Chapter 2

Astronomy Basics

It is always helpful to have a basic knowledge of general astronomy. If you don't, this chapter provides just that type of information; we will pick back up with Celestron's telescopes in the next chapter.

Astronomy is arguably humankind's oldest science. Historic and prehistoric accounts show that as long as humans have been recording things important to them, the sky has figured prominently. Although we have been able to very accurately determine the motion of the objects in the sky for more than 3,000 years, it is only a relatively recent development that we have come to understand why they move the way they do. Unfortunately, most folks still don't know the why, and most don't even notice the motion!

The Night Sky

After you spend a little time under the night sky you begin to notice things that were not immediately apparent. As the night passes, the various star patterns drift slowly overhead, coming up from the east and setting in the west. The stars differ in brightness and form recognizable patterns. Some nights are clearer than others. Occasionally a bright light passes overhead unexpectedly. Night after night the phase and location of the Moon changes dramatically. There is a lot to see if you are observant. At first it can be quite confusing, but there are some simple concepts that can help as you slowly start to make sense of it all.

M. Swanson, *The NexStar User's Guide II*, The Patrick Moore Practical Astronomy Series, DOI 10.1007/978-3-319-64933-7_2

Constellations

Stars are so far from us that their motion from year to year is almost negligible. The patterns that you come to recognize will remain virtually unchanged for hundreds of years. The planets and other Solar System objects wander around the sky, but the stars stay relatively fixed in relation to one another.

Many star patterns have names and are known to even the most casual observer of the night sky. For instance, in the spring, observers in the Northern Hemisphere easily identify the group of seven stars known as the Big Dipper. During the months from October through February, the hourglass shape of Orion is readily visible to observers in both the Northern and Southern Hemisphere. The Big Dipper constitutes the brightest stars in the constellation Ursa Major – the Big Bear. Orion, the Hunter, is a constellation in its own right. There are 88 constellations that professional astronomers established to separate the sky into regions in the same way that Earth is separated into continents and oceans.

The Motion of the Sky

The Big Dipper holds another distinction besides being one of the most recognizable constellations in northern skies. The two stars at the end of its bowl point directly to Polaris, the North Star. Located almost directly over Earth's North Pole, for northern observers Polaris is the pivot point that the sky seems to swing around as the night goes on. Unlike all other objects you see in the sky, Polaris stays put! And, as its name implies, it unfailingly points the way north. When you face north, all the stars around Polaris travel in a counterclockwise circle. The point that Polaris marks is known as the north celestial pole. Observers in the Southern Hemisphere see a mirror of this when they look to the south. Stars travel in a clockwise circle around the south celestial pole, although there is no bright star to mark that point.

The situation is different when we look away from the poles. When northern observers look south, or when southern observers look north, they will notice that the stars rise in the east and set in the west, just as the Sun does each day. All of this continuous motion is caused by Earth's 24-hour daily rotation. Earth spins on its axis of rotation once every 24 hours, causing the day and night as well as the moment-by-moment drift of the objects in the sky.

In addition to rotating on its axis, Earth also makes a long elliptical journey around the Sun. This trip takes about 365 days – one year. The stars and constellations are basically frozen in their relative locations, but Earth's movement around the Sun causes the constellations to drift a bit further to the west, night after night. The stars we see at night are those on the side of Earth away from the Sun, as shown in Fig. 2.1.

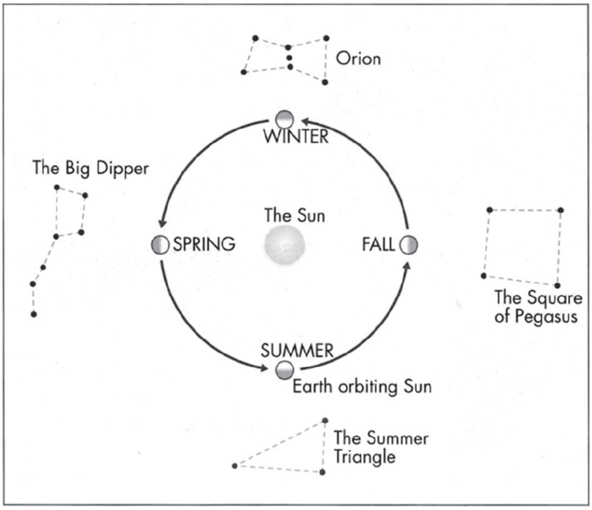


Fig. 2.1 As Earth travels around the Sun throughout the year, different sections of the sky are visible at night. This figure depicts the major star formations visible in the evening; the seasons indicated are in reference to the Northern Hemisphere

The constellations are always in the same place, but as the year progresses, the stars we were viewing a few months ago are in our daytime sky. For example, in the winter, Orion is prominent in our night sky. But in the summer, Orion is behind the Sun, or in other words, it is in our sky during the day when the brilliance of the Sun hides the stars from our view.

Sky Coordinates

Besides the constellations, we also refer to other imaginary boundaries in the sky. The horizon is the line where the land meets the sky. The zenith is the point directly overhead. The meridian is the line running from the northern horizon, up through the north celestial pole, overhead through the zenith, then down to the southern horizon. Thus, it splits the sky into eastern and western halves. The celestial equator is a line that runs from east to west, directly above Earth's equator. And finally, the ecliptic is a wavy line traveling north, then south of the celestial equator. The ecliptic is significant as the Sun, the Moon, and all the planets travel through our sky near to this line.

Similar to longitude and latitude used to pinpoint locations on Earth, we use right ascension (RA) and declination (Dec) to pinpoint locations in the sky. As shown in Fig. 2.2, lines of right ascension run from the north celestial pole to the south celestial pole, similar to longitude on Earth. Thus, they meet or converge at

Fig. 2.2 Lines of right ascension around the north celestial pole (Created in Patrick Chevalley's *Cartes du Ciel,* Sky Charts)

the celestial poles. Lines of declination run east to west, parallel to one another, just like latitude.

