is visible as just a hazy patch of light, and under excellent seeing a faint star-like nucleus may be glimpsed. In telescopes of about 10 m and greater, and providing that dark skies are available, the spiral arms can be glimpsed. But what makes this galaxy so special is that it is the archetypal active galaxy of a class known as Seyferts.[11] Carl Seyfert, who noticed that it had very prominent emission lines, first discovered it in the middle of the twentieth century. The lines are due to the high velocity of gas close to the nucleus of the galaxy. The high speed of the gas, in the order of 350 km/s, is believed to be due to the influence of a massive black hole. Seyferts are distant cousins of the more famous quasars. It is one of the brightest active galaxies visible to the amateur astronomer.

Caldwell 5	IC 342	$03^h\ 46.8^m$	+68° 05′	November 17
9.2 m [*15.2 m*]	17.8′| 17.4′		SAB(rs)cd	Difficult©

A very difficult galaxy to observe for the same reason that plagues so many others: its large size causes the surface brightness to be low. Reportedly impossible to see in a telescope of 20 cm unless conditions are perfect, and even then large apertures (40 cm) only show barely discernible structure. It suffers from being located in an area of the sky where the interstellar dust and gas dim its light appreciably. We can only wonder what it would look like if it were it at some other location. IC 342 is one of the brightest two galaxies in the IC 342/Maffei Group of galaxies, one of the galaxy groups that is closest to the Local Group. It is an active galaxy of the type known as a *starburst* galaxy. This means that it is undergoing a period of vigorous star formation. No one is sure what started this period of star forming – was it an encounter with another unseen galaxy, or perhaps something else?

December

See also:

Galaxy	Classification	Month
Messier 77	(R)SA(rs)b	November
Caldwell 5	SAB(rs)cd	November
Caldwell 7	SAB(s)cd	January

[10]Not least, it made up the bulk of this author's Ph.D. thesis!

[11]M77 is in fact classified as a Seyfert II galaxy, indicating that it has only narrow emission lines. A Seyfert I galaxy has both broad and narrow emission lines. The width of the line is a measure of the velocity of the gas that produced the emission line.

Barred Spiral Galaxies

January–June

Messier 95	NGC 3351	$10^h\ 44.0^m$	+11° 42′	March 3
10.0 m [*13.8 m*]	7.4′| 5.0′		SB(R)b	Moderate

This is a faint galaxy that shows little if any detail in binoculars, as it will just appear as a hazy patch; however it will be in the same field of view as M96. With a telescope of at least 15 cm, some structure can be glimpsed, with larger apertures showing the distinctive bar feature. It is a member of the Leo group of galaxies. There is some debate as to the real magnitude of the galaxy, with some observers putting it at mag 9.2. Does it seem that bright to you?

Messier 108	NGC 3556	$11^h\ 11.5^m$	+55° 40′	March 10
10.2 m [*13.3 m*]	8.7′| 2.2′		SB(s)cdsp	Moderate ©

This galaxy is visible in binoculars as a very faint streak of light. The central condensation has been reported visible in an 8 cm telescope. Larger aperture shows a surprising amount of detail with considerable mottling and structure. This is a very small galaxy, only one-twentieth the mass of the Milky Way, and seems to lack a central bulge. Although it is a recent addition to the Messier list, it is known that Messier was aware of the galaxy's existence; for some reason he just didn't include it.

Messier 109	NGC 3992	$11^h\ 57.6^m$	+53° 23′	March 21
9.9 m [*13.7 m*]	7.6′| 4.7′		SB(rs)bc	Moderate ©

Another recent addition to the Messier catalog, this galaxy can be glimpsed in binoculars providing the conditions are right. With a low power and small aperture, it is evident that you are looking at a galaxy, but no further detail can be seen. High power and larger aperture does begin to show some structure such as the core and halo regions. The central bar also becomes prominent with apertures around 25 cm. A member of the M109 group of galaxies containing more than 50 members and is the penultimate Messier object.

Caldwell 3	NGC 4236	$12^h\ 16.7^m$	+69° 27′	March 26
9.9 m [*15.3 m*]	21.9′| 7.2′		SB(s)dm	Difficult ©

Although this is a large galaxy, it is also very faint, and so difficult to locate. In addition, as it is edge-on to us, it presents a very slim view, and so the spiral arm features are absent. With apertures around 20 cm, its distinctive spindle shape is conspicuous. This is a nice galaxy for those who like to test the limits of a small telescope as well as their observing skill. It lies at a distance of about 12 million light-years and is a member of the M81 group of galaxies.

Messier 91	NGC 4548	$12^h\ 35.4^m$	+14° 30′	March 31
10.4 m [*13.6 m*]	5.4′| 4.3′		SB(rs)b	Difficult

Something of a mystery. If one tries to locate M91 from Messier's original notes, he or she will make an interesting discovery. There is nothing there! Most observers agree that he made a mistake and that in fact the galaxy NGC 4548 was what he originally observed but incorrectly plotted. Whatever the reason, the galaxy is a faint object, and telescopes of medium aperture will be needed for you to see any detail, although it is visible in apertures of 10 cm as a faint, hazy circular patch.

Caldwell 32	NGC 4631	$12^h\ 42.1^m$	+32° 32′	April 2
9.1 m [*13.0 m*]	15.5′| 2.7′		SB(s)dsp	Moderate

An often-neglected galaxy that is surprising, as it has a lot to offer. Visible in binoculars as a faint elongated object, it really needs a telescope to be appreciated. It is a very big galaxy, which owing to its appearance has led to it being unofficially nicknamed the Whale Galaxy. Its eastern end is appreciably thicker than its western, hence the name. This aspect can be seen with an aperture of 20 cm, and larger telescopes will show further details such as patches of light and dark, along with two prominent knots. On the northern side of the galaxy is a faint 12th magnitude star that, providing the seeing is good, will act as a pointer to a faint companion galaxy. Several theories have arisen as to the origin of its strange and disturbed appearance. The most probable is tidal interactions with several nearby galaxies.

See also:

Galaxy	Classification	Month
Caldwell 72	SB(s)m:sp	September
Caldwell 44	SB(s)c	September
NGC 1365	(R)SB(s)b	November
Caldwell 67	SB(s)b	November

July–December

Caldwell 67	NGC 1097	$02^h\ 46.3^m$	−30° 16′	November 2
9.4 m [*13.7 m*]	9.3′| 6.6′		SB(s)b	Easy

This is a nice galaxy, and its bar can be seen easily. With a 20 cm aperture telescope, the core is resolved and easy to see, as well as a faint elongated glow, which is in fact is the bar. Larger apertures will resolve this feature quite well, along with the spiral arms, which emanate from the bar's end. It is an active galaxy and classified as a Seyfert galaxy of Type I. This means that gas close to the nucleus is moving at extremely fast speeds, maybe in excess of 1,000 km/s. The most likely cause of this motion is the influence of a black hole.

Caldwell 72	NGC 55	00^h 15.1^m	–39° 13′	September 24
8.3 m [*13.8 m*]	32.4′| 5.6′		SB(s)m:sp	Easy

Although this galaxy lies so far south as to make it invisible from the northern hemisphere, it still warrants inclusion. In binoculars it appears as a faint spindle-shaped object, and large binoculars hint at some delicate structure. Telescopes show even more detail, and it is one of the few galaxies where an H-alpha filter will highlight its HII regions. It is one of the closest galaxies to the Local Group.

Caldwell 44	NGC 7479	23^h 04.9^m	+12° 19′	September 7
11.0 m [*13.6 m*]	4.1′| 3.1′		SB(s)c	Moderate

This faint galaxy can be glimpsed in a small telescope of aperture 8 cm, but do not expect any detail – it will just appear as a smudge. With aperture around 20 cm the central bar will be seen, along with a suggestion of some structure. The spiral arms at the end of the bar will need at least a 30 cm telescope, although some observers claim they can be seen with 25 cm aperture under perfect conditions. The nucleus is easily resolved, however. It has the honor, according to some amateurs, of being the finest barred spiral on offer for the northern hemisphere. It lies at about 100 million light-years from us – quite a distance!

–	NGC 1365	03^h 33.6^m	–36° 08′	November 14
9.5 m [*13.7 m*]	9.8′| 5.5′		(R)SB(s)b	Moderate

A very impressive galaxy, sometimes known as the Great Barred Spiral Galaxy, it is easily visible in binoculars as an elongated hazy object with a brighter center. In a telescope with an aperture as small as 8 cm, its galaxy origin is obvious, and larger apertures will show considerably more detail. Although not visible from the UK, it should be a nice observing target from the United States. Recent studies suggest that to an external observer the Milky Way may in fact look the same as NGC 1365 looks.

See also:

Galaxy	Classification	Month
Messier 95	SB(R)b	March
Messier 108	SB(s)cdsp	March
Messier 109	SB(rs)bc	March
Caldwell 3	SB(s)dm	March
Messier 91	SB(rs)b	March
Caldwell 32	SB(s)dsp	April

Elliptical Galaxies

January–June

Messier 105	NGC 3379	$10^h\ 47.8^m$	+12° 35′	March 4
9.4 m [*12.9 m*]	5.4′| 4.8′		E1	Easy

This is the third galaxy in a nice triple system that can be seen in the same field of view. The other members are M95 and M96. The galaxy can be seen in binoculars but will appear only as a small, completely featureless oval patch of light. With a telescope, not much more is seen. With a large aperture and medium to high magnification, a slight brightening of the core may be observed, but all in all, the galaxy remains a smooth-featured object. It lies at a distance of about 32 million light-years.

Messier 84	NGC 4374	$12^h\ 25.1^m$	+12° 53′	March 28
9.4 m [*13.3 m*]	6.5′| 5.6′		E1	Easy

This nice elliptical galaxy forms a pair with M86. Located close to the Virgo Cluster of galaxies, it presents a small oval patch of light when seen through binoculars. The bright nuclei can be glimpsed when conditions permit. As with most ellipticals observed with amateur telescopes, there is never much detail seen in the galaxy; most remain smooth objects with little structure, and perhaps only a brightening of the core is all that is ever resolved. Nevertheless they make worthwhile observing objects. There seems to be some debate as to whether M84 is in fact an E1 galaxy, or an S0, which is a galaxy somewhere between an elliptical and a spiral. It is located in the Virgo Cluster at about 50 million light-years. The area around M86 is full of very faint galaxies, and although only a handful will show any perceptible detail, it is nevertheless worthwhile sweeping the area for these most elusive objects.

Messier 86	NGC 4406	$12^h\ 26.6^m$	+12° 57′	March 29
9.0 m [*13.2 m*]	8.9′| 5.8′		S0(3)/E3	Easy

The companion to M84, this is the brighter of the two and is very similar in appearance, with M86 being perhaps slightly brighter with a less condensed core. It is visible in binoculars and telescopes of all sizes. As with the entry preceding this one, the area is full of galaxies, and with a dark sky, and patience, many more will be seen. It is also a member of the Markarian chain of galaxies.

Messier 49	NGC 4472	$12^h\ 29.8^m$	+08° 00′	March 30
8.4 m [*12.9 m*]	10.2′| 8.3′		E2	Easy

This is the second-brightest galaxy in Virgo and easily spotted in binoculars as a featureless, oval patch of light. Although most ellipticals are rather featureless, M49 stands up quite well with high power and large aperture, when some resolution can be seen in the nuclear area. It seems to have a bright nucleus surrounded by a diffuse core region, which in turn is surrounded by a rather diffuse halo. Some observers report that the nucleus shows a mottled appearance under magnification. The galaxy is at the center of a sub-cluster of galaxies called the Virgo Cloud, which in turn is part of the much larger Coma-Virgo Cluster. In addition it appears the elliptical galaxy is cocooned in an envelope of hot gas at a temperature of about 10,000,000 K. At such a high temperature, X-rays are formed, and it was with an X-ray telescope that this feature was detected.

Messier 87	NGC 4486	12^h 30.8^m	+12° 23′	March 30
8.8 m [*13.1 m*]	8.3′| 6.6′		E0.5P	Easy

This is a very special galaxy. It is bright and easily seen in binoculars, but with telescopes little else is resolved. But this rather bland appearance is deceiving. This is a monster of a galaxy, with a mass estimated to be that of 800 billion Suns, making it one of the most massive galaxies known in the entire universe. But that isn't all. It is an active galaxy, and lurking at its core is a black hole with a mass of seven trillion Suns. Another feature that some observers report seeing with telescopes of aperture 50 cm is the famous "jet" that streams out from M87. It would be a challenge indeed, and a triumph, were this ever to be observed from the light-polluted skies of the UK. The jet is a stream of plasma (hot ionized gas) several thousand light-years in length that is believed to be due to some sort of interaction between the black hole and its surroundings. However, the jet is relatively easy to photograph and image with a CCD camera.

