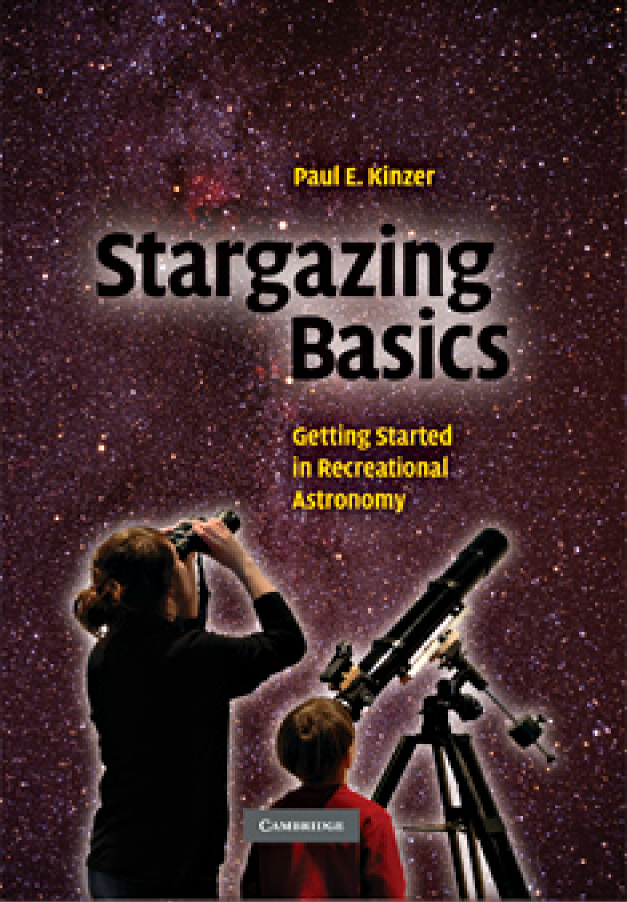

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Stargazing Basics
Getting Started in Recreational Astronomy

How do I get started in astronomy?
Should I buy binoculars or a telescope?
What can I expect to see?

This wonderful informal guide to astronomy has all the information an absolute beginner needs to get started. It starts by explaining the basic techniques and equipment you need for exploring the night sky, from observing with the naked eye to using binoculars and telescopes. It then takes you on a tour of the night sky, covering the Moon, Sun, stars, planets, and more. Any necessary technical terms are clearly explained.

In this book the author gives sound advice on using and purchasing affordable binoculars, telescopes, and accessories, and describes what is in the sky, and how and why it changes over time. The book is illustrated with photos taken by the author, showing how objects in the sky actually look through modest amateur equipment. It contains a comprehensive glossary and references to further astronomy resources and websites.

Whether you are a parent thinking of buying a telescope for your children, or a newcomer yourself, this book has all you need to know to take the first steps into the fascinating world of astronomy.

PAUL E. KINZER has many years' experience as an amateur astronomer and educator. He currently runs his own small business, traveling to schools and other venues with a Starlab portable planetarium, to share his knowledge of the night sky with groups of all ages.

Stargazing

Basics

Getting Started in Recreational Astronomy

Paul E. Kinzer

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To Wina and Bjorn

Contents

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Introduction: why another stargazing guide?

I had been an armchair astronomer for years: I loved reading about science, and I had some general knowledge about the Universe and how it works. However, I knew little about the actual night sky as it appears above the Earth, and I had never owned a decent telescope.

Then, in 1995, I started a nature program for urban nine- to twelve-year-olds. For the program, I bought a good Nikon “spotting scope”: a small telescope made primarily for viewing birds and other Earth-bound objects (see Figure 1). On an overnight camping trip, I aimed the telescope at the Moon, so the kids could see the detail: craters, mountains, and “seas.” The children were amazed, since most of them had never really seen the Moon before. I was impressed, because the telescope gave excellent views: the images were very sharp. But I had seen the Moon through binoculars, and it was familiar enough that it was not as thrilling for me as it had been for the children.

After the kids were asleep in their tents, I used the telescope again. The sky was very dark once the Moon had set, and I looked at fields of stars in the Milky Way for some time. Then I aimed the scope at a bright yellow star. I was not expecting much: stars are so far away that they appear

Figure 1 Spotting scopes, though designed for terrestrial (Earth-bound) use, can be useful for wide views of the nighttime sky. This model, with its angled eyepiece, provides comfortable upward viewing.

Figure 2 Even a small telescope can show the detail seen here when viewing Saturn; and the "live" view seems much more three-dimensional.

only as sharp points in even the largest telescopes. But this "star" had *rings*: I was looking at the planet Saturn!

I had known, of course, that Saturn was up there in the sky somewhere. I had also seen more detailed views of it in satellite photographs. But here it was, real and bright and sharp; a ringed ball floating in space right before my eyes! I had no idea that so small a telescope could show it so clearly; and I had just stumbled upon it, like a jewel on the beach.

Well, that was it: I was hooked. As soon as I could afford it, and after much research – often confusing and contradictory – I bought a larger telescope, on a sturdy mount that was better for astronomy. Though I have been finding more jewels ever since, I am still continually amazed at just how much I can see through a fairly small scope.

Until I actually started doing it, there was something about stargazing that I would not have guessed. It is *much* more satisfying to find objects myself than it is to look at a photograph in a book or magazine. To see the real thing. To know that the light hitting my eye actually left the object up there, and that that light may have traveled countless trillions of miles and, possibly, millions of years, seemingly just for me to find it. Of course, the light would have come even if I was not there to catch it, but each new catch is, literally, wonderful to me.

Others agree. It is always fun to see the happy, dumbstruck look on people's faces when *they* see Saturn (or Jupiter, or a close-up view of craters on the Moon, or a galaxy) for the first time through my telescope. They are filled with excited questions afterwards; and, at least for a little while, they are hooked, too.

Many of these people ask a particular question: can I recommend a single, basic book to help someone who is an absolute beginner get *started* in recreational astronomy?

Well, I know of many great books. Some were especially written to explain the make-up of the Universe. Others were written to help people learn the constellations and the night sky, and how they change through the night and year. Still others were written to help people choose and buy astronomy equipment. And a few do all of these things, thoroughly and well.

However, it has seemed to me that many people who have looked through my telescope want something that is more basic than what these books offer. They want a *simple* outline that will provide them with all the necessary information to make a good beginning, both on what is "Up There" and on the techniques and equipment used to view it; but not so much information that they will be overwhelmed or intimidated. (There is an amazing amount of jargon in astronomy publications, which often goes unexplained.)

In other words, I believe there is a need for a sort of road map that will allow people to get to a place where they can dip their toes into recreational astronomy before deciding whether to take the plunge. For someone who is enthusiastic, yet knows little, getting started can be a daunting job. It is for these people, and I think there are a lot of them, that I have written this guide.

What this guide is

Stargazing Basics is meant to be a starting point. I hope it will provide enough information to allow just about anyone to get started in recreational astronomy, or stargazing. The guide is divided into three sections:

First, Part I, "Stargazing techniques and equipment," starts with a brief description of how the night sky "works," and goes on to explain what the novice will need to view it; whether with eyes alone, binoculars, or a telescope. Since this is a guide for beginners, the equipment discussed is of small to moderate size, and relatively inexpensive.

Part II, "What's up there?", is a brief tour of the Universe that is observable to the beginner. We start nearby, in astronomical terms, and head outward.

More info boxes will appear along the way in both of the first two sections. These contain information which may add meaning to the main text, but which might be distracting if contained within it. The first two parts also have *Resources* sections at various points. These are references to equipment, books, magazines, websites, and organizations that can provide more information and assistance.

Finally, as you read these first two parts, you will notice that many words and phrases appear in **bold** print the first time they appear. These terms are described in alphabetical order in Part III, "A stargazing glossary." They are terms that may be commonly used in other publications, but not always clearly defined for a beginner. They may also be explained in the main body of the guide, but I thought it would be helpful to point out that clear, simple definitions are readily available for easy reference at a later time. If you see an unknown term, try looking it up in the Glossary.

What this guide is not

This guide is not "a complete guide." It may lead you toward completion, but it is not meant to be the only resource you need.

This guide is not really meant to be taken into the field. Simple star charts are included, but anything more would have made the book too expensive. Besides, there are already many good books specifically designed to show the detailed layout of the night sky, and it is possible to get up-to-the-minute sky maps from the Internet, which show the night sky as it will look from your exact location on Earth.

This is also not a complete guide to equipment buying. Astronomy can be both the least and most expensive of hobbies, and this guide emphasizes the least. If you are wondering whether you should buy that wide-field apochromatic refractor, or a 20″ Dobsonian reflector instead, then this book is not for you!

This guide is, finally, not very long. Too much information can be both confusing and intimidating to someone who is unfamiliar with a topic. I have tried to include only what the beginner may need or want to know at the very beginning.

Part I
Stargazing techniques and equipment

If you asked most people to name the one thing that is most needed by someone who is just starting out in **astronomy**, they would almost certainly say "a **telescope**." And if you then asked them to name the most important thing to look for when choosing that telescope, the answer – if there was one – might be "power" (as in **magnification**). The first answer is definitely questionable, and the second answer is simply wrong.

Many people believe both answers, and who can blame them? How would they know any differently? Few people have had any education in the understanding of amateur astronomy and its equipment, and cheap-telescope distributors know it.

Here is a typical experience from not so long ago:

A certain young person looked through a telescope on a camping trip one night, and became interested in the idea of pursuing this hobby (as many people do after looking through a *good* telescope). It seemed, to this person, only natural to think that the first thing to do was to buy his own telescope. He remembered seeing them in department stores, camera dealers, and at a gift shop in a museum. He went to one of these places and asked someone to help him, only to find that there was no one there who could. So all he had to go on was the information provided on the telescope packaging. All the boxes had large, bold print, boasting of things like "magnifications up to 600x!"

He bought the one with the "highest power" and took it home. That night, he set it up in his suburban backyard. He looked up at the sky, but wasn't sure where to aim the new scope. "Where's the **Moon**?" he wondered. Four nights ago, at the campground, he had looked through a telescope at the Moon. His friend had said it was just past full.

Oh, well. He had also looked at the **planet Jupiter**, and it had been amazing. He was almost certain it was that bright "**star**" up there. But where were all the other stars? He knew the city lights washed some of them out, but only now did he see how few were visible. Anyway, he tried to aim the telescope at what he thought was Jupiter, but the **finder scope** was next to impossible to adjust, or even to see through, and the telescope would not

Figure 3 An example of a telescope that is not very "powerful," but still very useful for astronomy.

stay where he aimed it because the **tripod** was too shaky. When he finally got the object in view, it would not come into clear focus, no matter what he did. It was a dim, fuzzy ball. It was not worth looking at, which was lucky, because just being near the telescope seemed enough to make the image bounce all over. And it kept moving out of the **field of view**. He felt like he had done something wrong, and was so frustrated that he packed the telescope up and never used it again.

This has been the first – and last – experience that many people have had with astronomy. It is, more or less, a description of *my* experience as a teen. Many of the problems I had were caused by my lack of knowledge, all of which will be explained by the end of this book. But if I had managed to get a steady, sharp view of Jupiter for even a few seconds, I might have tried harder to overcome my ignorance. Unfortunately, the "starter" telescopes sold at many stores are often just cheap junk.

However, there is good news: new technologies, and many new manufacturers and distributors, have led to keen competition, which has resulted in an improvement in quality, and the lowering of prices. Even department stores now often carry inexpensive, yet decent, beginner's equipment. (But beware: there is still plenty of junk!)

Figure 4 A very suspect claim. The telescope that came in the box with this printed on it, purchased at a well-known national chain store in the USA in 2007, could not produce *sharp* images even at its lowest magnification, 40×.

This first section of the guide discusses the selection of a first telescope. Having a little knowledge ahead of time will be a big help in avoiding disappointment.

However, there is much to getting started in stargazing that can come before the selection of a telescope. In fact, a telescope is not even a necessity for exploring and enjoying the night sky. Binoculars, and even your unaided eyes, can show you many wonderful sights! If I had known this as a teen, I could have saved a lot of money and disappointment. I might also have stuck with the hobby, instead of waiting decades to rediscover it.

With the naked eye alone 1

Note: It may be that the information presented in this first section would more properly fit in "Part II: What's up there?" But I wrote the guide with the idea in mind that people would probably read it from beginning to end. It seemed to me, then, that a very basic description of the night sky – as a whole – would be very helpful right at the start.

People have been looking up and pondering the night sky since – well, since there have been people. Every culture in the world, both past and present, has studied and tried to explain what is up there. However, until **Galileo Galilei**, in 1609, took a small telescope and aimed it upward, all others who had studied the stars used just their eyes.

Exploring the night sky with a telescope is made much easier if a person has at least some knowledge of the layout of the heavens. But it is also a great pleasure in itself to just lie back and look up at the wide expanse of the "starry bowl." It looks essentially the same as when ancient cultures named the stars and **constellations**, many of which have had the same names since before recorded history began (see Appendix 2 for a complete list).

More info

It is not strictly true that astronomers before Galileo used only their eyes to study the heavens. They had various devices for accurately measuring and mapping the positions of the stars. They made charts with the information gathered, which were used in surveying, and, especially, navigation. But none of these devices magnified the view.

The Celestial Sphere

Because this is a *simple* guide, and because there are excellent books devoted entirely to teaching the positions, names, and lore of the stars and constellations, I will not go into such detail here. However, a basic understanding of how the sky "works," how it changes over time (and how it does not), is very helpful to the beginning stargazer.

Amateur astronomers divide the Universe into two broad regions: the **Solar System** (containing the planets, their moons, and other objects under the gravitational influence of the **Sun**); and the **deep sky**, which contains everything beyond the Solar System. (It should be said that the term **deep-sky object** is often used by astronomers to describe all the objects

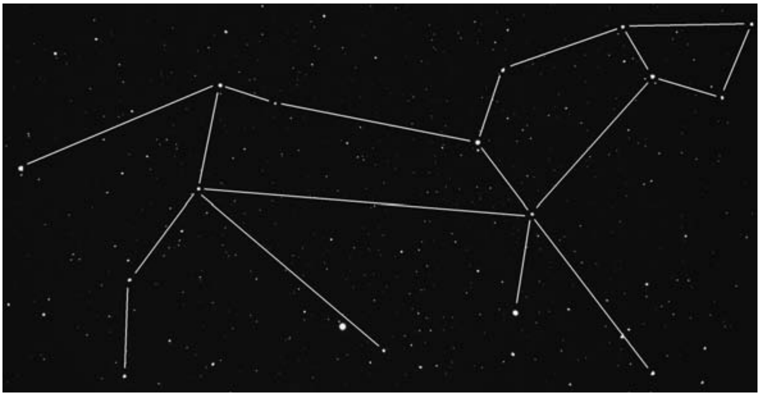


Figure 1.1 The constellation Leo, the Lion, actually looks like the creature it is meant to represent. This is definitely not the case with some other constellations. In this photograph, taken in 2008, one of Leo's rear legs seems to be stepping past the bright planet Saturn.

outside the Solar System *other than* stars. Still, stars *are* part of the deep sky. This possibly confusing point is made clear in Part II.)

The reason for separating these groups is this: all deep-sky objects are so far away that they seem, in a way, to be frozen in place in the sky. They may rise and set as the **Earth** spins, and they may also change position as the Earth **orbits** (travels in a near-circular path around) the Sun, but *they do not noticeably change position relative to each other*. In other words, the **Big Dipper** is the Big Dipper, whether it is this year or next, winter or summer, midnight or 3:00 am (or noon, for that matter). There is, it seems, a large unchanging bowl of stars hanging above our heads at night. The ancients named it the **Celestial** (or Heavenly) **Sphere**.

In contrast, all objects in the Solar System are close enough to us that they do not keep the same positions upon the bowl of heaven. Before the use of telescopes, only seven *planets* (the word originally meant *wanderer*) were known: the Moon, the Sun, **Mercury**, **Venus**, **Mars**, Jupiter, and **Saturn**. They were called wanderers because they, unlike the stars, crawled *across* the celestial dome. The motion cannot usually be seen from moment to moment, but it is there.

The ancients did not know it, but *we* now know that the planets, including the Earth, and the thousands of other objects within the Solar System, all orbit the Sun. We also know that they are far closer to us than any of the stars or other deep-sky objects.

Why is all of this important? Because it means that we can make maps of the deep sky, and that these maps can be used for decades to find interesting and beautiful

More info

I find it curious that it was not until the advent of the telescope that the planet **Uranus** was discovered. It is very dim, but it is visible to the naked eye, if you look in the right spot under dark skies. And since it moves across the sky, I am surprised that no one noticed this planet before **William Herschel** saw it through his telescope in 1781.

More info

Here is a basic description of why the sky changes through the night, as well as through the year. The Earth turns on its **axis** once every day. That means it spins around like a top. So objects in the sky seem to rise in the east and then set in the west, though it is actually the Earth that is turning.

The Earth also orbits the Sun. It completes a circle around our own star once in a year, or 365.24 days. A circle is divided into 360 **degrees**, so we travel about one degree a day around our orbit. (This is probably not a coincidence. The practice of dividing circles into 360 degrees dates back thousands of years, to the Babylonians, or even further. Their calendar also divided the year into 12 months, each 30 days in length, for a total of 360 days.) This means that, if you were to look at the sky *at the same time on the clock* over several nights, the bowl of the sky would seem to revolve about one degree to the west each night, or about 30 degrees in a month. Furthermore, the spinning of the Earth on its axis causes the sky to turn 15 degrees in an hour.

This is all confusing at first, but once you understand it, you will have a much easier time searching for things in the sky. And, of course, this is just an explanation for the movement of the deep sky; Solar System objects each move in their own paths (but more on that later).

The drawing below (Figure 1.2) shows that some objects, like the constellation **Orion**, are visible in the evening sky in December, but are in the sky during the day, and overwhelmed by the light of the Sun, in June. Others, like the “Teapot” shape seen in the constellation **Sagittarius**, appear at night in June, but are invisible in December.

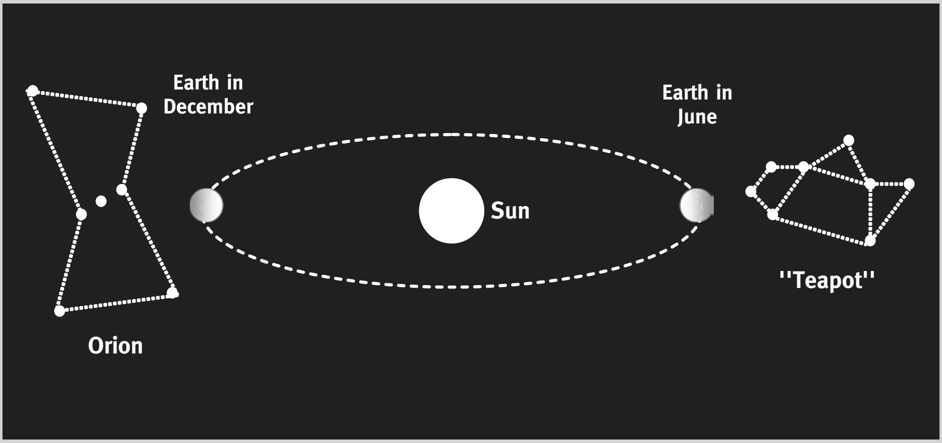


Figure 1.2 Orion and the Teapot.

things to study. But finding objects in the Solar System must be done differently, since they change position so quickly. Luckily, the most interesting planets to look at are bright enough that they are usually fairly easy to locate.

Making the most of the "wide-eye" view

If you want to look with unaided eyes at the whole sky (or, for that matter, any part of it), here are some tips:

- *The first thing to do is to get as far away from artificial light as you can*. **Light pollution** is a serious and growing problem, and it gets more difficult every year to find truly **dark sites**. Still, it can be done, and must be, if you want to pursue astronomy at its best, whether with the eye or the largest telescope in the world. There are certainly some things that can be studied from the brightest of places (the Moon and the brighter planets), but to enjoy the sweep of the whole night sky you should go where the most can be seen. (To learn more about light pollution, and the fight against it, visit the **International Dark-Sky Association** at www.darksky.org.) If it is possible, go to a higher elevation as well, since this will put you above some of the **atmosphere** that blocks and distorts the incoming light.
- *Plan your viewing for a night when the Moon will set early or rise late*. The Moon is fascinating, but only for a short while as a naked-eye object, and its light washes out that of less bright things (meaning everything else in the night sky!)
- *Dress appropriately*, both for the *weather*, and for the possibility of unwelcome guests: *insects*. Layers work well. Since the temperature will probably drop as the evening progresses, it is good to have more clothing to put on. And being virtually motionless for long periods of time requires you to dress more warmly than you might think. Being still also makes you a prime target for bugs, so go prepared!
- *Bring something comfortable to sit on*, *or better yet, for reclining, or lying down*. A lawn chair, an air mattress, a blanket or sleeping bag – all of these are great choices.
- *Be prepared to let your eyes adjust to the darkness*. It takes about half an hour for the human eye to become totally dark-adapted. If you look into headlights, or a bright flashlight, even for a second, be ready to start that half hour over again.
- *Try, for at least part of the time, to not look at a particular object in front of you, but to take in as much as is in your field of view as possible*. I used to tell the children I worked with to use their "wide eyes" when looking at the whole sky. Naked-eye stargazing is best for wide swaths of sky.

To make the experience more interesting, you may want to take a couple of items along. First, in order to know just what you are looking at, you may want a **planisphere** (see Figure 1.4 on page 15). This is an inexpensive device that shows you what will be visible in the deep sky at any hour of any date of the year. Of course, it can only contain a few hundred objects, at best, on its small surface. Practicing with it ahead of time can really make the changing (as in rotating) sky more easily understandable. Astronomy dealers sell them, and they can also be found, often for under $10, at book stores in the science section, or at museum gift shops. It is also possible to design and print out your own (see the *Resources* section on page 15).

A red **LED** (light emitting diode) flashlight is another handy item to have, if only to read your planisphere. Red light does not affect your night vision nearly as much as ordinary white light. Such LEDs are available from astronomy dealers, but I have also seen them at department stores. It is also possible to tape red plastic over a regular flashlight, but if it is too bright, even red light can ruin your night vision.

By the way, these tips will also be helpful when using **binoculars** or a telescope.

What might you see?

On any given night, you can study the *constellations*. Astronomers have divided the entire sky into 88 distinct sections that are recognized around the world. Most of these constellations were given to us by ancient cultures, but some came from explorers of later centuries. (The "official" names and boundaries, used and recognized internationally by professional astronomers, were not set until 1930.) The stories behind them are fascinating, and learning some of the lore adds something to the actual seeing. Of course, other cultures have divided the sky into their own constellations, and looking for these is also an interesting possibility. However, if you get to know the "map of the sky" that is used by the professionals, it will make finding objects up there *much* easier, whether with the naked eye, or a powerful telescope.

Under even fairly dark skies, you are likely to see a few **meteors** on any given night (and many more during a **meteor shower**). You will be able to see the brighter parts of the **Milky Way** (our own home **galaxy**, see Figure 1.3). If the Sun is "active," you may see **aurora** (the Northern or Southern Lights), if you live far enough north or south. If you know where to look, you can see **nebulae**, up to five (or six?) planets, and even another galaxy or two.

Of course, what you will see mostly is stars: thousands of stars. Though some brightly lit cities now only have a few visible, it is still possible to view virtually countless stars, if you can get to the right place.

However, if you are lucky, the best thing about getting out under a dark sky and looking up will not be what you *see*, but what you *feel*. Even

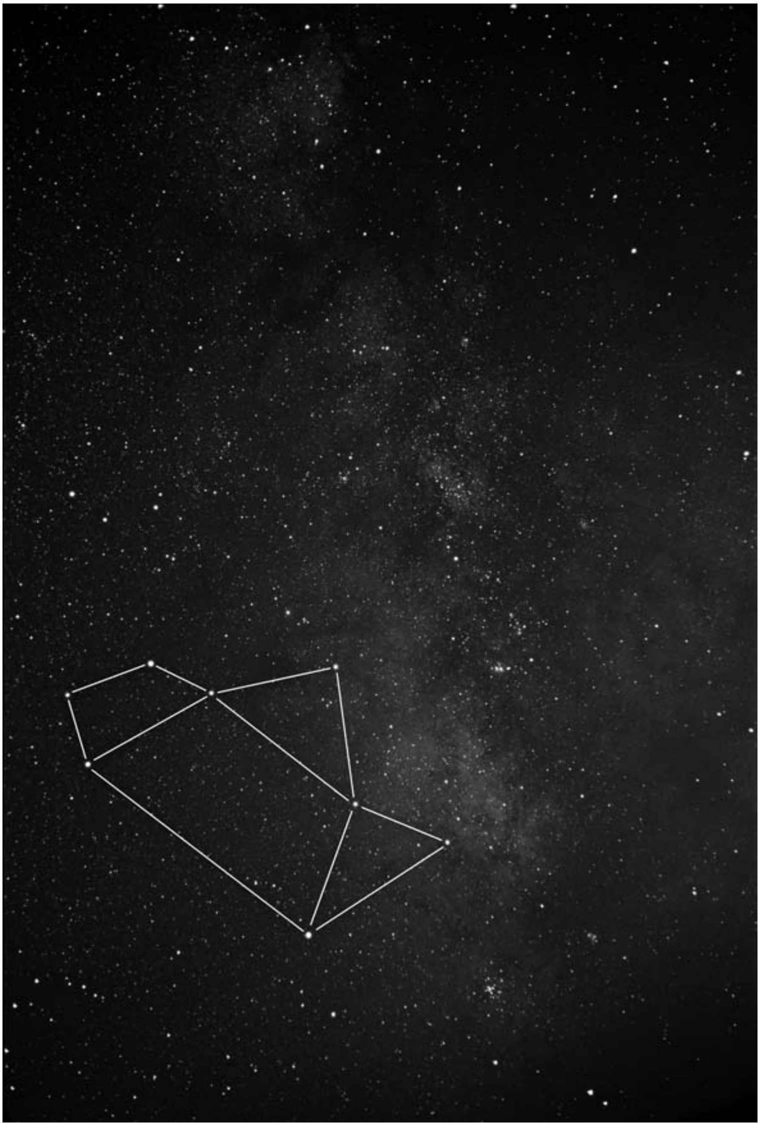


Figure 1.3 The clouds of "steam," seemingly rising here from the teapot shape in the constellation Sagittarius, are actually countless stars contained in the disc of our own galaxy, the Milky Way (the center of which is just off the "spout" of the teapot). These clouds of stars are clearly visible under dark skies.

though I have been exploring it for years, there are still times when I am nearly overwhelmed by the experience of the night sky. The Universe is vast beyond real comprehension; but sometimes, for no reason I can explain, it – or something in me – seems to open up, and I am chilled with joy. I can never predict when these moments of epiphany will strike, and they never last long, but I look forward to them: they bring me back to childhood, when everything seemed new and amazing.

Resources

Books

The Stars: A New Way to See Them, by H.A. Rey. Houghton Mifflin, 1976.

There are many good books devoted to teaching an understanding of the constellations and the workings of the celestial sphere, but I know of no better one for the beginner than this. Rey was the creator of the "Curious George" picture books for children. He was also an avid stargazer himself, and an excellent illustrator. This book was originally published more than 50 years ago, and some say it was written for children. But I did not read it until I was an adult, and it helped me get my mind around some concepts which other books had not. It is full of information that is explained simply, and very clearly and cleverly illustrated.

Websites

The Internet changes rapidly, and I hesitate to include specific sites, but some seem destined to last because they are so popular and useful. One of these is a site called cleardarkskies.com. It was created to give amateur astronomers in northern North America weather forecasts for the skies above their observatories or preferred viewing sites. It can also help anyone in this region find dark sites from which to observe, and to know what the weather will be like at that location up to 48 hours in the future.

Figure 1.4 Everything you need to begin at the beginning: A good planisphere; *The Stars: A New Way to See Them*, by H.A. Rey; a red LED flashlight; and a soft lawn for reclining under wide, dark skies.

Another great site is heavens-above.com. This website is full of fun stuff. Once you enter a town near your astronomical viewing location, you can call up a **star chart** for that site, for any time or date you like. And unlike a normal planisphere, this chart will show the location of the planets and the Moon, as well as a map of the entire visible sky. The site also has great information on Earth-orbiting **satellites**, **comets**, and more.

It seems a little unfair to single out only these websites, since there are literally thousands more that would be useful to stargazers. Just do a web search for an object or area of interest, and you will get more information than you can possibly use. This is one more reason for the increasing popularity of the hobby. Here are a few more sites to get you started, each of which should be around for some time. I include them because they are written, to an extent, with beginners in mind, and because each contains regularly updated information and links to more information:

antwrp.gsfc.nasa.gov/apod/ (Astronomy Picture of the Day)

www.SkyandTelescope.com

www.SpaceWeather.com

Software

Planispheres are designed to be used in particular regions of the world. Going east or west does not matter, but shifting north or south causes changes in what can be seen in the sky, and in what should be shown on a planisphere. If you live in Sweden, you cannot use a planisphere meant for people in New Zealand. *Planisphere* is a free, downloadable program that you can get by going to the web address nio.astronomy.cz/om/. It allows you to create a planisphere for your own place on the planet, though it does not cover the whole world.

If, by the time you read this book, this particular website has disappeared (as so many of them do), try doing a web search for “free planisphere software.” That is how I found this excellent program.

Binoculars: the next step 2

The human eye, under truly dark skies, can see a few thousand stars. We can see so many because, where there is no artificial light to interfere, the eye's **iris** contracts to its smallest size, allowing the **pupil** to open to its widest **diameter**. This allows the maximum amount of light to enter and shine upon the **retina**, the light-gathering area in the back of the eye.

Yet why do we only see a few thousand stars, when there are hundreds of billions in our own galaxy, and billions of galaxies? Because the human eye's pupil can only open to a diameter of about seven millimeters (a little more than a quarter inch). As we get older, this usually decreases to about five millimeters (about a fifth of an inch).

Why is this important? Because, contrary to what most people think, it is this small opening that primarily determines how much we can see in the night sky, *not* magnification. Most stars and other objects are simply too *dim* to be seen by the human eye. A larger **aperture** (usually expressed as the diameter of a light-gathering surface, but actually its **area**) is the key thing, for two reasons: it allows dimmer objects to be seen by gathering more light over a wider area, and it also causes objects to be seen more clearly (see *More info – Comparing apertures*, on page 20). The first seems obvious, the second less so; but both are true. **Nocturnal** animals have large eyes for good reasons!

Figure 2.1 Binoculars come in a wide range of shapes and sizes. Any of these would enhance the view when compared to the eye alone, but some choices are better – much better – than others.

However, so far anyway, *we* are stuck with the eyes we were born with. So how do we increase our apertures? With telescopes! The large **lenses** or mirrors of telescopes gather light and concentrate it for delivery to the eye. And the best and easiest telescopes to begin with are binoculars.

Why binoculars?

Binoculars are a good beginning choice for stargazing for many reasons:

1. *Many people already have them* for other purposes; so, for these people, there is no cost involved.
2. If you do not have them, a good pair is *not terribly expensive*.
3. They are *very portable;* just put them around your neck, and you are ready to go.
4. They are *easy to use*: just lift them to your eyes and focus.
5. Many people find that *using two eyes is more comfortable*, and some report that they can actually see more stars when using both eyes.
6. They show a ***correct image***. Astronomical telescopes may show images that are upside-down, inverted left to right, or both, depending on the equipment used. This can take getting used to. Binoculars, because of their special **prisms**, show images of things as they actually appear in the sky, or on star charts.
7. They give *low magnification for steadier views*. If you magnify an object by a given amount, you magnify any vibrations by an equal amount. Low magnification is why binoculars can be steadily hand-held.
8. Though they have low magnification, the large apertures of binoculars can take you from seeing a few thousand to *more than 100,000 stars*.
9. Binoculars are also a good starting place because *you will never move entirely beyond them*. No matter how large a telescope you may someday own, you will always want a good pair of binoculars. Why? First, because they are so easy to use, you will use them more often than a telescope, which takes time to set up. But, more importantly, because there are some things that are better viewed through binoculars than with either the naked eye or a telescope.