We measure right ascension in hours, minutes, and seconds. RA starts at 0h00m00s then goes clockwise around the north celestial pole until we come to 23h59m59s just before where we started. Thus, there are 24 hours of right ascension. Declination is measured in degrees (°), arcminutes (′), and arcseconds (″). The declination of the celestial equator (right above Earth's equator) is 0°00′00″ (0 degrees), the declination of the north celestial pole is 90° and the declination of the south celestial pole is −90°. From this system we can give the coordinates for any object in the sky. For example, the coordinates for Rigel, a bright star in the constellation Orion, are RA 05h14m30s, Dec −08°12′06″.

The line of right ascension directly above us at the meridian is known as local sidereal time (LST). Every hour, local sidereal time changes about one hour. In other words, if local sidereal time is currently 18h RA, in one hour LST will be 19h RA. Naturally this corresponds to the fact that Earth rotates once every 24 hours. Sidereal rate is the rate that objects move across the sky – approximately one hour of right ascension for every hour of time here on Earth. Since the 360 degrees of the circle divided by 24 hours yields 15, this rate of motion corresponds to 15 degrees at the celestial equator.

Measuring "Distance" Between Two Objects

We measure the "distance" between two objects as the angular separation between them. If you project a straight line from you to each object and measure the angle between the two lines, which is the angular separation. We express this as degrees, arcminutes, and arcseconds. The angular separation between Dubhe, the bright star at the end of the Big Dipper's bowl, and Polaris, the North Star, is about 28°42′30″ or nearly 30 degrees.

Estimating angular separation when you are outdoors is quite easy. Hold your hand up at arm's length and your little finger covers about 1°. Your index, middle, and ring finger (like the Boy Scout salute) measure about 5°. Your closed fist is about 10°, the distance between the tips of your index and little finger with your fully spread hand is about 15°, and from the tip of your thumb to the tip of your little finger with your fully spread hand is about 25°. The measurements for 1°, 5°, and 10° are remarkably close for most people, but the spread hand measurements vary somewhat from one person to another.

Magnitude - Measuring Brightness

More than 2,000 years ago, the first recorded attempt to quantify the brightness of sky objects was undertaken by the Greek astronomer Hipparcos. His scale of measurement varied from first to sixth magnitude. First magnitude stars were the brightest he could see, while sixth magnitude were the faintest. As the science of astronomy progressed, the magnitude system was refined to allow precise measurements of all celestial objects. For example, Venus is brighter than the brightest star and reaches a magnitude of more than −4 at times. The brightest star in the sky, Sirius, is magnitude −1. From a dark, clear site, the faintest stars most can see are magnitude 6, just as Hipparcos designated. Telescopes and binoculars collect and concentrate light, allowing us to see fainter objects. Table 2.1 estimates the magnitude limits visible during excellent seeing conditions in various-sized instruments.

A difference of 1 in magnitude is actually a difference of 2½ in absolute brightness. Thus, the difference in brightness between a magnitude 2 star and a magnitude 4 star is a factor of 6.25–2.5 times 2.5. This explains why larger and larger instruments only gain fractional improvements in limiting magnitude. Nonetheless, these fractional differences are significant. The relatively modest step of just 1 magnitude difference between a 5-inch and 8-inch telescope brings many more thousands of faint objects into view.

We can estimate the magnitude of naked-eye objects using a couple of the most recognizable star formations in the sky. For viewers in the Northern Hemisphere, turn to the Little Dipper. In the Southern Hemisphere, refer to the Southern Cross. The magnitudes of their various stars are shown in Fig. 2.3.

Table 2.1 Magnitude and resolving limits under excellent seeing conditions

Instrument	Aperture	Limiting magnitude	Resolving limit (arcseconds)
Naked eye	About 7 mm	6	
Binoculars	50 mm	11	
Telescopes:			
	60 mm/2.4 in.	11.4	2.3
	70 mm/2.8 in.	11.7	2
	80 mm/3.1 in.	12	1.8
	90 mm/3.5 in.	12.3	1.6
	102 mm/4 in.	12.5	1.4
	114 mm/4.5 in	12.8	1.2
	127 mm/5 in.	13	1.1
	6 in.	13.4	0.9
	8 in.	14	0.7
	9.25 in.	14.4	0.6
	11 in.	14.7	0.5

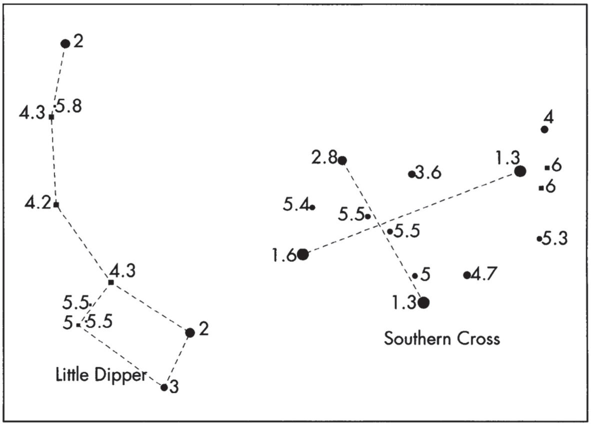


Fig. 2.3 The visual magnitude of easily identifiable stars

Magnitude figures for deep sky objects are not as clear-cut as those for stars and planets. Generally, the entire luminosity of the object is “summed up” and reported as if it were a single point light source (a star). So, a very large object of several arcminutes could be reported with a fairly bright magnitude, but appear very faint in the eyepiece. This is typically the case for nebulae and galaxies. Consider the Andromeda Galaxy, M31. It is generally reported as approximately magnitude 3.4, but that 3.4 is spread out in an area of about 180 by 60 arcminutes. This is about 6 times the width of the full Moon! So, while a star of magnitude 3.4 is easily visible to the naked eye, M31 requires clear dark skies to be glimpsed without optical aid.