M87 lies at the heart of the Coma-Virgo Cluster, and most of the surrounding galaxies are influenced by its tremendous gravitational attraction. The cluster has about 300 large galaxies and perhaps as many as 2,000 smaller ones. It is the closest large cluster, lying at a distance of around 55 million light-years. It spans over 100 square degrees in both Virgo and Coma Berenices. Such is its influence that the Milky Way is actually gravitationally attracted to it.

Messier 89	NGC 4552	12^h 35.7^m	+12° 33′	March 31
9.8 m [*13.2 m*]	5.1′| 4.7′		E0	Moderate

This is a difficult galaxy to find in binoculars, especially if the seeing conditions are far from ideal. Even if it is located it will appear as just a small hazy spot of light. With a telescope and medium magnification a bright and well-defined nucleus is seen enveloped by the mistiness of the halo. With large aperture and magnification some mottling has been reported on the halo, but again, the atmospheric conditions will limit observability. In the same field of view as M89 is the spiral galaxy M90. Both are members of the Coma-Virgo Cluster.

Messier 60	NGC 4649	12^h 43.7^m	+11° 33′	April 2
8.8 m [*12.9 m*]	7.4′| 6.0′		E2	Easy

This is one of the biggest ellipticals at 118,000 light-years across, and like its close companion M59 it, too, has a star-like nucleus surrounded by a faint halo. It is easier to see with binoculars, and the nucleus may be glimpsed with averted vision. Although there are no reports of any features visible telescopically, there are two aspects of interest. A close and tiny companion galaxy of M60 is located only 2.5′ to the northwest. This little spiral galaxy can only really be seen with averted vision. Also, M60 has been reported having a nice pale yellow tint. What do you see?

Messier 59	NGC 4621	12^h 42.0^m	+11° 39′	April 2
9.8 m [*13.0 m*]	5.4′| 3.7′		E5	Moderate

Although visible in binoculars, this galaxy will pose a challenge to most observers, as it will probably need the use of averted vision to be spied, and dark adaption will undoubtedly be needed. However, telescopically, M59 is rather nice as it is one of the few ellipticals that seems to show detail. It has a star-like nucleus, and some observers report a faint mottled appearance, although it must be mentioned that this could be an effect of foreground stars seen against the oval of the galaxy. It would be interesting to find out if this is correct. Try observing it under excellent conditions to see if you can detect any features. Also in the same field of view is the elliptical galaxy M60 (see previous entry).

Caldwell 52	NGC 4697	12^h 48.6^m	–05° 48′	April 3
9.2 m [*13.0 m*]	6.0′| 3.8′		E6	Moderate

This is a nice galaxy that is often ignored and left out of most observing schedules. It is rather bland in appearance, but stands out well against the background star field. Not really a binocular object, telescopically it is featureless, although at large aperture some increased brightness can be seen at its core. It is the dominant member of a small cluster of galaxies and lies at a distance of about 60 million light-years.

Caldwell 35	NGC 4889	13^h 00.1^m	+27° 59′	April 6
11.5 m [*13.3 m*]	2.8′| 2.0′		E4	Difficult

This is well worth seeking out, as it is a very distant galaxy at a distance of about 350 million light-years. Excellent seeing conditions are needed to glimpse this tiny object, with a telescope of at least a minimum 20 cm aperture. It has a bright core, surrounded by the usual faint halo. It is a dominant member of the Coma Galaxy Cluster, which contains about 1,000 galaxies (several of which can be seen in large-aperture telescopes of at least 40 cm). The cluster itself is made up of many elliptical galaxies and S0-type galaxies. Apparently it is the result of a merger of two older clusters. Observing any of these galaxies is a feat indeed, but well worth the effort.

See also:

Galaxy	Classification	Month
Caldwell 18	dE0P	September
Caldwell 17	dE4	September
Messier 110	E5P	October
Messier 32	E2	October

July–December

Caldwell 18	NGC 185	00^h 38.9^m	+48° 20′	September 30
9.3 m [14.4 m]	11.7′| 10′		dE0P	Moderate

This is another companion galaxy to M31, as mentioned in an earlier entry. However, this one is much easier to locate and observe. In a telescope of 10 cm it will just be detected, whereas in 20 cm it is easily seen. It remains featureless even at larger apertures (40 cm) but with a perceptibly brighter core. Several reports mention that with the very large aperture of 75 cm some resolution of the galaxy becomes apparent. Another dwarf elliptical galaxy, although recent research suggests it is a dwarf spheroidal galaxy, classification dSph.

Caldwell 17	NGC 147	00^h 33.2^m	+48° 31′	September 29
9.6 m [*14.6 m*]	13.2′| 7.8′		dE4	Difficult

Located in Cassiopeia, this is classified as a dwarf elliptical (spheroidal?) galaxy. Although some distance from M31, the Andromeda Galaxy, it is in fact a companion to that famous galaxy. It is difficult to locate and observe, however, so dark skies are a prerequisite. It has been said that a minimum of 20 cm aperture is needed to see this galaxy, but recent reports indicate that under excellent conditions a 10 cm telescope is sufficient, though averted vision was needed. The moral of this story is that dark skies are essential to see faint objects. Increased aperture will help as well as higher magnification, when its nuclear region then becomes visible. A member of the Local Group, it is one of over 30 galaxies believed to be companions to either M31 or the Milky Way.

Messier 110	NGC 205	00^h 40.4^m	+41° 41′	October 1
8.2 m [*14.1 m*]	21.9′| 11.0′		E5P	Easy

The final entry in the Messier catalog, added to the original list in 1967. It is the second satellite galaxy of M31, and although it has a brighter magnitude than M32, the first satellite, it has a much lower surface brightness. Consequently it is much harder to see. It is visible in large binoculars but will only appear as a very faint, featureless glow northwest of M31. In a telescope it shows a surprising amount of detail, and high magnification will bring out its mottled nucleus. In addition, it shows detail that is peculiar for an elliptical galaxy, details that are visible to the amateur. Of course, exceptionally dark skies and perfect seeing and transparency will be needed, but in a telescope of even modest aperture, say 10 cm, with a high magnification they are readily seen. Look for dark patches near a bright center. Strangely enough, they are reminiscent of features normally found in a spiral galaxy. A definite observing challenge!

Messier 32	NGC 221	00^h 42.7^m	+40° 52′	October 1
8.3 m [*12.6 m*]	8.7′| 6.5′		E2	Easy

The first satellite galaxy to M31 (see preceding entry) is visible in binoculars as a tiny round patch of light. However, it can often be mistaken for a star, so large binoculars are recommended. With a telescope, however, its elliptical shape becomes obvious, and under medium magnification a star-like nucleus can be glimpsed. Perhaps the most intriguing aspect of this little galaxy is the fact that it is believed to have a black hole at its heart. Just like its big brother, M31, although ten times less massive. There is evidence that M32 may have been a spiral galaxy that has been transformed into a compact elliptical by gravitational interaction with M31.

See also:

Galaxy	Classification	Month
Messier 105	E1	March
Messier 84	E1	March
Messier 86	S0(3)/E3	March
Messier 49	E2	March
Messier 87	E0.5P	March
Messier 89	E0	March
Messier 60	E2	April
Messier 59	E5	April
Caldwell 52	E6	April
Caldwell 35	E4	April

Lenticular, Peculiar and Irregular Galaxies

January–February

Messier 82	NGC 3034	09^h 55.8^m	+69° 41′	February 19
8.9 m [*12.9 m*]	11.0′| 4.6′		IOsp	Easy ©

A very strange galaxy whose strangeness becomes apparent when it is seen through a telescope. It can be glimpsed with binoculars, where it will appear as an elongated pale glow. Large binoculars will begin to hint at some detail, and with averted vision the dark dust lane may be seen. In even a small telescope of 10 cm aperture, it is evident that something strange has happened to M82. The western part is obviously brighter than the eastern and the core region appears jagged and angular. Throughout the length of the galaxy, starlight appears to stream through the gaps in the dark dust lanes. It is a galaxy that will repay long and detailed study, especially at large aperture and high magnification. This active galaxy is of the starburst type and is undergoing an immense amount of star formation, possibly caused by the close passage of its companion M81. During that time, which was about 40 million years ago, the gravitational effect of M81 caused the interstellar material within M82 to collapse and form new stars. Subsequently, material that was dragged from M82 is now believed to be falling back onto it, which gives rise to both its appearance and the new era of star formation. Although classified as an irregular galaxy, research in 2005 utilizing near-infrared observations detected spiral arms in M82. Both M81 and M82 can be seen in the same field of view and are a stunning sight.

Caldwell 53	NGC 3115	10^h 05.2^m	–07° 43′	February 21
8.6 m [*11.6 m*]	7.2′| 2.5′		SOsp	Easy

Also known as the Spindle Galaxy. This galaxy is often overlooked, which is a shame because it is a fine example of its type, as well as being quite bright. In binoculars it will appear as a small, faint elongated cloud, while in large binoculars it displays the characteristic lens shape. It is easily located in telescopes because of its high surface brightness. In telescopes of aperture 20 cm it will appear as a featureless oval cloud, with perhaps a slight brightening toward its center. Classed as an SO-type galaxy, it will not show any further detail even with larger aperture. It is a very big galaxy, some five times larger than the Milky Way. It is also one purported to have a dormant supermassive black hole at its center.

See also:

Galaxy	Classification	Month
Caldwell 60/61	Sp S(B)p	March
Messier 85	SA(s)OP	March
Caldwell 21	IBm	March
Caldwell 24	P	November

March–April

Caldwell 60/61	NGC 4038/9	12^h 01.6^m	−18° 52′	March 22
10.5/10.7 m [*13.3 m*]	7.6′| 4.9′		Sp S(B)p	Moderate

Also known as the Antennae or Ring-Tail galaxies. Together, these probably make up one of the most famous objects in the entire sky, but few amateurs ever observe it, believing it to be too faint. A telescopic object, it will appear as an asymmetrical blur in apertures of about 20 cm. Larger apertures will begin to hint at its detailed structure, and at 25 cm aperture it will begin to resemble the famous apostrophe shape. Using apertures of about 30 cm, along with medium to high magnification, will show you that there are two objects involved, and it would be a worthwhile project to see just how much detail is resolved with a different group of telescopes and observers. It is one of those celestial objects that is so familiar from photographs that your perception of what is seen will be tainted by what you expect to see. Nevertheless, it is a wonderful object. Sadly, it is very low down for far northern observers, so perfect observing conditions will be necessary. The marvelous shape of the Antennae is the result of spiral galaxies passing close by each other, so that tidal interaction causes material to be dispersed. Witness the amazing long tails that can be seen on deep images of these galaxies. Furthermore, recent work has shown that the interaction has led to a vast bout of star formation. Also, it has encouraged astronomers to put forward the idea that spiral galaxies evolve into elliptical galaxies after such an encounter.

Messier 85	NGC 4382	12^h 25.4^m	+18° 11′	March 28
9.2 m [*13.1 m*]	7.1′| 5.5′		SA(s)OP	Moderate

This is a bright galaxy that can be glimpsed in binoculars on clear nights. With large binoculars it is even easier to see, where it will show a star-like nucleus surrounded by the faint glow of the halo. Using a telescope will just magnify the rather featureless aspect, though a few observers report that at high magnification some faint detail can be glimpsed to the south of the nucleus, which may be a trace of some spiral structure. Also, there is an indication of a faint blue tint to the galaxy.

Caldwell 21	NGC 4449	12^h 28.2^m	+44° 05′	March 29
9.8 m [*13.2 m*]	6.0′| 4.5′		IBm	Moderate

A member of the Canes Venaticorum Group of galaxies, this is a faint and frequently ignored object. Its irregular shape is often mistaken for a comet. Under good skies, a telescope of 20-cm aperture will easily discern its fan-shaped morphology along with its faint nucleus. Larger telescopes will of course resolve the galaxy with a considerable amount of detail. An interesting point is that several HII regions are visible, especially one at the northern corner of the open fan shape. It is apparently a site of much ongoing star formation and is similar in many ways to the Large Magellanic Cloud.

See also:

Galaxy	Classification	Month
Messier 82	IOsp	February
Caldwell 53	SOsp	February

May–June

See:

Galaxy	Classification	Month
Caldwell 77	SOpec	April
Caldwell 57	IB(s)m	July

July–August

Caldwell 57	NGC 6822	19^h 44.9^m	−14° 48′	July 18
9.9 m [15.5 m]	15.5′| 13.5′		IB(s)m	Moderate

Also known as Barnard's Galaxy. This is a challenge for binoculars astronomers. Even though it is fairly bright, it has a low surface brightness and so is difficult to locate. Once found, however, it will appear as a hazy indistinct glow running east-west. This is in fact the bar of the galaxy. Strangely enough, it is one of those objects that seems to be easier to find using small aperture, say 10 cm, rather than large. Nevertheless, dark skies are essential to locate this galaxy. It is part of the Local Group.