Some objects in the sky are too small or dim to be seen without some aid, but fill too much sky to be viewed with the higher magnification of a telescope. Binoculars are the perfect step between the eye and the astronomical telescope.

> **More info...**
>
> Here are just a few binocular targets (items seen well or best through binoculars): Some comets, the whole Moon, the **Andromeda Galaxy**, many **open star clusters**, some large, bright nebulae, and Milky Way star fields.

Selecting binoculars for astronomy

If you already own a pair of binoculars, they may be very useful for stargazing, or they may not. Binoculars are almost always described and labeled with two numbers: 10 × 25, 7 × 35, 8 × 42, 10 × 42, 10 × 50; these are some common combinations. The first number is the *magnification*, or how many times larger an object will appear when viewed. The second number is the *aperture*: the diameter, in millimeters, of the **objective lens**. There are at least two important features you should consider when choosing binoculars for astronomy: *aperture* and ***exit pupil***.

In astronomy, a larger aperture means brighter, sharper images; so it would make sense to get the largest objective lenses possible. However, since using binoculars requires you to hold them steadily for long periods of time, weight is also important. Large apertures mean more weight. So a personal balance must be found.

The second thing to consider is the exit pupil. This is the size of the circle of light that leaves the **eyepiece**. It can be measured, but if you know the numbers, it is easier to just figure it out: divide the aperture by the magnification. So, for 7 × 35 binoculars, you get 35 (the aperture in millimeters) divided by 7 (the magnification) equals an exit pupil of 5 mm.

The exit pupil matters because it is best that the light entering the objective lens is used most efficiently by the eye. If the exit pupil is too large, you will have to move your eye around to see the entire view; if it is too small, the light-collecting surface of your dark-adapted eyes will not be entirely used. Since the human pupil can range in size from about five to seven millimeters, it makes sense to have an exit pupil on your binoculars of about the same size. An exit pupil of about five millimeters is a good choice for just about everyone.

The numbers 7 × 35 fit the ratio necessary for a 5 mm exit pupil, and it is a very common binocular ratio. But 10 × 50 also fits, and is a better choice for astronomy, since the larger objective lenses gather more than twice as much light. However, 10 × 50s are bound to be heavier, and holding them steady may be a problem for some.

> **More info**
>
> The exit pupil is only an important consideration at fairly low magnifications. When using a telescope at higher powers, the exit pupil has to become smaller: dividing a given aperture by a larger magnification gives a smaller result. So there is a trade-off that must take place.

Some other considerations

Eye relief. Depending on the **optics** used, binoculars (and telescope eyepieces) have different

More info – Comparing apertures

Apertures are circles, and the area (A) of the circle is what is important. It is measured by taking the **radius** (r) of the circle (half the diameter) and multiplying it by itself (or **squaring** it), and then multiplying by **pi** (π, about 3.14). So the mathematical formula (the only one in this book!) is $A = \pi r^2$. The squaring leads to results that may be surprising: If you double the diameter of an aperture, you multiply its light-gathering area by four times. So, increasing the aperture by what seems a small amount can increase its light gathering ability by quite a bit. This is useful to know and use when choosing binoculars or a telescope. For example, using the two binoculars described in the text, an aperture with a diameter of 35 mm gives the following: the radius, 17.5 mm (half of 35) times itself equals 306.25; this times pi gives an area of about 962 square millimeters. The 50 mm binoculars have a radius of 25 mm; squaring this gives 625; multiplying by pi shows an area of 1962.5 square millimeters. So, increasing the aperture by 15 mm more than doubles the light-gathering area of the 35 mm aperture.

eye relief. This is the distance, usually measured in millimeters, at which you must hold your eye from the eyepiece to get a proper view. Many binocular adverts or brochures will list this distance, and some will say that 14 mm is “ample” or “good.” But not if you wear glasses! I do, and I think 20 mm is an acceptable distance. Personally, I am still more comfortable taking my glasses off. However, if you plan to do the same, beware: some binoculars will not come to focus for those of us with particularly weak vision. Binoculars with long eye relief are sometimes referred to as **high eyepoint**.

Type of prisms used. Binoculars virtually always use one of two types of prism: **roof** and **porro**. Both types are designed to do the same things: provide a correct image, and shorten the distance from objective lens to eyepiece by reflecting the light along folded paths. *Roof* prisms are used in some of the least and some of the most expensive binoculars made. They allow for smaller, lighter designs; but it is expensive to make excellent roof prisms. As a result, binoculars using them that are large enough for astronomy are both rare and extremely expensive (see Figure 2.2).

Binoculars using *porro* prisms are the most familiar; and though somewhat bulkier, they are made in many sizes, can provide excellent images, and have prices much more within reach. A good pair of 10 × 50s can be bought for under $200, and can sometimes be found for quite a bit less.

Type of glass in prisms. Brochures or ads will often state that a pair of binoculars has **BK-7** or **BAK-4** prisms. This is a description of the chemical make-up of the glass from which the prisms are made; BAK-4 is typically the better choice, and should be looked for, because in most binoculars it produces brighter images across the entire field of view.

Tripod adaptability. Holding binoculars in your hands makes them very easy to use, but there are times when it is also good to be able to rest

Figure 2.2 These two pairs of binoculars are comparable in size (10 × 50) and quality, but the pair on the right, with roof prisms, is priced three times higher than the pair on the left, which uses porro prisms.

your arms, as well as get steadier views. This is why you should look for a pair that is adaptable for tripod use (most good ones are). A special adapter is required, but is not very expensive (see Figure 2.3).

Lens coatings. Any good pair of binoculars sold today will come with **coated lenses**. Coating a lens with special chemicals reduces internal reflections, which allows more light to reach the eye, and also reduces "ghost" images from around brighter objects. **Multi-coated** lenses have more than one type of coating, for further reflection reduction. **Fully coated** means that all lens surfaces that are exposed to air (and there can be several) are coated. **Fully multi-coated** (**FMC**) covers it all.

High-quality optics. Maybe this should go without saying, but I am including it because it is very difficult to simply look *at* a pair of binoculars to tell their quality. You must look *through* them. Is the focused image sharp, and sharp across most of the field of view? (Even great binoculars may blur some near the edges.) If not, try testing a different pair of the same model. The first pair may be a "lemon." If things still don't look pristine, try a different model or brand.

Find a balance. Of course, getting a pair of binoculars with all these features may put them out of your price range. You will need to do some research, and make some choices.

Things to avoid

***Zoom** binoculars*. Zoom lenses change magnification by moving **lens elements** internally. Their designs are usually not good for stargazing.

Water- or weather-proof binoculars. Since astronomy, almost by definition, takes place in dry conditions, it is not necessary, or desirable, to get binoculars with rubber- or plastic-armor coatings. It only adds weight to

Figure 2.3 Steady views are helpful for seeing detail, so a tripod adapter, and binoculars equipped to use them, are good investments.

them. Of course, if you are buying "multi-purpose" binoculars, to be used during the day as well, then that's a different story.

"Ruby" coatings. These red-tinted lenses look flashy, but the coatings are not ideal for astronomy. On well-made binoculars, they are meant to block the glare seen on bright, daylit objects. When used for astronomy, these coatings can block incoming light, and even change the color of objects seen. On cheap binoculars, ruby coatings are often just a cosmetic gimmick.

Big binoculars

There *are* binoculars that are especially designed for astronomy. They feature larger objective lenses, and, usually, higher magnification. Most are also, of course, heavier, and not really meant to be hand-held. They range in size from 9×63 to 25×150 or more. The wide, bright, seemingly

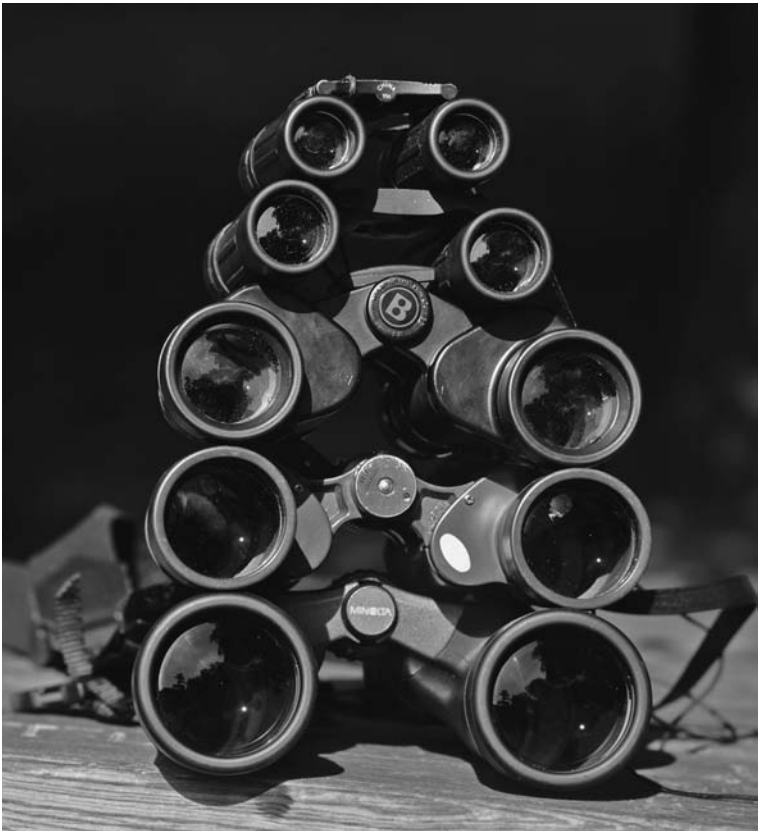


Figure 2.4 ***Comparing binoculars*****: From top to bottom, here are the pairs of numbers that describe the magnifications and apertures of each of these pairs of binoculars: 8 x 20, 10 x 25, 7 x 35, 10 x 42, and 10 x 50. The top two are not appropriate for astronomy: they are poorly made, with low-quality roof prisms, and each pair has an exit pupil of only 2.5 mm. The bottom three are much better choices: they all have good- to excellent-quality porro prisms; they have larger objective lenses; the exit pupils are at least 4.2 mm; and those circles between the lenses are covering threaded tripod-mounting holes. Note also the reflections off the objectives. The middle pair of the bottom three has the fewest, and this is a sign of excellent multi-coatings, which is also a likely pointer to overall quality. They are, in fact, the most expensive pair of the five.**

three-dimensional views they give to both eyes can be fantastic. Some of the smaller models are quite reasonably priced, and seem to get cheaper all the time.

Are binoculars the right choice for you?

The simple answer to this question is "yes".

Though there are some who may get complete satisfaction out of viewing the whole sky, with no more aid than their own eyes and possibly a planisphere, I believe most people will find that investing in a decent pair of binoculars is well worth it. They are so valuable and easy to use that, with virtually no practice, a whole new world will open up within a few seconds of putting them between your eyes and the night sky. That is a big claim, but it really is true. Especially with larger apertures (50 mm or more), and with the

Figure 2.5 What's up in the sky? Binoculars are the easiest way, and often the best way, to find out.

steadiness provided by a tripod, exploring the sky with binoculars can be truly awe-inspiring.

It may also be true for many who read this book that a good pair of binoculars is all the optical equipment that will ever be wanted or needed. Sweeping through the Milky Way; identifying features on the Moon; studying **sunspots** (with proper **filters**!); searching for "faint fuzzies" like star clusters, galaxies and nebulae; getting a closer, brighter look at a visiting comet; all of these can provide great enjoyment and challenge through a pair of binoculars.

Setting up and using a telescope takes at least a little effort. If you are not yet sure that astronomy is something you will vigorously pursue, then I strongly advise you get a good pair of binoculars first. You may decide they are all you want, or all you can afford. Even if you do go on to buy a telescope, your binoculars will always be useful for wide, beautiful, easily obtained viewing.

Resources

Binocular dealers

Any large camera shop or sporting-goods store probably has an adequate selection of binoculars for stargazing. Some department stores also carry decent brands. There are also many mail-order companies that feature them. These companies run advertisements in the magazines described below.

Magazines

There are two major magazines in the USA that cater specifically to the amateur astronomer: *Sky & Telescope* and *Astronomy*. Both feature articles on the latest astronomical discoveries, as well as information on amateur equipment and events. They have monthly features, including a sky chart that shows what is currently visible in the evening sky. They are excellent resources for people just starting out in the hobby (if only for the advertisements), though some of the articles may be intimidating to anyone without much knowledge of the field.

Books

Once you own a pair of binoculars, or even before, it is a good time to get an astronomy field guide. There are many great choices, but below are a few that I think would be useful for a beginner.

1. *Cambridge Guide to Stars and Planets*, by Patrick Moore and Wil Tirion. Cambridge University Press, 2000.

   This is a good, basic guide to what is up in the sky. The book arranges its star charts by constellation, which I believe helps one better learn the layout of the sky.

2. *A Field Guide to the Stars and Planets* (Peterson Field Guide Series), by Jay M. Pasachoff. Houghton Mifflin, 2000.

   This is a more complete guide, with much more detailed star charts. As with the guide above, the charts were compiled by Wil Tirion. It divides the sky into regions, and arranges its maps in a way that might be confusing for a novice, by spiraling around the sky from north to south.

3. *Stars and Planets*, by Ian Ridpath. Dorling Kindersley Handbooks, 2000.

   This is an excellent book, published by the company famous for creating the Eyewitness series of illustrated non-fiction. It is very well organized, and wonderfully illustrated.

4. *Sky & Telescope's Pocket Sky Atlas*, by Roger W. Sinnott. Sky Publishing, 2006.

   This book is different from most. Rather than arranging charts alphabetically by constellation, it divides the sky into 80 charts (and four close-up charts of smaller regions) arranged in a simple, user-friendly way. It is also not actually pocket-sized, which is probably a good thing since it allows for fairly large charts that cover wide areas of the sky. It is a sort of bridge between a traditional field guide and larger star charts, which are discussed later.

All of the above guides are reasonably priced, and designed to be taken into the field.

Several books which specialize in stargazing with binoculars are also available. Here are just a few of them:

1. *Exploring the Night Sky With Binoculars*, by Patrick Moore. Cambridge University Press, 2000.
2. *Touring the Universe Through Binoculars*, by Phillip S. Harrington. John Wiley & Sons, 1990.
3. *Discover the Stars: Starwatching Using the Naked Eye, Binoculars, or a Telescope*, by Richard Berry. Crown Publishing, 1987.

“But I want a telescope!” 3

Of course you do, but there are good reasons for waiting until this point to get to telescopes. Once you have learned something about the sky, by getting out under the stars with a planisphere, or a field guide, or one of the monthly magazines – whether with binoculars or just your eyes – then you have probably done two things. First, you have discovered whether or not you want to go further in pursuit of this hobby, and you have done so at a relatively small cost. You may have decided that your eyes, or binoculars, are enough. Many people do.

Second, you have probably gone some way toward making the use of a telescope easier, and so, more enjoyable. If you have a basic understanding of how the night sky “works,” and how to find specific things in it, then you will avoid much of the frustration that beginners often feel when first trying to find something in a telescope. It is much easier to view something through the telescope if you have some idea of where it is going to be, and when. And no matter how much you may read about it, there is no substitute for watching the sky change, over a stretch of hours, and a succession of weeks or months.

For these reasons, I strongly suggest that, if you have not already done so, you get out to a dark site and study the sky before you buy your first telescope.

The beginner’s telescope

My belief is that there are three primary concerns a beginner should have when buying a first scope: *cost, “size,”* and *ease of use*. We should look at each in detail.

Telescope cost

You will, of course, be the one to choose how much you spend on a complete, ready-to-use telescope package. I have somewhat arbitrarily chosen a *maximum*

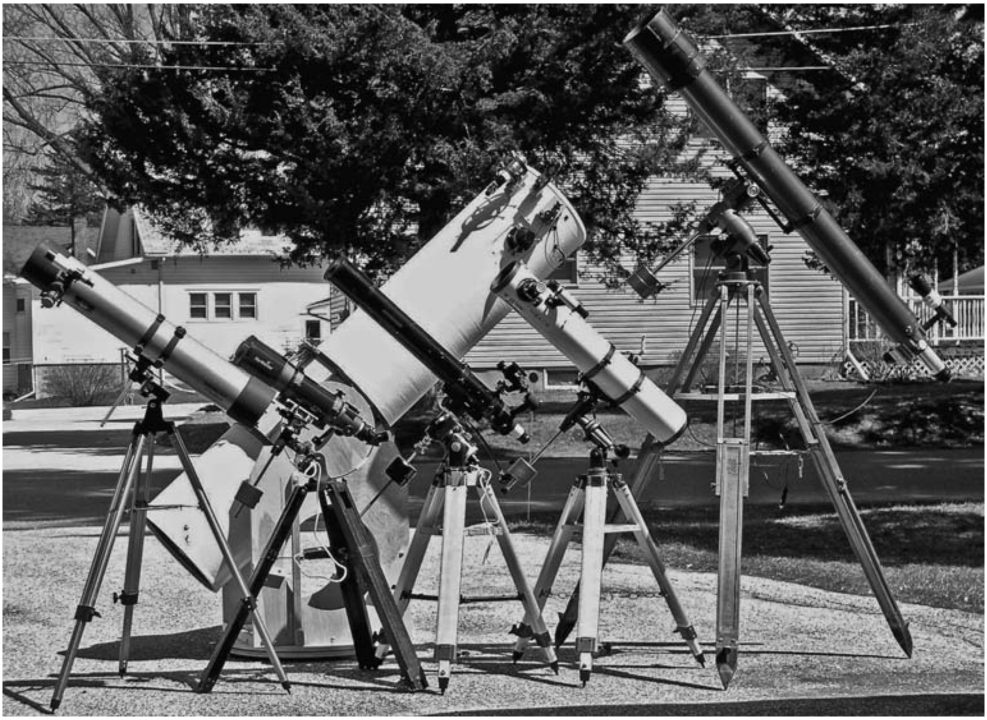


Figure 3.1 The author's scopes, with apertures from 80 mm (3.1 inches) to 317 mm (12.5 inches).

of $500 here in the United States, and based my choices on current (2008) prices. These prices may have changed by the time you read this, but the trend in telescopes for several years has been *falling* prices, so you may actually be able to go beyond what I am going to describe. Prices will, of course, vary from this in other parts of the world, but the *choices of available telescopes for a given price* should, I think, be the same. The italics explain the reason I think it makes sense to choose an arbitrary, maximum price: to make it possible to compare different telescope types within a moderate boundary.

Five hundred dollars is much more than I spent on my first, perfectly adequate, telescope. It should be enough for just about anyone. Personally, I do not think it makes sense to spend more, initially, on a pastime you may not yet be sure of. If you do decide to spend more, you should plan to do research beyond the scope of this book. The $500 maximum leaves out many choices of size and type of telescope and accessories, but that is a *good* thing: there are so many choices out there that it can get very confusing.

There is also a minimum that you should be willing to spend, if you want an instrument that is to be of any use. You will

More info

$500 may not seem like a "moderate boundary" to some, but astronomy equipment can get just about as expensive as the imagination can reach. Even some quite small (though wonderful) telescopes can cost many thousands of dollars.

Figure 3.2 When this 80 mm telescope was new, in the mid 1990s, it retailed for nearly $500. These days, in 2008, you can get a slightly larger (90 mm) scope package from the same manufacturer for less than half that price.

probably not be able to find a decent, complete telescope set-up for less than $200, unless you find a real bargain (which is possible, though not likely). A price range of $300–$500 is more realistic, for a scope that may be all you ever need. Something less expensive may *look* impressive, but probably will not be an impressive performer (see Figure 3.3).

Telescope “size”

This is much more complicated, and will take some explaining. There are two features to look for when determining any telescope’s “size:” *aperture* and

Figure 3.3 Although these two scopes look similar, the one on the left, which cost $100 and came in the box shown in Figure 4, is virtually useless, from almost any perspective (image clarity, sturdiness, focusing ... I could go on and on). The scope on the right – or a current model of similar quality – though still not as sturdy as it could be, is definitely useable, and you can find it for about $250.

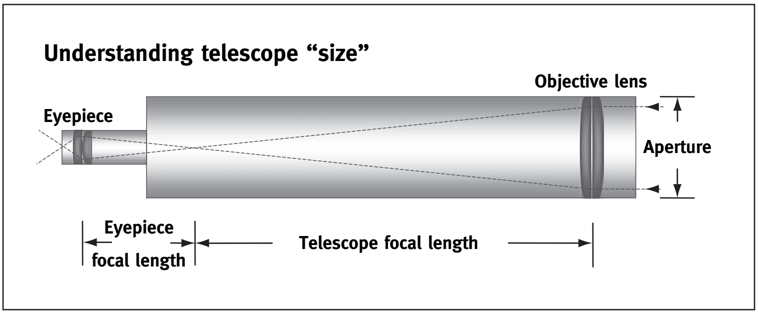


Figure 3.4 A simple drawing that shows what factors determine a telescope's "size."

focal length, and dividing the second by the first gives another important factor: ***focal ratio***.

Remember, a telescope's *aperture* is the diameter of its main light-gathering surface (either a lens or a mirror). It is the aperture that determines how bright and clear an image can appear through a telescope.

The *focal length* is the distance between the light-gathering surface and the **focal point**, the place at which the light rays, which have been bent by the lens or mirror, come to a point (or, more accurately, a small plane or spot). This measurement determines how “powerful” a telescope can be, when combined with a given eyepiece. Eyepieces have focal lengths of their own, and when you divide a telescope’s focal length by an eyepiece’s focal length, you get the magnification.

Here is an example. Let’s say you have a telescope with a focal length of 1000 mm. If you insert an eyepiece with a focal length of 25 mm into the focuser, images will be magnified by 40 times (1000 divided by 25 = 40). If you changed to a 4-mm eyepiece, the magnification goes up to 250 times (1000 divided by 4 = 250). It is focal length alone which determines magnification.

Which is more important: aperture or focal length?

Aperture, without a doubt. Why? Recall that it is the aperture that determines both brightness *and* clarity. (The measure of the clarity a telescope can be expected to have is called **resolution**, or resolving power.) So, in a telescope with a small aperture, images appear dimmer and blurrier than in a telescope with a larger aperture. At low powers, this may be acceptable (as in binoculars); but the higher the magnification, the dimmer and fuzzier the image seems.

Here is a good rule of thumb that is often used: useful magnification is equal to two times the aperture, when measured in millimeters; or fifty times the aperture, when measured in inches (since 1 inch is about

Figure 3.5 If all other things were equal, the telescope on the right, with an aperture of 100 mm (about 4 inches) should not only produce 56% brighter images, but also *sharper* images, than the 80 mm scope on the left.

> **More info**
>
> Sixty millimeters is the aperture of many "department-store junk" telescopes. They often have a focal length of 900 mm, and might come with an eyepiece with a very short focal length. This means they truly can reach "powers" as high as they claim, but their aperture makes the magnification a useless, very dim, frustrating blur. There ought to be a law!

25 mm). Of course, this assumes you have decent optics in your telescope. So, if you have a 60-mm telescope, the highest magnification you should expect from it is about 120×.

Notice that focal length does not matter here: a beginner's telescope with good optics and an aperture of 100 mm (4 inches) should not be expected to reach powers higher than 200×, whether it has a focal length of 500 mm and is used with a 2.5-mm eyepiece, or a focal length of 1500 mm with a 7.5-mm eyepiece.

Magnification limits

At this point, since I am discussing magnification, I should also mention this: the Earth's atmosphere can really cloud things up. Even the best telescopes with the largest apertures have their images blurred and distorted by **turbulence** in the atmosphere. When things are truly bad, stars appear to twinkle, even to the naked eye. In a telescope, images flare and spike and quiver. Astronomers call this bad "**seeing**." But even under very good conditions, atmospheric interference usually prevents useful magnifications above about 300×. With great optics under perfect skies, higher powers are sometimes possible for fleeting moments, but the beginner should not expect this. The good thing is, you will almost never want more than 300×, and you will almost always want much less.

Focal ratio

If you divide a telescope's focal length by its aperture, you get its *focal ratio*. For example, one of the telescopes above, with the 100-mm aperture and the 500-mm focal length, would have a focal ratio of five, usually written f/5; this might be called a "fast" scope. The 100-mm scope with the 1500-mm focal length would be f/15, and might be called "slow."

These speed references are terms from the world of photography, and have nothing to do with the brightness of objects viewed with the eye through a *given eyepiece*. There is a misconception out there, often found on the Internet, repeated by sales clerks, and even in books, which insists that, like camera lenses, telescopes with higher focal ratios do not let in as much light as those with lower focal ratios. This is simply not true. Using the two 100-mm aperture telescopes mentioned above as examples, the scope with a focal length of 500 mm (giving a focal ratio of f/5) would give a magnification of 20× if you inserted a 25-mm eyepiece (500 divided by 25 equals 20). The same eyepiece, when used in the 100-mm scope with a focal length of 1500 mm (f/15) would give a magnification of 60×. The magnification is different, *but the brightness is the same*. Others may tell you otherwise, but brightness is determined by aperture alone.

Figure 3.6 Two telescopes with different apertures, focal lengths, and focal ratios. The scope on the left, with an 80-mm aperture and 910-mm focal length (giving a focal ratio of about 11.4, when you divide the focal length by the aperture), is a good choice for a small, all-in-one scope for a beginner. It should be able to span a useful range of magnifications somewhere between 30× and 160×. The scope on the right, with an aperture of 100 mm, and a focal length of 500 mm (for a focal ratio of f/5) might seem like it could be used at higher magnification because of its larger aperture. But at f/5, and with such a short focal length, it is much better suited for wide views, and can give stunning images at powers as low as 16×.

Choosing the right "size"

For *aperture*, this is easy. Once you have chosen the type of telescope you want (we will get to that soon), get the largest aperture you can afford. Telescopes can get huge: there are two in Hawaii with mirrors more than thirty feet (10 meters) across. However, for under $500, physical size will probably not become a burden.

An aperture of 80 mm is, I believe, the *minimum* you should get (because of the **central obstruction** in some types of scope, 90–100 mm would be better). With anything much less than that, you would probably be better off sticking with binoculars. However, an aperture of 80 mm will give images more than two and a half times brighter than 50-mm binoculars, and will allow magnifications up to 160×, enough to see good detail on the Moon and some on the planets, and more than enough for most deep-sky objects you will be able to view.

For *focal length*, things get more complicated. A telescope with a longer focal length allows the use of eyepieces that are easier on the eye at higher magnifications (more on that later). Also, it is usually easier and cheaper to make good optics when using slower focal ratios (which means longer focal lengths). Even in great telescopes, **aberrations** (optical problems) creep in at short focal lengths. For these reasons, it might seem a long focal length is best.

On the other hand, telescopes with shorter focal lengths are often, well, shorter. This tends to make them lighter and more portable, which means they require a smaller, cheaper **mount**. Also, a shorter focal length means lower magnifications are possible, allowing wider views.

So, how to choose? Strike a balance. At any focal length less than 500mm, I think you would be better off with one of the less expensive pairs of "big" binoculars, which might be just fine. At anything more than 1,500mm, you begin to seriously limit yourself to using higher magnifications. You would have what amateur astronomers call a **planetary scope**. This also might be just fine. But somewhere in between these two will allow you to view a wide range of objects at a variety of magnifications, in a package portable enough to be easily used.

Ease of use

This is the last broad consideration when choosing a telescope, and it is another area where personal choice comes into play. Some telescopes are easier to set up and use than others. This is even more true of whatever it is they are mounted on. Some are easier to aim than others. Some are prone to one aberration, others to another.

The question comes down to this: what features are most important to you, and what are you willing to put up with to get them? One package may offer the brightest views, but be heavier and more awkward. Another may be light and portable, but have limited choices of magnification. After you learn what options are out there, it will be up to you to choose what you think will best meet your needs. However, be aware that if you find your telescope a pain to use, you probably will not use it.

I have my own personal biases, which are based on what I think an average beginner (me, some years back) would be happiest with. I will make recommendations, and I will give reasons for them; but in the end, you must decide what is best for you.

Telescope types available to the novice

There are three telescope designs, easily available to the beginning stargazer, which fit the constraints of cost, size, and ease of use that I have described. They are the **achromatic refractor**, the **Newtonian reflector**, and the **Maksutov–Cassegrain** (or **"Mak"**). Each has pluses and minuses, and each has its own devoted fans. Competition has led to widespread availability of all three types, in a wide variety of sizes.

The achromatic refractor

When most people think of a telescope, a refractor is the type that comes to mind, and with good reason. It was a refracting telescope (a telescope that refracts, or bends, light through lenses) that was the first to be built

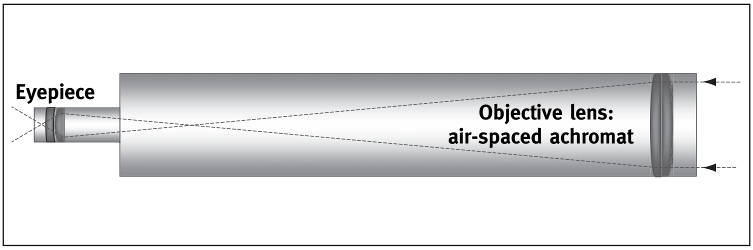


Figure 3.7 Inside an achromatic refractor.

and used by Galileo to look at the night sky. It was the only type to exist for some time. Also, the refractor has long been a popular choice among amateurs.

There are several different types of lenses used in refractors, but for the beginner, the choice will almost certainly be an objective lens made with an **air-spaced achromat**. Galileo's telescope used a simple objective lens (just one piece of glass). It worked, but simple lenses have a problem: while bending the light in a way that magnifies, they also act as a sort of prism, breaking the light that enters the scope into its component colors. This is called **chromatic aberration**. It was a huge problem in early refractors, and took centuries to solve.

Someone finally figured out that putting together two lenses of different shape (and usually of different types of glass) greatly reduces the **false color** created by chromatic aberration. The lenses usually have a very short space between them. This is the air-spaced achromat (achromat means "without color").

More info

Early telescope makers found that one way to minimize chromatic aberration was to make telescopes with very long focal lengths. Telescopes reached lengths of more than a hundred feet (30 meters). They became so long that tubes could not be used because they would sag and block the light. Lenses were suspended from wires inside large halls.

Advantages

1. The refractor is virtually *maintenance free*. The objective lens, when treated well and protected from dust, should last a lifetime or more.
2. Refractors have *no central obstruction*. In other types of telescopes, a mirror is placed in the center of the light's path in order to reflect it into the focuser. This obstruction decreases **contrast** in images seen through the telescope. These mirrors, on some scopes, also need periodic adjustment.
3. It is *easy to aim* because its focuser sticks out of the bottom, or back, and is in line with the direction of the targeted object.
4. Refractors come in a *wide variety of focal ratios*.

Figure 3.8 A classic "planetary" refractor. This scope, the author's home-built 120mm (4.7-inch) refractor, with a focal length of 1500mm (f/12.5) is beyond the price range of this guide; but not by much. A 120-mm refractor with a focal length of 1000mm (f/8.3) is a possibility within our price range.

5. ***Cooling time** is less of a problem*. In refractors, light travels down the tube just once, and heads out through the focuser. In other telescope designs, light is reflected back up the tube, and sometimes back down again. If the air inside the telescope tube is

at a different temperature from the air outside, **tube currents** can form which will distort images. The more times light travels through these currents, the more distorted the images become.