In the case of deep sky objects, a better measure of luminosity is "surface brightness." Surface brightness is not standardized and thus varies from one recorder to another, but is generally a measurement of magnitude per square arcminute. Using such a measure we can better compare deep sky objects and determine whether we should be able to view them in our telescope or binoculars. One slight complication for using surface brightness is the fact that not all objects are uniformly bright across their entire surface. Again consider M31. The core is many times brighter than the surrounding spiral arms. Thus, the surface brightness of the core is higher than the average surface brightness of the entire galaxy.

Seeing Conditions

Other than the obvious difference between a clear and a cloudy night, most folks don't realize how variable our view of the night sky really is. Some nights you can make out great detail on Jupiter, while other nights you are lucky to see two bands. One night you can see a faint globular cluster quite clearly, other nights it might be invisible. Various factors affect our viewing conditions, but three are most critical: seeing, transparency, and light pollution.

Seeing is mainly our observation of the distortion caused by different layers of air going in different directions due to wind, the jet stream, temperature differences, etc. This causes images to waver. Think of this as the hot air wavering above a blacktop road in the summer. In the night sky, it causes the stars to twinkle. In the eyepiece you can most easily see the wavering air when you increase the magnification on a planet or the Moon, but it affects all objects viewed.

Transparency is our observation of the distortion caused by particles in the air. Clouds are obviously the extreme, but dust, smog, moisture, and other particles all limit the transparency of the air. Transparency is the same factor that affects what pilots call visibility – "Today's visibility is 10 miles." When observing from a very dark site, poor transparency causes objects to appear less bright. When observing from a site with any appreciable light pollution (and light from the Moon) the effect is many times worse. Those particles reflect light back down to the ground. This results in a "glowing" sky and makes faint objects very difficult or impossible to see. The effect on contrast (difference in light levels) is to make the black velvety sky behind the object not black but gray. Sky contrast is critical for faint objects, but does not affect contrast much on the surface of bright objects such the Moon and brighter planets.

Light pollution is generally considered to be any manmade light that is directed upward. Houses, cars, storefronts, and streetlights are all prime sources of light pollution. Any level of light pollution will decrease the contrast between celestial objects and the background sky. Naturally the problem is worse around cities, but even small towns have appreciable levels of light pollution. The truth is that there are very few populated places on Earth that still offer truly dark skies. Growing up in rural Indiana, on very dark and clear nights I could actually see the "light dome" above Chicago from more than 70 miles away! Some communities have adopted local regulations to cut down on light pollution, for example, requirements for full-cutoff lights. Such lighting fixtures aim all the light downward. Besides spoiling the night sky, all light that goes up is simply wasted energy.

One of the best ways to gauge the night sky is by determining the faintest stars you are able to see from your site. Using the magnitudes listed in Fig. 2.3 earlier, you can accurately assess current conditions. Wait for your eyes to become at least initially dark-adapted (20–30 minutes), then determine the faintest magnitude visible.

Nights of poor transparency many times offer steady seeing. Steady seeing is critical for viewing details on the planets and the Moon. Good transparency usually means poor seeing, yet transparency is much more important for deep sky objects. If transparency is just average, even a quarter Moon will wash out most deep sky objects such as galaxies and nebulae. Other than traveling to a dark site, you cannot do much about the general light pollution in your area. But you will want to setup to observe in a location where all local light sources are blocked from your view. For example, moving around the corner of the house might block your neighbor's porch light. Most importantly, get out as often as you can, because you never know when that night of perfect seeing conditions will happen.

Observation Technique

Although buying a larger telescope is one way to see more difficult astronomical objects, improving your observing techniques plays a big role. Experienced observers can always see more in the eyepiece than a newcomer. Here are some pointers.

First of all, you will most likely need to temper your expectations. Don't expect the view through the eyepiece to match the wonderful photographs that you have seen in magazines. Most of those photos are long exposures that allow the light to "build up" on the imaging sensor, providing a bright, colorful image. Your views will be much fainter. Additionally, imaging sensors are much more sensitive to color in faint light than your eyes are. Other than the planets and a few stars, most objects will be gray in the eyepiece. And finally, things will be much smaller in the eyepiece than they are in an enlarged photograph.

Allow your eyes to become fully dark-adapted and guard that adaptation throughout the night. Everyone is familiar with the fact that after stepping out of a lighted building, it is not possible to see much at all. But within just a few minutes, you are able to see fainter objects (both on the ground and in the sky) than you could initially.

Your night vision improves dramatically in the first 30 minutes of avoiding bright lights. After that, the process slows down as your ability to see fainter light sources continues to improve slightly for a couple of hours. But all it takes is one look into a bright light and your eyes are forced to start over again. Red light is the least damaging to our night vision; thus astronomers use red flashlights when they need light. But the red light should be very dim, as even a bright red light reverses some of your dark adaptation. Also note that the Moon through binoculars or a telescope is an extremely bright object. Leave your lunar viewing for last if possible. If a local light source doesn't allow you to become fully dark-adapted, try draping a dark cloth over your head and the eyepiece.

Use the technique known as averted vision for faint objects such as galaxies, nebulae, and globular clusters. The central area of the retina is best at detecting color while the areas off center are better at detecting faint light. When viewing a faint object, try focusing to the side of the object while concentrating on the object itself. You will generally be able to make out fainter detail in this way. Look to the outside when viewing with one eye (to the right when using your right eye, to the left when using your left eye) or look up when using binoculars. It takes practice, but it is effective.