See also:

Galaxy	Classification	Month
Caldwell 57	IB(s)m	July
Caldwell 51	dIA	October

September–October

Caldwell 51	IC 1613	$01^h\ 04.8^m$	+02° 07′	October 7
9.2 m [–]	11.0′| 9.0′		dIA	Moderate

This is a very difficult galaxy to observe, but there are a few reports stating that it is visible in large binoculars as a very faint hazy glow, while others claim that a minimum of 20 cm aperture is needed. Whatever you choose, one thing is paramount, namely that a dark sky will be needed. A member of the Local Group, it is similar in many respects to Caldwell 57 (see previous entry). It is an old galaxy that is still forming stars.

See also:

Galaxy	Classification	Month
Caldwell 57	IB(s)m	July
Caldwell 24	P	November

November–December

Caldwell 24	NGC 1275	$03^h\ 19.8^m$	+41° 30′	November 10
12.0 m [*13.2 m*]	2.2′| 1.7′		P	Difficult

The final galaxy in our list is a very important galaxy, even though visually it is not impressive. It nevertheless should be observed for several reasons. It is the main member of the Perseus Galaxy Cluster, also known as Abell 426. Several amateurs have stated that it can be seen in telescopes as small as 15 cm aperture, while larger apertures will make it easier to locate. If you can have access to a telescope of aperture 40 cm or larger then use the opportunity to look at this galaxy, as it will be surrounded by several fainter ones that are all part of the cluster. In many respects it is the most concentrated field of galaxies in the winter sky for the northern observer. Caldwell 24 is a strong radio galaxy and is believed to be the remnant of a merger between two older galaxies. It is one of over 500 members of the Perseus Cluster. The cluster itself forms part of an even larger super cluster, the Pisces-Perseus Supercluster.

See also:

Galaxy	Classification	Month
Caldwell 51	dIA	October
Messier 82	IOsp	February
Caldwell 53	SOsp	February

Groups and Clusters of Galaxies

January–June

Hickson Group 68	NGC 5353	$13^h\ 53.4^m$	+40° 47′	April 20
11.1 m	→11.2′←	#5[12]		Moderate

This is a very nice group of galaxies for amateur instruments. The brightest member can be seen in a telescope as small as 6 cm, and with a 15 cm aperture it will show a slight brightening of its center. The other galaxies will appear as faint patches of light, and to see the faintest member would most certainly require an aperture of about 25 cm.

Copelands Septet	NGC 3753	$11^h\ 37.9^m$	+21° 59′	March 16
13.4 m	→7.0′←	#7		Difficult

Also known as the Hickson Galaxy Group 57. This is a very small group of galaxies. Situated in the constellation Leo, all within about 7 arcsec. Telescopes of at least 25 cm aperture will be needed, and even then you may not spot the fainter members of the group but just the four brighter galaxies. Larger apertures should of course allow you to spot them. Nevertheless, seeing conditions will determine

[12]# Indicates number of galaxies in cluster/group.

what you observe, regardless of aperture. The group is a mix of barred spirals, ordinary spirals and lenticular galaxies.

Coma Cluster	NGC 4889	$12^h\ 57.7^m$	+28° 15′	April 6
11.4 m	→120+′←	#10+		Difficult

This is a large cluster of galaxies. Many of its members are within reach of amateur telescopes of aperture 25 cm and larger. It is fairly well spread out, and so the field of view will be dotted with many indistinct faint patches of light. It contains many elliptical, spiral, barred spiral and lenticular galaxies.

Stephen's Quintet	NGC 7320	$22^h\ 36.1^m$	+33° 57′	April 6
12.6 m	→4′←		#5	Difficult

A very famous group of galaxies located in Pegasus, but one that has in the past proved strangely difficult for amateurs. Under absolutely perfect seeing conditions, the group is visible in a 20 cm telescope. The largest member of the quintet is only 2.2 or 1.2 arcsec in size, so it is very small, but it is the brightest. To actually see the group as a distinct unit and not a faint smudge of light will require a telescope of aperture 25 cm. This will show at least four of the group, but the fifth requires an aperture of at least 30 cm. Under high magnification and large aperture, structure can be seen within the brighter members. It is believed that four of the group are interacting with each other (also known as the Hickson Compact Group 92), and there is debate as to whether the fifth is in fact a line-of-sight galaxy. This is a challenge to the urban astronomer.

Seyfert′s Sextet	NGC 6027	$15^h\ 59.2^m$	+20° 46′	May 22
13.3 m	→1.5′←	#6		Very difficult

This is a real challenge! In all but the largest telescopes it is questionable if you will see anything at all, and even in apertures around 40 cm the galaxies will barely be resolved. Nevertheless, it would be interesting to find out what would be the smallest aperture required to spot these faint galaxies.

Virgo Cluster

See Messier 87 on p. 198.

Perseus Cluster

See Caldwell 24 on p. 205

See also:

Galaxy	Observability	Month
Fornax Cluster	Difficult	November

July–December

Fornax Cluster	NGC 1316	$03^h\ 20.9^m$	−37° 17′	November 10
11.4 m	→12+′←	#10+		Difficult

This is another large cluster of galaxies. Amateur telescopes should be able to pick out the brightest members with no difficulty. What makes this cluster so spectacular, however, is that with a modest aperture, say of 25 cm, and clear and dark skies, there are so many galaxies that identification is very difficult. The brightest member is visible even in an 8 cm telescope! A galaxy of note in the cluster is NGC 1365, which is a nice barred spiral 8 arcsec in length and visible in an 8 cm aperture telescope as a faint blur. The cluster also contains a galaxy known as the Fornax System, which is a dwarf spheroidal galaxy, a very small and faint class of galaxy. This galaxy may never been observed with amateur instruments.

See also:

Galaxy	Observability	Month
Hickson Group 68	Moderate	April
Copelands Septet	Difficult	March
Coma Cluster	Difficult	April
Stephen's Quintet	Difficult	April
Seyfert's Sextet	Very difficult	May

Chapter 6

Faint, Far Away and Invisible

After seeing the title of this chapter you're probably wondering what possible objects exist are that can be listed as faint, far away and invisible, and *still* be of interest to an amateur astronomer! But there are a few, if you think about it. Up to this point we have just covered objects that are familiar to nearly every amateur astronomer – stars, nebulae and galaxies – but in fact you're familiar with quite a few other objects that you undoubtedly have read about in other books or astronomy magazines but always assumed they were not visible using amateur equipment.

For example, quasars. You've heard of them, but have you ever observed one? As another example, you may have read about a lensed quasar but thought that there couldn't possibly be any that are visible – could there? Well, there is one – faint, tiny, but visible under perfect conditions. What about the center of our galaxy, or even a star that we know has planets orbiting it? (No, not the Sun!) These are the types of objects we will briefly cover.

Even knowing the position of these objects in the sky is a fascinating and worthwhile objective in itself. It is always intriguing to know that a particular star, which may look very ordinary, is in fact, very extraordinary, even though, when seen through as telescope, it appears much like every other star. In a similar vein, knowing that a rather featureless patch of sky actually harbors what is believed to be a black hole has always held a fascination. Many of the objects mentioned in this chapter will, to all intents and purposes, be invisible to amateur telescopes or show little or no detail, but nevertheless, that shouldn't deter you from seeking out the area of sky in which they lurk.

As usual, we'll begin with some background astronomy about the objects.

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_6,

The Center of the Milky Way

The Milky Way, our home galaxy, is, as you know, a barred spiral galaxy, similar to many that have been mentioned in Chap. 5. It is about 1,200 light-years thick and 100,000 light-years in diameter and contains over several hundred billion stars. It is classified as a SAB(rs)bc-type galaxy. The Solar System is located about halfway from the center of the galaxy to the edge of the disc, and around 70 light-years above the plane of the galaxy. It is near the inner edge of a short spiral arm called the Orion Arm, which is around 15,000 light-years long and contains the Cygnus Rift and the Orion Nebula (M42).

April–September

Galactic Center	Sgr A*	$17^h\ 45.6^m$	–29° 00′	June 18

The center of the galaxy has always posed several problems for astronomers, both amateur and professional. Unfortunately, owing to the vast amount of interstellar gas and dust that lies between us, it has been impossible to see in visible light. However all is not lost, as gamma rays, hard X-rays, infrared radiation and radio waves are able to pass through the interstellar medium, and so a picture can be built up of this inaccessible region.

What has been learned is impressive. There is a radio source located very near or even at the exact center, called Sagittarius A*[1] – pronounced ‘Sagittarius a star’ – and this was the first cosmic radio source discovered. Measurements of the radio source indicate that it is no bigger than the diameter of Mars’s orbit. One of the (many) surprising results is that Sagittarius A* is stationary, which would indicate that it is very massive.[2] The current estimate for the mass is about four million solar masses.

All this information suggests that at the center of our galaxy lies a supermassive black hole with a diameter of around 24 million km.[3] When you look through a telescope at the region, the field of view will be full of numerous star fields, but these actually lie much closer to us than to the center. However when observing this

[1]Sagittarius A* is now believed to be made of two components: SgrA East and SgrA West. The former is a supernova remnant, and the latter is an ultra compact, non-thermal source, i.e., a black hole.

[2]Recent analysis suggests that the density around the center of the galaxy is about a million times greater than any known star cluster. It is probably made up of stars, dead stars, gas and dust and of course a black hole.

[3]To get a sense of scale, consider that the Mercury is 46 million km from the Sun at perihelion.

region you may like to contemplate the almost certain fact that even though you cannot see the center, there in your eyepiece, ever invisible, lies a supermassive black hole, around which all people, the Solar System and the galaxy rotate.

Stellar Black Holes

Although black holes have been mentioned in preceding chapters, they have mainly been associated with galaxies and so naturally are massive beasts. There exist however (or should we say, are believed to exist) black holes that can have smaller mass and are associated with the evolution of stars. The current scenario[4] is for a star to evolve from the main sequence, becoming a red supergiant star, and, inevitably, a supernova ensues. If the resulting stellar remnant has a mass from about 1.4 to 3 times that of the Sun, it would eventually form a neutron star. But if the remnant's mass is greater than three times that of the Sun's, then not even the neutron degeneracy present in a neutron star will stop the collapse, and the star will shrink down to become a black hole.

But we encounter a big problem with detecting possible black holes. Due to their immense gravitational influence they do not emit radiation and so cannot be detected directly. So how does one begin to search for such an elusive and invisible object?

The answer is to search for the effect a black hole may have on a companion star. First search for a star whose motion, determined by measuring the Doppler shift in its spectrum, is a member of a binary star. (The Doppler shift is the change in the wavelength of light from an object that is moving away from or towards an observer.) If it proves possible to see both stars, then give up on that object. The search is for a binary system where one companion is invisible, no matter how powerful the telescope used.

However, just because it is unseen does not necessarily make it a black hole candidate. It may be just too faint to be seen, or the glare from the companion may swamp out its light. It could even be a neutron star. Thus further evidence is needed to see if the invisible companion has a mass greater than that allowable for a neutron star. Using the mathematical laws of Newton and Kepler it is possible to determine whether the star, or rather the invisible object, has a mass greater than three solar masses. If this is so, then the unseen companion may be a black hole. Still further information is still needed, however, and this may appear in the form of X-rays, which can arise either from material flowing from one star into the black hole or from an accretion disc that has formed around the black hole. Either way, the presence of X-ray emission is a good indicator that a black hole may be the unseen companion object.

[4]Please refer to the books listed in Appendix B of this book for a full and proper account of current theory on stellar evolution.

Of course, the measurements as stated above are a bit more complicated than this. For instance, it is known that neutron stars can emit X-rays and have an accretion disc. So careful analysis of the data is necessary. However, a few candidates are known, and one is even visible to the amateur astronomer. Or perhaps we should say that the companion star to the black hole is visible!

May–October

Cygnus X-1	HDE 226868	$19^h\ 58.4^m$	35° 12′	July 21

This is one of the strongest X-ray sources in the entire sky and is possibly the most convincing candidate for a black hole. Its position is coincident with the star HDE 226868, which is an O9.7 lab supergiant of magnitude 8.95. It lies about 0.5° ENE of Eta Cygni. It is a very hot star, of around 31,000 K, and analysis shows it is a binary with a period of around 5.6 days. Observations by satellite have detected variations in X-ray emission on a time scale of less than 50 milliseconds. The estimated mass of the unseen black hole companion is 8.7 solar masses with a diameter of about 52 km. Recent work suggests that the system possibly belongs to the stellar association Cygnus OB3, lying inward along the Orion Spur of the Milky Way where, incidentally, the Sun is also located, near where the spur approaches the Sagittarius Arm. Surprisingly, if it were not for the extinction of light due to the interstellar medium lying between us and the system, then HDE 226868 would be a fifth magnitude star and thus visible to the naked-eye!