Disadvantages

1. "*Faster" achromatic refractors (those with shorter focal lengths compared to their apertures) still have problems with false color*. The lenses act like prisms, and blue or purple edges might appear around objects being viewed. But above f/8 (a focal length eight times the aperture), a good lens will show truly objectionable color only on quite bright objects. At f/12 or higher, color should not be noticeably bothersome.
2. Because the focuser sticks out of the bottom of the telescope, *viewing might get uncomfortably close to the ground*.

More info

One of the more important advances in amateur telescopes of the past several decades was the introduction of the **apochromatic** refractor. Various designs are available, but all use special lens arrangements and/or glass types virtually to eliminate false color. Many people consider them the best telescopes made. For the extremely high prices charged for them, they should be!

More info – Changing times

Until a few years ago, *cost* would have been considered a major disadvantage of the refractor, but scopes with decent optics are now being made and sold by many companies. Competition among these companies has been stiff, and prices have gone down considerably. In larger diameters (and apochromatic designs), refractors are still the most expensive type of telescope, per unit of aperture. But in the sizes appropriate for a beginner, price is not as big an obstacle as it once was.

The Newtonian reflector

First developed by another pioneer in science, **Sir Isaac Newton**, the design of this telescope is fairly simple. Other than the lenses in the eyepiece, there is only one surface that has a curve in it (the **primary mirror**). Light enters the top of the telescope and travels to the bottom of the tube, where it is reflected off of the primary mirror, and focused back up the tube. Before reaching the focal point, the light is reflected off the **secondary mirror**, which is set at a 45 degree angle in the center of the tube, near the top. The light then leaves the scope through the side of the tube, where the focuser is placed.

The design is so simple that, prior to the arrival of large-telescope manufacturers, many amateur astronomers built their own reflectors, grinding the necessary curve into the glass of the primary mirror. Some still do.

Advantages

1. The single largest advantage of the Newtonian reflector is *cost*. Because of the simplicity of its design, it is by far the least

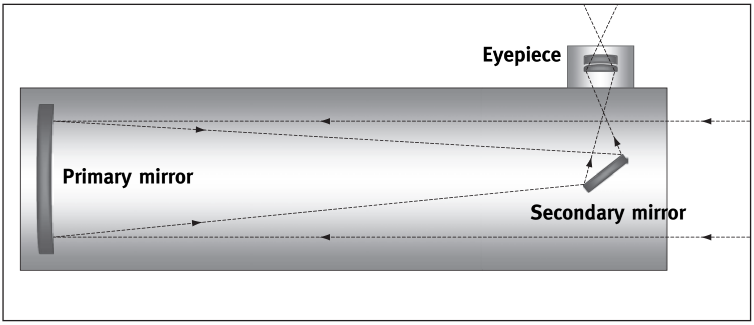


Figure 3.9 The simple design of the Newtonian reflector.

Figure 3.10 To get the 114-mm (4.5-inch) aperture of this reflector in another telescope design would cost about twice the price of this scope.

expensive type of telescope, per inch of aperture. For the price of some 4 inch apochromatic refractors, you could buy a 20 inch reflector. Of course, a larger aperture means brighter, clearer images; and the brighter the images, the more dim objects you can see.

2. Reflectors *do not suffer from chromatic aberration*, since the light is reflected off a single surface, instead of being refracted through a lens.
3. In the sizes available to the beginner, the *focuser* is usually placed at a *comfortable viewing position* near the top of the scope. (A ladder is needed to reach the focusers of larger, more expensive reflectors!)
4. Because one end of the tube is open, Newtonian reflectors *cool down more quickly* than some other types of telescope.

Disadvantages

1. Reflectors have their own type of aberration: ***coma***. Stars near the edge of the field of view seem to have tails, like little comets, or commas. The problem is worse in fast scopes (f/5 or faster).
2. Reflectors have a *central obstruction*. The secondary mirror blocks some of the incoming light, which lowers the contrast.
3. ***Diffraction spikes****:* the secondary mirrors in Newtonian reflectors are held in place by a **spider**, which is simply a structure with three or four thin vanes that stretch from the edge of the tube toward the middle, where the mirror is attached. This structure interferes with the view and causes *diffraction spikes*, small rays that appear on brighter stars in the pattern of the spider’s vanes (see Figure 3.11).
4. Reflectors need some *cooling time*. Because the light entering a reflector travels down and then back up the tube, it is more affected by tube currents. Time is needed for the temperature inside and outside of the tube to equalize. The larger the scope, the longer it takes; partially because the main mirror itself becomes so thick in bigger reflectors that it needs considerable time to cool.
5. Reflectors need to be ***collimated***. The mirrors need to be periodically lined up with each other and with the focuser; otherwise, images will be distorted. To do so is a fairly simple process, but Newtonian reflectors need it more often than other designs.
6. The *coatings on the mirrors are not permanent*. Though, with care, they should last for many years, mirror coatings will probably need eventual replacement. There are companies that do this for a reasonably small price.
7. Because the focuser sticks out at a 90 degree angle to the direction of targets, Newtonian reflectors are *somewhat difficult to aim*.

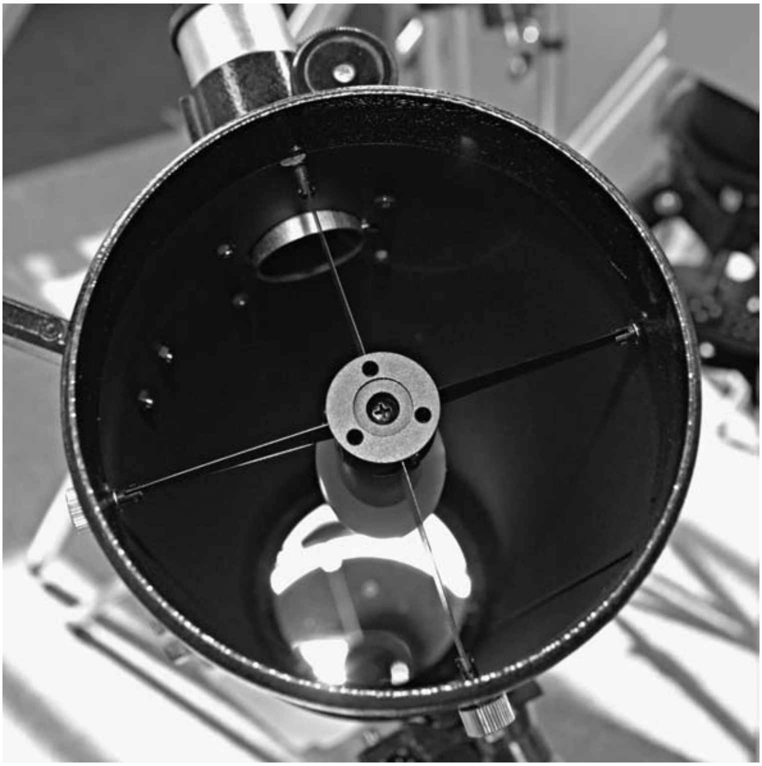


Figure 3.11 Looking down the front, or top, end of a Newtonian reflector, with a view of the spider, secondary mirror, focuser tube, and, at the bottom, the primary mirror.

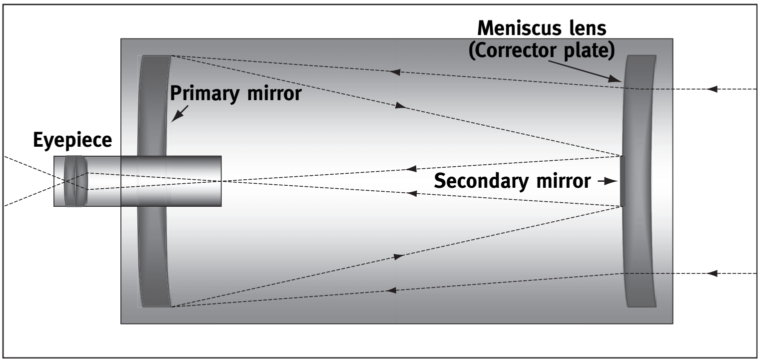


Figure 3.12 The complex light path through a Mak.

The Maksutov–Cassegrain (or Mak)

Of the three available to the beginner, the *Maksutov Cassegrain* (or *Mak*) is the newest telescope design. **Dmitri Maksutov** developed it in the Soviet Union in the 1940s. It uses both a lens and a mirror (telescopes that use both are called **catadioptric**), and has four curved surfaces that influence the incoming light: the two sides of the lens, the primary mirror, and the secondary mirror (which is actually just a coating applied to the back of the lens).

What makes the design affordable is that all four of these curves are **spherical**. It is much easier to grind precise spherical curves into glass than other shapes.

Spherical mirrors produce severe coma, and this is why the Mak has a lens: the curves in the lens are designed to correct the image created by the mirror in order to reduce coma. In fact, the lenses on catadioptric telescopes are more often called **corrector plates**.

More info – Some terminology

A Cassegrain telescope is any reflecting telescope that has a hole in its main mirror at the back of the scope, where the focuser is located. The lens on a Mak is a **meniscus lens**. Meniscus means "crescent shaped;" and a meniscus lens is one that is curved outward (**convex**) on one side, and inward (**concave**) on the other. This gives it a sort of crescent shape.

More info

There is another type of Mak: the **Maksutov Newtonian**; which, as the name implies, combines some features of the Maksutov Cassegrain and the Newtonian reflector (and was also designed by Dmitri Maksutov). As I write, this type of scope is not readily available within our price range of $500, so it will not be discussed in detail. But by the time you read this, that may have changed, and you may want to do some research on this excellent design.

Advantages

1. *Physical size* is the main advantage of the Mak. Because it bends light up and then back down the tube, off of two curved mirrors, it is possible to contain a long focal length in a short tube. This allows the use of smaller, cheaper mounts. It also makes for a very portable package (see Figure 3.13).
2. The closed tube and thick corrector plate, which are both part of the design of the Mak, mean s*turdy, solid construction*. The closed tube also protects the mirrors' coatings.
3. The corrector plate does just that: a well-made Mak will have *less coma* than a Newtonian reflector.

Disadvantages

1. The closed tube means that a Mak will need *longer cool-down time*. And because the light travels through the tube three times before reaching the focuser, tube currents in an uncooled tube will affect images more than in a Newtonian reflector or, especially, a refractor.
2. Like the Newtonian reflector, the Mak has a *central obstruction that will affect contrast*. (It does not, however, have diffraction spikes, since it has no spider vanes: its secondary mirror is applied directly to the corrector plate.)

Figure 3.13 (a) Because of the complex path and four curved surfaces of a Mak, this short (less than 12 inch) tube is able to house a 102-mm (4-inch) aperture scope with a focal length of 1300 mm. (b) The mechanics of a Mak: visible here are the meniscus lens/corrector plate, the secondary mirror attached to the plate's center, the primary mirror, and the focuser housing coming through the primary's center.

3. The design of the Mak makes it "slow." Most have focal ratios around f/13, or even higher. This makes them excellent for high magnification, but less well-suited to **wide-field** viewing.
4. At the beginner's level, *cost* is a factor with Maks. They are usually as expensive, per inch of aperture, as refractors; and much more expensive than Newtonian reflectors.

As important as your scope: the mount

This is not an exaggeration. If using your telescope is not an enjoyable experience, you will not use it; and shaky images or difficult aiming and **tracking** do not add up to fun!

Sturdiness is vital. A mount that allows you to move smoothly and easily from one target to another, or to easily bring objects back to the center of the field (as the Earth's rotation causes objects to move out of view), is also necessary. Finally, a telescope is much more enjoyable to use (especially by groups) if it can automatically keep objects in the field of view for long periods of time. There is only one type of mount available to the beginner that meets *all* of these requirements; but before getting to it, we will look first at the alternatives.

The alt-az mount

The term **alt-az** is short for altitude- (or vertical) azimuth (or horizontal). That is how these mounts move. A camera tripod is a basic alt-az mount, and

Figure 3.14 Alt-az mounts. (a) When you adjust the tension of the lever on top of the tripod, and the handle coming out from it, then you can easily turn the scope on this mount by hand, and have it stay where you put it. (b) A 6-inch (150-mm) reflector with a Dobsonian mount. You can easily adjust the aim of this scope by pushing and pulling on the round knob on the bottom of the front end.

the alt-az mounts designed for beginner scopes are not very different from camera tripods (see Figure 3.14 a.) They should, however, be sturdier, and should include controls that allow for slow-motion movements in both directions. Otherwise, the telescope is not worth using for astronomy. A shaky mount makes finding and focusing on objects almost impossible; and without slow-motion controls, keeping an object in view, as the Earth's rotation causes it to drift, just cannot be done. The junk telescope described at the beginning of the guide tells the effect of a *bad* alt-az mount: it gathers dust in a closet.

*The **Dobsonian** (or Dob) mount*. This is a simple, lightweight, inexpensive type of alt-az mount that is usually used with Newtonian reflectors (see Figure 3.14 b.) Popularized by amateur astronomer **John Dobson** in the 1970s, it is one of the reasons for the growth of astronomy as a hobby. It allowed the building, by amateurs, of huge yet inexpensive scopes. A good Dobsonian is sturdy and well balanced for easy movement.

Fork mounts. These are, basically, another type of alt-az mount. They have two tines that attach to the side of a telescope, and this is what gives them their name. They work best on telescope designs that use

More info – Fork equatorial mounts

A German equatorial mount is, basically, an alt-az mount that can be tilted to an angle at which the azimuth (horizontal) circle of motion can be matched to the equator. Fork mounts can be equipped with accessories that make them equatorial, too.

short tubes, and are usually associated with the **Schmidt–Cassegrain** telescopes (**SCTs**) sold by **Meade** and **Celestron** (the two largest American telescope manufacturers). Schmidt–Cassegrain telescopes are outside our price range.

The German equatorial mount (GEM)

Because the Earth spins, stars in the night sky appear to rise in the east and set in the west;

More info – Right ascension and declination

Locations on a globe of the Earth are marked with perpendicular lines. The lines running from north to south between the poles represent **longitude**; those circling the Earth from east to west represent **latitude**. These lines are divided into degrees (360 degrees make a circle); which are divided into **minutes of arc** (60 minutes make a degree); which are divided into **seconds of arc** (60 seconds make a minute). The "zero line" for longitude runs from the north pole, through Greenwich, England, and on to the south pole. For latitude, the equator is zero; the poles are 90 degrees. If you know a place's latitude and longitude, you can find it, easily and exactly, on a map.

The globe of the heavens is measured in a similar, though slightly different, way. Celestial latitude is called declination (Dec), and is also measured in degrees; zero at the equator, 90 degrees at the poles. Heavenly longitude is called right ascension (RA). It is different from longitude in that astronomers divide it into hours, instead of degrees. These hours are then divided into minutes and seconds.

or, if they are near the **celestial poles**, stars seem to go in a circle around these points. These two spots in the sky are exactly aligned with the Earth's *axis*, the imaginary line that runs through the north and south poles of the planet, and about which it spins like a top, once a day. The north celestial pole is very near the star **Polaris**; the south celestial pole has no bright stars very close to it.

When you look through a telescope, the image you see will drift out of the field of view as the Earth spins. The higher the magnification, the quicker the drift. At high powers, an object in the center of the field can disappear from view in less than a minute. This causes a problem for alt-az mounts. They move vertically and horizontally, but drifting objects almost always move diagonally (the angle depends on your location, and the object's place in the sky). So, to keep an object in view, you need to adjust an alt-az mount in both directions. If you plan to use your telescope for bird-watching or other terrestrial viewing, then you will want a good alt-az mount, but they are not the best choice for stargazing.

An **equatorial mount** is designed to remedy this problem. It has an axis of rotation that is adjustable, and meant to be centered on the celestial

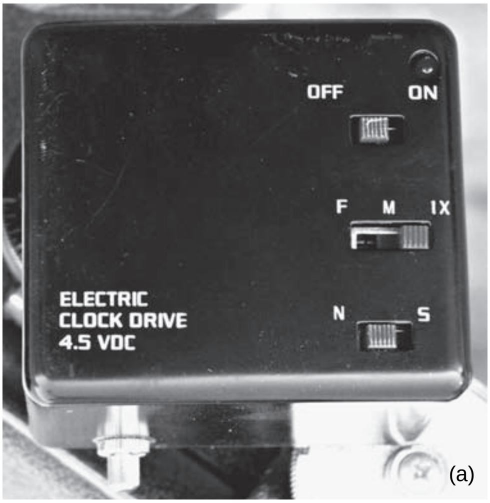


Figure 3.15 Electronic drives can be as simple as (a) a small, battery-operated motor that is attached directly to the RA control shaft; or (b) much more deluxe, with hand-held, push-button, variable-speed control of motion in both directions in both declination and right ascension.

pole. The most common design is called the German equatorial mount (or GEM). When you set one up, you do a **polar alignment**, so that the adjustable axis of your mount matches the axis of the Earth. Afterwards, once an object is centered in the field of view, the telescope will only need to be adjusted in one circular direction (called **right ascension** or **RA**) as the image drifts. *Exact* polar alignment is somewhat difficult, and not necessary most of the time. Without it, images will still drift a little. Minor adjustment is then made in **declination** (or **Dec**), the circle of motion **perpendicular** to right ascension. This may not seem like a big improvement over alt-az, but it makes things much easier if you want to study an object for a while, or share the view with others.

Things can be made even easier. Since adjustment (or tracking) only needs to be done in one constant, circular direction, a **clock drive** can be attached to the mount. This is a small motor, usually battery operated, which is attached to the RA axis. It makes the mount turn so that it closely matches the turning of the Earth. Once an image is centered in the field of view, and the motor is turned on, the mount will keep the image centered. This is called **motorized tracking**.

More advanced drives have two motors, so that periodic electronic adjustments can be made in declination and right ascension, if the image shifts a little. A **hand controller** is used to move the telescope precisely in any direction. A mount with this set-up has **dual-axis drives**. For mounts

Figure 3.16 The German equatorial mount. (1) Counterweight and counterweight shaft. The counterweight is used to balance the telescope, so that it is easy to move (either by hand or with the drive), and so that it stays in place once the movement is done. To use it, you loosen the bolt visible on the top of it, and slide the counterweight on the shaft to find the proper, balanced point, and then tighten again. (2) Declination lock lever (the RA lever is on the other side of the mount, so not visible in the photo). When the levers are unlocked, it is easy to move a well-balanced scope close to the observing target by simply pushing and pulling by hand. Once close, you can lock the levers, and make final adjustments with the slow-motion hand controls, or with the electronic hand controller. (3) Right ascension motor housing. When this motor is running, the mount's motion matches that of the turning of the Earth, keeping objects centered in the eyepiece. (4) Azimuth adjustment knobs. (5) Altitude adjustments bolts. The azimuth and altitude adjusters are used only to align the mount with the celestial pole; they are not meant to help you in aiming the telescope. (6) Polar alignment scope. This is a small telescope that is mounted right inside the mount, and is used to help you get accurate alignment with the pole.

with only one motor (a **single-axis drive**), periodic declination adjustments are done, easily enough, by turning a knob by hand.

A perfectly aligned mount with perfectly accurate gears and motors would keep an object perfectly centered for as long as you kept

Figure 3.17 The CG-3 (or EQ-2) mount; this one is equipped with a single-axis drive. Note the slow-motion control cable angling downward to the right.

the motor running. Since this is not realistically possible, adjustments will still have to be made every once in a while. But a casual polar alignment is enough for even a fairly cheap motor to keep adjustments down to only once every several minutes. With a little more careful alignment, an object can stay in the field of view, with no adjustments, for a half hour or more.

More advanced equatorial mounts have the option of mounting a **polar alignment scope** on them. This is a small, wide-field telescope, mounted along the RA axis, which helps in making a careful and accurate polar alignment. This is a great convenience if your telescope will be used by a group, or if you want to try some **astrophotography** (more on this later).

Some commonly available GEMs

Though there are many different companies that sell German equatorial mounts, most models for the beginner seem to fit one of four basic designs. They come with many different names, but the three most useful designs are basically "clones" of those sold for years by Celestron: the CG-3, CG-4, and CG-5. The CG-4 and -5 are themselves clones of the Polaris and Super Polaris mounts once – but no longer – made by the Vixen Company of Japan. In fact, the CG-4 and -5 were, at first, made by Vixen for Celestron, but were later

Figure 3.18 The mid-sized CG-4 (or EQ-3) mount.

replaced by less expensive (and lower quality) copies. The fit and finish of these mounts has improved over the years, but quality control can still be a problem, so let the buyer beware.

I have included this history because the names may come up when searching for a specific mount, and it will help to be able to compare apples to apples, rather than oranges. And the names I have given are only those I have come across in the USA; in other parts of the world, other names are

Figure 3.19 The CG-5 (or EQ-4 or EQ-5) mount.

almost certainly used. Use the accompanying photographs to help with identification.

The EQ-1 mount. This mount, or one very like it, is often included with very small, light telescopes (especially Maks), and with junk telescopes. I think it is just too flimsy to be of much use.

The CG-3. Sometimes called the EQ-2, this is the lightest-weight GEM that I have found to be useful. It can support small-to medium-sized telescopes, up to about 90 mm (3.5 inch) in aperture, as long as they are not very long (the longer a scope, the more prone it is to noticeable shaking). This mount can also be equipped with a single-axis drive. Celestron has recently begun selling a much different-looking, though probably quite similar, mount with the same name, CG-3.

The CG-4. This is the clone of Vixen's Polaris mount, and its copies are sometimes called EQ-3 or the EQ3–2. It is the least expensive mount that is available with the capacity to be equipped with a polar-alignment scope and dual-axis drives, necessary for longer-exposure astrophotography. It is quite adequate for visual use with a medium-sized telescope; up to a 100-mm (4-inch) refractor, or an even larger scope of any type, if it comes in a short tube.

The CG-5. This clone of the Vixen Super Polaris is sometimes sold under the name EQ-4 or EQ-5, and others. It is the top-end mount that might be within my price range for the beginner. The latest models are quite sturdy, and will support loads of more than 20 pounds (9 kilograms). Nearly all of the **astrophotos** in this book were taken with cameras and telescopes mounted on this GEM. Both Celestron and Meade sell heavier-duty **computer-guided** versions of this mount (see below). Celestron still uses the name CG-5; Meade calls theirs the LXD-75. Though both are outside the price limits of this book, the fact that these companies use the design means the mount should be around for some time to come.

Computer-guided mounts

One of the biggest changes in amateur astronomy in the past decade or so has been the rise of the computer-guided (or **"go-to"**) mount. To use them, the time and the viewing location (longitude and latitude, or postal code, or nearby city) are entered into the telescope's hand controller. The telescope is then pointed at two or three known stars, while these stars' names or identification numbers are entered into the hand controller. The built-in computer in the mount can then point the telescope at other objects (usually many thousands of them) contained within its memory.

There are telescopes for under $500 that come on computer-guided mounts. But, for the price of the mount, you trade aperture size, mount stability, and more. In our price range, the apertures available in a go-to scope may not even be able to show you some of what is in their computer's memory. And the tripods, finders, eyepieces, and other accessories that come with beginner go-to scopes just do not seem as robust as comparable non-go-to packages. However, this may soon change. Prices continue to fall, and decent-sized telescopes on good go-to mounts may soon be available for the absolute beginner. (On the other hand, the growing prevalence of go-to mounts has tended to drive down the prices of traditional non-go-to mounts, especially on the used market, making these simpler mounts even more attractive.)

Of course, there is also the question of whether a computer-guided telescope is a good idea for a beginner. Many beginners – who would otherwise have stayed away – have gotten started in the hobby, and kept on with it, through the use of a go-to scope. There are very dedicated fans of the various models. There are many advanced amateurs who would say that go-to mounts are *the* way for beginners to get started, since they bypass the need to understand the complexity of the night sky and how it changes from hour to hour and night to night.

There is sense in that argument, but it is my own belief that these mounts make things both too easy and too difficult: too easy, because they take away the necessity (and challenging fun!) of learning the night sky; too difficult, because they add yet another layer of learning to the process of just getting started, as well as an added possibility of getting something defective.

Figure 3.20 Perhaps the largest-aperture go-to telescope within this guide’s price range: a 130 mm (5.1 inch) Newtonian reflector with a focal length of 650 mm (for a focal ratio of f/5.)

There are more advanced go-to mounts that are very rugged, very stable, and very simple to use, almost as simple as turning them on and stepping to the eyepiece. But these are far beyond the price range set as a limit for this book. Beginners’ go-to scopes (at least for now) tend to be finicky, frail, and not very accurate in their pointing. It takes time, practice, and some slight knowledge of the sky to get them started each time they are used (unless they are not moved). Also, no beginner’s go-to scope that I know of can be operated manually. If the user becomes frustrated with the difficulty of getting an object centered in the eyepiece because of some glitch in the software, or because of a bad wire or battery, the scope will become a dust-gatherer.

Besides, there are many fascinating objects in the sky that are very easy to find without any special aid, or any great knowledge of the night sky. Getting started without a computer's help is not that hard.

There is an ongoing debate among amateur astronomers about this issue. In the end, it is another matter of choice. For myself, finding objects on my own provides much of the challenge and interest of stargazing. I have been at it for years, and have felt no need for help. In fact, much of the fun has been in stumbling upon things on my way to somewhere else, and then figuring out what they are by studying charts. I do not know how easy this would be with a go-to mount, or if it would even be possible. As I continue in the hobby, and search for ever dimmer and more elusive "faint fuzzies," I may change my mind; but for now, I see no need for a computer inside my mount.

The busy end of the telescope: eyepieces, Barlows, diagonals, and finders

There are many accessories available for the eyepiece end of the telescope. Some are necessary; others are very helpful. They range in quality from exquisite to useless.

Eyepieces

Astronomical telescopes come with focusers that use interchangeable eyepieces. These are lenses, or groups of lenses (anywhere from one to eight, or

Figure 3.21 In the small area near the focuser of this scope you can see many of the items described in this section: an eyepiece, diagonal, Barlow lens, and finder.

even more) bound together in a small tube. There are three standard eyepiece sizes, based on the diameter of the tube that slides into the focuser: 0.965 inches, 1.25 inches, and 2 inches (These are physical diameters of the eyepiece tubes, and should not be confused with their focal lengths, which can vary widely, and are almost always expressed in millimeters.). *You should avoid telescopes with 0.965-inch focusers*. Few eyepieces are available for them, and most of those are of poor quality. The 1.25-inch eyepieces are the most common, and all you may ever need. But if you can, get a telescope with a 2-inch focuser. They almost always include a simple adapter that allows the use of 1.25-inch eyepieces, and if they do not, the adapters are inexpensive. The 2-inch eyepieces allow lower magnification for wider views. You can use 1.25-inch eyepieces in 2-inch focusers, but it does not work the other way. You may not get any 2-inch eyepieces to start with (they are, all other things being equal, more expensive), but it is a good idea to have options for the future.

More info

This is a strange thing, but people in the telescope world – and not just in the USA – always seem to describe focusers using inches, and sometimes telescope apertures as well (especially larger ones); but other values, such as focal lengths, are almost always expressed in millimeters. If this is confusing to anyone unfamiliar with one or the other, just remember that one inch equals exactly 25.4 millimeters.

There are now so many choices available in eyepiece design and size that an entire book could be devoted just to them. However, many are far too expensive for the beginner; they will be left out of this guide. Others are so inadequate they are probably not worth having. Unfortunately, we cannot ignore *them*, because they are the eyepieces that sometimes come with a beginner's package (see Figure 3.23).

Some less expensive telescopes, especially the department store variety, include eyepieces of the **Huygens** or **Ramsden** design. If your telescope has eyepieces that have an "H" or an "R" written on them next to their

Figure 3.22 Eyepieces come in a wide range of size, focal length, and quality. Here are two 2-inch (on the left) and four 1.25-inch good-quality eyepieces that would provide magnifications, in a telescope with a focal length of 1000 mm, of, from left to right, 15.4×, 31×, 40×, 59×, 67×, and 167×.

More info

Eyepiece designs are usually named after the person who invented them. Huygens and Ramsden have been dead a very long time. Improvements have been made since.

More info

It is now possible to watch the Moon, Sun (with a proper **solar filter**), planets, and even some bright deep-sky objects live through your television. For not much more than the price of a decent Plossl eyepiece, you can buy electronic eyepieces that fit in a standard 1.25-inch focuser. These eyepieces are available in color and black-and-white versions (the color models typically have higher resolution and, of course, cost more). They are not much larger than a normal eyepiece, and have a cable that plugs directly into the video- or digital-recorder input on any television.

focal length, you will want to upgrade to better ones. In fact, you will probably want to avoid buying a telescope that includes these: if a manufacturer is willing to supply such eyepieces, the rest of the package is suspect as well.

Beginners' scopes might also include either **Kellner** or **modified achromat** eyepieces. While better than Huygens or Ramsdens, and even useable, the cheap ones usually included are still not very desirable.

The most common good eyepiece available for a reasonable price today is the **Plossl**. It is a decent all-around choice that provides quite sharp images. Plossls are also fairly inexpensive, especially if you get the "no-name" models that are often available from various telescope dealers or on the internet. Name-brand eyepieces may be of higher quality; but then again, they may not, or the difference may not be noticeable. The brand name *will* raise the price.

Choosing eyepieces

It may be that the telescope you select already comes with a couple of decent eyepieces, preferably Plossls. If it does not, or if it only comes with one (as many do), you will want to get one or more of your own. Two eyepieces are definitely enough to start with, and may be all you ever need, especially if you also get a **Barlow** lens (see below).

When choosing eyepieces, once you have decided on the type, you should keep two things in mind: *focal length* and *eye relief*.

Focal length. Remember, it is the focal length of both the telescope and eyepiece which determine magnification. You should choose the focal length of your eyepieces based on the magnification it will give you with your particular scope.

Here is an example: If you have a telescope (the type does not matter) with a focal length of 1000 mm, a 32-mm eyepiece will give a magnification of about 31× (1000 divided by 32 = 31.25). A 10-mm eyepiece will produce 100×. These are two useful "powers" to have.

If you have a telescope with a longer focal length, you would need eyepieces with proportionally longer focal lengths to get the same magnification. Shorter-focal-length telescopes require shorter-focal-length eyepieces. Beyond a certain point in either direction, this becomes difficult. To get wide-field views (say, 40×) with a telescope of 2000 mm

Figure 3.23 It is not just focal length that is responsible for short eye relief. The cheap, 0.965-inch eyepiece of unknown design on the left has a focal length of 20mm, but it has much less eye relief, and a much smaller eye lens, than the 1.25-inch, 15-mm focal length Plossl eyepiece on the right.

focal length, it would take an eyepiece with a focal length of 50mm. They are available, but usually in expensive, 2-inch sizes. At the other extreme, to get 200× using a telescope with a focal length of 500mm would require an eyepiece with a focal length of 2.5mm. Such an eyepiece would be virtually unusable, except for some of special design, and high price. This is because, typically, the shorter the focal length of an eyepiece, the smaller the eye relief.

Eye relief. The focal length of an eyepiece is also often an indicator of its relative eye relief. In other words, an eyepiece with a longer focal length will almost certainly have more eye relief than an eyepiece of the same type with a shorter focal length.

Some beginner scopes come with eyepieces that have focal lengths of 4mm, or even less. To use them, it is necessary to get your eye so close that it is, at best, very uncomfortable; and at worst, virtually impossible.

Eye relief is often stated in company advertisements or brochures for eyepieces. Anything less than 10mm is, for me anyway, getting too close. One problem I have noticed is that my lashes touch the **eye lens**, the lens that comes closest to the eye, and oil deposits are left on the glass.

What all of this means is that, if you have a telescope with a relatively short focal length, higher powers are going to be difficult to get, or uncomfortable to use.

There are special eyepiece designs that provide short focal lengths *and* long eye relief. They cost more, but may be worth considering, especially if you wear glasses.