Move the 'scope slightly side to side or tap it. Sometimes an object will be in the eyepiece, but you can't locate it. If you move the 'scope slightly, the motion will often make the object visible. Once you have located it in this way, you can generally study it with averted vision.

Try different magnifications on an object. Brighter, compact objects hold up well and show more detail with higher magnification. Planets, planetary nebulae, globular clusters, and some small galaxies are in this category. Larger and more diffuse objects generally require low magnification to display the best view. Nebulae, open clusters, and most galaxies fall into this group.

Spend some time on each object. When you first start out in astronomy, the tendency is to jump from object to object, as everything is new to you. Resist that urge and spend some time on each object. What details can you make out on a planet's disk? Moments of clear seeing will reward you with subtle details that are not initially obvious. Can you make out any features in that faint smudge that is a galaxy millions of light years away? How many stars can you individually pick out in that star cluster?

If you wear glasses but do not suffer from astigmatism, feel free to remove your glasses and focus the telescope for a sharp view. The only disadvantages are that anyone else looking through your 'scope will need to refocus, and you might need to use your glasses to view charts and other materials.

Telescopes require time to cool down to the surrounding night air. Until they reach equilibrium, air currents inside the 'scope will spoil high magnification views. Large, closed tube telescopes may require more than an hour, while small, open tube 'scopes may equalize in a matter of minutes. Some large 'scopes may not be able to cool fast enough to keep up with quickly dropping nighttime temperatures. To help minimize cool down time, it is best to store your telescope in a dry, unheated building. If this is not practical, get a head start by setting your 'scope outside as soon as the Sun goes down, before you intend to use it.

Similarly, heat rising from an asphalt surface or dark-tiled roof will spoil views. This causes the view in the eyepiece to waver and "boil." Consider the surroundings when choosing a location to set up your telescope.

Many amateur astronomers record their observation sessions in a log. In simplest form a log is a small notebook where the observer records the date, the objects viewed, and a short description of each. On the other end of the scale are complex databases running on a personal computer that help you to easily search your entries, group together each observation of a particular object, record the eyepiece, record the magnification, and much more. Most settle on something in between.

A comprehensive approach to recording an observing session includes noting the following in your log:

- location, date, and time
- Instrument(s) used and vital statistics about the instrument(s) - aperture, focal length, eyepiece, etc.
- Seeing conditions: seeing (steadiness of the air), transparency, and level of light pollution
- Objects and a description of your observations of each

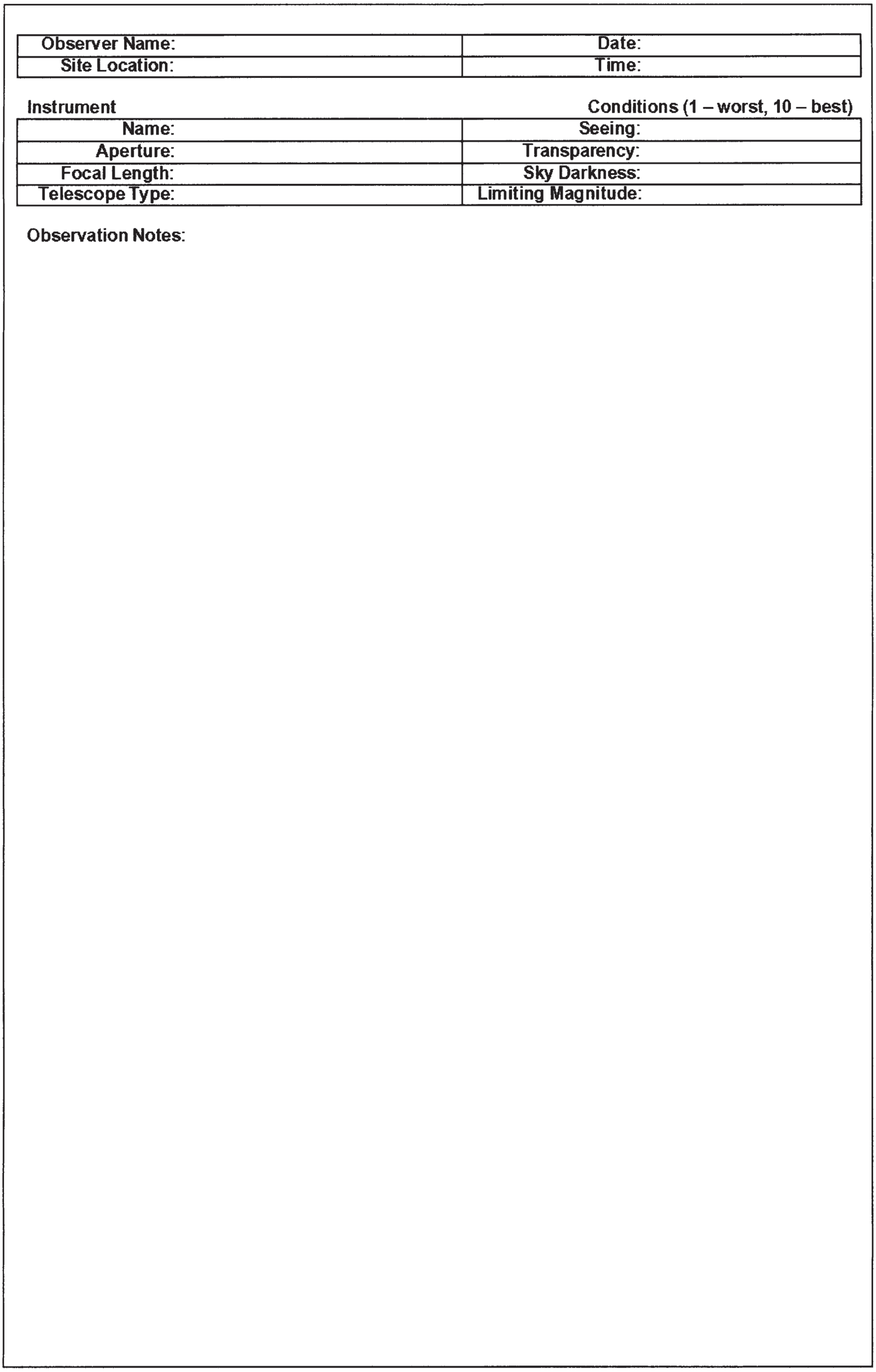
You certainly will not want to spend much time writing grammatically perfect notes while you are out under the stars, so try this instead. Take a small notepad (or loose paper on a clipboard) out with you and leave your “official” logbook inside. Start by noting the location, date, and time on the notepad. Then simply jot notes about each object. Later that night, or perhaps in the next day or two, refer to your notes to record complete entries in your permanent logbook.