Quasars

There can't be many amateur astronomers who haven't heard of the term *quasar*. It actually stands for the words, *QUA*si-*S*tell*A*r *R*adio source. Their discovery came about like this: in1963 astronomer Maarten Schmidt was looking at spectra of what was believed to be radio stars when he noticed that one object (which looked to all appearances like a star) was in fact something very different. Analyzing the spectra he discovered that the object was in fact *very* luminous, *very* far away and was moving away from us at 45,000 km s^{-1}, or about 15% of the speed of light. Obviously something strange and spectacular was going on. The object in question was known as 3 C 273.[5]

We now know that quasars, and their radio-quiet relatives, QSOs (quasi-stellar objects), are in fact the ultra-luminous central regions of very young galaxies.

[5]It is entry number 273 in the 3rd Cambridge catalog of radio sources.

They appear star-like owing to their vast distances and are very bright because it is believed that supermassive black holes lie at their hearts, creating immense amounts of energy. Some very luminous quasars are thought to have black holes with masses of up to three billion solar masses. Because they are so far away the host galaxies in which they reside are too faint to be seen, so you only see the energy that is produced from the region around the black hole.

Quasars are classed as active galaxies and are an important aspect of a galaxy's evolution. The active galaxies mentioned earlier in the book such as Seyfert galaxies can be thought of as having mini-quasars at their cores. Many more quasars have been found, and they are among the furthest and, subsequently the youngest, objects in the universe.

Visually, a quasar will look just like a faint star. After all, this is what astronomers believed them to be up until recently. However, the brightest and most famous, 3 C 273, is easily within reach of amateur telescopes. Needless to say, dark skies and excellent seeing are necessary. Also, a good star atlas is a must, as there will be countless background stars visible.

January–June

3 C 273		$12^h\ 29.1^m$	02° 03′	March 29
12.9 m	Redshift (z) 0.158			2.6 billion light-years

This quasar is the brightest in the sky and within reach of medium-to-large-aperture telescopes. There are even reports that it has been glimpsed in telescopes of 20 cm and thus is well within reach of most amateurs. Averted vision will also help locate this distant object. The following information might help you locate it:

1. It is situated about 3.5° northeast of Eta Virginis and 3° southeast of the galaxy M61. Find the galaxy NGC 4536 (magnitude 10.6, surface brightness 13.2, at position R.A.$12^h\ 34.5^m$ Dec. 02° 11′).
2. At about 1.25° east of the galaxy is the quasar.
3. In the immediate vicinity is a double star, arranged east-west with 3 arcs' separation.
4. The double has magnitudes 12.8 and 13, and the quasar is a bright, blue-tinted stellar object east of the double system.

See also:

Quasar	Magnitude	Month
PKS 0405-12	14.8	November

July–December

PKS 0405-12	MSH 04-12	04^h 07.8^m	−12° 11′	November 22
14.8 m	Redshift (z) 0.57			6 billion light-years

This is another quasar that should be within the reach of amateur astronomers and has been glimpsed in telescopes of 20 cm. It is located in the constellation Eridanus.

The quasar lies about 3° to the northeast of Zaurak ([Gamma] g Eri). When seen through an eyepiece, you may spot a tiny green dot to the left. This is the planetary nebula NGC 1535 (Cleopatra's Eye). If you do manage to see the quasar, you will need detailed star maps to confirm the observation, but then you will be a member of a very small and elite group of observers. It is also incredible to note that the light that enters your eye from this quasar started its journey some 1.5 billion years *before* the Solar System was formed!

See also:

Quasar	Magnitude	Month
3 C 273	12.9 m	March

Gravitational Lensing

Before we leave the topic of quasars for the final time, there is one more amazing aspect of them that, under the right conditions, allows us see one of the most fascinating consequences of Einstein's General theory of Relativity.

The general theory of relativity is far beyond the scope of this book, but a simple outline of what happens is fairly straightforward. Gravity has the ability to "bend" light, if the gravitational force is strong enough. The first experimental justification of Einstein's theory was in fact a measure of this light bending, when on May 29, 1919, the British astronomer Arthur S. Eddington measured the amount that starlight was deflected by the Sun. He used a total eclipse of the Sun so that any faint stars would not be rendered invisible by the glare of the Sun. The accuracy of the measurements was about 20%, but it was enough to vindicate the theory. Subsequent measurements using radio waves have managed to confirm the predictions made by Einstein to within 1%.

The Sun is not the only thing that can bend a ray of light. Any object that has sufficient mass can deflect light waves. Calculations show that when light rays from a distant object pass close to a compact but massive galaxy, the bending of the light can result in the appearance of multiple or twisted images. It is as if the galaxy were acting like a lens, and so any object emitting light from *behind* the galaxy has its light bent as it passes close to the galaxy. This bizarre effect is called *gravitational lensing*.

In 1979, astronomers noticed that a pair of quasars known as QSO 0957+561 had identical spectra and red shifts, and it was suggested that these two quasars might in fact be one, whereby the two images were produced by an intervening object. This was subsequently proved to be the true explanation, with a cluster of galaxies responsible for the lensing of the light from the distant quasars.

You may have seen images of such objects in various books and magazines and always thought that it would be nearly impossible to see these through a telescope. The examples always given are usually of quasars so distant that the Hubble Space Telescope or at least the world's largest ground-based telescopes are needed to image them. This is (only) more or less true, but there are one or two quasars that can be and have been seen by amateurs. It isn't easy. It must be stressed that good seeing conditions are essential to observe these faint objects, and that a detailed star atlas is required to confirm the observation.

January–December

Twin quasar	Q0957+0561A/B	$10^h\ 01^m$	55° 53′	February 20
16.8 m (17.1 17.4 A/B)		Separation 6″		9 billion light-years

The quasar is in the constellation Ursa Major and so is a fine target for northern hemisphere observers. The starting point for the quasar is the bright edge-on galaxy NGC 3079 (8.1′|1.4′, magnitude 11.5, within reach of a 20 cm telescope; several fainter galaxies lie nearby). The galaxy points to the quasar to the southeast, about two galaxy lengths away near a parallelogram of 13th and 14th magnitude stars. The quasar lies off the southeastern corner.

The two components 17.1 and 17.4 magnitude are separated by 6″. Observers with very large instruments of aperture 50 cm have reported seeing the two objects cleanly split. Like most quasars, Q0957+0561 is slightly variable in brightness. With small telescopes, the two images will appear as one, but slightly elongated. In this case, the lensing is done by a cluster of galaxies, which lay 3.5 billion light-years away, and is splitting the light of the more distant Q0957+0561 into multiple images. Two of these images are much brighter than the others, and this is what is observed. It may be wise to try as high a magnification as possible. This is a good observing challenge for CCD owners. The quasar lies at a distance of at almost 8 billion light-years and may well be the most distant object visible to the amateur astronomer.

Leo Double Quasar	QSO 1120+019	$11^h\ 23.3^m$	01° 37′	March 13
15.7 20.1 m (A/B)		Redshift (z) 1.477		

An extremely difficult quasar to resolve. The brighter A component is easily seen in large telescopes, but the fainter B component is very difficult.

Cloverleaf Quasar	H 1413+117	14^h 15.8^m	11° 29′	April 25
17 m (A/B/C/D)		Redshift (z) 2.558		

An exceedingly difficult object to observe and only with perfect conditions and very large-aperture telescopes will it be seen. The greatest separation among the four is about 1.36″. It may never have been visually been observed from the UK, but U. S. observers report seeing just an asymmetric, faint hazy and tiny blob of light, although it has been imaged by CCD.

Chapter 7

Naked-Eye Objects

All the objects discussed so far in the book have needed some sort of telescopic equipment, be it binoculars or varying sizes of telescope, in order to be seen. However, it may come as a surprise to you to know that there are a number of interesting celestial objects that can be glimpsed with the naked eye!

Be aware though that they will NOT appear anything like the views seen through an eyepiece. In fact, more often than not, all that will be seen is a very faint star-like object. Nevertheless, it is possible to see unique stars, star clusters, nebulae and galaxies all with the naked eye.

Remember that exceptionally clear and transparent skies will be needed, as well as a minimum of light pollution. From discussions with very experienced amateur astronomers, in order to see these elusive objects, a good knowledge of the night sky also helps, as is good eyesight.

Please note that those objects listed are ones that I know from personal experience and correspondence with other astronomers. Many more can possibly be seen that have yet to be reported or even attempted. To that end I have set up a dedicated website that seeks to list all those deep sky objects that can be seen; http://web.me.com/mdiastro/faintestobject.

The usual information that is provided in previous object descriptions is used here.

The following descriptions also contain detail that can be seen with telescopes.

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3_7,

Double and Red Stars

ζ^2 Sco	HD 152334	16^h 54.6^m	−42° 22′	June 5
3.62 m	0.3 M	K4 III	Scorpius	Easy

The brighter of the two stars in this naked-eye optical double star system, the orange supergiant star contrasts nicely with its slightly fainter blue supergiant companion.

θ Orionis C	θ Ori	05^h 35.3^m	−05° 23′	December 14
5.13 m	−3.2 M	O6 pe V	Orion	Easy

A member of the famous Trapezium multiple-star system in the Orion Nebula. Splitting the group is always a test for small telescopes. A fairly new star, maybe only several thousand years old, and as a consequence most of the star's light is emitted at ultraviolet wavelengths. It has the honor of having highest surface temperature of any star that is visible to the naked eye.

La Superba	Y Canum Venaticorum	12^h 45.1^m	+45° 26′	April 2
4.8_vm	B-V:2.9	C7		Easy

One of the reddest stars in the sky, the color of this star is best seen through binoculars or a small telescope. With a period of 159 days and varying in magnitude between 4.9 and 6.0 m, this red giant has a diameter of 400 million km. La Superba (Y CVn) also has two other surprises: it is the brightest J-star in the sky, a very rare category of carbon stars that contain large amounts of carbon-13 (carbon atoms with seven neutrons instead of the usual six) and is one of the coolest of naked-eye stars, with a temperature[1] around 2,200 K.

ζ Ursae Majoris	ADS 8891	13^h 23.9^m	+54° 56′	April 12
2.3, 4.0 m	P.A. 152°| Sep. 14.4"			Very easy ©

The famous double Mizar and Alcor (80 UMa). Visible to the naked eye and very nice in binoculars. A small telescope will resolve Mizar's fourth magnitude companion. Alcor and both members of Mizar are themselves spectroscopic binaries. Thus there are six stars in the system. Mizar also has several other distinctions: the first double to be discovered by telescope, by Riccioli in 1650; the first to be photographed, by Bond in 1857; and the first spectroscopic binary detected, by Pickering in 1889.

[1]Research indicates the figure could be 2,800 K.

α Capricorni	ADS 13632	20^h 18.1^m	−12° 33′	July 26
3.6, 4.2 m	P.A. 29°| Sep. 378”			Very easy

A widely spaced, naked-eye optical double. Both stars are a yellow-orange color, but when they are viewed through small telescopes it will be seen that both stars are themselves binaries.

ε Lyrae[1,2]	ADS 11635	18^h 44.3^m	+39° 40′	July 2
4.7, 6.2 m	P.A. 357°| Sep. 2.6″			Easy/moderate
5.1, 5.5 m	P.A. 94° | Sep. 2.3″			Easy/moderate

The famous Double-Double, easily split, but to resolve the components of each star, ε^1 (magnitude 4.7) and ε^3 (magnitude 4.6), requires a high power. The stars themselves are at a P.A. 173°, separated by 208″, which is near the naked-eye limit, and some keen-eyed observers report being able to resolve them under perfect seeing. However, there is fierce debate among amateurs – some saying the double is difficult to resolve, others the opposite. All stars are white- or cream-white colored. This system is definitely a highlight of the summer sky.

Garnet Star	μ Cephei	21^h 43.5^m	+58° 47′	August 17
4.04_vm	B-V:2.26	M2Ia		Easy

Located on the northeastern edge of the nebulosity IC1396, the Garnet Star, named by William Herschel, is one of the reddest stars in the entire sky. It has a deep orange or red color seen against a backdrop of faint white stars. It is a pulsating red supergiant star, with a period of about 730 days, varying from 3.4 to 5.1 m. It is in the last stages of its life and could go supernova anytime now, relatively speaking of course.