More info – Eyepiece filters

Though not necessary to the absolute beginner, glass filters are available which are meant to be screwed onto the ends of eyepieces to enhance the view through the telescope. By blocking certain colors, some filters help the viewing of planets; others are meant to block light pollution; still others are meant to help with the false color which occurs in modestly priced refractors (these are often called **"minus-violet" filters**). You may want to choose eyepieces that have threads to accept these filters.

It should be remembered, though, that no filter actually makes anything brighter. They remove certain wavelengths of light so that others can be more noticed. Also, *NEVER use any eyepiece filter meant to block the light of the Sun!* The concentrated light reaching such a filter is extremely hazardous; it can crack such filters and cause immediate eye damage. There are filters meant for solar viewing, but a proper one is designed to be placed over the large end of the scope.

Barlow lenses

The specialized eyepieces mentioned above usually attain longer eye relief by incorporating a special lens, called a Barlow, within them. A Barlow lens has the effect of lengthening a telescope's focal length (or, put another way, of halving the focal length of the eyepiece). Barlows are typically purchased as separate units and usually come with 2× or 3× designations.

Barlows are a good investment. If you have two eyepieces and a Barlow, it is like having four eyepieces. You insert the barlow into the focuser, and then the eyepiece into the Barlow. Using an example from above, a 1000-mm telescope and a 32-mm eyepiece using a 2× Barlow would give 62.5× (1000 × 2 divided by 32=62.5); a 10-mm eyepiece would yield 200×. This would result in an eyepiece collection that gave 31×, 62×, 100×, and 200×. This is a good, even spread over a wide range. You may never want more.

Barlows are a good choice for another important reason: *they increase magnification without decreasing eye relief*. That 10-mm eyepiece will become, in essence, a 5-mm eyepiece, but it will keep the same eye relief. For scopes with shorter focal lengths, this may be the best (only?) way comfortably to reach higher magnifications.

When buying a Barlow, avoid the cheapest ones. The view through a telescope is only as good as the weakest optics used. If you have a decent telescope and good eyepieces, spend a little extra for this accessory; it will be worth it.

More info

Notice that, if purchasing a 2× Barlow, you need to think carefully about the focal lengths you choose for your eyepieces. It would not make sense, for example, to buy a 10-mm and a 20-mm eyepiece, since the Barlow will, in effect, convert the 20-mm eyepiece into a 10-mm eyepiece.

Diagonals

Because focusers on telescopes can end up in awkward positions when viewing (especially in refractors and Maks), it is often helpful to use

Figure 3.24 Two high-quality Barlow lenses.

a **diagonal**. This is a handy attachment that is placed between the focuser and eyepiece, and uses a prism or mirror to change the angle of view by 90 or 45 degrees. Some even use special prisms that provide a correct, upright, image (remember, astronomical telescopes usually show things upside down).

A diagonal is very helpful if two or more people of quite different height are going to use a telescope. It is often possible to find comfortable viewing angles for a variety of heights just by turning the diagonal in the focuser.

Finders and finder scopes

Even the smallest beginner’s telescope will probably come with an even smaller one attached to it. This is the **finder scope**. It is a low-power, wide-angle scope meant to help in the initial pointing of your main scope toward an intended target. Finder scopes usually have **cross-hairs** that help in centering; and some give a correct image, which makes using field guides or star charts easier. Since the field is so wide in the finder, it is easier to aim with this first. Finders need to be adjusted when you set up your telescope, so that the center of the eyepiece in your main scope matches up with the

Figure 3.25 Top: a 1.25-inch, 45-degree "correct-image" prism diagonal that would be very useful for both astronomical and terrestrial use; middle: a 1.25-inch, 90-degree mirror diagonal; bottom: a 2-inch, 90-degree mirror diagonal.

center of the field in the finder scope. A finder is only useful if it can be used to find things. Like binoculars, finders are usually described using numbers; anything smaller than 6×30 is not very useful.

Some telescopes now come with **red-dot finders**. These do not magnify an image through a lens (which is why they are also sometimes called unit power finders), but rather project a tiny red dot or circle against

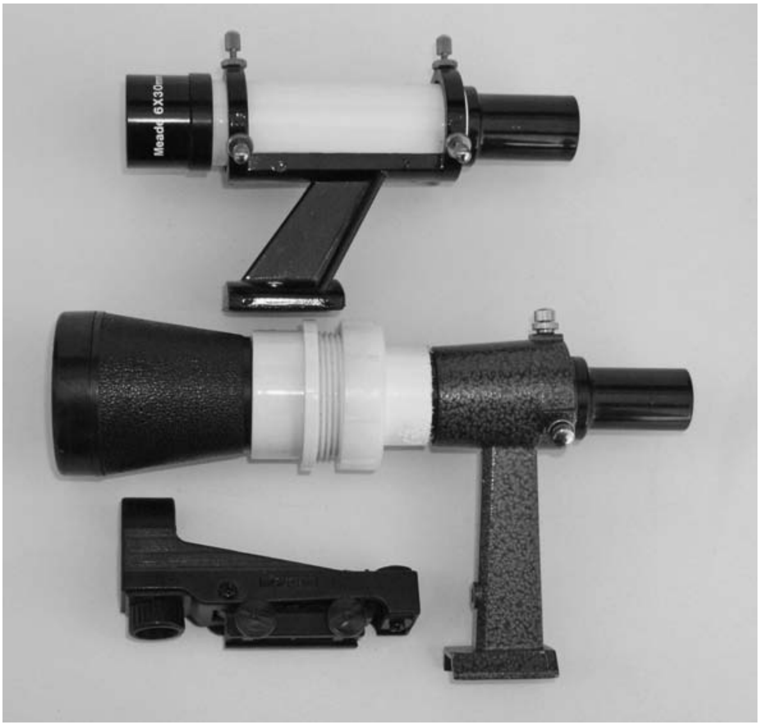


Figure 3.26 Three quite different finders. Top: a 6 x 30 finder scope that comes as a standard on many smaller scopes; middle: a finder that started out as a 6 x 30, but which has been modified with the objective end of a broken pair of binoculars into an approximately 8 x 50 finder scope; bottom: a "red-dot" or unit power finder.

a special piece of clear glass. Somehow, even if you move your head around, the dot continues to appear on the same spot in the background sky. They are very comfortable and easy to use. If a low-power eyepiece is used in the telescope when first aiming, these finders work well.

Astrophotography

If you are someone who enjoys taking pictures, you may want to keep this in mind when choosing your astronomy equipment. Cameras work by focusing light through a lens onto a surface (either film or a computer chip) that collects and stores it. When the camera's release button is pressed, a shutter curtain opens and closes to allow the light for each photo to strike the film or chip. The larger the aperture of the lens and the longer the shutter is left open, the brighter the final photo will be. Photos taken in daylight, or with a flash, freeze any motion because the shutter is only open for a short fraction of a second. **Astrophotos** typically require the shutter to be open for at least several seconds, and often for many minutes. With a clock drive on an equatorial mount to stop the apparent motion of the stars, even a beginner's equipment is enough to capture great shots of celestial objects, providing

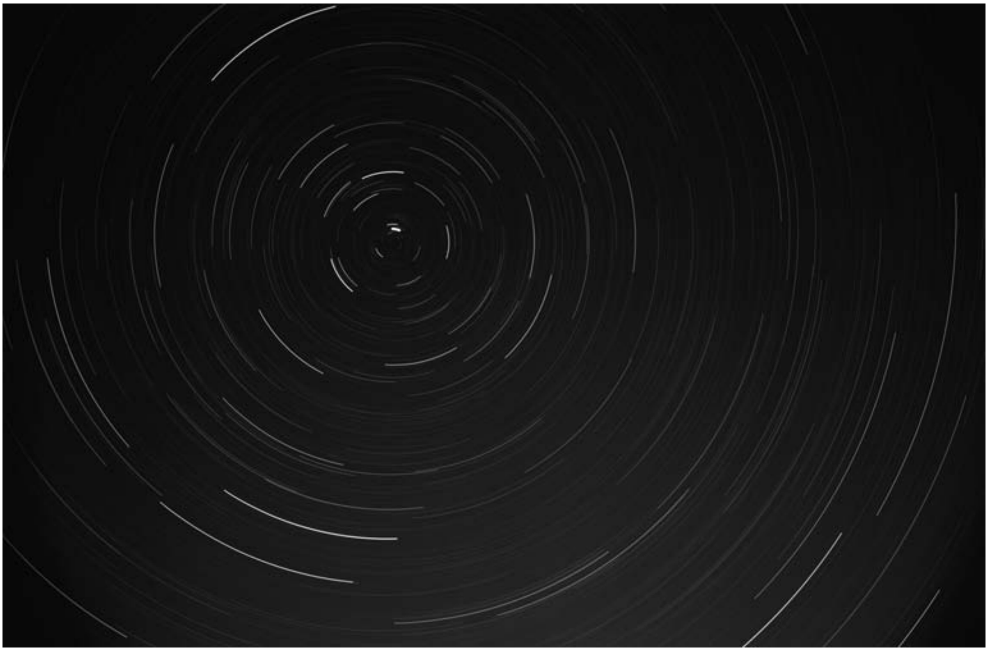


Figure 3.27 An approximately two-hour exposure of star trails; interesting here, but beautiful when seen in the colors that the stars recorded on the film.

the exposures are relatively short, and the magnification not too high. Getting a package that can be used for astrophotos will probably be cheaper than upgrading later.

Of course, the simplest astrophotos do not require a telescope at all. A camera with a normal or wide-angle lens, mounted on a sturdy tripod, is all you need, as long as the camera has a "b" setting, allowing the shutter to remain open indefinitely. With **fast film** (ISO 400 or higher), brighter constellations can show up with exposures of 20 seconds or less, and the turning of the Earth will not blur the image much. Longer exposures will show **star trails**, curved streaks on the film caused by the Earth's rotation, and these can be very pleasing.

Photos with a telescope

There are three main techniques used for taking astrophotos using a telescope that might be possible for a beginner: **afocal**, **piggy-back**, and **prime focus**.

An *afocal* astrophoto is the easiest to take, and only works for very short exposures of bright objects like the Sun, Moon, and planets. You simply focus the lens of a tripod-mounted camera on the image in the eyepiece of your separately-mounted telescope, and shoot. It is also possible to buy adapters that allow cameras with their lenses to be directly attached to telescopes with eyepieces. **Digital cameras** work especially well with this technique, since even inexpensive point-and-shoot models

Figure 3.28 Afocal astrophotography: A point-and-shoot digital camera attached, with a screw-on adapter, to an eyepiece inserted into a telescope's focuser.

can take very quick shots of dim objects, and the results can be immediately viewed. Eyepieces with long eye relief work the best. No other special equipment is needed.

For a *piggy-backed* astrophoto, you mount a camera on top of your polar-aligned, motorized telescope. Many telescopes come with piggy-back mounting adapters already part of the package, but they can also be bought later for a small cost. You then use your telescope and its mount to **guide** the photo (if you expose for more than a minute or two, or are using a **telephoto lens**). This is done by centering a star in the field, and keeping it centered by using the hand controller. This works best if you use an eyepiece with cross-hairs that are lit up with an LED. This is called an **illuminated reticle eye-piece**. Piggy-backing works well for wider angle shots; of constellations, the Milky Way, or comets. A camera with a "b" setting and a **cable release** are necessary for piggy-backing. It is best if the camera's shutter does not need a battery to hold it open for long exposures, since these pictures sometimes need several minutes or more. This is a technique that does not work well with inexpensive digital cameras, since they are not capable of very long exposures.

Prime-focus astrophotos are those taken with a camera attached directly to the telescope, with no lens on the camera, and no eyepiece in the telescope. This is, strictly speaking, not really a beginner's technique. It requires the use of a camera with interchangeable lenses; almost always a 35-mm **single-lens reflex (SLR)**. Old, used, (cheap!) manual cameras work best, since features like light meters or auto-focus are not necessary. What are necessary are adapters to attach the camera to the telescope; these are available from telescope dealers, and are not very expensive. The telescope essentially becomes a very powerful lens for the camera. The Moon is an excellent beginner's target for prime-focus shots using film; the Sun (with a proper solar filter) is another. Dimmer targets need longer exposures and,

Figure 3.29 A telescope set up for "piggy-back" astrophotography; the cable release on the camera, and the illuminated reticle eyepiece seen in the telescope's focuser, are almost essential for sharp, guided photos.

Figure 3.30 An old SLR film camera attached with an adapter directly to a telescope's focuser, for prime-focus astrophotography.

since any movement of the field of view will cause blurring, this means that almost perfect guiding is necessary. Such photographs require careful polar alignment and special ways of guiding the telescope that are beyond the scope of this beginner's guide.

Figure 3.31 A small digital astrocamera, made to photograph bright objects like the Moon and planets. It requires a computer at the telescope.

There are also new digital **astrocameras** specifically designed for use as prime-focus instruments. They use digital chips originally designed for "web cams," and are relatively inexpensive. They are meant for taking images of the Sun, Moon, and planets; and can be purchased for less than $100. However, to use them, it is necessary to have a computer at the scope.

Newer-model digital SLRs (or **DSLR**s) are also capable of taking any of the three types of astrophotos just described. (Older models cannot take long exposures because of excessive electronic "noise.") These cameras are still quite expensive, but if you already own one, it can certainly be used. In fact, they have many features that make them especially well suited to astrophotography; being able to view the results immediately is one of the most important. However, the very sensitive electronic sensors used in these cameras (instead of film) are equipped with filters that block most of the red light seen in certain deep-sky objects. In order to photograph these objects well, DSLRs must be professionally modified. The cost of this modification is also quite high.

"Finally, what should I buy?"

There is no easy answer to this question. There are too many choices, and too many variables amongst those choices. Most importantly, there is personal preference.

If you want to see the largest number of objects possible, and you *know* you will not mind the extra effort, then you should opt for the most aperture for the money: a Newtonian reflector on a Dobsonian mount. A good 203-mm (8-inch) f/6 (1200-mm focal length) model can easily be had for under $500; even a 254-mm (10-inch) f/5 (1250-mm focal length) is possible. Such a large aperture will certainly show you the brightest views, and thus also the most objects. Many experts think this is the ideal choice for the beginner.

If you are primarily viewing from a city or town where light pollution will block dimmer objects, and/or are primarily interested in the Moon and planets, and/or you really need a compact package, then a Mak might be for you. A 102-mm (4-inch) model is available on a GEM within our price range.

If you want versatility and ease of use, and you can handle a somewhat larger outfit, or you plan to use your scope for group viewing or astrophotography, then an equatorally mounted refractor may be best. I have seen both a 102-mm (4-inch) f/10 (1000-mm focal length), and a 120-mm (4.7-inch) f/8.3 (1000-mm focal length) scope package for under $500.

Yet, of course, a reflector can be put on an equatorial mount. Short-tube refractors and reflectors are compact, too. Many combinations are possible. The choice is yours, and you should now know enough at least to ask the right questions when choosing.

Still, if you cannot make up your mind, then here is my advice:

Get a refractor; get the largest aperture you can afford, with a focal length from 600–1200 mm; and, if possible, a 2-inch focuser and a piggyback adapter. Get it on the sturdiest German equatorial mount possible (many scopes come on mounts too flimsy for them); a mount that is upgradable for use with a clock drive. Get two Plossl eyepieces, a good 2× Barlow, and a diagonal. With this set-up, you will be ready, and then some, to begin exploring the Universe.

Others would surely disagree with me, and recommend a Dobsonian reflector: to get the "most bang for the buck," because there is very little to set up, and because aiming is as simple as pushing and pulling the tube in the right directions. They may be right. But Dobs have their own problems (size, collimation, balancing, near-constant re-centering at higher magnifications), which I believe could be very frustrating for someone absolutely new to telescope use. Once someone gets over the initial learning curve of using a refractor on an equatorial mount – and it *is* confusing at first – they are simple, versatile, and worry-free to use. I think this is most important.

In a nutshell

Below is a table comparing telescope types available to the beginner. It would not mean much without the explanation provided on the preceding

Comparing beginners' telescopes

Telescope type	Advantages	Disadvantages	Largest aperture available for less than $500 in a new, complete set-up
Refractor	No (or low) maintenance Easy to aim Fewer tube-current problems Variety of focal lengths	Chromatic aberration (false color) More expensive (per unit of aperture) than reflector	120 mm (4.7 inch) f/8.3 (1000-mm focal length) on equatorial mount 102 mm (4 inch) f/10 (1000-mm focal length) on EQ mount with single-axis drive
Newtonian reflector	Least expensive (per unit of aperture) Shorter cool-down time than comparable Maks No false color	Requires maintenance: frequent collimation and eventual re-coating of mirrors Awkward to aim Coma Larger mirrors need long cool-down Some tube currents	254 mm (10 inch) f/5 (1250-mm focal length) with Dobsonian mount 152 mm (6 inch) f/5 (750-mm focal length) on EQ mount with single-axis drive 130 mm (5.1 inch) f/6.9 (900-mm focal length) on EQ mount 130 mm (5.1 inch) f/5 (650 mm-focal length) on go-to mount
Maksutov–Cassegrain	Well-corrected for aberrations Small tube size (allows smaller mount, portability) Easy to aim	Long cool-down time High f/ratios make wide-field viewing difficult Most expensive beginner type (per unit of aperture)	102 mm (4 inch) f/12.7 (1300-mm focal length) on equatorial mount with single-axis drive

pages, but with an understanding of the terms used, this table may help you to decide what is best for you.

Resources

Telescope dealers

I strongly recommend that you buy your astronomy equipment from a store that specializes in it. Many camera stores sell telescopes, but most (though certainly not all) have a very limited selection, especially in good equipment for beginners; and, correspondingly, the staff may have little knowledge about what they sell.

However, if there are no telescope shops nearby, which is likely for most people, there are some advantages to shopping at least at a store that sells telescopes as a side line, even if you end up buying your scope through a mail-order company. It is always helpful actually to see and touch something before buying it. If you have done research and have a good idea about what you would like to get, check any local stores that might carry it. The odds are high that you will not find just what you are looking for, but even something similar will help you in making a final decision. If the total package is even somewhat close to what you have been considering, is it portable enough for your storage and transportation needs? Can it be used comfortably? How smooth is the focuser when you turn it? Is the mount solid and stable enough for the telescope included with it? (Give the end of the telescope a good tap with one hand while resting the other hand on the mount. Does the telescope bounce back and forth? How long does it take for the whole thing to stop vibrating? Vibrations should be slight, and should not take more than a few seconds to stop.) Answers to these questions are nice to have *before* making a purchase, rather than upon assembling a package that has been paid for and shipped to you.

Hundreds of companies specialize in selling telescope equipment. They range in size from large mail-order houses that publish glossy catalogs to small, one- or two-person operations. I have had great experiences at both ends of this spectrum. Get a current copy of *Astronomy* or *Sky & Telescope*, and page through the advertisements. You should find a company that can meet your needs. Or, you could do a web search. The internet and amateur astronomy are very cozy companions. Try a search for "telescope dealers." I just did, and got 2580 results. One of the first sites listed was a page with links to more than a hundred companies around the world that sell astronomy equipment.

Customer service is an important factor when choosing a dealer. Astronomy equipment is delicate, and subject to defects. Unfortunately, as in every field, there are unscrupulous astronomy dealers. You may want to contact other astronomers to find out what they know. Try calling the astronomy department at a nearby college, or your local **astronomy club**. There are also telescope-review websites. They can not only help you decide what equipment to buy; some of them have reviews of dealers, too.

Upgrades: If you think that a telescope package you are considering comes on too flimsy a mount (they often do), or if the eyepieces included are not what you want, or if other aspects are not quite what you are looking for, you might want to ask a dealer if they would give a discount for an upgrade to another level. There is no guarantee that they will, but if two or more dealers are offering similar packages, it is worth shopping around to find out.

Mixing and matching: It is also worth thinking about making your own package by shopping around for different components. Many dealers sell mounts, eyepieces, and **optical tube assemblies (OTAs)** separately. One might have a great deal on an OTA (a telescope without a mount), while another has a sale on mounts, and you might see a great deal on eyepieces on eBay. Pre-packaged scopes are always less work to find, and they are usually the least expensive way of buying components from one place; but shopping around can often save money, and is more likely to provide exactly the set-up you are trying to assemble.

Used equipment or "scratch and dents:" If you are willing to use less than pristine equipment, you might consider buying it used, or slightly damaged. Many dealers sell such equipment, often with warranties. Look on their websites, or ask them on the phone if they have any used equipment, or "seconds." A scratch in the paint on the tube could save you so much money that you might be able to afford something outside the scope of this guide. And you cannot see scratches in the dark!

You might also consider buying equipment through online *classified advertisements*. There are several such websites that I know of. Astromart.com is very popular, and takes great care to prevent fraud, and many reputable telescope dealers also sell items at this site. But it is mostly individual amateurs who use it, and it is always risky to send money to people you do not know. Still, if you are looking for something very specific, or want to save money, try Astromart.com, or do a web search for "astronomy classifieds" or "telescope classifieds."

Telescope reviews

If you have a specific telescope, or mount, or eyepiece, in mind, or you cannot decide which among several you should choose, try looking for a review of it online. New equipment comes onto the market so often and so quickly that this may be the best way to find out about it. Try searching for "telescope reviews." There are several excellent websites that review specific scopes, binoculars, mounts, eyepieces, Barlows, etc. Some of them even have categories devoted specifically to beginner equipment. Cloudy Nights Telescope Reviews at cloudynights.com is a site I particularly enjoy.

Star parties

Both professional observatories and local or regional astronomy clubs have occasional get-togethers called **star parties**. The public is invited to come and share the night sky through their own, or others', equipment. Some of these parties are huge, require reservations, attract people from everywhere, and last for days. These are usually annual events, and their dates are often published in *Astronomy* or *Sky & Telescope*. Other star parties are smaller and last just one evening. These are often given on a scheduled basis by clubs, planetariums, or observatories: every other week, or once a month, and so on.

Star parties are excellent places to "test drive" equipment before you buy, or to try equipment that you could never afford yourself. They are also places to meet other, like-minded people. But *beware:* you could catch *aperture fever*. You look through the eyepiece of a monster scope and see things you did not know were possible; and, besides, the scope itself is so cool! You get very excited, and start trying to figure out how to find the money to get one yourself. This really happens. Believe me.

Astronomy clubs

You may want to try to find out if there is a local club in your area. They often have access to dark-sky sites, and many clubs even have their own observatories. Membership in such groups gives you the chance to meet others who share your interest, and you can often get discounts on various astronomy goodies. Try another web search, for "astronomy clubs," and include your town, state, province, or country in the search. Or, in the USA, look up the *Astronomical League* at astroleague.org. They are a federation of local and regional groups, and can point you toward a club in your area.

Books

Here are a couple of books that go into more complex and complete detail than I have about astronomy equipment. They cover a wider range of options as well, since they are not devoted to the absolute beginner. If you think you want to know more, or simply have more money to spend, you may want to check them out. The first one is primarily devoted to equipment; the second is more general, and covers a wide range of topics. Both are excellent. Try to get the latest editions available.

1. *Star Ware: The Amateur Astronomer's Ultimate Guide to Choosing, Buying, and Using Telescopes and Accessories* (4th edition), by Phillip S. Harrington. John Wiley & Sons, 2007.
2. *The Backyard Astronomer's Guide*, by Terence Dickinson and Alan Dyer. Firefly Books, 2002.

There are also books specifically written for people interested in astrophotography. Here are four that include information that could be useful for beginners.

1. *Astrophotography: An Introduction*, by H.J.P. Arnold. Sky Publishing, 1999.
2. *Astrophotography for the Amateur* (2nd Edition), by Michael A. Covington. Cambridge University Press, 1999.

3. *Digital SLR Astrophotography*, by Michael A. Covington. Cambridge University Press, 2007. (This book is written in a personable, very clear, step-by-step way, and should be of great help to anyone new to using DSLRs for astro-imaging.)

4. *Wide-Field Astrophotography*, by Robert Reeves. Willmann-Bell, Incorporated, 2000.

Figure 4A A wide-angle astrophoto, taken on August 12, 2007, shows several items described in Part II. (1) A Perseid meteor; (2) the Double Cluster, an open star cluster; (3) the constellation Cassiopeia, the Queen; (4) the Andromeda Galaxy; (5) the Hyades, an open star cluster; (6) the planet Mars; and (7) the Pleiades, or Seven Sisters, another open star cluster. All of these – except that specific meteor – are visible to the naked eye under dark skies, and most are greatly enhanced with either binoculars or a telescope.

Part II
What's up there?

To infinity...or close enough!

Once you have the equipment needed – or better yet, before you do – you will want to get right out there to start exploring the night sky. Part II attempts to answer the question its title asks in as basic a way as possible. It will not give you all the information you need to find the objects in the sky; for that you will need a field guide, or star charts. It is merely meant to be a very brief tour, to give the novice some understanding of what the various objects are, as well as an idea of what they might look like through a beginner scope. The trip will start nearby, and move outward.

However, before getting to specific object descriptions, I should start with a *warning:* you will only be disappointed if, when looking through your telescope, you expect to see things as they appear in books or magazines, or on television or the internet. The brightness and, especially, the color in those images cannot be seen through the eyepiece of an amateur scope. Such things are only possible to record through **time-exposure** astrophotos, and such photos are often taken through giant telescopes at professional observatories, or even by artificial satellites and other spacecraft. Amateurs have taken and do take great astrophotos, and even a beginner's equipment is enough for shooting some targets. All the photos in this book were taken, by me, with modest amateur equipment. But the best amateur equipment available cannot show such detail or color directly to the eye: the objects are just too dim.

On the other hand, the human eye is *more* sensitive than photography in at least one way: it can see detail in images across a very wide range of brightness *at the same time*. Through the eyepiece, it is possible to see, for example, fine detail in the wisps of **hydrogen** on the edges of the **Great Orion Nebula**, while also seeing the individual bright stars in the center of it. A photograph would either wash out the brightness, or miss the faint detail. It is true that computer software can now be used to combine photos to show more range in detail, but the eye does it literally "live."

So, what can you expect to see? Within the Solar System, even with the minimum 80-mm aperture, you will be able to see close-up views of mountains, and "seas," and hundreds of craters on the Moon. With a proper solar filter, you can see features like sunspots on our very own star, the Sun. Seven other planets, and several of their moons, can be seen. If you know when to look, you can see meteor showers (no telescope necessary). If you know where to look, you can view **asteroids** and comets, smaller objects that also orbit the Sun.

Beyond the Solar System, you will, of course, be able to see countless stars: single stars, **double stars**, **multiple stars**, and star clusters, both open and **globular**. Stars are one type of object often bright enough to show their color in telescopes: red, orange, yellow, white, and blue are the most common, but some people even report seeing green or turquoise.

Nebulae (of several kinds) and galaxies (including our own) are the other targets of the deep sky. Some are actually visible to the unaided eye, but the apertures of binoculars and telescopes make it possible to view hundreds of these fantastic, varied objects.

Every night, the sky is filled with potential celestial targets. They are beautiful things to behold, simply as lights and patterns in the sky, and can be greatly admired and appreciated as such. However, knowing what they are, how far away, how large, how old, how they came to be, and what might one day happen to them – all of this knowledge *adds* to the impact of seeing them "live and in person" through the eyepiece. From small rocks spinning and hurtling around the Sun, to entire "island universes" containing hundreds of billions of suns: when you know what it is you are looking at, and you try to get your mind around the vastness and complexity of it all, it is easy to get truly lost in awe. And guess what? You can do it again and again, night after night, and never come close to seeing it all. The information in Part II might help you get *started* on the road to that awe-inspiring knowledge. I hope your own experiences at the eyepiece make you hungry for more!

More info

Here's something else: stargazing takes practice, like any other skill. The more you do it, the better you get at it. Just like playing the piano or typing, where your fingers eventually seem to know what to do, with stargazing it is your eyes that seem to change, gaining in the ability to see faint, fine detail. Amateurs with years of experience can truly see things, through the same telescope and eyepiece, which less experienced observers cannot.

The Solar System 4

Our own star is called **Sol**. It, and all that orbit it, are part of the Solar System. This includes, at this time, eight planets (or maybe nine; or possibly twelve or more: the scientific definition of "planet" is under debate), a large and growing number of known moons that orbit these planets, and millions of smaller asteroids and comets, which range in size from several hundred kilometers in diameter to microscopic.

Most of these objects are not visible to even the largest telescopes, since the tiny greatly outnumber the large. But many of them are excellent targets for even the smallest scope. The Sun and the Moon are the only two bodies in the heavens that clearly appear as disks to the unaided eye, rather than as points of light. Seven planets show disks when viewed through telescopes. Some of their moons are also visible.

However, what makes these objects into targets worth visiting often is that they *change*. The **phases** of the Moon, Mercury, and Venus; the appearance and passage of spots across the surface of the Sun; the polar caps of Mars; the dance of the moons of Jupiter and Saturn; all of these and more are there to see, even through beginner scopes.

In addition to these regular denizens of the solar neighborhood, there are periodic visitations from lesser-known objects. These include asteroids, comets, and meteors.

This chapter will give a brief description of all of these objects. The sections on the Moon, the Sun, and the planets will start with some statistical information; one term needs definition: **angular size** is the *apparent* diameter of an object, when viewed in the Earth's sky. It is given in degrees (one 360th of a circle,) minutes (one sixtieth of a degree,) or seconds (one sixtieth of a minute.) The Sun and the Moon, for example, each have an angular size of about 30 minutes (written 30′) or half a degree. This is an amazing coincidence, and is the reason that **total solar eclipses** are so spectacular. But the angular sizes of these two bodies have nothing to do with their *actual* sizes: the actual diameter of the Moon is 3476 kilometers (2140 miles); the diameter of the Sun is about 1,390,000 kilometers (862,000 miles). The Sun is about

More info

Many "deep-sky" objects, strange as it may seem, appear much larger in our sky than anything in the Solar System. The Andromeda Galaxy, for example, spreads across at least three degrees; more than six times the diameter of the Moon. Of course, it is also very dim, especially at the edges; though under even medium-dark skies, it can be seen with unaided vision. It *appears* so large because it is large: it measures more than one hundred thousand **light years** across!

400 times wider than the Moon. Now here's the amazing coincidence: the Sun is also about 400 times farther away from the Earth! That is why the two appear to be the same size when seen in our sky.

All other objects in the Solar System appear so small that their measurements must be given in seconds of arc. This means that, even at very high magnification, they will not fill much of the field of view in an eyepiece. Still, with good optics, you will be able to see **surface features** on other worlds, hundreds of millions of kilometers away!

Measurements

The Moon	
Angular size:	30′
Diameter:	3476 kilometers (2140 miles)
Average distance from Earth:	380,000 kilometers (238,000 miles)

Our nearest neighbor

The Moon

The closest heavenly body regularly seen from the Earth is, of course, the Moon. It is a dead ball of rock, with no life, and no atmosphere. It is covered with craters caused by the bombardment of thousands of objects early in the history of the Solar System, a few billions of years ago, and less frequently, since then.

The Moon orbits the Earth in about a month (the word "month" is derived from "moon"). The force of the Earth's **gravity** has caused one side of the Moon to become "locked" toward us; this means that it turns once on its axis during one orbit of the Earth. So, though only one side ever faces us, both sides of the Moon get exposed to the Sun (and that means there is no "dark side of the Moon;" but there is a "far side"). This may be hard to visualize at first.

Moon phases

The Moon orbits us, and we orbit the Sun. As Figure 4.2 shows, when the Moon is on the opposite side of the Earth from the Sun, the side of the Moon that faces us is completely lit up by the Sun. This is the **full Moon**.

When the Moon is close to the Sun in the sky, the other side of it is lit, and the side facing us is dark. This is called the **new Moon**.

A week after the new Moon comes the **first quarter Moon**. This may seem confusing, since *half* of the Moon's face is lit up, but it is actually a way of saying "the first quarter of the month."