Besides providing a permanent record of your nighttime adventures, a logbook also helps you to see more. In your quest to record what you observe, you concentrate on small details and really see the object. Some observers include sketches of objects in their logbook. More than any other activity, drawing will truly help you to see more detail than you thought possible.

Even if you don’t continue your log throughout your viewing career, you will find that maintaining a logbook for your first year will really help you to improve in your observation abilities and will build a firm foundation for a lifetime of enjoyment. Plus, the initial wonder of it all will be reflected in your log entries, and skimming through your logbook on cloudy nights can recapture that “newcomer” feeling from when you first started out.

Figure 2.4 shows a sample log sheet. Figure 2.5 is a sample sketch sheet. Both can be printed on standard paper and kept in a loose-leaf binder. Visit the Downloads section of the author’s NexStar Resource Site (http://www.NexStarSite.com) to find printable copies.

As you gain more observing experience, you will notice that even your first looks at an object yield greater detail than your painstaking efforts as a beginner. The most important thing is to have fun and learn as you observe. Develop your observation technique and you will develop a life-long interest in astronomy.



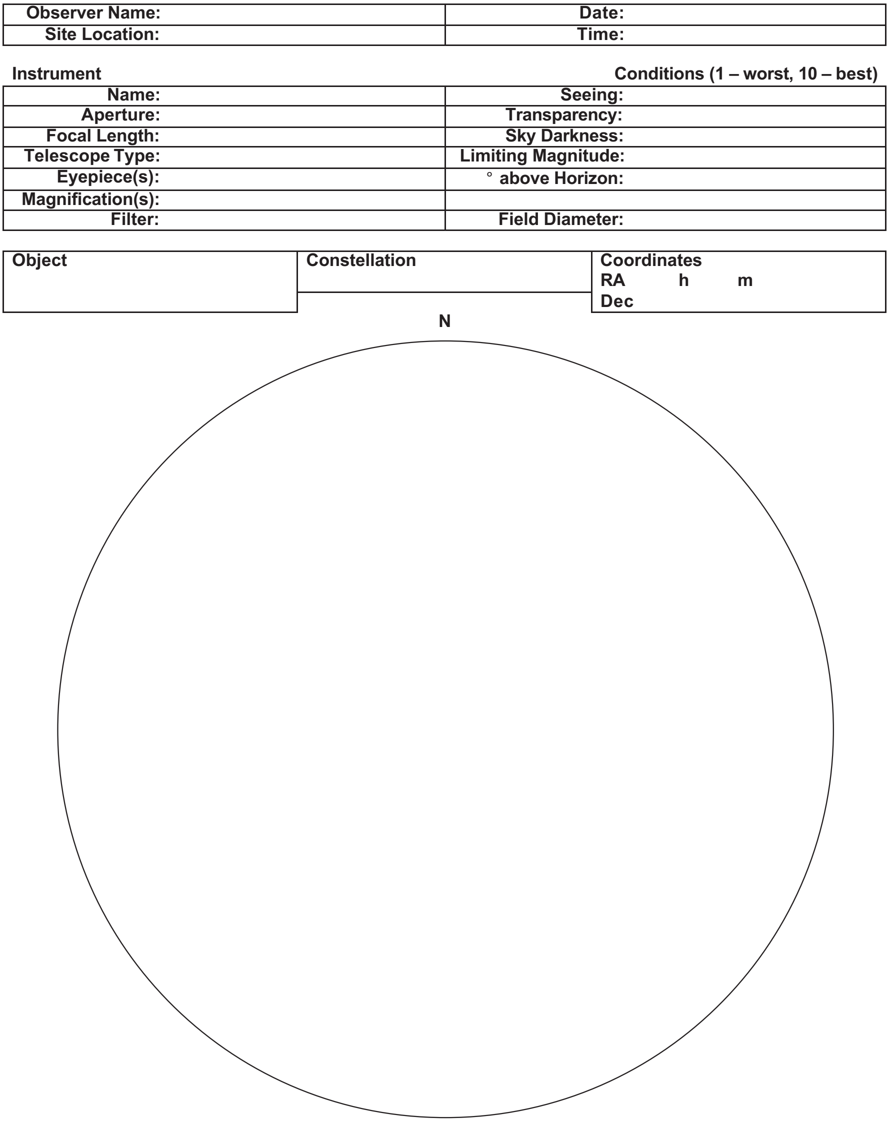
Observer Name:	**Date:**
Site Location:	**Time:**

Instrument **Conditions (1 – worst, 10 – best)**

Name:	**Seeing:**
Aperture:	**Transparency:**
Focal Length:	**Sky Darkness:**
Telescope Type:	**Limiting Magnitude:**

Observation Notes:

Fig. 2.4 Sample observation logbook sheet



Observer Name:	**Date:**
Site Location:	**Time:**

Instrument	**Conditions (1 – worst, 10 – best)**
Name:	**Seeing:**
Aperture:	**Transparency:**
Focal Length:	**Sky Darkness:**
Telescope Type:	**Limiting Magnitude:**
Eyepiece(s):	**° above Horizon:**
Magnification(s):	
Filter:	**Field Diameter:**

Object	**Constellation**	**Coordinates** **RA h m** **Dec**

Fig. 2.5 Sample sketch sheet

Astrophotography

There is something alluring about using your own equipment to produce a photograph of a celestial object. Hanging in your home or office, such photos never fail to draw attention and comments. When asked if you got the image from a magazine, you can imagine the pride experienced when you say, “No, I took that myself.”