Star Clusters

Open Clusters

Messier 41	NGC 2287	06^h 47.0^m	−20° 44′	January 2
4.5 m	⊕ 38′	70	II 3 m	Easy

Easily visible to the naked eye on very clear nights as a cloudy spot slightly larger in size than the full Moon. Nicely resolved in binoculars, it becomes very impressive with medium aperture, with many double- and multiple-star combinations. Contains blue B-type giant stars as well as several K-type giants. Current research indicates that the cluster is about 100 million years old and occupies a volume of space 80 light-years in diameter.

Messier 50	NGC 2323	07^h 03.2^m	–80° 20′	January 6
5.9 m	⊕ 16′	80	II 3 m	Easy

The only Messier object in Monoceros and one that is often overlooked by amateurs. Discovered by Cassini, this is a fine, heart-shaped cluster easily seen in binoculars and visible to the naked eye on clear nights. Within the large, bright and irregular cluster of blue stars is a striking red star. What makes the cluster particularly challenging is that the area of the sky where it resides is full of small stellar groupings and asterisms. The question often arises, where does the cluster end and the background star field begin?

Messier 44	NGC 2632	08^h 40.1^m	+19° 59′	January 30
3.1 m	⊕ 95′	60	II 2 m	Easy

A famous cluster, called Praesepe (the Manger) or the Beehive. One of the largest and brightest open clusters from the viewpoint of an observer. An old cluster, about 700 million years old, distance 500 light-years, with the same space motion and velocity as the Hyades, which suggests a common origin for the two clusters. A nice triple star, Burnham 584 is located within M44, just south of the cluster's center. A unique Messier object in that it is brighter than the stars of the constellation within which it resides. Owing to its large angular size in the sky, it is best seen through binoculars or a low-power eyepiece.

Melotte 111	–	12^h 25.0^m	+26°	March 28
1.8 m	⊕ 275′	75	II 3 p	Easy

Also known as the Coma Star Cluster, this is a large and impressive cluster of fifth- and sixth-magnitude stars, spanning about 5°. Owing to its large size, it is only worth observing with binoculars because telescope observation will lose the clustering effect. Believed to be 400 million years old and 260 light-years distant, it is the third nearest cluster. Because of its extremely weak gravitational field the cluster may be on the verge of complete disruption. Paradoxically, although this cluster is visible to the naked eye, it has neither a Messier nor an NGC designation.

Messier 6	NGC 6405	17^h 40.1^m	–32° 13′	June 16
4.2 m	⊕ 33′	100	II 3 r	Easy

Also known as the Butterfly Cluster. Easily seen with the naked eye as a dim patch of light. It is perhaps one of the few stellar objects that actually looks like the entity after which it is named. A fine sight in binoculars, it contains the lovely orange-tinted star BM Scorpii east of its center. This star is a semi-regular variable, period 850 days, which changes from magnitude 5.5 to 7. Surrounding it are many nice steely blue-white stars. Believed to be at a distance of 1,590 light-years.

–	IC 4665	$17^h\ 46.3^m$	+05° 43′	June 18
4.2 m	⊕ 40′	30	III 2 m	Easy

A naked-eye object under perfect seeing conditions, this large cluster appears as a hazy spot measuring over two full Moon diameters. With binoculars, nearly 30 blue-white sixth magnitude stars can be seen. Its position in a sparse area of the sky emphasizes the cluster, even though it is not a particularly dense collection of stars.

Messier 7	NGC 6475	$17^h\ 53.9^m$	–34° 49′	June 20
3.3 m	⊕ 80′	80	I 3 r	Easy

An enormous and spectacular cluster. It presents a fine spectacle in binoculars and telescopes, containing over 80 blue-white and pale yellow stars. It is only just over 800 light-years away but is over 200 million years old. Many of the stars are around sixth and seventh magnitude and thus should be resolvable with the naked eye. Try it and see.

Messier 24[2]	–	$18^h\ 16.5^m$	–18° 50′	June 25
2.5 m	⊕ 95′× 35′		–	Easy

Another superb object for binoculars. This is the Small Sagittarius Star Cloud, visible to the naked eye on clear nights and nearly four times the angular size of the Moon. The cluster is in fact part of the Norma Spiral Arm of our galaxy, located about 15,000 light-years from us. The faint background glow from innumerable unresolved stars is a backdrop to a breathtaking display of sixth- to tenth-magnitude stars. It also includes several dark nebulae, which adds to the three-dimensional impression. Many regard the cluster as truly a showpiece of the sky. Spend a long time observing this jewel!

Messier 25	IC 4725	$18^h\ 31.6^m$	–19° 15′	June 29
4.6 m	⊕ 32′	40	I 3 m	Easy

Visible to the naked eye, this is a pleasing cluster suitable for binocular observation. It contains several star chains and is also noteworthy for small areas of dark nebulosity that seem to blanket out areas within the cluster, but you will need perfect conditions to appreciate these. Unique for two reasons: it is the only Messier object referenced in the *Index Catalogue* (IC) and is one of the few clusters to contain a Cepheid-type variable star – U Sagittarii. The star displays a magnitude change from 6.3 to 7.1 over a period of 6 days and 18 h.

[2]Located within Sagittarius are numerous open clusters. Only the brightest are listed here.

Collinder 399	–	19^h 25.4^m	+20° 11′	July 13
3.6 m	⊕ 60′	35	III 3 m	Easy

Also known as the Coathanger or Brocchi's Cluster. Often overlooked by observers, this is a large, dissipated cluster easily seen with binoculars; indeed, several of the brightest members should be visible with the naked eye. It contains a nice orange-tinted star and several blue tinted stars. Its three dozen members are set against a background filled with fainter stars. Well worth observing during warm summer evenings.

Herschel 30	NGC 7789	23^h 57.0^m	+56° 44′	September 20
6.9 m	⊕ 15′	300	II 1 r	Medium ©

Visible as a hazy spot to the naked eye and even with small binoculars is never fully resolvable; it is believed to be one of the major omissions from the Messier catalog. Through a telescope it is seen as a very rich and compressed cluster. With large aperture, the cluster is superb and has been likened to a field of scattered diamond dust. Contains hundreds of stars of tenth magnitude and fainter.

Caldwell 14	NGC 869	02^h 19.0^m	+57° 09′	October 26
5.3 m	⊕ 29′	200	I 3 r	Easy ©
	NGC 884	02^h 22.4^m	+57° 07′	
6.1 m	⊕ 29′	115	II 2 p	

Glorious! The famous Double Cluster in Perseus should be on every amateur's observing schedule and is a highlight of the northern hemisphere's winter sky. Strangely, never cataloged by Messier even though it is visible to the naked eye, but it is best seen using a low-power, wide-field optical system. Whatever system is used, the views are marvelous. NGC 869 has around 200 members, while NGC 884 has about 150. Both are composed of A- and B-type supergiant stars with many nice red giant stars. However, the systems are dissimilar. NGC 869 is 5.6 million years old (at a distance of 7,200 light-years), whereas NGC 884 is younger, at 3.2 million (at a distance of 7,500 light-years). But be advised that in astrophysics, especially as concerns distance and age determination, there are very large errors!

Also, it was found that nearly half the stars are variables of the type Be, indicating that they are young stars with possible circumstellar discs of dust. Both are part of the Perseus OB1 Association from which the Perseus spiral arm of the galaxy has been named. Don't rush these clusters; spend a long time observing both of them and the background star fields.

Messier 34	NGC 1039	02^h 42.0^m	+42° 47′	November 1
5.2 m	⊕ 35′	60	II 3 m	Easy

A nice cluster easily found, about the same size as the full Moon. It can be glimpsed with the naked eye and is best seen with medium-sized binoculars, as a telescope will spread out the cluster and so lessen its impact. At the center of the cluster is the double star H1123, both members being eighth-magnitude and of type A0. The pure-white stars are very concentrated toward the cluster's center, while the fainter members disperse toward its periphery. Thought to be about 200 million years old, lying at a distance of 1,500 light-years from us.

Messier 45	Melotte 22	$03^h\ 47.0^m$	+24° 07′	November 17
1.2 m	⊕ 110′	100	I 3 r	Easy

Outstanding! Without a doubt the sky's premier star cluster. The Seven Sisters, or Pleiades, is beautiful however you observe it – naked-eye, through binoculars or with a telescope. To see all the members at one go will require binoculars or a rich-field telescope. Consisting of over 100 stars, spanning an area four times that of the full Moon, it will never cease to amaze. It is often stated that from an urban location six to seven stars may be glimpsed with the naked eye. However, it may come as a surprise to many of you that it has ten stars brighter than sixth magnitude, and that seasoned amateurs with perfect conditions have reported 18 being visible with the naked eye. It lies at a distance of 410 light-years, is about 20 million years old (although some report it as 70 million) and is the fourth-nearest cluster. It contains many stunning blue and white B-type giants.

The cluster contains many double and multiple stars. Under perfect conditions with exceptionally clean optics, the faint nebula NGC 1435, the Merope Nebula surrounding the star of the same name (Merope – 23 Tauri), can be glimpsed and was described by W. Tempel in 1859 as "a breath on a mirror." However, this and the nebulosity associated with the other Pleiades are not, as they were once thought to be, the remnants of the original progenitor dust and gas cloud. The cluster is just passing through an edge of the Taurus Dark Cloud Complex. It is moving through space at a velocity of about 40 km a second, so by A.D. 32,000 it will have moved an angular distance equal to that of the full Moon. The cluster contains the stars Pleione, Atlas, Alcyone, Merope, Maia, Electra, Celaeno, Taygeta and Asterope. A true celestial showpiece.

Caldwell 41	Melotte 25	$04^h\ 27.0^m$	+16° 00′	November 27
0.5 m	⊕ 330′	40	II 3 m	Easy

Also known as the Hyades. The nearest cluster after the Ursa Major Moving Stream, lying at a distance of 151 light-years, with an age of about 625 million years. Even though the cluster is widely dispersed both in space and over the sky, it nevertheless is gravitationally bound, with the more massive stars lying at the center of the cluster.

Best seen with binoculars owing to the large extent of the cluster – over 5½°. Hundreds of stars are visible, including the fine orange giant stars γ, δ, ε and θ^{-1} Tauri. Aldebaran, the lovely orange K-type giant star is not a true member of the cluster but is a foreground star only 70 light-years away. Visible even from light-polluted urban areas – a rarity!

Herschel 47	NGC 1502	$04^h\ 07.7^m$	+62° 20′	November 22
5.7 m	⊕ 8′	45	II 3 p	Medium©

This cluster is easy to see, but can prove difficult to locate, even though it is in a relatively sparse area of the sky. Visible to the naked eye on clear nights. It is a rich and bright cluster but small and may resemble a fan shape, although this does depend on what the observer sees. What do you see? Also contained in the cluster are two multiple stars: Struve 484 and 485. The former is a nice triple system, but the latter is a true spectacle with nine components! Seven of these are visible in a telescope of 10 cm aperture, ranging between 7th and 13th magnitude. The remaining two components, 13.6 and 14.1 magnitude, should be visible in a 20 cm telescope. In addition, the system's brightest component, SZ Camelopardalis, is an eclipsing variable star, which changes magnitude by 0.3 over 2.7 days. What makes this cluster so special is its proximity to the asterism called Kemble's Cascade. This is a long string (2.5°) of eighth-magnitude stars to the northwest of H47. The cascade is best seen in low-power binoculars.

Melotte 28	NGC 1746	$05^h\ 03.6^m$	+23° 49′	December 6
6.1 m	⊕ 42′	20	III 2 p	Easy

Another large and scattered cluster, visible on clear nights with the naked eye. Within the cluster are two other smaller ones, each with its own classification – NGC 1750 and 1758. This phenomenon makes it difficult to determine accurately the true diameter of the cluster.

Messier 38	NGC 1912	$05^h\ 28.7^m$	+35° 50′	December 13
6.4 m	⊕ 21′	75	III 2 m	Easy

One of the three Messier clusters in Auriga visible to the naked eye. It contains many A-type main sequence and G-type giant stars, with a G0 giant being the brightest, magnitude 7.9. Is elongated in shape with several double stars and voids within it. Seen as a small glow in binoculars, it is truly lovely in small telescopes. It is an old galactic cluster with a star density calculated to be about eight stars per cubic parsec.

Messier 36	NGC 1960	$05^h\ 36.1^m$	+34° 08′	December 15
6.0 m	⊕ 12′	70	II 3 m	Easy

About half the size of M38, seen as a glow in binoculars. It is a large, bright cluster. Measurements indicate that it is ten times farther away than the Pleiades. It contains a nice double star at its center. Owing to the faintness of its outlying members it is difficult to ascertain where the cluster ends. Visible to naked eye.