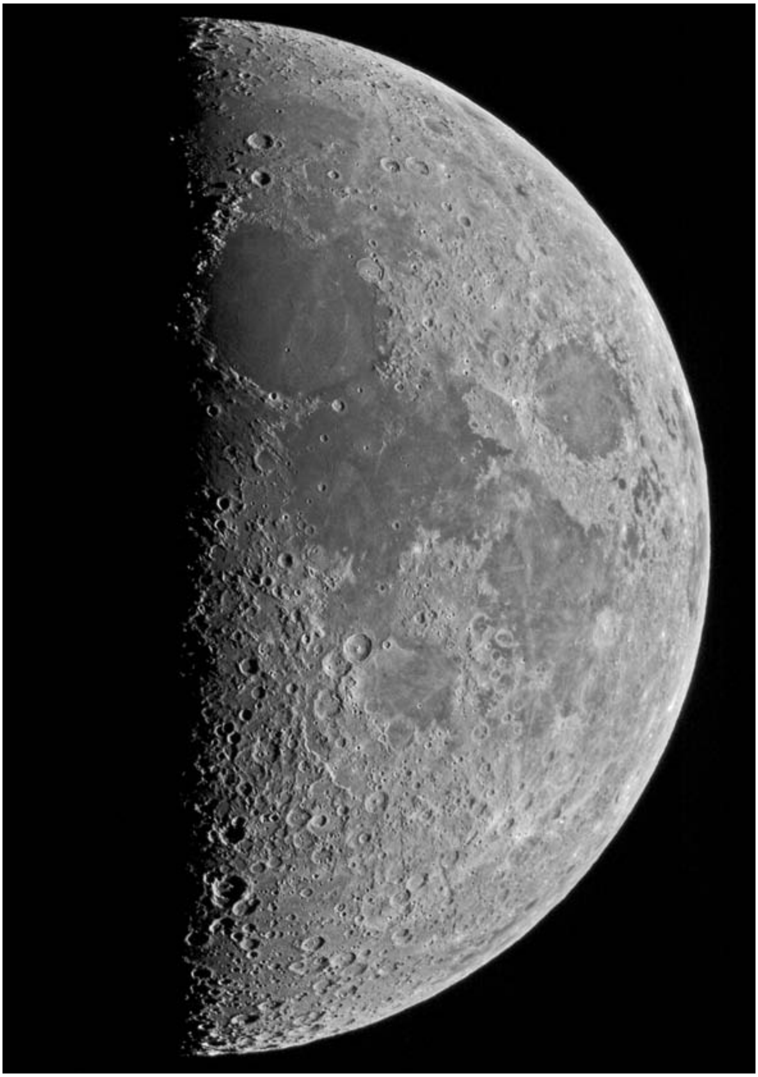


Figure 4.1 No object in the night sky shows as much detail to us as the Moon; and the detail changes from night to night on Earth, as the line between night and day on the Moon slowly crosses its face.

A week after the full moon comes the **last quarter Moon**.

The Moon is a **crescent** when it is less than half lit up, but not new, and **gibbous** when more than half lit, but not full. It is said to be **waxing** as it is "growing" between new and full; and **waning** as it "shrinks" between full and new.

As a month passes (not a calendar month, but an orbit of the Moon around the Earth), the Moon rises later each night. When it is new, it is very

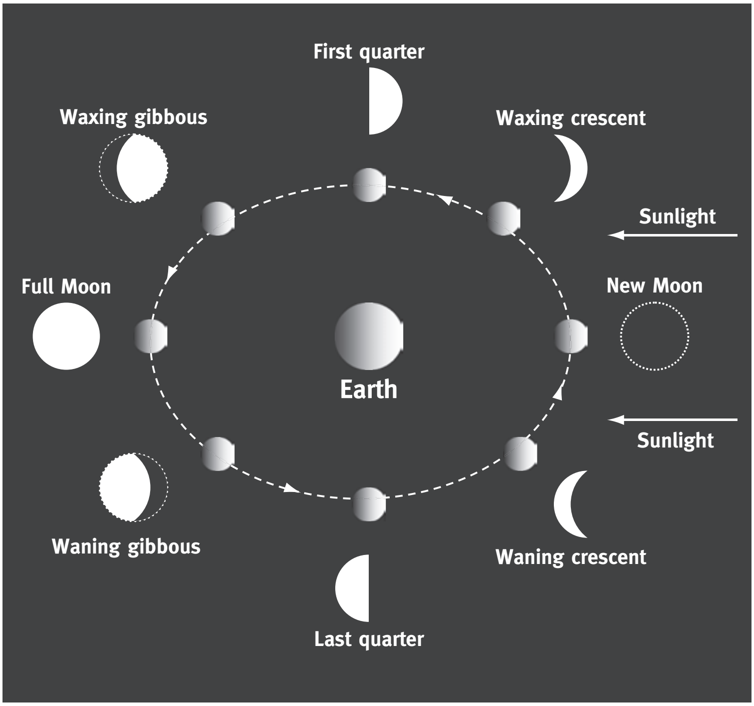


Figure 4.2 **The changing face of the Moon as it orbits the Earth each month. The inner circle of small images shows the Moon's movement around the Earth. The outer circle shows the phases of the Moon as they appear to viewers in the northern hemisphere on Earth. Southern-hemisphere viewers see an inverted view (and can just turn the book upside-down), since they themselves are "upside-down" relative to people in the north.**

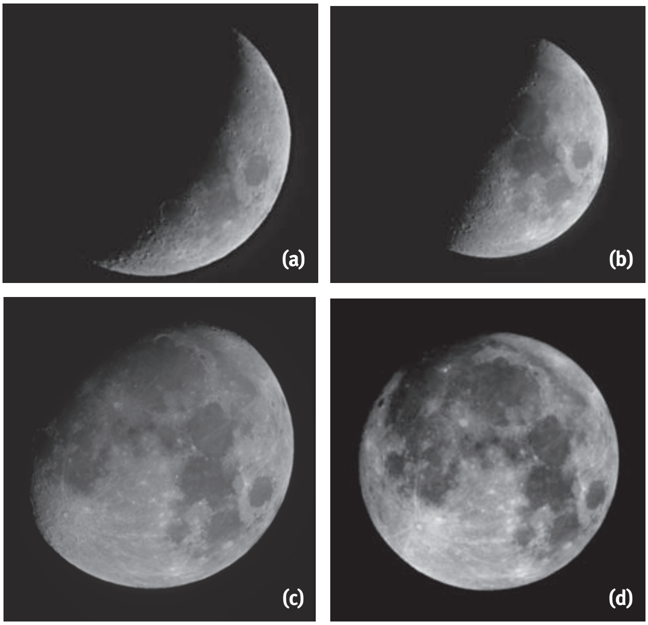


Figure 4.3 **The waxing (growing) Moon: (a) crescent; (b) first quarter; (c) gibbous; and (d) full.**

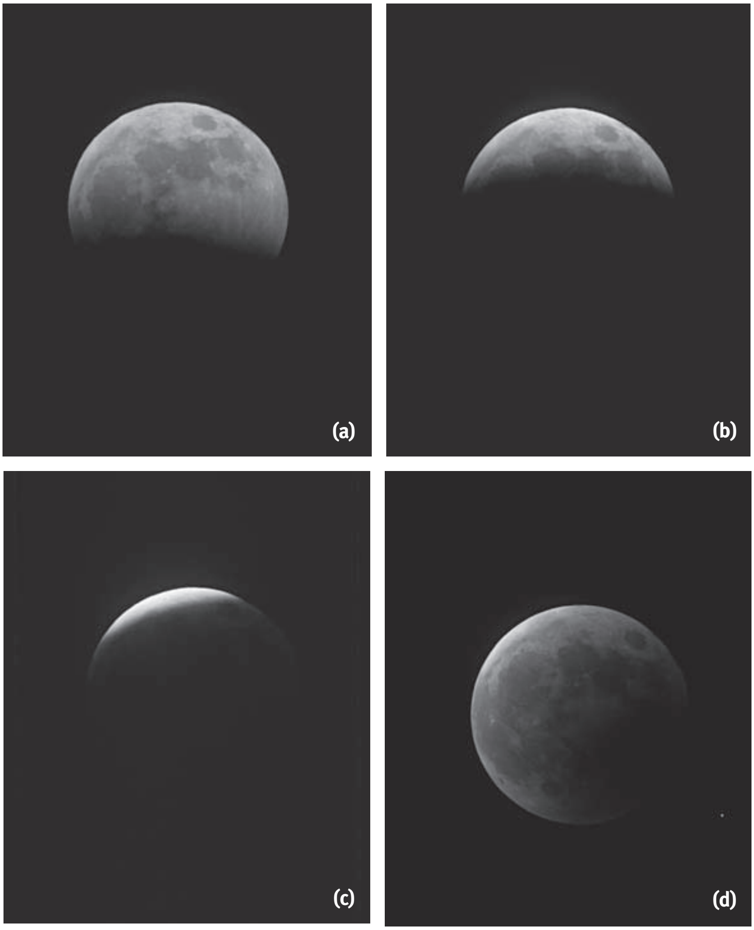


Figure 4.4 A lunar eclipse. The Earth's shadow slowly covers the face of the full Moon in (a), (b), and (c); but it completely covers it in (d), which was a much longer exposure, showing an orange Moon in the original slide, darkly lit by sunlight shining through the Earth's atmosphere (see the back cover). Note the star visible to the Moon's right in (d). It is only possible to see stars this close to the full Moon during an eclipse; they are usually washed out by the light of this, the second brightest object in the sky, after the Sun.

close to the Sun in the sky, so it rises and sets at about the same time as the Sun. At first quarter, the Moon rises around midday, and sets around midnight. The full Moon rises near sunset, and stays in the sky all night. The last quarter Moon rises around midnight, and sets around noon.

Observing the Moon

About the *worst* time to view the Moon through binoculars or a telescope is when it is full. The Moon's surface is covered with craters, mountains, and valleys. During a full Moon, the Sun comes closest to shining straight down on all of these, making any shadows cast by them very short. To see detail on the surface, it is best to view where the shadows are longest: along the line between the lit and unlit parts of the surface. This line is called the **terminator**, and it is slowly moving – at about 10 miles (16 kilometers) per hour – all the time.

A great time to watch the Moon with your eyes, binoculars, or at low telescope magnification is during a **lunar eclipse**. Lunar eclipses happen when the Earth gets directly between the Moon and the Sun (and so, of course, only when the Moon is full). Because the Earth has an atmosphere, its shadow as it crosses the Moon varies in darkness. Sometimes, the Moon passes through the very dark center of the Earth's shadow; at other times, it skirts along the edge. So some lunar eclipses are very dark, while others are less so. But all seem, to me, both beautiful and sort of eerie.

Lunar eclipses are sedate and slow, compared to solar eclipses, because the Earth's shadow is so much larger than the Moon. It can cover the Moon completely for well over an hour.

No other object in the sky has as much detail visible through the telescope as the Moon: it is our closest neighbor; it is quite large (compared to other moons); and it has one more thing going for it, at least from an astronomer's point of view: it has no atmosphere to get in the way of viewing. There are many hundreds of named features on its surface, and many books are devoted entirely to observing it.

Our own star

Sol (the Sun)

Next to the Moon, there is nothing else in the sky that is easier to see and study than the Sun. Surface details are visible without any magnification. Sunspots larger than the Earth are often visible as they crawl across the solar surface while it slowly spins on its axis about once every 27 days.

The Sun is a star, and a fairly average one. Stars are huge balls of gas (mostly hydrogen, usually). They are held together by their own gravity, and they have so much **mass** that gravity squeezes them tightly enough to cause **nuclear fusion**: hydrogen atoms are forced together to form **helium** atoms, a huge amount of energy, and some leftovers. This nuclear energy is what causes stars to shine. It also keeps them stable. Stars have so much mass that, without the outward pressure of the heat from the nuclear reactions, the inward pressure of gravity would (and sometimes does) cause them to collapse into much smaller, denser bodies. The Sun has been steadily burning for more than four billion years, and should continue to do so for billions more.

Measurements

Sol (the Sun)	
Angular size:	30′
Diameter:	1,390,000 kilometers (862,000 miles)
Average distance from Earth:	150,000,000 kilometers (93,000,000 miles)

Observing the Sun

The first thing to be said on this subject is that *it is never safe to view the Sun without a solar filter approved for the purpose!* In fact, even some of those should not be used. I have read that some telescopes may still be sold with solar filters that are meant to be screwed onto an eyepiece. *These filters are not safe and should be thrown away!* The objective lens or primary mirror of a telescope will focus the intense energy of the Sun on such a filter, which could crack it and cause immediate, serious damage to the eye of anyone looking through it. Solar filters should fit over the object end of the telescope, thus filtering the Sun's energy before it ever reaches a lens or mirror. Some filters are made of a plastic material called **mylar**, which is inexpensive, but can turn the image of the Sun blue. Other plastic filters are available that give a more "natural" orange appearance. Glass filters are also available, but cost much more.

Indirect observation of the Sun is also possible. After you cover or remove the finder scope for safety, you can aim your unfiltered scope at the Sun by watching the telescope's shadow on the ground as you adjust its position (obviously, you do not want to look through the telescope or its finder at the Sun). When the shadow of the tube becomes a circle, you are centered on the Sun. You can then hold a stiff piece of white paper several inches behind the eyepiece. Move it in and out until a clear image of the Sun appears. Tripod-mounted binoculars also work well for this purpose, as long as you cover one objective lens.

Figure 4.5 A solar filter in its proper place: in front of the objective lens or mirror of a telescope. This one is made of mylar.

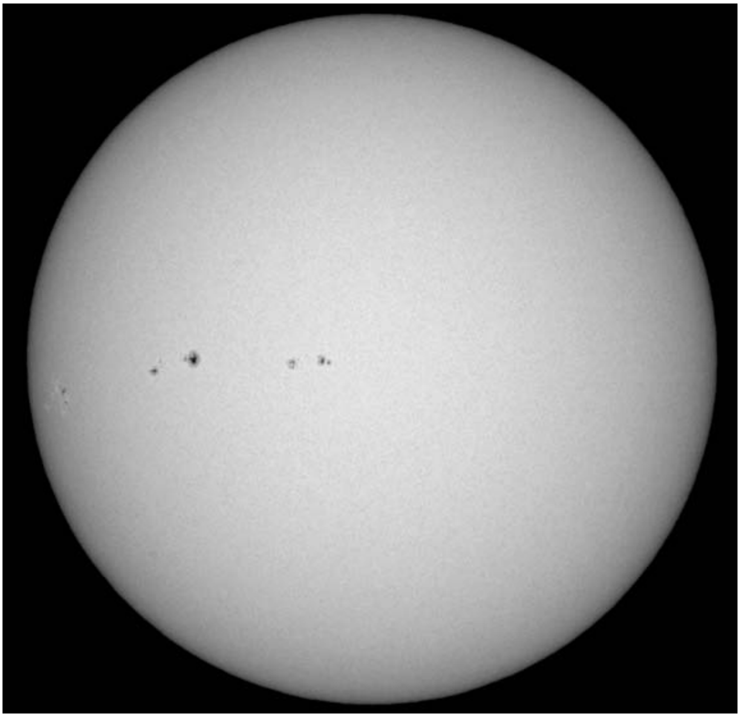


Figure 4.6 A photo of the Sun, taken in March, 2008. The Sun follows an approximately 11-year cycle of activity. A new cycle had just begun a few months before this photo was taken, but solar cycles overlap slightly, and these sunspots were actually one of the last groups produced by the one just ending. This photo was taken through the "planetary scope" shown in Figure 3.8 on page 36, equipped with a safe yet inexpensive homemade solar filter (total cost was less than $10). This was also the last photo taken for the book, and the only one taken with a DSLR.

Sunspots are clearly visible. They appear to be small, dark splotches on the face of the Sun. But they are actually huge (remember, the Sun is nearly a million miles across!), and they are only dark in comparison to the extremely bright regions around them.

Though relatively few people are lucky enough to see many of them, total solar eclipses are one of the most impressive spectacles in nature. When the Moon is the right distance from the Earth (and it can vary), and it passes directly between us and the Sun, a total solar eclipse is the result. These are quite rare for a given spot on the Earth – the next over the United States will not occur until 2017 – and **totality** never lasts longer than several minutes. **Annular eclipses** occur when the Moon is farther from the Earth, and does not completely mask the Sun. **Partial eclipses**, when the Moon covers only a portion of the Sun's disk, are much more common, and seeing a "crescent" Sun is very impressive in itself.

Even more rare than solar eclipses are **transits** of the planets Mercury and Venus, though they are visible over a larger geographical area. Transits occur when the orbits of Earth and these two planets line up such that they pass between us and the face of the Sun. Because it is much closer to the Sun, transits of Mercury are more common, and they occur thirteen or fourteen times per century, though times between transits vary, from 3.5 to 13 years. Partially because their timing involves the orbit of the

Earth (which, by definition, lasts exactly one year), transits always happen around the same dates in our calendar. Mercury transits are in either May or November. Since 1993, there have been four Mercury transits, but we are now in the midst of a long gap. Here are the dates for the next few transits of Mercury across the face of the Sun: May 9, 2016; November 11, 2019; and November 13, 2032.

Transits of Venus are far more rare. They occur in pairs, eight years apart, almost to the day. But between those paired transits more than a century passes. We are currently in the middle of one of the pairings. A transit occurred on June 8, 2004; and the next will happen on June 6, 2012. Watch this event – through a proper solar filter! – and know that you may not have another chance to do so in your lifetime, since the next transit of Venus will not occur until December 11, 2117.

The planets

Even a moderate beginner's scope will allow you to see all the planets in the Solar System, except for tiny, distant **Pluto** (currently downgraded to the status of "dwarf planet"). However, for different reasons, only three of the seven show much detail, even to the largest Earth-bound observatories.

Finding the planets in the sky is more challenging than finding deep-sky objects, at least in one respect. Since both the Earth and the other planets orbit the Sun, each at a different distance and speed, their positions across the background of the sky change. The change is slow for those planets farther from the Sun, but it can be fairly quick for the inner planets.

Luckily for the observer, none of them move randomly across the whole sky. All of the planets (except, again, for lonely, virtually invisible, controversial Pluto) orbit the Sun in a fairly flat disk, which means that they seem to stay near a single, specific line that encircles our night sky. This line is called the **ecliptic**. It has this name because it is along this line that the Sun, like the planets, seems to travel around the sky each year (see Figure 4.7.) So it is also the line along which solar eclipses occur. The ecliptic passes through twelve famous constellations: the signs of the **zodiac**. Several of these constellations are fairly dim, but they are famous because of **astrology**. The ecliptic passes through a few other, less famous constellations as well, including **Cetus** (the Whale) and **Ophiuchus** (the Snake Holder.) The positions of the planets are plotted each month in *Sky & Telescope* and *Astronomy*, as well as on various websites.

More info

Pluto has become controversial. In 2006, the International Astronomical Union, a group charged with the authority to give astronomical definitions, downgraded its status to "dwarf planet." This decision has met with protest from some quarters. Still, large telescopes have found other bodies in the outer reaches of the Solar System that may be nearly as large as Pluto, and at least one that is larger. Is Pluto a planet, or isn't it? And if it is, what of the others out there?

Figure 4.7 Four naked-eye planets together in the sky. From left to right, starting with the triangle just left of center: Saturn, Mars, and very bright Venus. Using the triangle as an arrow to find it, with Venus as the tip, Mercury can be seen just above the center tree's top. The fifth and last of the naked-eye planets, Jupiter, was not far away to the upper left but does not appear in the photo. All of them are near the ecliptic, a path around the sky that corresponds to the flat disk of the Solar System.

Mercury

Mercury is the closest planet to the Sun; so close, in fact, that it is never visible above the horizon when the sky is truly dark. Much of the time, it is so close to the Sun in our sky that it is not viewable.

Even when it is apparent in our sky, Mercury is so small (only Pluto is smaller, and a couple of moons are bigger), and so far away, and so washed out by the glare of the Sun, that no features are visible on its surface. All that can be seen of it through telescopes are its phases. It has phases, like the Moon, because it is closer to the Sun than we are; so, like the Moon, it can get between us and the Sun, and show us its night side.

More info

When the Sun, traveling along its path on the ecliptic, is high in the sky during summer days, most of the planets, when they are up during summer evenings, tend to be low in the sky. This is because they are then located on the part of the ecliptic where the Sun will be in winter. Conversely, when the Sun is low in the winter, evening planets are usually much higher in the sky, making them easier to view, since there is much less of Earth's atmosphere to look through.

Measurements

Mercury

Angular size:	5–13″
Diameter:	4878 kilometers (3031 miles)
Average distance from Sun:	58,000,000 kilometers (36,000,000 miles)

Venus

Venus is the second planet from the Sun. It also shows phases, since it too is closer to the Sun than we are. It appears smallest when it is "full" because at that time it is on the opposite side of the Sun from the Earth. When it is a very thin crescent, it appears far larger, because it can then be as close to us as about 40 million kilometers (25 million miles), closer than any other planet. Because it gets so close, it is often the third brightest object in the sky, after the Sun and Moon.

Venus is called the Morning or Evening "Star" because it never strays too far from the Sun, again like Mercury. However, because it orbits further out, Venus can be seen much higher above the horizon than Mercury, and it can stay up much longer than Mercury does after the Sun sets, or rise quite a while before dawn.

Though Venus gets closer to us than any other planet, it is as featureless as Mercury through a beginner's scope. This is because of its thick, impenetrable atmosphere, 100 times thicker than our own. (This thick, highly reflective atmosphere is another reason that Venus is so bright.) Scientists knew almost nothing about its surface until radar was bounced off it a few decades ago. They could not even be sure how long it took to spin on its axis, or if it did at all. The phases are easily visible, but that is about all.

Measurements

Venus

Angular size:	10–64″
Diameter:	12,104 kilometers (7521 miles)
Average distance from Sun:	108,200,000 kilometers (67,200,000 miles)

More info

The thick atmosphere of Venus makes it, on average, the hottest planet in the Solar System; even hotter than Mercury, since the Sun's heat is trapped and spread by the poisonous gases in the Venusian sky. Though closest to Earth in both distance and size, there is possibly no planet in the Solar System less hospitable to life than Venus.

Mars

Mars is the fourth planet from the Sun, and can be the second closest to the Earth. It has two small moons, called **Phobos** and **Deimos**, which are too small and close to the planet to be seen in beginners' scopes.

Mars is much smaller than the Earth, but the two planets have much in common. Mars has an atmosphere, though it is only one percent as dense as ours. Temperatures there can get above the freezing point of water (though not usually by much, and not very often). Satellites orbiting Mars have photographed areas that seem to have been carved by running water, and recent satellite surveys seem to prove that there is indeed much water

Figure 4.8 Venus and the Moon often appear near each other in the sky; sometimes the Moon actually passes in front of Venus. Because they are both so bright, photographing them is not difficult. Here, the photo has been over-exposed to show Earthshine on the part of the Moon not directly lit up by the sun. It is caused by sunlight reflecting off of the Earth onto the Moon, and then back to the Earth again.

Figure 4.9 A crescent Venus, bright but featureless, as it might be seen through a beginner's scope. The thick atmosphere of Venus never shows much detail and, as with a crescent Moon, this crescent Venus was quite close to the Sun as viewed from Earth. The Sun itself was just below the horizon, so Venus was very low in the sky. Objects near the horizon have much more atmosphere blocking them than things higher up, so the lack of detail seen here is no surprise.

just below the surface. All of this makes Mars one of the most likely places other than Earth to harbor life or, at least, life's remains. This in itself makes Mars an interesting place, and gives you thoughts to ponder while looking through the eyepiece.

Because it has a thin atmosphere, and because at its closest approach it can come to within 56 million kilometers (35 million miles) of the Earth, Mars is the only other planet in the Solar System whose true surface features can be seen through Earth-bound telescopes, even beginners' scopes (the "surface features" of any other planets are actually cloud-tops). And, because Mars has an atmosphere, those surface features can change; which is one more reason to return to Mars again and again.

Observing Mars

Mars has detail worth seeing, so it is desirable to get as close a view as possible. Mars takes 687 days, or almost two years, to travel around the Sun. The Earth, of course, takes one year. Because both planets are traveling in the same direction, it takes just over two years to go from one close approach of Mars to the next. At such times, Mars is said to be at **opposition**. This term is used because Mars (or any other body at opposition) is on the exact opposite side of the Earth from the Sun. Because both the Earth and Mars are traveling in orbits with the Sun at or near their centers, it makes sense that the shortest line between the planets happens around opposition (see Figure 4.11).

Through smaller telescopes, the most visible feature on Mars will be the polar ice caps, made of both water and frozen carbon dioxide ("dry ice"). It is possible, though difficult, to see other features: lighter and darker areas on the planet's ruddy surface. But it takes patience and practice, since the disk is never large.

Measurements

Mars

Angular size:	4–25″
Diameter:	6787 kilometers (4222 miles)
Average distance from Sun:	228,000,000 kilometers (142,000,000 miles)

Figure 4.10 A photo of Mars, taken with an inexpensive "web cam," during its close approach to the Earth in 2005, through a 120 mm (4.7-inch) refractor and a 3× Barlow. To see this amount of detail through the eyepiece at a beginner's scope would be very difficult. Patience and practice are needed to tease things out.

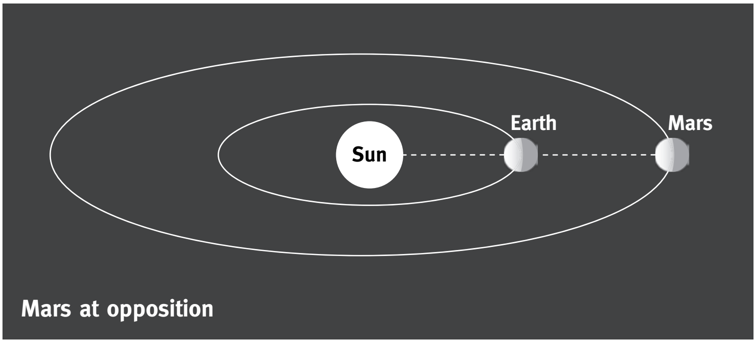


Figure 4.11 Mars and the other "outer" planets are typically closest to Earth when on the opposite side of it from the Sun.

The best time to view Mars is for a few months around opposition. It is a small planet, and when farther from the Earth it is not a very rewarding target. However, during a close approach, it can rival Jupiter in brightness. Below is a table showing the dates for oppositions of Mars through to the year 2020, and the maximum angular size it will reach. Notice that it is much larger during some oppositions than others. This is because Mars has an **eccentric orbit**. Its distance from the Sun can vary by tens of millions of kilometers. Every fifteen to seventeen years, Mars comes closest to Earth around the same time that it is closest to the Sun. Such oppositions are called **perihelic** (closest to the Sun). In 2003, it came closer to us than it has in recorded history (though not by much). The next close opposition will be in 2018. These are clearly the best times to view Mars from the Earth, and astronomers eagerly await them.

How do you find Mars in the sky? Well, at or near these times of opposition, look for the brightest reddish "star" in the sky! By definition, an object at opposition reaches its highest point in the sky around midnight.

Oppositions of Mars

Date	Angular Size
January 29, 2010	14.0″
March 3, 2012	14.0″
April 8, 2014	15.1″
May 22, 2016	18.4″
July 27, 2018	24.1″
October 13, 2020	22.6″

Measurements

Jupiter

Angular size:	31–48″
Diameter:	142,800 kilometers (88,700 miles)
Average distance from Sun:	778,000,000 kilometers (484,000,000 miles)

For more detailed information, or to find its location at other times, check out *Sky & Telescope* or *Astronomy*, or go online.

Jupiter

By far the largest planet in the Solar System, Jupiter is also one of the most dynamic, interesting targets in the night sky, for several reasons.

First, it is the biggest, not only in reality, but through the eyepiece of a telescope, most of the time. (Venus can appear larger at times, when it is a crescent near the Sun in the sky.) Any time Jupiter is visible in the night sky, it is worth looking at.

Second, even small scopes will show some surface detail on the planet: a couple of prominent, dark **belts**, and the paler **zones** between them. Larger apertures will show more detail, including the **Great Red Spot**, a giant storm that has been raging for at least several hundred years. And since Jupiter spins once on its axis in about ten hours, it is possible to see a large part of its surface in a single, patient night of observing.

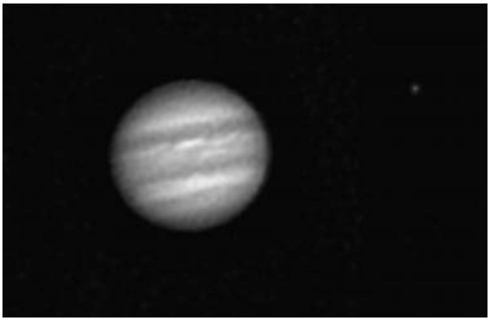


Figure 4.12 A close-up of Jupiter and one of its four large moons.

Jupiter's travels

Year	Months	Constellation
2008		Sagittarius
2009	January	Sagittarius
	February–December	**Capricornus**
2010	January	Capricornus
	February–May	**Aquarius**
	June–October	**Pisces**
	November–December	Aquarius
2011	January–February	Pisces
	March	Cetus
	April–June	Pisces
	July–December	**Aries**
2012	January	Pisces
	February–May	Aries
	June–December	Taurus
2013	January–June	Taurus
	July–December	**Gemini**
2014	January–June	Gemini
	July–September	**Cancer**
	October–December	Leo
2015	January	Leo
	February–May	Cancer
	June–December	Leo
2016	January–July	Leo
	August–December	**Virgo**
2017	January–October	Virgo
	November–December	**Libra**
2018	January–November	Libra
	December	Ophiuchus
2019	January–November	Ophiuchus
	December	Sagittarius
2020		Sagittarius

Figure 4.13 Jupiter and three of its four large moons, looking much as they would through a beginner's scope.

Finally, Jupiter has four moons that are easily visible, even through steadily held or mounted binoculars (it has many others too small to see). Discovered by Galileo around 1610, they are called, in order of distance from the planet, **Io**, **Europa**, **Ganymede**, and **Callisto**. They are so large and bright that, were it not for the glare of the giant they circle, each would be visible to the naked eye under dark skies. They dance around Jupiter at different distances and speeds, and often cross in front of it in a transit. At such times the moon casts a black shadow on the bright cloud tops of Jupiter. The moons also disappear behind Jupiter or its shadow (an eclipse). All of these happenings are quite predictable, and information on times is available in the magazines, or on various websites.

Observing Jupiter

Since Jupiter is a worthy target whenever it is in the sky, knowing when it is at opposition is not necessary (though it *is* best at that time). Knowing where it is in the sky is another matter. Jupiter takes 12 years to travel through a complete circle of the constellations along the ecliptic. Opposite is a table that shows what constellations Jupiter will be in through to the year 2020. You can use this table and a planisphere to figure out when and where Jupiter will be in your sky, and the best time of year to see it. For example, from mid 2012 to mid 2013, Jupiter will be traveling through **Taurus**. Taurus is highest in the sky during December and January, a fact your planisphere will show you; so Jupiter will be as well. Jupiter will almost certainly be the brightest object in or around whatever constellation it's in, unless Venus is nearby.