What you may not be able to imagine is the hours of hard, often tedious, work that you will endure to create a photograph you can proudly display. For every acceptable image produced, many more will be thrown out. But certainly that makes the good ones all that much more special.

A true introduction to astrophotography is a book unto itself, well beyond the scope of this book. As such, here are a few resources you can consult to get you started.

Online Resources

- *Sky & Telescope* (http://www.skyandtelescope.com) offers a free eBook on astrophotography in the resources section of its website.
- Oceanside Photography and Telescopes (http://www.OPTcorp.com) has produced several YouTube videos on image processing.
- Starizona (http://starizona.com) has several articles in the CCD imaging section of its website.
- Cloudy Nights astrophotography forums are a great source of information and inspiration.

Books

There are many great books to choose from; here are a few presented in no particular order:

- *The Deep-sky Imaging Primer Paperback* by Charles Bracken
- *The New CCD Astronomy: How to Capture the Stars With a CCD Camera in Your Own Backyard* by Ron Wodaski (a classic, and although dated, the Kindle version is a bargain)
- *The Astrophotography Manual: A Practical and Scientific Approach to Deep Space Imaging* by Chris Woodhouse
- *Astrophotography* by Thierry Legault
- *Getting Started: Budget Astrophotography* by Allan Hall
- *Getting Started: Long Exposure Astrophotography* by Allan Hall

What’s Up There?

Astronomy is not simply a visual activity; it is also a mental activity. It is much more enjoyable to understand a little about the objects you are viewing rather than just jumping from object to object in order to simply put another checkmark next to an item on a list.

The planets and other Solar System objects can provide hours of enjoyment, both with naked-eye views and views through a telescope. There are nine major planets, countless asteroids and comets, and many more objects revolving around the Sun. Each is held in its orbit by the mutual gravity of the object and the Sun. Some, such as the planets and major asteroids, are visible at frequent intervals of at least every year, while others, such as comets, might only venture close enough to Earth to be seen once every few hundred years.

Each of the planets has a different length of year, and their individual motion, coupled with the motion of our Earth causes them to move against the backdrop of the much more distant stars. For example, though the constellation Orion will always be visible during December during our lifetimes, the planet Jupiter might be high overhead in December one year but not until January the next, and then not until February the next. The closer a planet is to the Sun, the faster it moves – in other words, the shorter its year. You can keep track of the current locations of the planets with the monthly pullout star charts in various magazines or on several Internet websites; in this book refer to Chap. 8 and Appendix A for suggestions.

The Sun

At the heart of our little corner of the universe is the local star, our Sun (Fig. 2.6). Traveling around the Sun in elliptical orbits are the eight planets of our Solar System. Besides making summer days almost too hot to bear and turning many of us pink when we don't pay the proper respect, the Sun provides the energy that is the source of most life on Earth.

Although most think of astronomy as a strictly nighttime activity, we can also study the Sun with the proper equipment. But, it is *extremely dangerous* to view the Sun without taking the proper precautions. Refer to Chap. 9 in this book for advice on equipment necessary for solar viewing. After we are properly equipped, we can observe the changing pattern of sunspots as they move across the surface of the Sun. Most of the sunspots we can easily see are several times the diameter of Earth! Approximately every 11 years the Sun reaches maximum activity with many more sunspots than usual. The most recent solar maximum was 2013, although it was marked by relatively low activity.

The Moon

The closest major body to Earth is of course our only natural satellite, the Moon. At about a quarter the diameter of Earth, the Moon is a cold, barren place. Long ago it lost any atmosphere it might have had. Other than very small amounts of ice in craters near its poles, there is no water to speak of. The craters covering its surface are a silent reminder of the violent past (and occasionally violent present) of our Solar System; they were all created as objects impacted the lunar surface (Fig. 2.7).

Fig. 2.6 Venus transiting the Sun, accompanied by several sunspots (Image by author with a NexStar 102SLT and digital SLR camera)

However, it is those amazing surface features that fascinate us when viewed with even the slightest magnification. It is easy to get lost among the various craters, mountains, valleys, fissures, and other geological formations. As the Moon makes it way around Earth about once every 29 days, it presents us with differing phases as the angle between us, the Moon and the Sun varies. Contrary to popular belief, the best time to view the Moon is not when it is full. Rather, at any other time, the greatest detail can be seen along the terminator – the line between the sunlit and dark sides of the Moon. The surface of the Moon at the terminator is experiencing sunrise or sunset, and the low angle of the Sun produces long shadows, just as it does here on Earth. Those long shadows make surface features more pronounced and much easier to see.

Fig. 2.7 The Moon imaged with a NexStar 8SE and a digital camera (Image by author)

As your early observations of the Moon will show – it's bright! One accessory that is a necessity for every amateur astronomer is a Moon filter, as discussed in Chap. 9 in this book. This cuts down most of the glare and makes viewing the Moon much more comfortable. Even with a Moon filter you should generally do your lunar observing last on any night, as viewing the Moon will ruin your eyes' dark adaptation.