Messier 37	NGC 2099	$05^h\ 52.4^m$	+32° 33′	December 19
5.6 m	⊕ 20′	150	II 1 r	Easy

In a word – superb! The finest cluster in Auriga. It really can be likened to a sprinkling of stardust, and some observers liken it to a scattering of gold dust. Contains many A-type stars and several red giants. Visible at all apertures, from a soft glow with a few stars in binoculars to a fine, star-studded field in medium-aperture telescopes. In small telescopes using a low magnification it can appear as a globular cluster. The central star is colored a lovely deep red, although several observers report it as a much paler red, which may indicate that it is a variable star. Visible to the naked eye.

Messier 35	NGC 2168	$06^h\ 08.9^m$	+24° 20′	December 23
5.1 m	⊕ 28′	200	III 2 m	Easy

One of the most magnificent clusters in the sky. Visible to the naked eye on clear winter nights with a diameter as big as that of the full Moon, and it seems as if the cluster is just beyond being resolved. Many more stars are visible in binoculars set against the hazy glow of unresolved members of the cluster. With telescopes, the magnificence of the cluster becomes apparent, with many curving chains of stars.

Globular Clusters

Messier 3	NGC 5272	$13^h\ 42.2^m$	+28° 23′	April 17
6.2 m	⊕ 18′		VI	Easy

A splendid object, easily seen in binoculars and a good test for the naked eye. If using giant binoculars with perfect seeing, some stars may be resolved. A beautiful and stunning cluster in telescopes, it easily rivals M13 in Hercules. It definitely shows pale colored tints, and reported colors include, yellow, blue and even green; in fact, it is often quoted as the most colorful globular in the northern sky. Full of structure and detail including several dark and mysterious tiny dark patches. Many of the stars in the cluster are also variable. One of the three brightest clusters in the northern hemisphere. Located at a distance of about 34,000 light-years.

Messier 5	NGC 5904	$15^h\ 18.6^m$	+02° 05′	May 11
6.65 m	⊕ 23.0′		V	Easy

A wonderful cluster and visible to the naked eye on clear nights. Easily seen as a disc with binoculars, and with large telescopes the view is breathtaking – presenting an almost three-dimensional vista. One of the few colored globular clusters, with a faint, pale yellow outer region surrounding a blue-tinted interior. It gets even better with higher magnification, as more detail and stars become apparent. Possibly containing over half a million stars, this is one of the finest clusters in the northern hemisphere; many say it is *the* finest.

Messier 13	NGC 6205	16^h 41.7^m	+36° 28′	June 1
5.8 m	⊕ 20′		V	Easy

Also known as the Great Hercules Cluster. A splendid object and the premier cluster of the northern hemisphere. Visible to the naked eye, it has a hazy appearance in binoculars; with telescopes, however, it is magnificent, with a dense core surrounded by a sphere of a diamond dust-like array of stars. In larger telescopes, several dark bands can be seen bisecting the cluster. It appears bright because it is close to us at only 25,000 light-years and also because it is inherently bright, shining at a luminosity equivalent to over 250,000 Suns. At only around 160 light-years in diameter, the stars must be very crowded, with several stars per cubic light-year, a density some 500 times that of our vicinity. All in all a magnificent cluster.

Messier 10	NGC 6254	16^h 57.1^m	–04° 06′	June 5
6.4 m	⊕ 20′		VII	Easy

Similar to M12, it is however slightly brighter and more concentrated. Can be seen with the naked eye on dark nights. It lies close to the orange star 30 Ophiuchi (spectral type K4, magnitude 5), and so if you locate this star then by using averted vision M10 should be easily seen. With apertures of 20 cm and more, the stars are easily resolved right to the cluster's center. Under medium aperture and magnification, several colored components have been reported: a pale blue tinted outer region surrounding a very faint pink area, with a yellow star at the cluster's center.

Messier 92	NGC 6341	17^h 17.1^m	–43° 08′	June 10
6.4 m	⊕ 11′		IV	Medium

A beautiful cluster often overshadowed by its more illustrious neighbor, M13. It is a somewhat difficult object to locate, but once found is truly spectacular. It can be glimpsed with the naked eye. In binoculars it will appear as a hazy small patch, but in 20 cm telescopes its true beauty becomes apparent with a bright, strongly concentrated core. It also has several very distinct dark lanes running across the face of the cluster. A very old cluster, 25,000 light-years distant.

Messier 22	NGC 6656	18^h 36.4^m	–23° 54′	June 30
5.1 m	⊕ 32′		VII	Easy

Wonderful, a truly spectacular globular cluster visible under perfect conditions to the naked eye. Low-power eyepieces will show a hazy spot of light, while high power will resolve a few stars. A 15 cm telescope will give an amazing view of minute bright stars evenly spaced over a huge area. Often passed over by northern hemisphere observers owing to its low declination. Only 10,000 light-years away, nearly twice as close as M13.

Messier 55	NGC 6809	$19^h\ 40.0^m$	–30° 58′	July 17
6.3 m	⊕ 19′		XI	Easy

A lovely cluster, easily seen in binoculars and just visible with the naked eye. Small-aperture telescopes (15 cm) show a bright, easily resolved cluster with a nice concentrated halo. Because it is very open, a lot of detail can be seen such as star arcs and dark lanes, even with quite small telescopes. With a larger aperture, hundreds of stars are seen.

Messier 15	NGC 7078	$21^h\ 30.0^m$	+12° 10′	August 13
6.2 m	⊕ 18′		IV	Easy

An impressive cluster in telescopes, this can be glimpsed with the naked eye. In binoculars it appears as a hazy object with no stars visible. Averted vision will be necessary in order to see the central stars. It does, however, under medium magnification and aperture, show considerable detail such as dark lanes, arcs of stars and a noticeable asymmetry. It is one of only four globular clusters that have a planetary nebula located within it – Pease-1, which is seen only in apertures of 30 cm and greater. The cluster is also an X-ray source.

Messier 2	NGC 7089	$21^h\ 33.5^m$	–00° 49′	August 14
6.5 m	⊕ 16′		II	Easy

This is a very impressive non-stellar object. It can be seen with the naked eye, although averted vision will be necessary. However, as it is located in a barren area of the sky it can prove difficult to locate. But when found it is a rewarding object, and even in large binoculars its oval shape is apparent. Telescopes will show its bright core, and larger instruments will show several star chains snaking out from the core. Believed to be about 37,000 light-years away and to contain over 100,000 stars.

Stellar Associations and Streams

So far we have discussed groups of stars that can easily be recognized as either an open cluster or a globular cluster, but there exists another type of grouping of stars that is much more ephemeral and spread over a very large region of the sky. In fact, after reading this section you may think that stellar associations are not a further classification of cluster at all but something very different!

A *stellar association* is a loosely bound group of very young stars. They may be swathed in the dust and gas cloud formed within, and continuing star formation is a distinct possibility. But where they differ from open clusters is in their size – they are enormous, covering both a sizable angular area of the night sky and at the same time encompass a comparably large volume in space. As an illustration of this huge size, the Scorpius-Centaurus Association is around 700 by 760 light-years in extent and covers about 80° in the sky.

There are three types of stellar associations:

1. *OB associations*, containing very luminous O- and B- type main sequence, giant and supergiant stars.
2. *B associations*, containing only B-type main sequence and giant stars but with an absence of O-type stars. These associations are just older versions of the OB association, and thus the faster evolving O-type stars have been lost to the group as supernovae.
3. *T Associations*, which are groupings of T Tauri type stars. These are irregular variable stars that are still contracting and evolving toward being A-, F- and G-type main sequence stars. As they are still in their infancy, more often than not they will be shrouded in dark dust clouds, and those that are visible will be embedded in small reflection and emission nebulae (see Chap. 4).

The OB associations are truly enormous objects, often covering many hundreds of light-years. This is a consequence of the fact that massive O- and B-type stars can only be formed within the huge giant molecular clouds that are themselves hundreds of light-years across. On the other hand, the T associations are much smaller affairs, perhaps only a few light-years in diameter. In some cases, the T association is itself located within, or near, an OB association.

The lifetime of an association is comparatively short. As mentioned earlier, the very luminous O-type stars evolve rapidly to become supernovae, and, as usual, the ever-pervasive gravitational effects of the galaxy soon disrupt the association. The coherence and identity of the group can only exist for as long as the brighter components stay in the same general area of a spiral arm, as well as having a similar space motion through the galaxy. As time passes, the B-type stars will disappear through stellar evolution, and the remaining A-type and later stars will now be spread over an enormous volume of space. The only common factor among them will be their motion through space. The association is now called a *stellar stream*. An example of such a stream and one that often surprises the amateur is the Ursa Major Stream.[3] This is an enormous group of stars, with the five central stars of Ursa Major (the Plough) being its most concentrated and brightest members. Furthermore, the stream is also known as the Sirius Supercluster after its brightest member. The Sun actually lies within this stream (more information about this fascinating stream can be found below).

Although there are over 70 stellar associations and streams known to exist, only a handful are visible using the naked eye or amateur telescopes. Nevertheless, they are wonderful objects due to the fact that they cover an appreciable area in the sky and are composed of dozens of stars of naked-eye visibility. In fact they may be among the few deep-sky objects that can be observed without any optical aid. Even if the observing conditions for deep sky work are less than favorable, it should be possible to see these amazing objects.

[3]There is some debate as to whether these five stars are in fact the central stars of an open cluster. If so, it is the nearest to the Solar System at a distance of 75 light-years.

As stellar associations cover such a large area of the sky, it is difficult, and even pointless, to specify a specific set of coordinates for a particular association. Thus, any details listed below will refer to the association as a whole and not just to any one specific star, unless otherwise stated.

The Orion Association 1,600 l.y

This association includes most of the stars in the constellation down to 3.5 magnitude, except for γ Orionis and π^3 Orionis. Also included are several fourth, fifth and sixth magnitude stars. The wonderful nebula M42 is also part of this spectacular association. Several other nebulae[4] (including dark, reflection and emission nebulae), are all located within a vast Giant Molecular Cloud, which is the birthplace of all the O- and B-type supergiant, giant and main sequence stars in Orion. The association is believed to be 800 light-years across and 1,000 light-years. deep. By looking at this association, you are in fact looking deep into our own spiral arm that, incidentally, is called the Cygnus-Carina Arm.

The Scorpius-Centaurus Association 550 l.y

A much older but closer association than the Orion association. It includes most of the stars of first, second and third magnitude in Scorpius down through Lupus and Centaurus to Crux. Classed as a B-type association because it lacks O-type stars, its angular size on the sky is around 80°. It is estimated to be 750 × 300 light-years in size and 400 light-years deep, with the center of the association midway between α Lupi and ξ Centauri. Its elongated shape is thought to be the result of rotational stresses induced by its rotation about the galactic center. Bright stars in this association include θ Ophiuchi, β, ν, δ, and σ Scorpii, α, γ Lupi, ε, δ, and ε Centauri, and β Crucis.

The Zeta Persei Association 1300 l.y

Also known as Per OB2, this association includes ζ and ξ Persei, as well as 40, 42 and o Persei. The California Nebula, NGC 1499, is also within this association.

The Ursa Major Stream 75 l.y

Mentioned earlier in this section, this stream includes the five central stars of the Plough. It is spread over a vast area of the sky, approximately 24°, and is around 20 × 30 light-years in extent. It includes as members *Sirius* [α Canis Majoris],

[4] These nebulae are be described in Chap. 4.

α Coronae Borealis, δ Leonis, β Eridani, δ Aquarii, and β Serpentis. Due to the predominance of A1 and A0 stars within the association, its age has been estimated at 300 million years.

The Hyades Stream

There is some evidence (although it is not fully agreed upon), that the Ursa Major stream is itself located within a much older and larger stream. This older component includes M44, Praesepe in Cancer and the Hyades in Taurus, with these two open clusters being the core of a very large but loose grouping of stars. Included within this are Capella [α Aurigae], α Canum Venaticorum,[5] δ Cassiopeiae and λ Ursae Majoris. The stream extends to over 200 light-years beyond the Hyades star cluster and 300 light-years behind the Sun, and thus the Sun is believed to lie within this stream.[6]

The Alpha Persei Stream 540 l.y

Also known as Melotte 20, this is a group of about 100 stars, including α Persei, ψ Persei, 29, and 34 Persei. The stars δ and ε Persei are believed to be among its most outlying members, as they also share the same space motion as the main groups of stars. The inner region of the stream is measured to be over 33 light-years in length; the distance between 29 and ψ Persei.