Measurements

Saturn

Angular size:	15–21″ (not including rings)
Diameter:	120,660 kilometers (74,600 miles)
Average distance from Sun:	1,427,000,000 kilometers (886,700,000 miles)

Saturn

Many people consider Saturn the most striking object in the sky. Though not as large or bright through the eyepiece as Jupiter, the amazing and beautiful ring system that surrounds it gives Saturn a three-dimensional reality that,

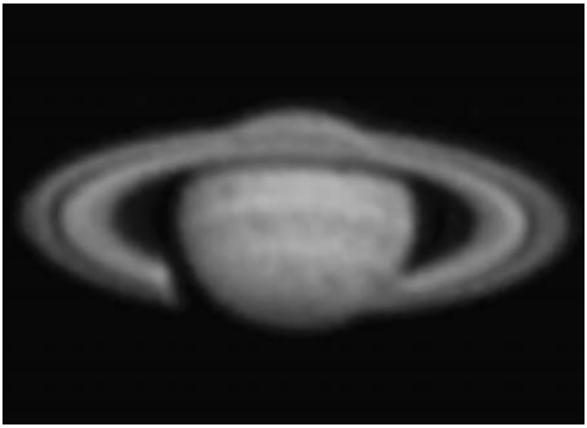


Figure 4.14 Saturn, with its rings nearly wide open. Though this photo captures a fair amount of detail (good "seeing" – or a larger aperture – would have made it sharper), it does not convey the amazing reality that one sees when viewing through the eyepiece. Viewed "live" through a telescope, Saturn seems clearly to be what it actually is: a brilliant, fully three-dimensional globe and rings hanging in the blackness of space.

I believe, nothing else can match. Even a small scope will show the rings distinctly, and good optics should allow you to see a break within them called **Cassini's Division** (named for the astronomer **Giovanni Cassini** who first described it in the seventeenth century). Saturn is a fantastic sight, and photographs just do not seem to catch the apparent depth and magic of the real thing.

Saturn takes nearly 30 years to orbit the Sun. Like the Earth, its axis of rotation is tilted in relation to its orbit. This is lucky for us. If it were not tilted, the rings would be very difficult to see since they would appear edge-on, or nearly so. As it is, there are still times during its 30-year cycle when the rings are difficult to see. They slowly open up and then close again over a period of 14 to 15 years (half the planet's orbital period). As I write this, in 2008, they are several years past a peak in their expansion. By 2009, they will be nearly invisible. Then the rings will start to slowly open up, until they again reach their widest in 2016.

In addition to the rings, Saturn also has many moons, at least one of which should be visible in beginner's scopes. This is **Titan**. Titan is the only moon in the Solar System known to have a significant atmosphere. It can always be seen a few ring widths away from Saturn. Since Saturn is tilted, so are the orbits of its moons. This means they do not usually cross the planet's face or hide behind it, but seem to travel around it in a flattened oval.

Observing Saturn

Like Jupiter, but unlike Mars or Venus, Saturn does not vary much in apparent size during the year. This is because it is *always* very far away: its relative distance from us does not vary as much, so neither does its size through the eyepiece. So, again like Jupiter, Saturn is a good target whenever it is in the nighttime sky.

Below is a table showing what constellation Saturn can be found in through the year 2020. As you can see, it moves much more sedately across the sky than Jupiter.

Saturn's stroll

Year	Months	Constellation
2008		Leo
2009	January–September	Leo
	October–December	Virgo
2010		Virgo
2011		Virgo
2012		Virgo
2013	January–May	Libra
	June–August	Virgo
	September–December	Libra
2014		Libra
2015	January–May	**Scorpius**
	June–September	Libra
	October–November	Scorpius
	December	Ophiuchus
2016		Ophiuchus
2017	January–February	Ophiuchus
	March–May	Sagittarius
	June–November	Ophiuchus
	December	Sagittarius
2018		Sagittarius
2019		Sagittarius
2020	January–March	Sagittarius
	April–June	Capricornus
	July–December	Sagittarius

Saturn does not always dominate the section of sky it is in the way Jupiter does. But it is usually quite bright, and shines with a pale yellow hue. If you can locate the constellation it is in, finding it should not be very difficult, since it will not appear on a planisphere or star chart, so it will be the extra "star" you see.

Uranus

Uranus is the seventh planet from the Sun, and the first to be discovered through a telescope. It is actually visible to the keen-eyed without magnification, and is fairly easy to spot through binoculars. The problem is, you might look right at it and not know whether it was a planet or star. Since it is so far away, it will seem like just another point of light. It takes a telescope aimed in the right direction to know for certain. At higher magnifications, Uranus will appear as a small, but distinct, disk; stars are *always* points.

For the beginner, just finding Uranus is the thrill; it is too distant for amateur scopes to show anything but a bluish dot. Larger scopes do allow some of its moons to be seen.

Measurements

Uranus	
Angular size:	3–4″
Diameter:	51,000 kilometers (32,600 miles)
Average distance from Sun:	2,871,000,000 kilometers (1,784,000,000 miles)

Uranus takes 84 years to circle the Sun, so no tables are necessary to show its location: it moved into Aquarius in 2003, and will stay there pretty much through to 2010, when it will move in for a long stay in Pisces. Finding it takes patience, and an accurate star chart. *Sky & Telescope* publishes such a chart in an issue once a year. Locating a finder chart on the Internet should also be easy.

Neptune

Neptune is like Uranus, only more so. It can be seen in amateur scopes, but that is about all; and because it has an even smaller angular size, finding it is more of a challenge. It takes twice as long as Uranus to orbit the Sun: 165 years! It will be in Capricorn until 2010, when it will move into Aquarius. Charts showing its location appear in the same issue of *Sky & Telescope* mentioned above.

Measurements

Neptune	
Angular size:	2.5″
Diameter:	48,600 kilometers (30,200 miles)
Average distance from Sun:	4,500,000,000 kilometers (2,800,000,000 miles)

Other objects in the Solar System

The Solar System contains countless other objects, but most of them are too dim for beginners' equipment, or their appearance is not predictable. Following are brief descriptions of several types of object which you might encounter.

Meteors

These are small to tiny pieces of material that happen to be traveling through space when they suddenly run into the Earth's atmosphere, about 80 kilometers (50 miles) up. Though the atmosphere is thin there, these objects are moving so quickly that slamming into the atmosphere causes

Some well-known meteor showers

Meteor Shower	Location of radiant	Date of shower peak
Quadrantid*	**Draco**	January 4
Lyrid	**Lyra**	April 22
Eta Aquarid	Aquarius	May 6
Delta Aquarid	Aquarius	July 28
Perseid	Perseus	August 12
Orionid	Orion	October 21
Leonid	Leo	November 17
Geminid	Gemini	December 14

*Named for a defunct constellation that used to exist in the part of the sky where we now see Draco.

them to burn up in a brilliant flash. Most meteors are no larger than a pebble, though a very few are much larger (but they are certainly never "shooting stars"!). Bright meteors sometimes leave behind what is called a **meteor train**; a dim cloud of hot gas that can last several minutes.

On any given night under dark skies, you may see a few meteors; but during certain times, the numbers rise dramatically. These times are when meteor showers occur, and they happen when the Earth travels through the trails of old comets. Perhaps the most famous shower is the **Perseid**, so called because an imaginary line from the actual paths of the meteors lead back to, or **radiate** from, a spot – aptly called the **radiant –** in the constellation **Perseus**. The Perseid shower is popular because it is fairly reliable in its numbers, and because it peaks on the night of August 12, a time of year when stargazing weather can be quite pleasant (in the northern hemisphere, at least). But there are many other showers that occur each year. The table above lists several of the best.

Observing meteor showers

Viewing meteors is one astronomical pursuit that is actually hindered by the use of binoculars or a telescope. This is because their locations are unpredictable; most flash into and out of existence in a second or less; and they cross a large arc of sky. Observing them requires the "wide-eye" technique mentioned earlier in the guide. It is also best to be in a reclining position when viewing, so the most sky can be comfortably viewed simultaneously.

The number and brightness of meteors varies greatly between the different showers, since each is caused by different comet trails. Also, though some showers are fairly consistent in their numbers from year to year, others are quite variable.

Figure 4.15 A Leonid meteor and the Big Dipper. The constellation Leo is "below" the Big Dipper in the sky, and this meteor appears to be coming "up" from it.

Sky darkness is very important for viewing the most possible meteors, since many are quite dim. Moonlight and light pollution wash out the light of many. Once you know that the Moon will not be in the sky on the night you will be observing, it is best to get to the darkest site you can.

Typically, meteor showers peak after midnight, since they happen as the leading edge of the Earth plows through debris from a comet. Before midnight, an observer is on the trailing edge of our planet. Still, many showers take place over several nights, so evening viewing is still worthwhile.

Comets

At least every few decades, a bright comet appears in our skies. The last one visible in the northern hemisphere was Hale-Bopp, in 1997. Comet McNaught, in 2007, was actually brighter, but was visible primarily to people in the southern hemisphere.

Comets have been called "dirty snowballs." They are mostly made of frozen gases, but they have some solid material in them as well. Usually just a few kilometers across when frozen solid, comets are ancient objects, mostly unchanged since the time the Solar System formed. Most are believed to come from the outer fringes of the area influenced by the Sun. Something disturbs them in their far, cold orbits, and they begin to fall slowly inward. As they near the Sun, they speed up; and when they get quite close, they begin to "melt". It is then that they can become brilliant. The small, original **nucleus** becomes surrounded by a huge ball of gas (often

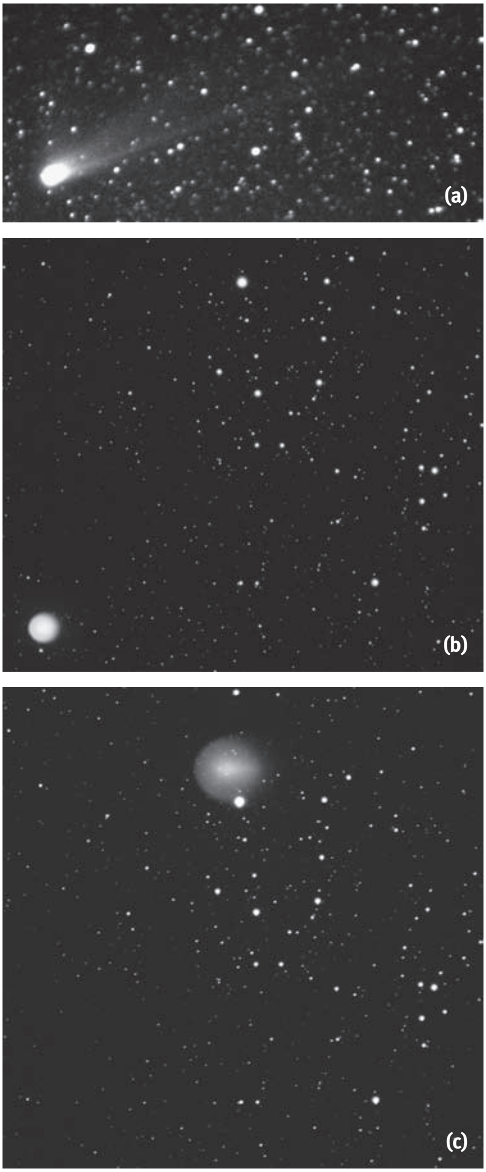


Figure 4.16 Two very different comets. (a) A typical comet that passed through the Earth's evening sky in 2004, never getting bright enough to see without binoculars. (b) The very strange comet 17P/Holmes, on November 3, 2007. (The "17P" signifies that this was the seventeenth periodic comet discovered; Holmes is the name of the man who discovered it, in 1892.) On October 24, 2007, this comet, which never comes closer to the Sun than Mars, and which is usually much too dim to see in even large amateur scopes, suddenly brightened by nearly a million times. (c) Comet Holmes on November 20, 2007. Over the weeks following the outburst, the shell of gas and dust surrounding the nucleus expanded until it actually became larger than the Sun! Note the motion of the comet over the seventeen days between photos: the brightest star in both photos is Mirfak (seen just below the comet in (c)), the brightest star in the constellation Perseus. The comet was still visible in binoculars, and much larger yet, as late as early 2008.

much larger than the Earth) called the coma. Tails of gas and dust millions of miles long can trail across long stretches of the night sky.

Some comets sweep into the inner Solar System, whip around the Sun, and fly out again on courses that will take them back out of history. Others, periodic comets, are caught, and will return someday. The most famous of these is Comet Halley, which will return in 2061.

What most people do not know is that comets are fairly common visitors. The brilliant headline makers are fairly rare; but dimmer, less flashy comets, often only visible through binoculars or telescopes, occur in most years. There is something ethereal and almost magical about looking at these silent, ghostlike travelers through an eyepiece. You know they are moving at incredible speeds, but they seem to be just quietly drifting through the night; and they might be visible for several nights, weeks, or even months. Since it is not possible to predict when the next new comet will be spotted, and because they get little media attention unless they are spectacular, few people other than astronomers notice when most of these visitors travel through.

Asteroids

There is really no *true* difference between an asteroid and a rocky planet, except size. (The current definition of a "planet" is under debate.) Both are solid bodies orbiting the Sun. There are now more than 100,000 known asteroids. The larger ones, and some smaller ones that come close to Earth, are often visible through amateur scopes. *Sky & Telescope* often publishes information on finding them. Through the eyepiece they will appear as dim stars, and the only way to be sure you've spotted one is to watch it move over time. The closer they are to us, the more quickly they appear to move.

The deep sky 5

Targets for the amateur astronomer that are outside the Solar System are both easier and more difficult to find. Easier, because they stay in pretty much the same spot on the celestial sphere for centuries or longer, so planispheres, field guides and star charts that show their positions can be used at any time of year, and for many years. More difficult, because they are dimmer, usually *much* dimmer, than the planets, though they often cover a much larger area of the sky. This makes many deep-sky objects prime targets for binoculars rather than telescopes, since the higher magnification of telescopes makes it impossible to fit many of these objects entirely within view at one time.

There are several types of deep-sky objects that can be viewed by the amateur: stars, star clusters, galaxies, and nebulae (or nebulas); and all of these categories contain their own types. Each is described below. There are other types of objects out there, like quasars and black holes, but they are not visible in beginners' scopes (or at all!), so they will be left alone.

Stars

Stars are immense balls of compressed gas, so squeezed by their own gravity that nuclear reactions take place within them, and they begin to shine. They can be smaller than the Earth in diameter, or larger than the diameter of the orbit of Mars. They can be red, orange, yellow, white, or blue; and to the human eye at the telescope, other colors are also seen. Yet no matter how large in reality, or what color, stars are so far away that they always appear as points of light. No amount of magnification will change this.

Star brightness

Because of their varying distance from Earth, and because of actual physical differences between them, some stars shine brighter in our sky than others.

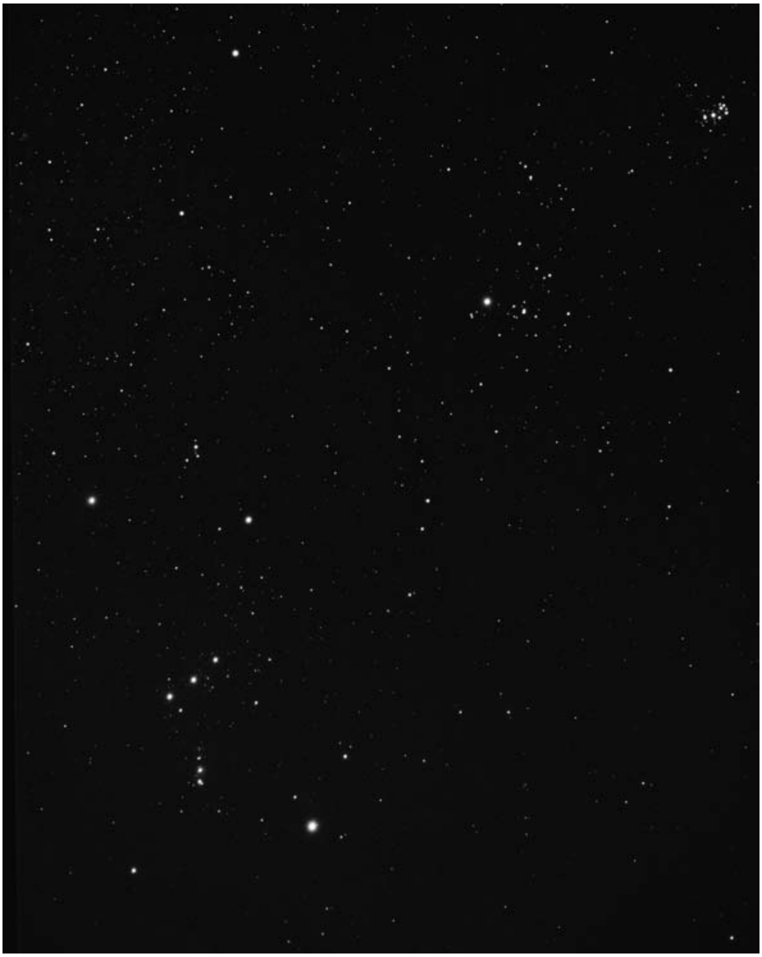


Figure 5.1 A wide view of some constellations seen in the evening skies in December. Orion, the Hunter, on the lower left, uses his shield to fend off Taurus, the Bull, above. The Pleiades, or Seven Sisters, are in the upper right.

Charts use various methods to show a star's **magnitude**, or level of brightness. However, there is a standardized system of measurement. The lower the magnitude number, the brighter the star. A star of magnitude 1 is about 2.5 times brighter than a star of magnitude 2, which is itself about 2.5 times brighter than a star of magnitude 3, and so on. A difference of five magnitudes is a difference of exactly 100 times in brightness. For example, the brightest star in the sky, **Sirius**, actually has a negative magnitude number; it shines at –1.46. Polaris, the North Star, has a magnitude of about 2.1.

Star names

There are two primary methods used to name individually the brighter stars. First, several hundred of the brightest have proper names, most of them very old, and many derived from Arabic. However, the names often "evolved" as

More info

To add a little complexity, many stars go up and down in brightness over time. The period of time can vary greatly, and so can the change in brightness. These are called **variable stars**, and there are several reasons for the variability. Some actually change in brightness because of physical changes in a single star (Polaris is one of these). Others change because the "star" is actually two or more stars that circle so close to each other that we cannot separate them visually, and when one sometimes passes in front of (eclipses) the other, overall brightness changes. These, naturally enough, are called **eclipsing variable stars**. The most famous of these is the star **Algol** in the constellation Perseus. Every three days or so, its brightness drops by more than half for about 10 hours.

More info

Other deep-sky objects are also assigned magnitude numbers, but they are somewhat misleading: the number indicates the object's total brightness, but since the object is spread over a large area, it will appear dimmer than its number would suggest.

they were translated from one language to another. For example, Orion's left shoulder is the star **Betelgeuse**, which some sources claim comes from an Arabic word for "shoulder" or "armpit." Others claim it comes from words that originally meant "hand of the center one." Sirius, the brightest star, is said to get its name from a Greek word meaning "scorching."

The other way brighter stars have been named is through a system created several centuries ago. Greek letters are used to designate the brightest stars in a given constellation, starting with alpha (α), the first letter, for the brightest star; and continuing through the Greek alphabet (see Appendix 1 on page 133) as stars decrease in brightness. So Sirius, the brightest star in the constellation **Canis Major** (the Greater Dog) is called α (alpha) Canis Majoris. This system is a good one, but can be a bit confusing, since mistakes were made with it when stars were first named. Betelgeuse is called α (alpha) Orionis, but is actually the *second* brightest star in the constellation Orion.

Of course, this system also works only with the brightest stars. There are only 24 letters in the Greek alphabet, and only 88 constellations. This provides a total of 2112 star designations, and there are hundreds of billions of stars in our galaxy alone (though only a very small percentage of these have been cataloged.) Other systems are used for naming dimmer stars.

Double and multiple stars

The Sun is a single star, which is probably lucky for us. Many stars come in pairs or groups, held together by gravitational attraction. They are so close together in our sky that, to the naked eye or at low magnification, they appear to be a single object. They are even listed under one name on charts. But when magnification is increased, separate stars are seen. Often there are two (this is a *double star*); sometimes three or even more (a *multiple star*). Some are so close together that they can not be separated visually, and are only known to be pairs by their effect upon each other, or through other indirect means. Others only *appear* close together from Earth, because they happen to fall along the same line-of-sight, but are actually not related at all, and are very distant from each other.

Some amateurs are keenly interested in double and multiple stars. They are challenged by the task of trying to see the separation between close doubles, or are captivated by the contrast between the colors of some groupings.

One famous double star is **Albireo**, the “head” of the swan in the constellation **Cygnus**. It is easily separable in beginners’ scopes. It contains two stars that appear yellow and blue–green, and is considered by some to be the most beautiful double star in the sky.

Star clusters

Sometimes, stars are gathered into larger groups called clusters. They are beautiful objects to view, and can cover both very large and very small parts of the sky. Clusters are divided into two forms: *open clusters*, and *globular clusters*. The two are different in both structure and size.

Open star clusters

These are irregular groupings of stars that are smaller, and closer to the Earth than globulars. They can contain anywhere from several stars to many hundreds of stars. Some open star clusters are called “tight” because their stars are more tightly packed together; others are called “loose.” The most famous open cluster in the sky is M45, the **Pleiades**, or Seven Sisters, in the constellation Taurus. Easily visible to the naked eye as a group of about six stars (the keen-eyed report more), this cluster is stunning through binoculars, and dozens of stars become visible. The **Hyades**, a much looser open star cluster, is not far away in the sky (see Figure 5.2). The **Double Cluster**, in the constellation Perseus, is, as its name states, two clusters which appear close together in our sky, and which make for great viewing through a pair of binoculars.

Globular star clusters

Much larger than open star clusters, globulars usually appear smaller because they are far more distant. Globular star clusters are also much more uniformly structured. Almost all are spherical, and the stars grow ever more tightly packed together toward the center. Some are so closely packed that the smaller apertures of beginner scopes will only show the cluster as a fuzzy patch, almost like an unfocused star.

The most famous globular cluster visible to northern observers is **M13** in the constellation **Hercules**. But the brightest of them all is ω **(omega) Centauri**, in the southern constellation **Centaurus**. It is visible to the naked eye even under somewhat light-polluted skies as a blurry star, but telescopes show it to be what it really is: a huge, dense collection of millions of stars.

Figure 5.2 Two open clusters and a wandering visitor. The Pleiades, or Seven Sisters, is possibly the most well-known open cluster in the sky, and is prominent on the lower right in this photo. Less easily seen to the left is the larger, more open, V-shaped cluster called the Hyades. Both are in the constellation Taurus, the Bull. Between them is the bright planet Mars, which passed through Taurus when this photo was taken, in August, 2007.

Galaxies

Galaxies have sometimes been called "island universes." They are almost unimaginable in their size: up to perhaps a trillion stars collected together in a group by their gravitational attraction. They are divided into three main types, based on their shapes: **elliptical, spiral**, and **irregular**.

Our own spiral galaxy, the Milky Way, is visible at dark sites as a long, dim cloud that spans the entire sky (see Figure 5.3.) Certain areas of it are brighter than others, and when viewed through binoculars or telescopes at low magnifications, these cloudy patches reveal themselves as dense patches of countless stars. The view toward the center of the Milky Way is located in the constellation Sagittarius, but it is blocked by huge clouds of interstellar dust. Still, the area around Sagittarius and neighboring constellations is an amazing place to explore at low powers.

The closest large galaxy to our own is M31, the Andromeda Galaxy. Though it is about two and a half *million* light years away, it still spreads across more than three degrees of sky: six times the width of the full Moon! Visible to the unaided eye under dark skies as a dim, slightly elongated smudge, it is the furthest naked-eye object visible to most people. Good binoculars show more detail, including dust lanes in the arms of our spiral neighbor.

Two other galaxies are easily visible to southern viewers: the **Small** and **Large Magellanic Clouds**. These are smaller, irregular galaxies, and are much closer to us than M31. Though small by galactic standards, they still contain billions of stars between them.

Figure 5.3 In the brightest part of this photo, in the constellation Sagittarius, you can see the center of our own galaxy, the Milky Way. The bright areas going from bottom to top are clouds of stars and glowing gas; the dark areas are caused by obscuring dust. Our galaxy is a flattened disk, and since we are inside of it, the disk forms a great circle around our sky.

All other galaxies are too small and dim in our sky to be seen with unaided vision for any but the keenest-eyed under the darkest skies. But many are visible through binoculars, and far more through telescopes. Some of the brightest of these include **M51**, known as the **Whirlpool Galaxy**, and the pair of **M81** and **M82**, all near the Big Dipper. A bright galaxy for southern viewers is **M83**, a spiral in the constellation **Hydra**, the Water Snake. It should be noted that none of these will appear as much more than "faint fuzzies" through a beginner's scope, but just think about what they are!

> **More info**
>
> **Charles Messier** was an eighteenth century comet hunter. He compiled a list of more than 100 "nebulous objects" that could be mistaken for comets, so that he and others could avoid them when searching (though it stretches the imagination to see how some of them could ever be mistaken for comets). This **Messier Catalog** has become the most famous list of deep-sky objects among amateurs. It includes clusters, galaxies, and nebulae; all of them visible in basic equipment, comparable to – or better than – what Messier had available over 200 years ago. Messier objects are designated by numbers preceded by the letter "M", as in M31, M45, M81, etc.

Nebulae

The word "nebula" (plural "nebulae") is Latin for *mist* or *cloud*, and before the advent of modern, large telescopes, it was used to describe nearly all objects in the night sky other than stars and planets. Today, it is still used for several types of objects: **emission nebulae**, **reflection nebulae**, **dark nebulae**, **planetary nebulae**, and **supernova remnants**.

Emission nebulae

In regions of space where stars are being formed, large clouds of gas have their atoms "excited" by the light of nearby giant stars. This causes the gas (primarily hydrogen) to glow. In long exposure photographs, they appear red, but through the eyepieces of beginners' scopes, they will appear pale gray or green.

There are many well-known emission nebulae, but perhaps the most famous is the Great Orion Nebula, M42. It is part of Orion's "sword," and easily visible to the naked eye from nearly anywhere on Earth. Binoculars and telescopes show that it is a complex structure with wisps and strands of ghostly material. Photographs do not usually capture all these details, since some parts of the nebula must be over-exposed in order to bring out the dimmer areas (see Figure 5.4.)

There are many emission nebulae to be seen in or around the constellation Sagittarius. These include **M8** (the **Lagoon Nebula**), **M20** (the **Trifid Nebula**), and **M16** (the **Eagle Nebula**). Perhaps the largest known emission nebula is the **Tarantula Nebula**, located in the Large Magellanic Cloud, so not viewable to those in the north. Since it is in another galaxy, it is *much* farther away than other observable nebulae, so its size in our sky is smaller than one might suppose.

Reflection nebulae

These are different from emission nebulae in that they are starlight reflected from great clouds of dust. They usually appear blue in photographs because they are reflecting the light of bright, hot, blue stars. They are typically dimmer than emission nebulae because they do not actually shine on their own. The Pleiades are embedded in a reflection nebula, and larger apertures will barely show some of it; this nebula shows up much better in long-exposure astrophotos. Another famous example is the Trifid Nebula, M20. It contains areas of both emission and reflection, indistinguishable at the eyepiece.

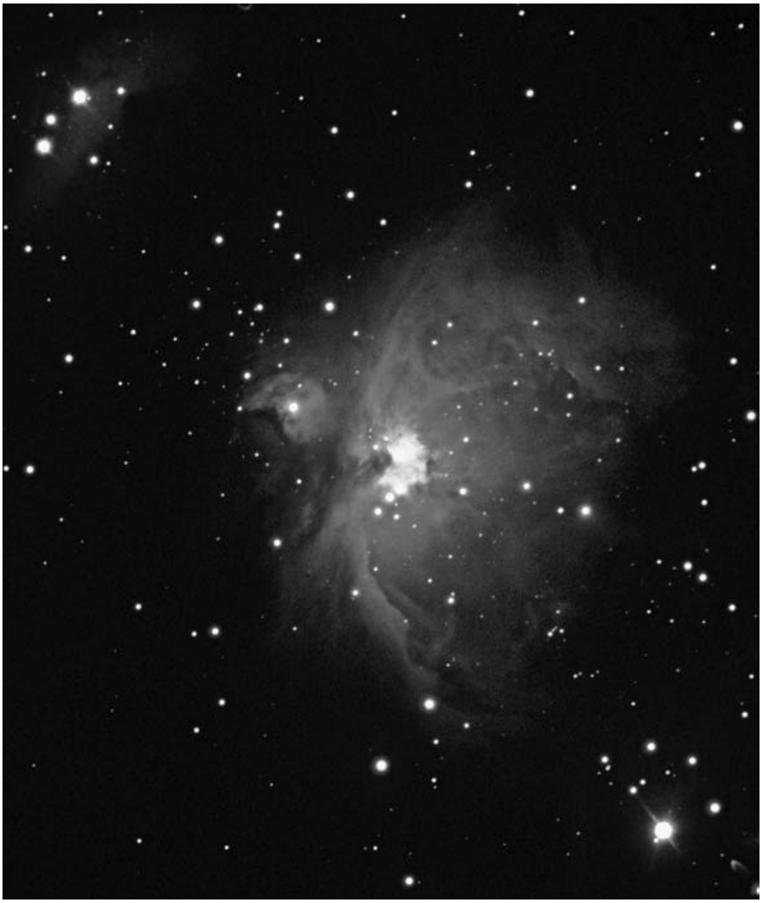


Figure 5.4 The Great Orion Nebula.

Dark nebulae

Also composed of interstellar dust, dark nebulae simply block the light of whatever is behind them, whether star fields in the Milky Way, or the light of emission or reflection nebulae. Perhaps the most famous is the **Horsehead Nebula** in Orion, though this one is too small and dim to see though a beginner's equipment. The Trifid Nebula has dark lanes of dust running through it that divide it into the three main sections that give it its name.

Planetary nebulae

These are completely different, at least in their origin. Planetary nebulae got their name because they are typically small and round and appear about as large in the eyepiece as one of the planets. They are shells of gas that have been blown off stars as they go through changes when they age. They are much smaller than most emission nebulae, though they glow for the same reason: excited particles of glowing gas.

Two bright examples of planetary nebulae are the **Ring Nebula, M57**, in the constellation Lyra; and the **Dumbbell Nebula, M27** in **Vulpecula**. There are hundreds of others in the sky.

Supernova remnants

These are the gaseous remains of exploded stars. Stars end their lives in a variety of ways, and supernovas are the most spectacular. Only large, bright, relatively short-lived stars go out with the bang of a supernova, so they are fairly rare, especially at distances close enough to Earth to leave behind debris visible in small telescopes. (It has been centuries since the last close supernova was seen.) Supernova remnants are typically quite dim, and often spread over a wide swath of sky. The **Crab Nebula**, **M1**, is one of the few remnants that can be seen through a small scope. It resulted from a supernova seen in the year 1054.

Resources

Books

The field guides already mentioned go into more detail than I have about what's out there, but there are many excellent books written specifically to describe the origins, workings, and ultimate fate of what you will be seeing. Some deal specifically with the Solar System; others describe what's beyond it. Many contain beautiful photographs. Here is a warning, however: the technology that is currently (or soon to be) available to astronomers has revolutionized the field. If you are interested in current thinking, get the latest publications you can find. Knowledge advances so quickly that, by the time a book reaches the shelf, its information may well be outdated. This is why I will not make specific recommendations here about books dealing with the *science* of astronomy; and it is one more reason to check out the magazines: they are always publishing the latest thoughts, theories, and images.

There are, however, two more books I would like to recommend. Each contains more detailed information on specific objects to observe than I have, and using either (or both) of them will provide many, many hours of stargazing opportunities.

1. *Turn Left at Orion: A Hundred Night Sky Objects to See in a Small Telescope – and How to Find Them*, by Guy Consolmagno and Dan M. Davis. Cambridge University Press, 2000.
2. *NightWatch: A Practical Guide to Viewing the Universe* (Fourth edition) by Terrence Dickinson. Firefly Books, 2006.

Star charts

A field guide (or even a planisphere) is all that is needed to get started on your search of the cosmos; but once you have been at it for a while, you may want to graduate to the next step. Star charts show a larger area of sky, on a larger scale, and, typically, in more detail, than a field guide. Here is one of the standards:

> *Sky Atlas 2000.0*, by Wil Tirion and Roger W. Sinnott. Sky Publishing and Cambridge University Press, 1998.