Also, when the Moon is more than just a sliver in the sky, it tends to wash out the fainter deep-sky objects. Thus, your observations of galaxies, nebulae, and such will generally need to wait until the Moon sets or you should hunt for them before the Moon rises. During nights near the full Moon, only the very brightest deep sky objects will provide satisfying views in the eyepiece.

Mercury

The planet with the closest orbit to the Sun is Mercury. Mercury is so close to the Sun that we seldom see it, and when we do it is just after sunset or just before sunrise. Due to the angle between Earth, Mercury and the Sun, Mercury exhibits phases when viewed through a telescope, as we can see both the side illuminated by the Sun and the side in the shadow of Mercury's night. Other than these phases, you will not see any other detail when viewing Mercury. Use care; don't accidentally point at the Sun when attempting to view Mercury!

Venus

Next in order from the Sun is the planet Venus. Venus is the brightest nighttime object in the sky, after the Moon. The dazzling brightness of the planet causes some to mistake it for aircraft lights! Venus is also relatively close to the Sun, visible either in the few hours after sunset or before sunrise. When Venus is out after sunset, it is often called the "Evening Star" (although we amateur astronomers know it is a planet, not a star!) as it is the first "star" to show as the sky darkens through twilight. When visible before sunrise, Venus becomes the "Morning Star." The stunning brightness is largely due to the light-colored clouds that continually cover the planet. For the same reasons as Mercury, in a telescope Venus displays phases as it travels around the Sun. There is no real detail to be seen viewing Venus other than the changing phases.

Most find Venus to be simply a beautiful sight with the naked eye, since there really isn't much to see in the telescope. Occasionally Venus, or any of the other planets for that matter, will pass in front of – occult – a background star. Or, the Moon will rarely occult one of the planets. These are occasions to train our telescopes on Venus, rare opportunities not to be missed.

Mars

The planet occupying the orbit outside of Earth's is the red planet, Mars. A bit smaller than Earth, Mars is a rocky, dusty planet. Past robot missions to Mars show evidence that in the past water flowed on the surface of Mars. While none exists now, astronomers have recently found evidence of water ice below the surface, as well as that found in the polar ice caps (Fig. 2.8).

Viewing Mars is best when it is at opposition – when Mars and Earth are on the same side of the Sun, with all three forming a straight line. Oppositions occur about every two years, and some oppositions are much better than others. About every fifteen or sixteen years, the elliptical orbits of Earth and Mars cooperate to bring us much closer to Mars than during other oppositions. The cycle is not exact by human standards, so it is best to keep up to date with information in monthly magazines, newsletters, and websites.

Viewing Mars in a telescope should present a pink- to red-colored disk. Look for surface features such as the light-colored polar caps and various dark surface markings. The angle of Mars will not always present a good view of the caps, and generally only one of them will be visible. Watch for changes in the size of the caps as Mars moves through its seasons. Very good conditions will be required to see the caps in smaller 'scopes.

Fig. 2.8 Mars imaged with a NexStar 8SE and astro webcam (Image by Justin Fuller)

The dark surface features also change with time. Dust storms on Mars are usually the cause, as fierce winds shift the lighter-colored dust over the darker-colored bedrock. Occasionally a dust storm will cover most of the planet obscuring all surface features. Try your hand at sketching Mars as many nights as possible, and compare your drawings to a map of the Martian surface. You might find that some of the dark patches you draw are markedly different throughout the month.

Asteroids

Asteroids, or as they are sometimes called, minor planets, are distributed in various places throughout the Solar System. There are many in Jupiter's orbit in two clusters in front of and behind Jupiter. There are some in errant orbits that occasionally bring them too close to Earth for comfort. There are asteroids beyond count in the Kuiper Belt, the area beyond Pluto's orbit. But the ones of most interest to amateur astronomers are located in an orbit between Mars and Jupiter – an area known as the Asteroid Belt. Several of these asteroids are within reach of backyard telescopes, although just as points of light.

Jupiter

King of the planets, Jupiter is larger in mass than all of the other 8 planets combined. Jupiter is a large ball consisting mainly of gases. Jupiter, Saturn, Uranus, and Neptune are similar in nature and are known as the gas giants. And giant it is, even from our vantage point here on Earth. Only Venus, due to its much closer proximity,

Fig. 2.9 Jupiter imaged with a NexStar Evolution 9.25 and CCD camera (Image by Bill Koestring)

occasionally presents a larger sized disk in the eyepiece of a telescope. And only Venus is brighter than Jupiter (Fig. 2.9).

However, none of the other planets compare to the view of Jupiter in a telescope. Jupiter shows detail in small telescopes and even the smallest optical aid will show its four bright moons. In small telescopes you can make out two or three of the darkest cloud bands, and as the 'scope gets bigger, the more you will see. 4-inch 'scopes can see multiple bands and the Great Red Spot. Larger 'scopes can see details in the bands such as texture, loops, and ovals, often in vivid color. Also visible in larger 'scopes are transits of the moons across Jupiter's surface as well as the inky black dots of the moons' shadows as they cross the planet surface.

Jupiter spins at an incredible rate of one rotation in less than 10 hours, and thus the view is changing continuously throughout the night. It is common for an observer to revisit Jupiter many times during a long session. Try your hand at sketching Jupiter – the concentration will bring out more detail than just a casual look. You will soon know why it is called the "amateur's planet."

Saturn

Although Jupiter provides the most detail in the eyepiece of amateur astronomy equipment, Saturn is the most dazzling sight (Fig. 2.10). Even small telescopes will show Saturn's rings, eliciting a "wow" from almost every first-time viewer.