Emission Nebulae

Messier 8	NGC 6523	$18^h\ 03.8^m$	–24° 23′	June 22
5.8 m (4.6 m)	• 1–5	⊕ 46|32′		Easy

The Lagoon Nebula is one of the finest emission nebulae in the entire sky, thought by many to be the premier emission nebula of the summer sky and visible to the naked eye on summer evenings. Binoculars will show a vast expanse of glowing green-blue gas split by a very prominent dark lane. Using light filters and telescopes of aperture 30 cm will show much intricate and delicate detail, including many dark bands. The Lagoon Nebula is located in the Sagittarius-Carina Spiral Arm of our galaxy, at a distance of around 5,400 light-years. A favorite for those equipped with CCD cameras.

[5] Capella and a Canum Venaticorum are also thought to be members of the even larger Taurus Stream, which has a motion through space similar to the Hyades and thus may be related.

[6] The bright stars that extend from Perseus, Taurus and Orion , and down to Centaurus and Scorpius, including the Orion and Scorpius-Centaurus associations, lie at an angle of about 1° 5 (?) to the Milky Way, and thus to the equatorial plane of the galaxy. This group or band of stars is often called Gould's Belt.

Messier 17	NGC 6618	18^h 20.8^m	−16° 11′	June 27
6.0 m	• 1–5	⊕ 40|30′		Easy

Also known as the Swan or Omega Nebula. This is a magnificent object in binoculars and is perhaps a rival to the Orion Nebula, M42, for the summer sky. Not often observed by amateurs, which is a pity, as it offers much. With telescopes the detail of the nebula becomes apparent, and with the addition of a light filter it can in some instances surpass M42. Certainly, it has many more dark and light patches than its winter cousin, although it definitely needs an OIII filter for the regions to be fully appreciated. Unlike the Trifid nebula, the stars responsible for nebulae are obscured within the cloud itself. Another celestial object that warrants slow, and careful, study.

Caldwell 20	NGC 7000	20^h 58.8^m	+44° 20′	August 6
4.0 m	• 1–5	⊕ 120|100′		Easy

Also known as the North America Nebula. A famous emission nebula, located just west of Deneb, it is magnificent in binoculars, melding as it does into the stunning star fields of Cygnus. Providing you know where to look and what to look for, the nebula is visible to the naked eye. With small- and large-aperture telescopes details within the nebula become visible, though several amateurs have reported that increasing aperture decreases the nebula's impact. The dark nebula lying between it and the Pelican Nebula is responsible for their characteristic shape. Until recently, Deneb was thought to be the star responsible for providing the energy to make the nebula glow, but recent research points to several unseen stars being the power sources.

–	IC 1396	21^h 39.1^m	+57° 30′	August 16
3.5 m	• 3–5	⊕ 170|40′		Easy ©

One of the few emission nebulae visible to the naked eye (under perfect seeing of course!), and easily spotted in binoculars. It is an enormous patch of nebulosity, over 3°, spreading south of the orange star Mu (μ) Cephei. Any telescope will lessen the impact of the nebula, but the use of filters will help to locate knots and patches of brighter nebulosity and dark dust lanes. Dark adaption and averted vision will all enhance the observation of this giant emission nebula.

–	NGC 1499	04^h 00.7^m	+36° 37′	November 21
6 m	• 1–5	⊕ 160|50′		Easy/moderate

Also known as the California Nebula. This emission nebula presents a paradox. Some observers state that it can be glimpsed with the naked eye, others that binoculars are needed. The combined light from the emission nebula results in a magnitude of 6, but the surface brightness falls to around the 14th magnitude when observed through a telescope. Most observers agree, however, that the use of filters is necessary, especially from an urban location and when the seeing is not ideal. Clean optics is also a must to locate this nebula. Glimpsed as a faint patch in binoculars, with telescopes of aperture 20 cm, the emission nebula is seen to be nearly 3° long. Whatever optical instrument is used, it will remain faint and elusive.

Messier 42	NGC 1976	05^h 35.4^m	–05° 23.5′	December 15
4.0 m	• 1–5	⊕ 85|60′		Easy

Now for the sky's most famous nebula. Visible to the naked eye as a barely resolved patch of light, the Orion Nebula shows detail from the smallest aperture upwards. It is really one of those objects where words cannot describe the view seen. In binoculars its pearly glow will show structure and detail, and in telescopes of aperture 10 cm the whole field will be filled. The entire nebulosity is glowing owing to the light (and thus energy) provided by the famous Trapezium group of four stars located within it. What is also readily seen along with the glowing nebula are the dark, apparently empty and starless regions. These are still part of the huge complex of dust and gas, but are not glowing by the process of fluorescence – instead they are vast clouds of obscuring dust. The emission nebula is one of the few that shows definite color and many observers report seeing a greenish glow, along with pale gray and blue. The British amateur astronomer Don Tinkler has this to say about M42: "The size of M42 always amazes me. Under dark skies it seems endless, with no edge or boundary. A wonderful nebula and a celestial showpiece." It has been reported that with very large apertures of 35 cm a pinkish glow can be seen. Located within the nebula are the famous Kleinmann-Low Sources and the Becklin–Neugebauer Object, which are believed to be dust-enshrouded young stars. The whole nebula complex is a vast stellar nursery, and in fact the stars AE Aurigae, 53 Arietis, and m (Mu) Columbae, believed to have been formed in the nebula, are currently moving away from it at velocities greater than 100 km/s. Such objects are termed runaway stars. Messier 42 is at a distance of 1,344 light-years and is about 40 light-years in diameter. Try to spend a long time observing this object – you will benefit from it, and many observers just let the nebula drift into the field of view. Truly wonderful!

Dark Nebulae

Barnard 59, 65–7	LDN 1773	17^h 21.0^m	–27° 23′	June 11
❐ 6	⊕ 300|60′			Easy

Also known as the Pipe Nebula (Stem) and Lynds Dark Nebula 1773. This is a large dark nebula visible to the naked eye. It is conspicuous because it stands against a star-studded field. Best viewed with lower-power binoculars. With the unaided eye, it appears as a straight line, but under magnification its many variations can be glimpsed.

Lynds 906		20^h 40.0^m	+42° 00′	August 1
❒ 5	⊕ –			Easy

Also known as the Northern Coalsack. This is probably the largest dark nebulosity of the northern sky. It is an immense region, easily visible on clear moonless nights just south of Deneb. It lies just at the northern boundary of the Great Rift, a collection of several dark nebulae that bisects the Milky Way. The Rift is of course part of a spiral arm of the galaxy. To get an idea of what it would look like from a view outside the Milky Way, check out photographs of other galaxies such as NGC 891 in Andromeda.

Supernova Remnant

Sharpless 2-276		05^h 31^m	–04° 54′	December 20
6.5 m?	⊕ 600′			Difficult

Also known as Barnard's Loop. Often mentioned in books, but very rarely observed, this is a huge arcing loop of gas located to the east of the constellation Orion. It encloses both the sword and belt of Orion, and if it were a complete circle it would be about 10° in diameter. Barnard's Loop is currently believed to have originated from a supernova that occurred 2–3 million years ago. In addition, it may also have given rise to several runaway stars that include AE Aurigae, μ (Mu) Columbae and 53 Arietis. It continues to glow due to a group of hot young stars in the Orion OB1 Association.

Observationally, the eastern part of the loop is well defined, but the western part is exceedingly difficult to locate and possibly has never been seen visually, only being observed by the use of photography or using a CCD. Impossible to see through a telescope, recent rumors have emerged that it has been glimpsed by a select few, by using either an OIII filter or an ultra-high-contrast filter. Needless to say, perfect conditions and very dark skies will greatly heighten the chances of it being seen. This is possibly the greatest observing challenge to the naked-eye observer.

Galaxies

Messier 81	NGC 3031	09^h 55.6^m	+69° 04′	February 18
7.3 m [*13.6 m*]	26′| 14′		SA(s)ab	Easy ©

Also known as Bode's Galaxy, this is a spectacular object! In binoculars it will show a distinct oval form, and using high-power binoculars the nuclear region will easily stand out from the spiral arms. Using a telescope will show considerable detail, and it is one of the grandest spiral galaxies on view. With an aperture of about 15 cm, traces of several of the spiral arms will be glimpsed. A real challenge, however, is to see if you can locate this galaxy with the naked eye. Several observers have reported seeing it from dark locations. If you do glimpse it without any optical aid, then you are probably looking at one of the furthest objects[7] that can be seen with the naked eye, lying at a distance of some 12 million light-years. M81 is partner galaxy to M82 (see the information in this book on irregular galaxies), and both these spectacular objects can be glimpsed in the same field of view.

Messier 31	NGC 224	00*h* 42.7*m*	+41° 16′	October 1
3.6 m [*13.6 m*]	3°| 1°		SA(s)b	Easy

Also known as the Andromeda Galaxy and the most famous galaxy in the sky is probably also the most often visited one. Always a first observing object for the beginner it is visible to the naked eye, even on those nights when the conditions are far from perfect. Many naked-eye observers, this author included, claim to have seen the galaxy spread over at least 2½° of sky, but this depends on the transparency. In binoculars it presents a splendid view, with the galactic halo easily seen along with the bright nucleus. Large binoculars may even show one or two dust lanes. Using averted vision and with a very dark sky, several amateurs report that the galaxy can be traced to about 3° of sky in telescopes of aperture 10 cm. In larger telescopes a wealth of detail becomes visible. With an aperture of about 20 cm, a star-like nucleus is apparent, cocooned within several elliptical haloes. Another striking feature are the dust lanes, especially the one running along its northwestern edge. Many observers are often disappointed with what they see when observing M31, as the photographs seen in books actually belie what is seen at the eyepiece. M31 is so big that any telescope cannot really encompass all there is to show. Patience when observing this wonderful galaxy will reward you with a lot of surprises. Spend several nights observing, and try to choose a dark night in a country location. This really is a spectacular galaxy. It contains nearly a trillion stars with a diameter of 130,000 light-years and is among the largest galaxies known. It is the largest member of the Local Group. In older texts it is often referred to as the Great Nebula in Andromeda.

Messier 33	NGC 598	01*h* 33.9*m*	+30° 39′	October 14
5.8 m [*14.4 m*]	70.8′| 41.7′		SA(s)cd	Easy

Also known as the Pinwheel Galaxy, this is famous for several reasons. It is without doubt one of the most impressive examples of a face-on spiral. But at the same time it has a reputation as one of the most difficult galaxies to find. Many

[7] The galaxy M83 lies at the same distance and has reportedly been seen with the naked eye.

amateurs have never seen it, while others have no trouble locating it. The problem arises from its having such a large surface area. Although it has an integrated magnitude of 5.8, it spreads out the light to such an extent that it is very faint. As a result, the galaxy may be all but invisible in telescopes, whereas it will be easily found with binoculars. It will look like a large, very faint cloud, with a slight brightening at its center. In addition, there are several reports of it being visible to the naked eye, and this author can testify to that, as it was strikingly visible from a totally dark sight under perfect conditions, when it was impossible not to see it! In a telescope of aperture 10 cm, several spiral arms can be glimpsed arcing from the very small nucleus. With large telescopes a plethora of detail becomes visible, such as star clusters, stellar associations and nebulae, all located within the galaxy.[8] This truly is a spectacular galaxy.

Caldwell 77	NGC 5128	$13^h\ 25.5^m$	–43° 01′	April 13
6.8 m [*12.9 m*]	18.2′| 14.5′		SOpec	Easy

This famous galaxy is also known as Centaurus A. Although this galaxy is too far south for some northern observers, it nevertheless warrants inclusion because it is so spectacular. Photographs show it as a nearly circular object bisected by a very prominent dark dust lane. Visible in binoculars as a hazy star, with larger binoculars the famous dark lane can just be glimpsed. In small telescopes, aperture 15 cm, the dark lane is easily seen. Larger aperture will of course give a more detailed view, with the dark lane showing some structure. The well-known writer and astronomer Iain Nicolson says about the galaxy, “Centaurus A (NGC 5128) is a magical object, one of those rare extragalactic objects that, when it swims into the field of view, looks just like the photographs that grace the pages of astronomy books. The first time I saw it, it seemed almost to fill the field of view. It’s a beautiful object in its own right: a near-spherical elliptical galaxy with a pronounced dark lane right through the middle. It is especially intriguing because of its status as the nearest active galaxy. To know that this object has a compact core that probably houses a supermassive black hole makes Centaurus, for me, one of the most exciting objects in the sky.” Its peculiar morphology is believed to be the result of a merger between two smaller galaxies.

Extra-Solar Planets

It is sobering to think that in a period of about 15 years our view of the universe has changed so much that we no longer believe that our Solar System is the only one but in fact is just one of many that exist in the Milky Way.