The *Sky Atlas* charts are available in three different formats, but all contain 26 maps of the entire sky, plus seven close-up charts of areas of special interest. Tens of thousands of stars, and 2,700 deep-sky objects are accurately plotted. These are the charts I own, and it will be a long time before I need any others.

Software

You can get much more detail than is possible with paper charts by using a computer. There are dozens of different programs available that all fit under the heading of *planetarium software*. Some have only very basic capabilities and show relatively few objects; while others may be able to show you millions of different stars, many thousands of deep-sky objects, and the past, current, and future positions of the Sun, Moon, planets, and thousands of asteroids and comets. Many of the most detailed programs must be purchased, and can be quite expensive. But there are plenty of others, many of them quite complete, which are available for free on the Internet. A web search for “free planetarium software” should lead you to some of them. Try more than one, since each is slightly different in the way it works, and in the presentation of the sky.

It is easy to lose yourself in all the information and graphics these programs offer. It may be very interesting – and loads of fun – to recreate a solar eclipse in a simulation of the sky over Rome on July 17, 709 BC. But be sure to remember to go outside sometime soon to see the *real* sky!

Part III
A stargazing glossary

This section of the guide is meant to be used as a reference to astronomy terminology. It contains all the words in the text that were printed in **bold** type. Some of the more obscure words will have their pronunciations given. Deep-sky objects that have Messier Numbers (for example, M42 or M57) will be found under their common names, unless they do not have a well-known common name. An Internet search using many of these terms would give much more information; more than almost anyone could use.

aberration A problem, a deviation; either inherent in a design, or a flaw in the manufacture of telescopes.

achromatic refractor A refracting telescope that uses a lens with two elements (separate pieces of glass) to help relieve chromatic aberration (false color).

afocal Not a part of the focusing system; separate from the telescope. In astrophotography, when a camera is placed near a telescope's eyepiece, and focused separately.

air-spaced achromat An achromatic lens with a very short space between the two elements.

Albireo (al-BEER-ee-oh) A beautiful double star that is the "head" of the swan in the constellation Cygnus.

Algol An eclipsing variable star in the constellation Perseus.

alt-az mount Short for altitude-azimuth; a type of mount that is adjustable up and down, and left and right.

Andromeda A constellation in the northern sky, named for the mythical maiden rescued by the hero Perseus. The constellation is best known for containing M31, the Andromeda Galaxy.

Andromeda Galaxy (M31) The closest spiral galaxy to our own Milky Way, but still more than two million light years away! It is so large that, even at that distance, it takes up more than three degrees of sky. It is visible to the unaided eye under dark skies, and features become discernible with binoculars.

angular size The *apparent* size of an object in the Earth's sky, measured in degrees of arc.

annular eclipse An eclipse of the Sun by the Moon that occurs when the Moon is far enough from the Earth in its orbit that it does not completely block out the entire disk of the Sun.

aperture Literally, an opening or hole; in a telescope, it is expressed as the diameter of the main light-gathering surface.

apochromatic Various lens designs that virtually eliminate chromatic aberration in refractors; the word means "without color."

Aquarius A constellation in the zodiac; the Water Bearer.

area (of a circle) A measure of the space contained within the circumference of a circle. It is measured using the formula $A = \pi r^2$; area (A) equals π (pi: about 3.14) times the radius (r) times itself (squared).

Aries A constellation in the zodiac; the Ram.

asterism A part of an official constellation whose shape is recognized and named; like the Big Dipper, which is actually part of the constellation **Ursa Major**, the Great Bear.

asteroid Any small body that orbits the Sun rather than a planet, and that is not a planet itself, or a comet (comets differ in that they sometimes glow within a halo of their own melted gases). Tens of thousands are now known, at least one surpassing the size of Pluto. Sometimes they are called "minor planets."

astrocamera Any camera designed specifically for taking astrophotos. They can range from relatively simple and inexpensive modified "web cams" to liquid-cooled large-format digital cameras costing tens of thousands of dollars.

astrology A system of belief that claims to be able to predict personal fate or world events based upon the positions of the stars and planets at the time of a person's birth. It has no basis in fact.

astronomy The modern study of the heavens and everything contained within them. It is entirely based on experiment, observation, and theory based on these.

astronomy club An organized group, usually local or regional, formed in order to share the science and joy of stargazing.

astrophoto Any photo that is primarily of something astronomical.

astrophotography The art and science of taking photographs of astronomical phenomena.

atmosphere A layer of gas that surrounds some massive objects in space. All of the planets have significant atmospheres, except for Mercury. Pluto (the planetary status of which is now in some doubt) may have one that exists as a gas only when Pluto is at its closest to the Sun; farther out it may freeze. (There is a probe on its way to Pluto to find out.) Only one moon (Saturn's Titan) has an atmosphere.

aurora The Northern or Southern Lights; caused by interactions between material ejected from the Sun and the Earth's magnetic field in its upper atmosphere. Strong Solar storms can result in spectacular curtains of color that sometimes fill the entire sky.

axis (or axis of rotation) The imaginary line about which a spinning body rotates.

BAK-4 A type of glass (barium crown) used in optics, particularly binocular prisms. It is typically superior for this purpose to another type: BK-7.

Barlow lens A special lens that, in effect, lengthens a telescope's focal length, thereby increasing magnification. It does so without decreasing eye relief.

belts The dark bands visible across Jupiter's surface, even in beginners' scopes.

Betelgeuse The bright orange star that marks the left shoulder of the constellation Orion, the Hunter. The name comes from Arabic origins.

Big Dipper The name used in North America for the familiar, bright grouping of seven stars in the northern sky that form the rough shape of a dipper, or ladle. In other parts of the world it is known as the Plough, or the Great Wagon, or other names. It is not actually a constellation itself, but a part of the constellation Ursa Major, the Greater Bear. Such groupings within constellations are called ***asterisms***.

binoculars Two small telescopes bound together to allow the use of both eyes when viewing. Special prisms bend the light paths to give correct, real-world images, while also providing for compact, lightweight housings.

BK-7 A type of glass (borosilicate) used in optics, particularly binocular prisms. It is usually not as good for this purpose as another type: BAK-4.

cable release A device that is attached to a camera that allows the shutter to be tripped from a distance to avoid shaking during an exposure.

Callisto One of the four Galilean moons of Jupiter (named after their discoverer), and the furthest of the four from the giant planet. With a diameter of 4,800 kilometers (about 2,900 miles), it is about the same size as Mercury.

Cancer A constellation in the zodiac; the Crab.

Canis Major A constellation, the Greater Dog. It is near Orion in the sky, and contains the brightest star, as seen from Earth: Sirius.

Capricornus A constellation in the zodiac; the Sea Goat (?!)

Cassini, Giovanni (1625–1712) Among other things, this astronomer was the first to record the division in the rings of Saturn that now bears his name; he also discovered several of its moons.

Cassini's Division A gap between two of the rings of Saturn; visible even in some small scopes, it was first recorded by the Italian astronomer Giovanni Cassini.

Cassiopeia A constellation in the northern sky; the Queen.

catadioptric Any telescope design that incorporates both mirrors and lenses.

celestial From a Latin word meaning "of the sky" or "of the heavens."

Celestial poles The two points in the sky directly above the Earth's poles; the only places in the sky that do not appear to rotate as the Earth spins.

Celestial Sphere An ancient concept about the workings of the night sky. At one time, people believed that all the stars in the heavens existed as they appear to be: immovable lights upon a huge sphere that spun in the sky above the Earth. It was thought that the planets traveled around this bowl, or that they somehow moved in spheres of their own.

Celestron One of the two largest telescope manufacturers in the United States; the other is Meade.

Centaurus A constellation in the southern sky; the Centaur (a mythical creature, half horse, half human). It is a constellation filled with interesting objects, including the brightest globular cluster – ω (omega) Centauri – and the closest star system to our own – α (alpha) Centauri.

central obstruction The design of all reflecting telescopes requires a second mirror to bounce the image out of the telescope tube and into the focuser. This mirror is typically in the center of the tube, and blocks some of the incoming light.

Cetus A constellation through which the ecliptic passes (though Cetus is not part of the zodiac); the Whale.

chromatic aberration A problem in refractors, where the shape of the objective lens allows for magnification, but also acts as a sort of prism, breaking light into its component colors.

clock drive An electric motor which, when attached to an equatorial mount, rotates it around its right ascension axis in order to compensate for the rotation of the Earth. When the RA axis is accurately aligned with the celestial pole, objects will stay centered in the eyepiece.

coated lenses Good quality lenses are coated with various materials to reduce internal reflections.

collimation	The lining up of the centers of the mirrors in a reflecting telescope with the center of the focuser; extremely important for sharp focusing.
coma	1. A type of aberration common in reflecting telescopes, in which stars toward the edge of the field appear stretched, like little comets. 2. The large shell of glowing gas and dust surrounding the nucleus of a comet.
comet	A ball of frozen gas, dust, and other solid material. Comets dwell far from the Sun, but sometimes their orbits are disturbed and they begin to fall inward. When they near the Sun, the gases begin to melt, sometimes giving spectacular views before flying off into the void again.
computer-guided mount	Telescope mount with the electronic ability to find targets contained within a computer database.
concave	A mirror or lens face that curves inward (like a cave). The opposite of concave is convex.
constellation	One of the 88 recognized groupings of stars that divide up the entire sky as seen from Earth. The official names of constellations are usually expressed in Latin.
contrast	The difference in brightness between the light and dark areas in an image.
convex	A mirror or lens surface that curves outward. The opposite of convex is concave.
cooling time	The time necessary for the temperature of a telescope to cool to the temperature outside, or at least close enough to make for decent viewing. Until this happens, currents of air often form inside the telescope, distorting the images seen through it.
correct image	An image in an eyepiece that appears right-side-up and non-inverted, like the real world.
corrector plate	The lens on the front of a catadioptric telescope that helps these designs overcome aberrations.
Crab Nebula (M1)	A supernova remnant in the constellation Taurus; visible, but not very impressive, in beginners' scopes.
crescent	Of the Moon (or Mercury or Venus), when less than half of the surface, as viewed from Earth, is lit up by the Sun.

cross-hairs Small threads that form an x-shaped pattern; contained inside eyepieces and finder scopes to help center an image.

Cygnus A constellation, through which the Milky Way runs; the Swan.

dark nebula Clouds of interstellar dust which block the light of objects behind them.

dark site Any location relatively unaffected by artificial light; a diminishing resource.

declination (Dec) Celestial latitude; the angular distance an object is from the celestial equator, at 0 degrees; the poles are at 90 degrees.

deep sky Everything outside the Solar System.

deep-sky object Any object outside the Solar System; the term is usually used to designate all objects other than stars.

degree (of arc) An angular distance equal to 1/360th of the circumference of a circle.

Deimos The smaller and outermost of the two moons of Mars. Deimos is named for one of the dogs of the god of war, and means "panic."

diagonal A handy device that uses a prism or mirror to angle the light path of a telescope for more comfortable positioning of the eyepiece.

diameter The width of a circle, measured through its center.

diffraction spikes "Rays" that appear on stars in Newtonian reflectors, caused by the vanes of the spider that holds the secondary mirror.

digital camera A camera that uses a special sensor that is electronically responsive to light, rather than photographic film.

Dobson, John The amateur astronomer who popularized the use of an inexpensive alt-az mount for reflectors that has come to bear his name.

Dobsonian mount A simple alt-az mount popularized by John Dobson for use with Newtonian reflectors.

Double Cluster A pair of beautiful open star clusters, so close together in the constellation Perseus that they can be

	viewed at the same time in binoculars, or at low magnification through a telescope.
double star	Two stars so close to each other in the sky (though not always close in reality) that they appear as one star to the unaided eye.
Draco	A constellation, the Dragon, which lies in the far northern sky.
DSLR	A digital single-lens reflex camera. Like a film SLR, this type of camera uses interchangeable lenses, and focuses through the lenses and a mirror and prism. But rather than using film, it uses a special computer chip to collect and store the light of the image.
dual-axis drive	Motor drives on both the declination and right ascension axes of a telescope mount.
Dumbbell Nebula (M27)	A large, bright, planetary nebula in the constellation Vulpecula, the Fox.
Eagle Nebula (M16)	A star cluster imbedded in an emission nebula in the constellation Serpens, the Snake.
Earth	The third planet from the Sun; *possibly* the only body in the Solar System to currently contain life.
Earthshine	Sunlight which reflects off of the Earth onto the Moon and then back again, allowing the dark regions of the Moon (those unlit at the time by the Sun) to be dimly seen.
eccentric orbit	Orbits can be almost exactly circular, or very elongated ovals; the more elongated, the more *eccentric*.
eclipse	The blocking of the view of one celestial body (the Sun, the Moon, a planet, or other moon) as seen from Earth, by the passing of another in front of it.
eclipsing variable star	A “star” that varies in brightness because it is actually two or more stars orbiting very close together. When one passes in front of (eclipses) the other, the overall brightness of the “star” changes.
ecliptic	The line around the entire sky along which the Sun seems to travel as the Earth orbits it. The planets (except Pluto) all stay very close to this line as they cross our sky, since they and the Earth orbit the Sun in a flat disk.

elliptical galaxy An oval shaped galaxy that is more or less evenly lit across its surface.

emission nebula A nebula whose light is produced by the glow of particles being excited by hot, bright, nearby stars.

equatorial mount A telescope mount that has one axis of rotation that is set to match the motion of the wheeling sky.

Europa One of the four Galilean moons of Jupiter (called so after their discoverer); it is the smallest of the four, with a diameter of 3,100 kilometer (about 1,900 miles), a little smaller than our own Moon. Current theory says there may be a vast water ocean under a relatively thin layer of ice on Europa, a possible abode of life.

exit pupil The diameter of the circle of light that leaves the eyepiece.

eye lens The lens in an eyepiece that comes closest to the eye during use.

eye relief The farthest distance, usually expressed in millimeters, at which you can hold your eye from an eyepiece and still see a clear image. This is an important factor to consider, especially if you wear eyeglasses.

eyepiece The lens (or, usually, group of lenses) on a telescope to which you hold your eye for viewing.

false color The usually blue halo seen around brighter objects viewed through achromatic refractors, which suffer from chromatic aberration.

fast film Photographic film is sold in different "speeds," which are indicated by special numbers (the ISO number). Slower film, up to ISO 100, is usually very sharp, but the shutter of the camera must stay open longer to produce an image. Fast film, ISO 400 or above, can be "grainier" than slow film, but images form much more quickly.

field of view The circular area of sky visible through the eyepiece.

filter An optically flat piece of glass (or sometimes plastic for solar filters) that is coated in some way to change the color or brightness of an image viewed through it.

	Filters can only remove some of the incoming light; they do not add to it.
finder	A small, low-power telescope or other device attached to the main scope, used to assist in initial pointing.
first quarter Moon	When a waxing (growing) Moon has half its Earth-facing side lit by the Sun; it really means "first quarter of the month."
focal length	The distance from a lens or mirror to its focal point, or more accurately, focal plane. Longer focal length in a telescope means *higher* magnification; longer focal length in an eyepiece means *lower* magnification. This is because magnification is equal to the focal length of the telescope divided by the focal length of the eyepiece.
focal point	The place at which light rays converge after being reflected or refracted by a lens or curved mirror; in reality this is not a point, but a small spot.
focal ratio	This is equal to focal length divided by aperture.
fork mount	A mount that has two tines that attach to either side of a telescope; really only appropriate for designs with short tubes, like Maks or Schmidt – Cassegrains.
full Moon	When the entire Earth-facing side of the Moon is lit by the Sun.
fully coated	A telescope, pair of binoculars, or eyepiece that has been coated on all exposed lens surfaces.
fully multi-coated (FMC)	A telescope, pair of binoculars, or eyepiece that has multiple coatings on all exposed lens surfaces.
galaxy	A vast collection of stars held together by gravitational attraction; may contain millions to hundreds of billions of stars. Our own galaxy is called the Milky Way.
Galileo Galilei (1564–1642)	The Italian scientist who first turned a telescope skyward to discover mountains and "seas" on the Moon, moons around Jupiter, "handles" on Saturn, and countless stars in the Milky Way.
Ganymede	One of the four Galilean satellites of Jupiter; third out from the giant planet. With a diameter of 5,200 kilometers (about 3,200 miles) Ganymede is

the largest moon in the Solar System, and is even bigger than either Pluto or Mercury.

Gemini A constellation in the zodiac; the Twins.

gibbous Of the Moon or the planets, when more than half, yet less than all of the Earth-facing side is lit by the Sun.

globular star cluster A typically spherical, tightly packed group of many thousands of stars.

go-to mount A computer-guided telescope mount.

gravity One of the basic forces of the universe; all matter exerts this attractive force, but it is so weak that only large bodies show its effects.

Great Orion Nebula (M42) The brightest emission nebula that is visible throughout most of the world; easily visible to the naked eye, even in suburban areas, and beautiful when viewed at any magnification.

Great Red Spot (GRS) A giant storm visible in the atmosphere of Jupiter, first recorded by Cassini in 1665. In recent years, it has grown smaller, and is more beige than red, making it more difficult to spot in smaller scopes. In 2006, a smaller white spot also became reddish. Some are calling it Red Spot Junior.

guide To use a star centered in an eyepiece (preferably one with cross-hairs) to steer a telescope while taking a long-exposure photograph.

hand controller A small box with electric switches, used to steer a telescope with a motor drive. More advanced hand controllers are used with computer-guided scopes.

helium The second simplest and second most common element (after hydrogen) in the Universe.

Hercules A constellation named for the mythical Greek hero; it contains the brightest globular cluster visible to most northern hemisphere viewers: M13.

Herschel, William (1738–1822) The German-born English astronomer who discovered Uranus in 1781.

high eyepoint A term for binoculars with long eye relief, suitable for those who wear glasses.

Horsehead Nebula	A dark nebula with the shape of a horse's head in the constellation Orion. Not visible in beginners' scopes, but often photographed in long exposures.
Huygens	A very old and, by modern standards, not very useful eyepiece design.
Hyades	(HI-uh-deez) A loose open star cluster in the constellation Taurus.
Hydra	A long, southern constellation; the Water Snake.
hydrogen	The simplest and most abundant element; most stars are made primarily of hydrogen.
illuminated reticle eyepiece	A special eyepiece that is used to help guide a telescope during a long photographic exposure. The eyepiece has cross-hairs (the reticle) that meet in the middle, which are lit up (illuminated) by a dim red LED so they can be seen in the dark.
International Dark-Sky Association	An organization dedicated to the reduction of light pollution; visit them at www.darksky.org.
Io	(EYE– oh) One of the four Galilean moons of Jupiter, and the one closest to the planet; so close, in fact, that tidal forces caused by Jupiter's gravity make Io the most volcanically active body known. It has a diameter of 3,600 kilometers (2,200 miles), slightly larger than the Moon.
iris	In the eye, the colored muscles that close around the pupil as light gets brighter; a mechanical device with a similar purpose, and the same name, is used in camera lenses.
irregular galaxy	Any galaxy with a shape that is not spiral or elliptical.
Jupiter	The fifth planet from the Sun, and the largest in the Solar System.
Kellner eyepiece	An eyepiece design no longer held in favor with many amateur astronomers; sometimes included with beginner scopes.
Lagoon Nebula (M8)	A bright emission nebula in the constellation Sagittarius; it can be seen with the unaided eye under relatively dark skies. It is less than two degrees away from another bright nebula: M20, the Trifid Nebula.

Large Magellanic Cloud — A "small," irregular galaxy that is a satellite of our own Milky Way. Not visible in the northern hemisphere, it is named for the Portuguese explorer, Ferdinand Magellan (1480[?]–1521), who commanded the first circumnavigation of the world. It lies in the constellations Dorado, the Dolphin, and Mensa, the Table Mountain. It contains billions of stars.

last quarter Moon — When exactly half of the Earth-facing side of a waning Moon is lit by the Sun, short for "last quarter of the month".

latitude — The angular distance north or south of the equator, measured in degrees.

LED — Light emitting diode; a type of electric light source that uses very little power, yet is bright enough to allow the reading of star charts. A flashlight that uses red LEDs is ideal for use in astronomy.

lens — Any transparent material with one or both surfaces curved in order to focus light.

lens elements — Nearly all modern eyepieces and camera lenses are actually made up of several separate pieces of glass working together. Each of these pieces of glass is one of the lenses' *elements*.

Leo — A constellation in the zodiac; the Lion.

Libra — A constellation in the zodiac; the Scales.

light pollution — Artificial light that is inadvertently aimed outward and/or upward to no useful purpose. It is one source of pollution for which there are easy and economically beneficial solutions.

light year — Not a measure of time, but of distance: how far light travels in a year; more than nine trillion kilometers (about six trillion miles).

longitude — The angular distance east or west, measured in degrees, from the Prime Meridian, which (arbitrarily) runs from the south pole, through Greenwich, England, and on to the north pole.

lunar eclipse — An event that occurs when the Earth is directly between the full Moon and the Sun. The Earth's shadow slowly covers the Moon, and because Earth is much larger than the Moon, the eclipse can last much longer than

	a Solar one. The Earth's shadow can completely cover the Moon for over an hour; solar eclipses never last longer than several minutes. The Earth's large size also makes lunar eclipses more common than solar eclipses.
Lyra	A small, northern constellation, the Lyre, or Harp, that contains the planetary nebula, M57, the Ring Nebula.
M13	A globular cluster in the constellation Hercules; the brightest visible to many northern hemisphere viewers.
M81	A beautiful, almost perfect spiral galaxy in the constellation Ursa Major, the Great Bear. Visible in small scopes as an oval smudge (but visible!), it is about half a degree distant from M82.
M82	An irregular galaxy in the constellation Ursa Major, the Great Bear. Visible in small scopes, it is about half a degree distant from M81.
M83	A bright spiral galaxy in the constellation Hydra, the Water Snake.
magnification	Through optical means, the enlarging of an image of an object.
magnitude	A measure of a celestial object's brightness. By definition, a star of magnitude 1 is 100 times brighter than a star of magnitude 6 (a difference of five magnitudes). There is an approximate increase in brightness of 2.5 times between each magnitude level, and brightness increases as magnitude levels decrease. *Apparent magnitude* is the magnitude of a star as seen in the Earth's sky, and does not take into account the varying distances of stars; *absolute magnitude* is a star's true brightness, when measured from a standard distance.
Mak	Short for Maksutov; there are two common telescope designs that were originated by this optical designer in the first half of the twentieth century: the Maksutov–Cassegrain, and the Maksutov–Newtonian.
Maksutov, Dmitri (1896–1964)	The Russian optical designer who originated two popular types of telescope that bear his name: the Maksutov–Cassegrain and the Maksutov–Newtonian.

Maksutov–Cassegrain A telescope design that uses spherical curves on its mirrors and lenses to deliver well-corrected views in an inexpensive, compact, rugged package.

Maksutov–Newtonian A telescope design by Dmitri Maksutov that combines features of the Newtonian reflector and the Maksutov–Cassegrain.

Mars The fourth planet from the Sun, and the only planet other than Earth that has an atmosphere that is transparent enough to show true surface detail. It comes closer to Earth than any other planet except Venus, and its proximity and surface detail have tantalized astronomers for centuries.

mass Basically, the amount of matter an object contains. The air inside a balloon may have the same mass as a paper clip, though it is much less densely packed. A human who weighs 60 kilograms (132 pounds) on the Earth may weigh only 10 kilograms (22 pounds) on the Moon, because the Moon's gravitational pull is less; but that person's mass would be the same in both places.

Meade One of the two largest telescope manufacturers in the United States; the other is Celestron.

meniscus lens A crescent-shaped lens that curves inward on one side, and outward on the other.

Mercury The closest planet to the Sun, and the second smallest, after Pluto (or the smallest, according to some, since Pluto has been demoted).

Messier Catalog A catalog of deep-sky objects compiled by French astronomer Charles Messier.

Messier, Charles (1730–1817) The French astronomer and comet hunter who compiled a list of deep-sky objects that now bear his name, or at least his initial. The commonly accepted story is that he compiled the list, and accurately marked each object's celestial position, so that these objects could be avoided when searching for comets. The telescopes he used would only be comparable to a very moderate modern beginner scope, so all the 109 objects in his Catalog, which includes galaxies, nebulae, and star clusters, are easily accessible with a beginner's equipment under moderately dark skies.

meteor	A small piece of interplanetary debris, usually no larger than a pebble or a grain of sand, that strikes the Earth's upper atmosphere at incredible speed. Friction usually causes it to burn up entirely in no more than a second or two. Before hitting the atmosphere, these objects are called *meteoroids*; if they are large enough that part of them actually reaches the ground, that remnant is called a *meteorite*.
meteor shower	Periodic occurrences during which the number of meteors greatly increases because the Earth passes through the debris path left by a comet. The meteors seem to radiate from a specific spot in the sky, which is aptly called the *radiant*. Regularly occurring showers are given names based on the constellation that contains the radiant. For example, the Perseids radiate from Perseus, and peak on August 12; the Leonids radiate from Leo, and peak on November 17–18.
meteor train	A dim cloud of hot gas, high in the atmosphere, that can last up to several minutes; caused by the interaction of larger meteors with atmospheric particles.
Milky Way	Our own galaxy, which under dark skies can be seen to span the entire sky.
minus-violet filter	An eyepiece filter designed specifically to help remove the false color often seen in inexpensive refractors using air-spaced achromatic lenses.
minute of arc	A unit of measurement equal to 1/60th of a degree.
Mirfak	The brightest star in the constellation Perseus. Mirfak (sometimes spelled "Mirphak") comes from an Arabic word meaning "elbow." Another name sometimes used for this star is Algenib, "the side."
modified achromat eyepiece	An eyepiece of inexpensive and mediocre design that is often included in beginner's scope packages.
Moon	Our nearest celestial neighbor. It is so large in comparison to its host planet (Earth) that some have suggested we be called a double planet. Its diameter, 3476 km (2140 miles) is more than one quarter of the Earth's.

motorized tracking A system that uses electric motors to cause a mount to compensate for the spinning of the Earth, thus keeping objects centered in the eyepiece.

mount The device upon which a telescope is placed which allows it to be smoothly and precisely moved, either between targets, or to follow a target as the Earth turns; not to be confused with a tripod, which is simply one type of stand for the telescope and mount.

multi-coated Several layers of chemical film that are applied to a lens to reduce internal reflections.

multiple star A group of up to several stars that appear as a single star until magnified.

mylar A type of nearly opaque plastic film that can be used as a solar filter.

nebula (NEB-you-la, plural: nebulae, NEB-you-lee); from the Latin for *mist* or *cloud*. Before large modern telescopes, any deep-sky object that was not a star appeared as a cloudy smudge when viewed through the eyepiece, and was given the designation *nebula*. Now, the term applies to actual clouds of interstellar gas and dust which make up *emission, reflection, dark*, and *planetary nebulae*, as well as *supernova remnants*.

Neptune The eighth planet from the Sun, and the second to be discovered through a telescope. Because it is a large planet, it is visible (barely) through small scopes, even at the distance of 4.5 billion km (2.8 billion miles). Because of the strange path of Pluto's orbit, Neptune was, in the last two decades of the twentieth century, the farthest planet from the Sun. It is still the most distant Solar-System object visible in most beginners' scopes.

new Moon When the Moon is closest to the Sun in the Earth's sky, and has virtually none of its Earth-facing side lit.

Newton, Sir Isaac (1646–1723) An English scientist who, among other things, first described gravity and invented the telescope design that bears his name.

Newtonian reflector A simple telescope design invented by Isaac Newton that uses a single curved surface, the primary or main mirror, to reflect a magnified image off a smaller flat mirror, which is placed at an angle to bounce the

	image into the focuser on the side of the tube; the least expensive telescope design, per unit of aperture.
nocturnal	Active primarily at night; the dream of many amateur astronomers.
nuclear fusion	The combining of atoms of one element to form atoms of another, a great amount of energy, and some leftovers.
nucleus	The small core of a comet.
objective lens	The lens in a refracting telescope or binoculars that is aimed at an object; the main light-gathering surface.
ω (Omega) Centauri	The brightest globular cluster in the sky, in the southern constellation Centaurus, the Centaur.
open star cluster	A collection of several to hundreds of loosely gravitationally attracted stars.
Ophiuchus	(oaf-ee-YOO-cuss), a constellation through which the ecliptic passes (though it is not part of the zodiac); the Snake Holder.
opposition	When a celestial object is on the opposite side of the Earth from the Sun, which means it will reach its highest point in the sky around midnight. The outer planets are at about their closest approach to Earth at these times.
optical tube assembly (OTA)	A telescope by itself, without a mount; and usually without eyepieces or other accessories.
optics	The lenses or mirrors used in the gathering of light for observation. Also, the name of the branch of physics that deals with light and its properties.
orbit	The path that a body follows around another more massive body to which it is gravitationally attached. The shapes of orbits, as Johannes Kepler realized some four hundred years ago, are elliptical (oval), though many are very nearly circles.
Orion	The brightest constellation in the sky, and the location of some of the sky's most sought-after targets; the Horsehead Nebula and The Great Orion Nebula (M42) are just two of them.
partial eclipse	When part of one celestial body partially covers the view of another as seen by an observer.

perihelic	(pear-uh-HEE-lick) Literally, "near the Sun."
perpendicular	At a right angle to; separated by 90 degrees of arc.
Perseid (PER-see-id) meteor shower	A meteor shower that radiates from the constellation Perseus, peaking on August 12. Often known simply as Perseids.
Perseus (PER-see-us)	A constellation, named after the mythical Greek hero who destroyed the Medusa.
phase	The name for the various states of illumination of the Moon (or Mercury or Venus): first quarter, gibbous, full, etc.
Phobos	The larger and innermost of the two moons of Mars. Phobos is named for one of the dogs of the god of war, and means "fear."
pi (π)	A letter in the Greek alphabet, and a mathematical symbol representing the number equal to the length of any circle's circumference divided by its diameter: equal to somewhere in the neighborhood of 3.1415926535897932384626433832795028841971693993751.
piggy-back	An astrophotography set-up in which a camera is mounted (piggy-backed) to a telescope. While the camera and its lens expose the film, the telescope is used to track the motion of the sky.
Pisces	A constellation in the zodiac; the Fishes.
planet	The definition of this word is currently under debate. A planet is a body that orbits a star; but when does it become so small that it is considered only an asteroid? And when does it become large and "hot" enough to be considered a star? Discoveries of huge "planets" orbiting other stars, and huge asteroids far out in our own Solar System, have raised questions about what has, until recently, been an easy definition. A planet *used to be* one of the nine bodies we learned about in school; now even that assumption has become controversial: is Pluto a planet, or merely a "dwarf planet?"
planetary nebula	A huge shell of glowing gas thrown off by a star in later life. These nebulae are called "planetary" because, when first seen through more primitive telescopes

centuries ago, they appeared round, and about the same size as the planets, though much dimmer.

planetary scope A telescope with a "slow" focal ratio: a long focal length for the size of its aperture; making it most useful for viewing bright objects at higher magnifications, which is just right for the planets.

planisphere A simple device made of two round wheels of cardboard or plastic attached together in the center, and able to spin freely. The front wheel has an oval hole in it that allows one to see part of the map of the entire sky (or, that part of it visible from a band of given latitude on Earth) that is printed on the back wheel. By matching an edge containing all the dates of the year on one wheel with an adjacent edge on the second wheel that charts the hours from midnight through midnight, one can see what section of sky will be visible at any time on any date of the year.

Pleiades (M45) (PLEE-uh-deez) The brightest and most famous open star cluster, located in the constellation Taurus, the Bull. Though called the Seven Sisters (after the daughters of mythical Atlas), six stars in a tight dipper shape are visible to most people without aid. Binoculars and telescopes show at least dozens more.

Plossl eyepiece The eyepiece design favored as the best all-around choice for the budget-minded amateur.

Pluto Until recently, the ninth, and probably the last, planet out from the Sun. It was also the smallest planet; with a diameter of 2320 kilometers (1,440 miles) it is smaller even than several moons, including our own. It was discovered in 1930 by American astronomer Clyde Tombaugh (1906–1997), who found it by searching photographic plates. It has three moons of its own, one of which has a diameter that is more than half of Pluto's. Discovered in 1978, this larger moon is called Charon (KARE-on). The other two were only recently discovered; they are much smaller, and little is known about them. More will be learned when a fly-by spacecraft mission reaches Pluto in 2015.

polar alignment Lining up the right ascension axis of an equatorial mount with the celestial pole so that it matches the axis of the Earth. This allows the tracking of targets with adjustments in only one direction.

polar alignment scope A small, wide-field telescope that usually is placed in the center of the shaft of the right ascension axis of an equatorial mount, used to help in gaining accurate polar alignment.

Polaris The Pole Star, or North Star; in the constellation **Ursa Minor**, the Lesser Bear, which is better known as the Little Dipper. Polaris is the star at the outer end of the Dipper's "handle." It is the closest bright star to the north celestial pole, at a distance of about one degree. Contrary to a commonly held belief, it is *not* the brightest star in the sky (Sirius is); it is not even in the top 20!

porro prism The most common type of prism used in binoculars, and the most economical for use with the large apertures necessary for astronomy.

primary mirror The main light-gathering source in any type of reflecting or catadioptric telescope.

prime focus The focusing point of the main mirror or objective lens of a telescope. A *prime-focus astrophoto* is one in which a camera is attached directly to a telescope, without an intervening eyepiece or camera lens; the telescope is used, in effect, as a very long camera lens.

prism A piece of glass that is cut in such a way that it changes the direction or orientation of a light beam's path, and/or splits it into its component colors.

pupil The small hole in the eye through which light enters.

radiant The point from which meteors of a given meteor shower radiate.

radiate To extend in straight lines from a central point.

radius The distance from the center of a circle to its edge; half the diameter.

Ramsden eyepiece A cheap, almost useless eyepiece design.

red-dot finder A finder that does not magnify an image, but rather projects a small red dot against a piece of clear glass, showing the point in the sky at which the telescope is aimed.

reflection nebula	A nebula whose light is formed by reflection of the light of nearby bright stars off interstellar dust.
reflector	Any telescope that uses a mirror as its main light gathering surface, without the addition of intervening lenses.
refractor	Any telescope that uses a lens as its main light-gathering surface.
resolution	The fineness of detail that can be viewed through a telescope; also called resolving power.
retina	The area in the back of the eye that collects light and transmits visual information to the brain.
right ascension (RA)	Celestial longitude, measured in a circle of 24 hours (each divided into minutes and seconds), with the zero hour being the vernal equinox (the point at which the Sun, traveling along the ecliptic in the spring, crosses the celestial equator); located in the constellation Pisces, the Fishes.
Ring Nebula (M57)	A bright, donut-shaped planetary nebula in the constellation Lyra, the Lyre.
roof prism	The less common type of prism used in binoculars. While allowing for a lighter, more compact package, good roof prisms are expensive to manufacture, and are not usually available in sizes useful or affordable to amateur astronomers.
Sagittarius	The Archer; a constellation in, possibly, the most interesting part of the sky. The center of our galaxy lies behind clouds of obscuring dust in Sagittarius; and no less than fifteen Messier objects are charted within it (more than any other constellation).
satellite	any body, even an artificial one, which orbits a larger one.
Saturn	The sixth planet from the Sun; the second largest; and by almost anyone’s standard, the most beautiful because of its bright rings.
Schmidt–Cassegrain telescope (SCT)	A popular, portable catadioptric telescope design that is relatively inexpensive to mass produce compared to some other designs, but still outside the price range of this book. Both Meade and Celestron have sold many thousands of them.

Scorpius A constellation in the zodiac; the Scorpion.

secondary mirror In a reflector or catadioptric telescope, the smaller mirror that reflects the image from the main mirror into the focuser.

second of arc A unit of measure equal to 1/60th of a minute of arc, or 1/3600th of a degree.

seeing A term used by astronomers to describe the steadiness of the atmosphere. Excellent seeing means that stars appear as stable points through the eyepiece; when seeing is poor, stars (and everything else in the sky) roil and shimmy.

single-axis drive A single motor attached to the right ascension (RA) axis of an equatorial mount, used to rotate the mount to follow the spinning of the Earth.

single-lens reflex (SLR) a type of camera design that uses interchangeable lenses, and which is focused through the lens with a mirror and prism.

Sirius The brightest star in the sky, at magnitude –1.46; in the constellation Canis Major, the Greater Dog. Sirius is said to come from a Greek word meaning "scorching."

Small Magellanic Cloud A "small" irregular galaxy that is gravitationally attached to our own Milky Way. Visible only to southern hemisphere viewers, it was named for the Portuguese explorer, Ferdinand Magellan (1480[?]–1521), who commanded the first circumnavigation of the world. It lies in the constellation Tucana, the Toucan.

Sol The name of our own star, from which we get "Solar System." It is better known simply as the Sun.

solar filter An acceptable solar filter is one that fits over the object end of a telescope, and that blocks almost all of the incoming light.

Solar System The region of space that is under the influence of our local star, Sol (the Sun).

spherical A curve that is shaped as a section of a sphere.

spider The vaned mechanism that holds a Newtonian reflector's secondary mirror in place.

spiral galaxy Any galaxy with arms that spiral out from the center.

squaring Multiplying a number by itself.

star — A ball of gas, usually made up mostly of hydrogen, so massive that its own gravity forces it to collapse until nuclear fusion takes place within it, causing it to shine.

star charts — Maps of the Heavens, either in a field guide, or in larger formats. Some show only brighter stars; more detailed, comprehensive charts show stars and objects that have higher magnitudes, which are both dimmer and more numerous.

star party — A scheduled meeting of amateur and/or professional astronomers for the purpose of sharing their equipment, their time, and the night sky.

star trails — Curved lines seen in the simplest of astrophotos, left by stars during long exposures as the Earth spins on its axis.

Sun — Our own star; an apparently average one, in the middle of life.

sunspots — Cooler areas on the surface of the Sun that only appear to be dark when contrasted against the neighboring brightness. Sunspots occur in places where magnetic fields burst through the surface.

supernova remnant — The highly charged shell of gaseous remains left after a large star collapses and then explodes at the end of its life.

surface features — The actual features visible on the Sun, Moon, or planets; sometimes actual details of the solid surface, but in some instances, the tops of their atmospheres.

Tarantula Nebula — A huge emission nebula in the Large Magellanic Cloud. In actual size, it dwarfs any other known nebula anywhere near our galaxy.

Taurus — A constellation in the zodiac; the Bull. It contains two famous open star clusters: the Pleiades (M45); and the Hyades.

telephoto lens — Any camera lens that magnifies an image.

telescope — Any instrument that uses mirrors and/or lenses to give magnified images of objects toward which it is aimed.

terminator — The line between the sunlit and dark sides of a celestial body.

time-exposure photo A photograph in which the film is exposed for an extended period of time.

Titan The largest moon of the planet Saturn, and the only moon in the Solar System to possess an atmosphere. It is the second largest moon in the Solar System, just barely smaller than Jupiter's Ganymede.

total solar eclipse By an amazing coincidence, the Moon and the Sun both usually appear about the same size in the Earth's sky. Occasionally, the Moon crosses in front of the Sun and completely covers its disk for a short time (up to several minutes, but often much shorter), providing lucky observers beneath with one of nature's greatest shows.

totality The time during which an entire celestial body is eclipsed by another.

tracking Following a celestial object with a telescope as it wheels across the sky; it can be done either manually or electronically.

transit When a smaller celestial object crosses the face of a larger one as viewed by an observer.

Trifid Nebula (M20) A fairly bright nebula in the constellation Sagittarius, the Archer. It has dark portions, emission portions, and reflection portions (though the last two can only be distinguished by their color in long-exposure photographs). It lies less than two degrees from the brighter Lagoon Nebula (M8).

tripod A three-legged stand used to hold cameras, or telescopes and their mounts.

tube currents Waves of air that form in the tubes of telescopes when the temperature inside the tube is different from the temperature outside, often causing distorted views.

turbulence Disturbed currents of air that cause star images to flutter and roil.

Uranus The seventh planet from the Sun, and the first to be discovered through a telescope, by William Herschel in 1781. Visible even without aid, if you know exactly where to look, it is best to try to view Uranus through a telescope. When this is done, the giant planet can clearly be seen as a disk. Since no star ever shows as anything but a point, you can then be certain you have actually viewed the seventh planet.

Ursa Major	A constellation, the Greater Bear, located near the north celestial pole; the Big Dipper is contained within it.
Ursa Minor	A constellation, the Lesser Bear; better known as the Little Dipper (in North America, at least.)
variable star	A star that varies in brightness over time. Some vary by a little, others by a large amount. Some cycles of variability are very regular; others are erratic. There are several types of variable star.
Venus	The second planet from the Sun, and the one that approaches closest to the Earth. Its thick atmosphere and nearness to the Sun make it the hottest planet known.
Virgo	A constellation in the zodiac; the Virgin.
Vulpecula	A constellation; the Little Fox. It contains the large, bright planetary nebula, M27, the Dumbbell Nebula.
waning	Shrinking.
waxing	Growing.
Whirlpool Galaxy (M51)	One of the brightest face-on spiral galaxies, visible as a blur in small scopes. It is just below the handle of the Big Dipper.
wide field	Basically, low magnification. There are times when a wide field of view is desirable: when trying to aim a telescope or mount at a target, or when trying to view a celestial object that takes up a large section of sky.
zodiac	The twelve ancient constellations that lie along the ecliptic, and that are so important to believers in astrology. As a group, their importance to amateur astronomers is limited to the help they can give one who is searching for planets.
zones	The lighter areas between the dark bands on the surface of Jupiter.
zoom lens	A type of lens design that allows a change in magnification through the internal movement of lens elements. They are not typically useful in astronomy.

Appendix 1: the Greek alphabet

α	alpha	ι	iota	ρ	rho
β	beta	κ	kappa	σ	sigma
γ	gamma	λ	lambda	τ	tau
δ	delta	μ	mu	υ	upsilon
ε	epsilon	ν	nu	φ or ϕ	phi
ζ	zeta	ξ	xi	χ	chi
η	eta	ο	omicron	ψ	psi
θ or ϑ	theta	π	pi	ω	omega

Appendix 2: the constellations

Below is a table showing all 88 of the constellations recognized by the scientific community of the world today. The table also shows how to pronounce the names, and what the constellations are often called in English. They are not always direct translations; Cassiopeia is the name of a particular mythical queen, not just a word meaning "queen."

The entire sky is divided into 88 jigsaw-like pieces, and these are the names that go with those pieces. Most of the constellations are very ancient, and refer to mythological creatures, gods, and heroes; often very strange to us now (what, for instance, is a sea goat?) But many of the constellations were created much later, by some of the first European astronomers to travel far enough south to see new stars (new to them, at least) and shapes made by those stars. The shapes they saw and named were then put on charts and accepted by astronomers at the time. They have since come down to us and are now official. Oddly, many of these shapes are also named for things obscure to us now, especially those named (rather unimaginatively) after scientific instruments of the time. (What, exactly, is an octant, and how do you use it?)

I should also say that some of the constellations are very dim, with not a single bright star. Many of these (for example: Lynx, Camelopardalis, and Antlia) were created in later years just to fill in the gaps between the brighter spots in the sky. A few, like Cancer and Equuleus, are ancient.

Constellation name	Pronunciation	English translation or description
Andromeda	*an-DRAH-mih-duh*	The Chained Lady
Antlia	*ANT-lee-uh*	The Air Pump
Apus	*APE-us*	The Bird of Paradise
Aquarius	*uh-KWAIR-ee-us*	The Water Bearer
Aquila	*ACK-will-uh* or *uh-QUILL-uh*	The Eagle

Ara	*AIR-uh* or *AR-uh*	The Altar
Aries	*AIR-eez*	The Ram
Auriga	*or-EYE-guh*	The Charioteer
Boötes	*bo-OH-teez*	The Herdsman
Caelum	*SEE-lum*	The Chisel
Camelopardalis	*cuh-MEL-oh-PAR-duh-liss*	The Giraffe
Cancer	*CAN-ser*	The Crab
Canes Venatici	*CANE-eez* (or *CAN-eez*)	The Hunting Dogs
	ve-NAT-iss-eye	
Canis Major	*CANE-iss* (or *CAN-iss*) *MAY-jer*	The Greater Dog
Canis Minor	*CANE-iss* (or *CAN-iss*) *MY-ner*	The Lesser Dog
Capricornus	*CAP-rih-CORN-us*	The Sea Goat
Carina	*car-EYE-nuh* or *car-EE-nuh*	The Keel
Cassiopeia	*CASS-ee-uh-PEE-uh*	The Queen
Centaurus	*sen-TOR-us*	The Centaur
Cepheus	*SEE-fyoos* or *SEE-fee-us*	The King
	or *SEF-ee-us*	
Cetus	*SEE-tus*	The Whale (or Sea Monster)
Chamaeleon	*cuh-MEAL-ee-un*	The Chameleon
Circinus	*SIR-sin-us*	The Surveying Compass
Columba	*cuh-LUM-buh*	The Dove
Coma Berenices	*COE-muh BARE-uh-NICE-eez*	Berenice's Hair
Corona Australis	*cuh-ROE-nuh aw-STRAL-iss*	The Southern Crown
Corona Borealis	*cuh-ROE-nuh bor-ee-AL-iss*	The Northern Crown
Corvus	*COR-vus*	The Crow
Crater	*CRAY-ter*	The Cup
Crux	*CRUCKS* or *CROOKS*	The Southern Cross
Cygnus	*SIG-nus*	The Swan
Delphinus	*del-FINE-us* or *del-FIN-us*	The Dolphin
Dorado	*doh-RAH-do*	The Dolphin (fish; not mammal)
Draco	*DRAY-co*	The Dragon
Equuleus	*eh-KWOO-lee-us*	The Little Horse
Eridanus	*eh-RID-un-us*	The River
Fornax	*FOR-naks*	The Furnace
Gemini	*JEM-uh-nye* or *JEM-uh-nee*	The Twins
Grus	*GRUSS* or *GROOS*	The Crane

Hercules	*HER-kyuh-leez*	Hercules
Horologium	*hor-uh-LOE-jee-um*	The Clock
Hydra	*HIGH-druh*	The Water Snake (or Sea Monster)
Hydrus	*HIGH-drus*	The Male Water Snake
Indus	*IN-dus*	The Indian
Lacerta	*luh-SER-tuh*	The Lizard
Leo	*LEE-oh*	The Lion
Leo Minor	*LEE-oh MY-ner*	The Lesser Lion
Lepus	*LEEP-us* or *LEP-us*	The Hare
Libra	*LEE-bruh* or *LYE-bruh*	The Scales
Lupus	*LOOP-us*	The Wolf
Lynx	*LINKS*	The Lynx
Lyra	*LYE-ruh*	The Lyre (or Harp)
Mensa	*MEN-suh*	Table Mountain
Microscopium	*my-cruh-SCOPE-ee-um*	The Microscope
Monoceros	*muh-NAH-ser-us*	The Unicorn
Musca	*MUSS-cuh*	The Fly
Norma	*NOR-muh*	The Carpenter’s Square
Octans	*OCK-tenz*	The Octant
Ophiuchus	*OFF-ee-YOO-kus*	The Serpent Bearer
	or *OAF-ee-YOO-kus*	
Orion	*oh-RYE-un*	The Hunter
Pavo	*PAY-vo*	The Peacock
Pegasus	*PEG-us-us*	The Winged Horse
Perseus	*PER-see-us* or *PER-syoos*	The Hero
Phoenix	*FEE-nix*	The Phoenix
Pictor	*PICK-ter*	The Painter’s Easel
Pisces	*PICE-eez* or *PISS-eez*	The Fishes
Piscis Austrinus	*PICE-iss* (or *PISS-iss*) *aw-STRY-nus*	The Southern Fish
Puppis	*PUP-iss*	The Stern
Pyxis	*PIX-iss*	The Magnetic Compass
Reticulum	*rih-TICK-yuh-lum*	The Reticle
Sagitta	*suh-JIT-uh*	The Arrow
Sagittarius	*SAJ-ih-TARE-ee-us*	The Archer
Scorpius	*SCOR-pee-us*	The Scorpion
Sculptor	*SCULP-ter*	The Sculptor

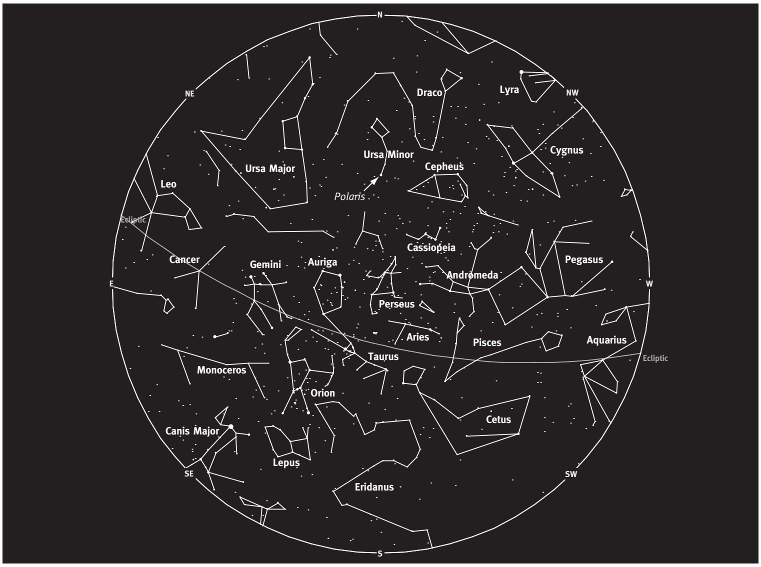
Scutum	*SCOOT-um* or *SCYOOT-um*	The Shield
Serpens	*SER-punz*	The Snake
Sextans	*SEX-tunz*	The Sextant
Taurus	*TOR-us*	The Bull
Telescopium	*tel-ih-SCOPE-ee-um*	The Telescope
Triangulum	*try-ANG-gyuh-lum*	The Triangle
Triangulum Australe	*try-ANG-gyuh-lum aw-STRAL-ee*	The Southern Triangle
Tucana	*too-KAY-nuh* or *too-KAH-nuh*	The Toucan
Ursa Major	*ER-suh MAY-jur*	The Great Bear
Ursa Minor	*ER-suh MY-ner*	The Lesser Bear
Vela	*VEE-luh* or *VAY-luh*	The Sails
Virgo	*VER-go*	The Maiden
Volans	*VOH-lanz*	The Flying Fish
Vulpecula	*vul-PECK-yuh-luh*	The Little Fox

Some simple star charts

Here are eight maps of the night sky; one for each of the seasons, for both the northern and southern hemispheres. They were created, in part, with the planetarium software program *SkyChart III*, (available at www.southernstars.com/skychart/). Because of the scale used for this guide, the charts show little detail, but I have included them as a starting point. Under the starry sky, they should help you to find the brighter constellations; and the line marking the ecliptic might help you find planets. The lines used to show the constellation figures are those designed by H.A. Rey, for the book *The Stars: A New Way to See Them* (see page 15).

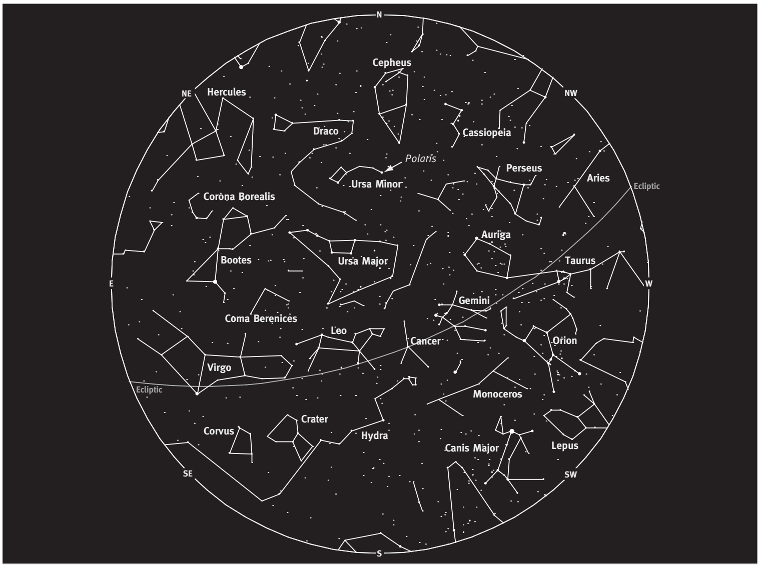
To use them outside, simply face in one of the directions marked around the edge of the chart that corresponds closely to the time and date at which you are using it. Then lift the book up, turning it so that the direction you are facing is at the bottom. You should now be able to match the chart with the sky. Start with a shape you are familiar with (the Big Dipper in the north, and the Southern Cross in the south are visible at virtually any time of year), and use it and the chart to move on to new constellations.

I used the latitudes 45 degrees north and 30 degrees south because these seemed the best for the most people around the world. If you live north or south of these latitudes, the sky will not match the charts; but, unless you are quite distant, you should still get some use from them.



1 Northern evening sky, winter (latitude 45 degrees). The sky as it appears at these times on these dates:

12:00 am
November 15
11:00 pm
November 30
10:00 pm
December 15
9:00 pm
December 30
8:00 pm
January 15
7:00 pm
January 30

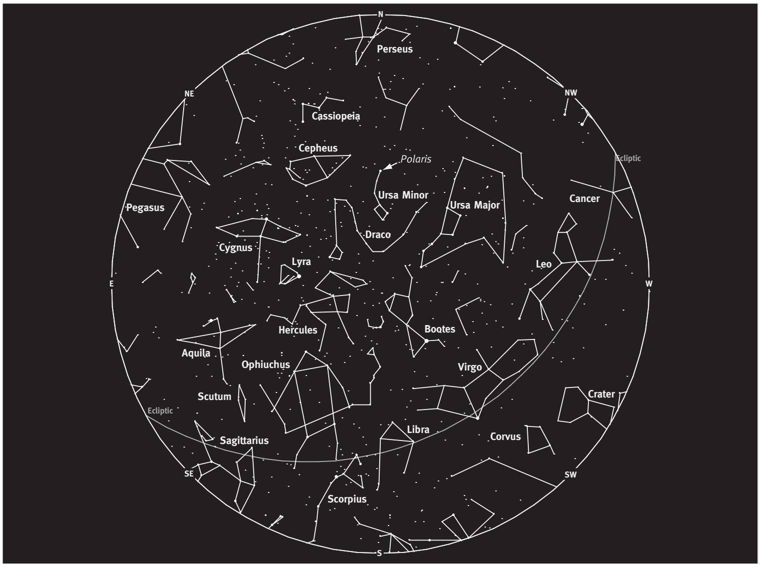


2 Northern evening sky, spring. The sky as it appears at these times on these dates:

12:00 am
February 15
11:00 pm
February 30
10:00 pm
March 15
9:00 pm
March 30
8:00 pm
April 15

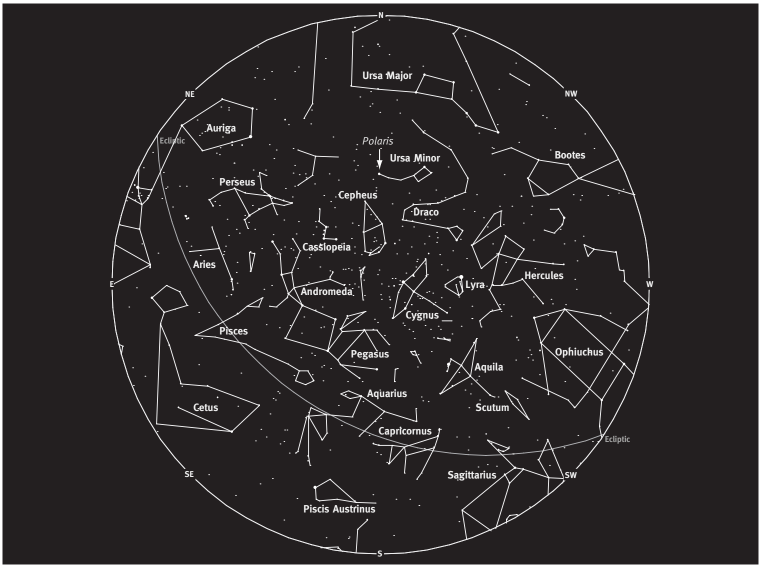
3 Northern evening sky, summer. The sky as it appears at these times on these dates:

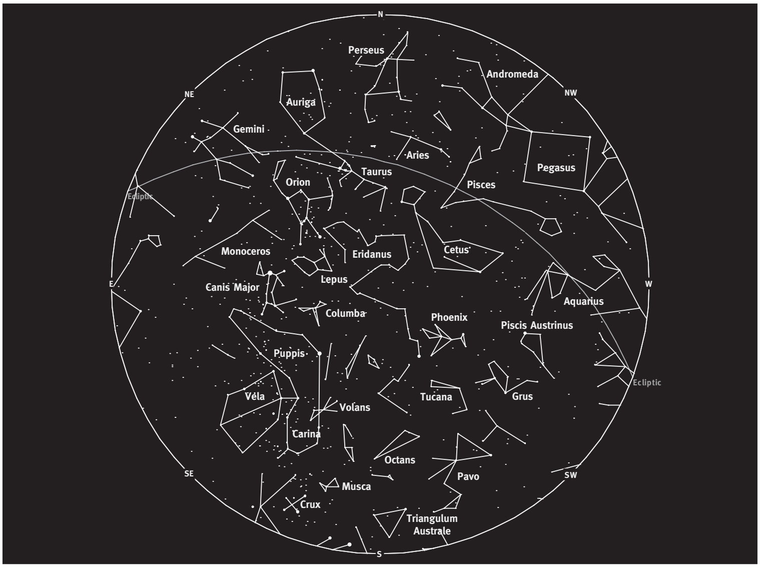
12:00 am
May 15
11:00 pm
May 30
10:00 pm
June 15
9:00 pm
June 30



4 Northern evening sky, autumn. The sky as it appears at these times on these dates:

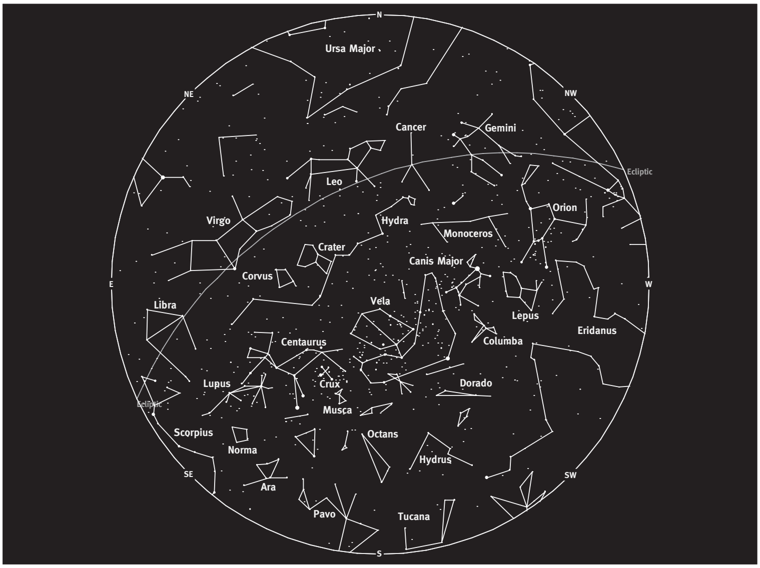
12:00 am
August 15
11:00 pm
August 30
10:00 pm
September 15
9:00 pm
September 30
8:00 pm
October 15
7:00 pm
October 30





5 Southern evening sky, summer (30 degrees latitude). The sky as it appears at these times on these dates:

12:00 am November 15
11:00 pm November 30
10:00 pm December 15
9:00 pm December 30

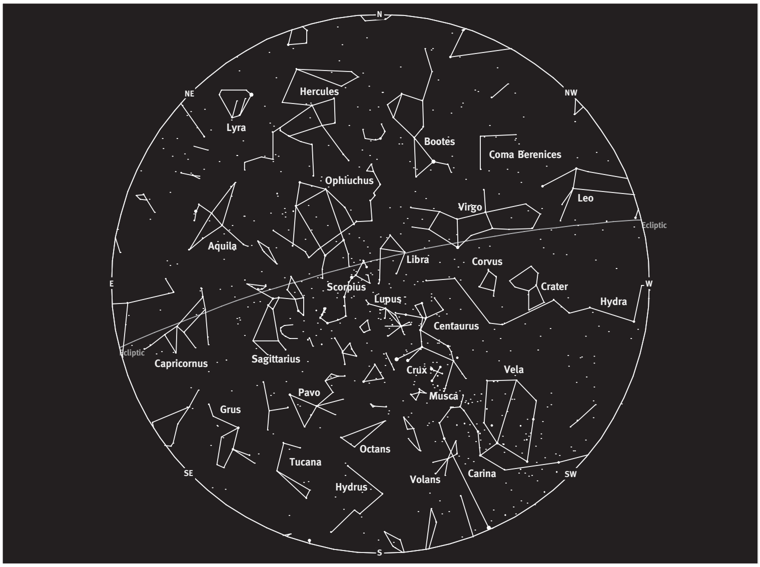


6 Southern evening sky, autumn. The sky as it appears at these times on these dates:

12:00 am February 15
11:00 pm February 30
10:00 pm March 15
9:00 pm March 30
8:00 pm April 15

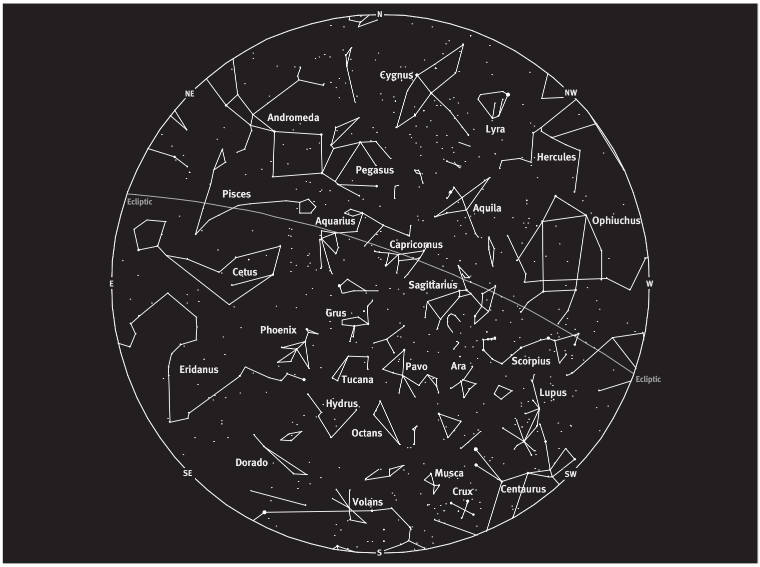
7 Southern evening sky, winter. The sky as it appears at these times on these dates:

12:00 am
May 15
11:00 pm
May 30
10:00 pm
June 15
9:00 pm
June 30
8:00 pm
July 15



8 Southern evening sky, spring. The sky as it appears at these times on these dates:

12:00 am
August 15
11:00 pm
August 30
10:00 pm
September 15
9:00 pm
September 30
8:00 pm
October 15



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(*Italics* indicate an illustration; **bold** print indicates an entry in the glossary.)

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