As these words are being written yet another star has been discovered that has planets orbiting it. It is as if there are new solar systems being discovered every

[8] A large HII region, NGC 604, is visible. See the entry under emission nebulae in Chap. 4.

month! Soon, with the advent of larger telescopes and improved image-processing techniques it will only be a matter of time before the first clear and detailed image of a non-solar-system planet is obtained. That will be a very special day. However, until then any indication as to what these new planets will look like will have to come from the minds of artists and scientists (not forgetting amateur astronomers).

Surprisingly many of the stars that have been reported as having planets are quite bright, and so easily within reach of small telescopes. Even though any signs of planets will be absent if these stars are observed, it is still a sobering and also wonderful thing to be able to view them and to think that circling these bright stellar objects are new worlds. And what else besides, one wonders…

One of the techniques used for detecting these planets makes use of the Doppler effect, which is the change in the wavelength of light from an object that is moving away from or towards an observer. The gravitational pull of a large planet orbiting a star causes the star to wobble slightly. When a star wobbles towards Earth, the star's light appears from Earth to be shifted towards the blue part of the visible light. When the star wobbles away from Earth, the opposite effect occurs.

The Doppler shift is proportional to the speed with which the star approaches or recedes from an observer on Earth. Unfortunately the Doppler shift caused by the wobbling of stars with companion planets is very small; the wavelength of the star's light changes by only about 1 part in ten million under the influence of a large, Jupiter-sized planet. For example, the Sun's "wobble speed" is only about 12.5 m/s.

The wobble motion of a star with a planetary companion can provide a great deal of information about the star's companion planet, including an estimate of its mass and the size and frequency of its orbit. The orbital period of a planet (the time it takes the planet to complete one full revolution around its star) is equal to the time it takes the star to finish one wobble cycle. The size of the star's wobble is also proportional to the size of the planet's orbit, and by using Kepler's third law of planetary motion, which states that the cube of the average distance between two orbiting bodies equals the orbital period squared (p^2), the distance between the star and its companion can be determined. Knowing that the orbital period is the same as the period of the star's wobble, one can calculate the average distance between a star and its companion.

Since the first extra-solar planet was discovered in 1989 hundreds more have been discovered,[9] and so to list them all would be impossible. So here are the brightest candidates for observation. A website is given in the appendix of this book that lists up-to-date information on all the planetary systems discovered.

The usual nomenclature is given in the details below, with the addition of the number of suspected planets in the system.

55 Cancri	HD 75732	$08^h\ 52.6^m$	+28° 20′	February 2
5.96 m	5.47 M	G8V	5 planets	41 l.y.

[9] As of autumn 2011, 474 planetary systems had been discovered.

Also known as ρ[1] Cancri. This is one of the so-called "51 Peg" planets (see 51 Pegasi). The star is surrounded by a dust disc extending at least a 40 AU, with an inclination ≈ 25°. Furthermore, there may by a hole with a radius of ~10 AU in the disc. The star has a companion ρ[2] Cancri, about 1,150 AU away.

See also:

Star	Planets	Month
47 Ursae Majoris	3	March

March

47 Ursae Majoris	HD 95128	10^h 59.4^m	+40° 25′	March 7
5.03 m	4.29 M	G0V	3 planets	46 l.y.

These planets are among the few that appear to fit all the current models and theories about planetary formation.

See also:

Star	Planets	Month
70 Virginis	1	April
τ Boötis	1	April

April

70 Virginis	HD 117179	13^h 28.3^m	+13° 46′	April 13
4.97 m	3.68 M	G5V	1 planet	59 l.y.

This planet is so large that it may be reclassified as a brown dwarf. This is an object that is intermediate between a planet and a star. The planet also has a very eccentric orbit, with an eccentricity of 0.4. A value of 0 would be a perfect circle, while a value of 1.0 is a long flattened oval. Mercury and Pluto have the largest eccentricities in our Solar System, with values around 0.2.

τ Boötis	HD 120136	13^h 47.2^m	+17° 27′	April 18
4.50 m	3.53 M	F6IV	1 planet	51 l.y.

This is another of the 51 Peg planets. It is the only system (so far) that has had a probable detection of the starlight reflected by the planet. This, the albedo, is claimed to be detected only in the wavelength range from 456 to 524 nm. The star has a companion (GJ 527B) about 240 AU away.

See also:

Star	Planet(s)	Month
47 Ursae Majoris	3	March
ρ Coronae Borealis	1	May
14 Herculis	1	May

May

ρ Coronae Borealis	HD 143761	$16^h\ 01.1^m$	+33° 18′	May 22
5.41 m	4.18 M	G2V	1 planet	57 l.y.

Recent observations using infrared techniques have led astronomers to believe that there is a circumstellar disc of gas and dust around the star. From the disc inclination (46°) a planet of mass 1.5 that of Jupiter's can be inferred; however, this value differs from other results. The orbital period and amplitude imply a mass of around 1.1 Jupiter masses, and a semi-major axis (which is half the distance across the long axis of an ellipse, usually referred to as the average distance of an orbiting object) of around .23 AU, or roughly half the distance between the Sun and Mercury. In situ formation of such a planet is thought to be unlikely. A more plausible scenario is that the planet formed at several AU from the parent star by means of gas accretion onto a rocky core and then migrated inward. This could have happened by interactions with another giant gas planet that was ejected in the process, through interactions with the protoplanetary gas disc, or by interactions with planetesimals – the building blocks of planets, formed by accretion in the solar nebula.

14 Herculis	HD 145675	$16^h\ 10.4^m$	+43° 49′	May 24
6.46 m	5.32 M	K0V	1 planet	59 l.y.

14 Herculis (Gliese 614) is a star somewhat less massive than the Sun (80%), and its sole planet has a slightly elongated orbit of 4.4 years. Its mass is about 3.3 times that of Jupiter, and it is at a distance of 2.5 AU from 14 Her. This giant planet is twice as close to 14 Her as Jupiter is to our Sun. The content in heavy chemical elements of 14 Her is rather large compared with that of the Sun, a discovery that reinforces the suggestion that giant planets are more frequently observed around metal-rich stars. Heavy chemical elements are needed to form dust or ice particles, and then, by agglomeration, planetesimals and the cores of giant planets. If the quantity of dust is large enough, this is certainly a factor in favor of the formation of giant planets.

See also:

16 Cygni B	HD 186427	$19^h\ 41.8^m$	+50° 31′	July 17
6.25 m	3.40 M	G5V	1 planet	70 l.y.

June

See:

Star	Planets	Month
70 Virginis	1	April
τ Boötis	1	April

July

See:

Star	Planets	Month
ρ Coronae Borealis	1	May
14 Herculis	1	May

The star is a visual binary, and the companion, 16 Cyg A, is about 700 AU away. The planet also has a very large eccentricity, value 0.6, which is causing some concern among astronomers, as they cannot explain it!

August

See:

Star	Planets	Month
51 Pegasi	1	September
Formalhaut	1	September

September

51 Pegasi	HD 217014	$22^h\ 57.4^m$	+20° 46′	September 5
5.49 m	4.52 M	G5V	1 planet	50 l.y.

This is a peculiar type of system characterized by orbital periods shorter than 15 days. The orbits are small, with radii less than 0.11 AU, which is about a tenth the distance between Earth and the Sun. Such an orbit is in fact much smaller than that of Mercury's (radius 0.38 AU, period 88 days). However, these planets are similar in mass to that of Jupiter and in some cases even larger. Research indicates that the planets have circular orbits. The 51 Peg planets are a problem because they do not fit current planet formation theory. This predicts that giant planets like those in our Solar System (Jupiter, Saturn, Neptune and Uranus) should be formed in the colder, more distant parts of a proto-planetary disc, some 5 AU from a star. It seems that a possible solution to this problem may be the rotation of a young star. Such a star spins very rapidly, perhaps making one complete revolution in about 5–10 days. As a planet approaches the star, tides will be raised on the star. However, the star is spinning quicker than the planet orbits around it, and so the bulge caused by the planet on the star will move in front of the motion of the planet, rather than staying directly in line with the planet. The net result will be that the gravitational pull from the tide on the star pulls the planet closer. The temperature of the planet is calculated to be in the range of 1,200–1,400 K.

Formalhaut	Pisces Austrini	22^h 57.6^m	–29° 37′	September 5
1.16 m	1.74 M	A3 V		25.07 l.y.

This system is important in extra-solar planetary research for two reasons. The star is surrounded by a dusty torus of material, often referred to as Formalhaut's own "Kuiper Belt" and is believed to be a proto-planetary disc. In addition, a planet was located just within the dust ring and was the first ever to be seen in visible light, when the Hubble Space Telescope imaged it on November 2008.

See also:

Star	Planets	Month
υ Andromedae	4	October

October

υ Andromedae	HD 982	01^h 36.8^m	+41° 24′	October 15
4.1 m	3.45 M	F8V	4 planets	44 l.y.

This is another of the 51 Peg-type planets and was the first multiple-planet system discovered. formation of these planets has posed several problems. The usual picture is that gas giant planets form at least 4 AU away from a star, where temperatures are low enough for ice to condense and start the process of planet formation, but all three giant planets around Upsilon Andromedae now reside inside this theoretical ice boundary.

See also:

Star	Planets	Month
51 Pegasi	1	September
Formalhaut	1	September

November

See:

Star	Planets	Month
υ Andromedae	4	October

Appendix A

Books, Magazines and Organizations

There are many fine astronomy and astrophysics books in print, and to choose among them is a difficult task. Nevertheless the few selected here are among the best on offer. You do not need to buy, or even read, them all, but it would be in your best interests to check at your local library to see if they have some of them.

Star Guides and Reference Books

Norton's Star Atlas & Reference Handbook, I. Ridpath (Ed.)
Sky Atlas 2000.0, W. Tirion, R. Sinnott, Sky Publishing & Cambridge University Press
Millennium Star Atlas, R. Sinnott, M. Perryman, Sky Publishing
Observing Handbook and Catalogue of Deep-Sky Objects, C. Luginbuhl, B. Skiff, Cambridge University press
The Night Sky Observer's Guide, Vols.,I II, and *III* G. Kepple, G. Sanner, Willman-Bell
Deep-Sky Companions: The Messier Objects, S. O'Meara, Cambridge University Press
Deep-Sky Companions: The Caldwell Objects, S. O'Meara, Cambridge University Press
Deep-Sky Companions: Hidden Treasures, S. O'Meara, Cambridge University Press
Herschell 400 Observing Guide, S. O'Meara, Cambridge University Press
The Caldwell Objects and How To Observe Them, M. Mobberley, Springer

M.D. Inglis, *A Field Guide to Deep-Sky Objects*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4614-1266-3,

Nebulae and How To Observe Them, S. Coe, Springer
Double and Multiple Stars and How To Observe Them, J. Mullaney, Springer
Galaxies and How To Observe Them, W. Steinicke & R. Jakiel, Springer
The Herschel Objects and How To Observe Them, J. Mullaney, Springer
Star Clusters and How To Observe Them, M. Allison, Springer
Atlas of the Messier Objects, R. Stoyan et al. Cambridge University Press
Burnham's Celestial Handbook, R. Burnham, Dover Books

Astronomy and Astrophysics Books

Amateur Astronomer's Handbook, J. Sidgwick, Pelham Books
Astrophysical Techniques, C. Kitchin, Institute of Physics
Telescopes & Techniques, C. Kitchin, Springer-Verlag
Discovering the Cosmos, R. Bless, University Science Books
Discovering the Universe, W. Kaufmann, N. Comins, Freeman
The Cosmic Perspective, J. Bennett, M. Donahue, N. Schneider, M. Voit, Addison Wesley
Voyages Through The Universe, A. Fraknoi, D. Morrison, S. Wolff, Saunders College Publishing
Introductory Astronomy & Astrophysics, M. Zeilik, S. Gregory, E. Smith, Saunders College Publishing
The Physics of Stars, A. Phillips, Wiley
Stars, Nebulae and the Interstellar Medium, C. Kitchin, Adam Hilger
Galaxies and Galactic Structure, D. Elmegreen, Prentice Hall

Magazines

Astronomy Now
Sky & Telescope
New Scientist
Scientific American
Science
Nature

The first three magazines are aimed at a general audience and so are applicable to everyone; the last three are aimed at the well informed layperson. In addition there are many research-level journals that can be found in university libraries and observatories.

Organizations

The Federation of Astronomical Societies
[http://www.fedastro.org.uk/fas/]
Society for Popular Astronomy
[http://www.popastro.com/]
The British Astronomical Association
[http://britastro.org/baa/]
The Royal Astronomical Society
[http://www.ras.org.uk/membership.htm]
Campaign for Dark Skies
[http://www.britastro.org/dark-skies/]
International Dark-Sky Association
[http://www.darksky.org/]
The Astronomical League
[http://www.astroleague.org/]
The Webb Deep-Sky Society
[http://www.webbdeepsky.com/]

Index

N

O

P