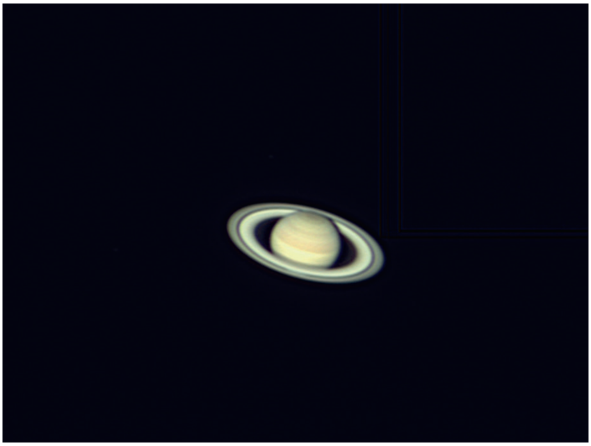


Fig. 2.10 Saturn imaged with a NexStar Evolution 6 and CCD camera (Image by Cyrus W. Beh)

Moderately sized ‘scopes will show the dark void between the “A” and “B” rings – the Cassini Division. Larger telescopes will show a fainter “C” ring, also known as the Crepe ring. As Earth and Saturn make their way around the Sun, periodically Earth passes through the plane of the rings and they are not visible. At this time, we are viewing these very thin structures edge-on.

Beyond simply seeing the rings, look for the rings’ shadows on the planet surface. Also, look for the planet’s shadow on the part of the rings behind the planet. In a larger ‘scope, you can make out faint detail on the surface of the planet. Saturn, like Jupiter, has cloud bands in its upper atmosphere. The planet itself is also flattened prominently due to Saturn’s low density and high rate of spin. This is easily observed in a telescope.

Saturn has a dozen named moons and many more unnamed. The largest and brightest, Titan, is visible in most telescopes. Larger telescopes will show at least five of Saturn’s moons.

Uranus, Neptune, and Pluto

Seventh from the Sun is the planet Uranus. Although the other five planets discussed thus far are visible to the naked eye, optical aid is required to sight Uranus. In fact, this is the first planet to have been discovered after the invention of the telescope. Although it can be found in small telescopes, it was not until 1781 that William Herschel discovered Uranus. A small telescope will see it as a pale disk; a larger telescope will show a fairly bright disk, blue in color. Uranus has faint rings, but they cannot be seen in Earth-based telescopes.

Neptune is the eighth planet from the Sun, at least most of the time. Pluto's orbit crosses inside of Neptune's during 20 years of its 249 year trip around the Sun. In a telescope, Neptune presents a disk that is easily distinguished from background stars. Pluto, the largest minor planet in our Solar System, is hard to make out in anything less than a 6-inch 'scope. Even then, you will need a good star atlas to help you discern the faint star-like point of light that is Pluto.

Comets

Comets are the true wanderers of our Solar System – icy bodies in wildly elliptical orbits that plunge towards the Sun and are whipped back out to the far reaches of the Solar System. Not all comets are so lucky; some are vaporized by hurtling directly into the Sun or by simply passing too close. Most of the comets in our Solar System are long-period comets that are from the Oort Cloud, a region far from the Sun containing perhaps millions of potential comets. Short period comets come from the Kuiper Belt, a doughnut-shaped region beyond the orbit of Neptune. Pluto and its moon Charon, though certainly not comets, are the most prominent residents of the Kuiper Belt region.

As a comet approaches the Sun, the solar wind – charged particles and radiation speeding away from the Sun – creates a tail (sometimes more than one!) of glowing gases extending from the head of the comet. This tail always points away from the Sun in response to the solar wind. Some comets have tails extending millions of miles into space. Occasionally, a comet comes along that is readily visible to the naked eye, but most comets require use of binoculars or a telescope to be seen.

Meteors and Meteorites

When objects enter Earth's atmosphere, friction causes them to burn brightly. These streaks of light, sometimes called "shooting stars," are known as meteors. Most of these objects are tiny, just grains of sand, and burn completely in the upper atmosphere. Occasionally, a much larger object enters the atmosphere and survives all the way to the surface. The survivors are known as meteorites.

From a truly dark site, you can observe meteors every night. On certain nights each year we experience meteor showers, when the frequency may climb to hundreds per hour. Rarely one of these annual showers becomes a meteor storm with hundreds of meteors visible per minute. These annual showers are the results of Earth passing through the trail of debris left behind by a comet. Table 2.2 presents some of the best annual meteor showers.

The dates given are approximate and vary from year to year. Also, the days before and after a peak usually experience increased meteor activity. The radiant is the constellation that the majority of the meteors seem to trace back to.

Table 2.2 Annual meteor showers

Shower	Date	Radiant
Quadrantid	Jan. 3/4	Draco
Lyrid	Apr. 21/22	Lyra
Perseid	Aug. 12/13	Perseus
Leonid	Nov. 18/19	Leo
Geminid	Dec. 13/14	Gemini

To view meteors you do not need any optical gear – just your eyes and a clear, dark sky. Most meteors are seen in the early morning hours after about 1 AM, as your location on Earth is headed into the wind, so to speak, at that time. Set up a reclining lawn chair or simply lie on a blanket on the ground and look in the general direction of the radiant. Remember to dress warmly; it can be quite chilly before dawn any time of year.

Manmade Satellites

Since the first satellite, Sputnik, was launched in 1957, we have put thousands of objects in orbit around Earth. Many of these objects are visible to the naked eye just after sunset. Watch for a bright object traveling briskly along until it suddenly snaps off, as if someone turned off a light switch. Most likely you will have just seen a communications satellite. If a light trail is especially bright and travels across much of the sky, you likely got a firsthand view of the International Space Station (ISS). Don’t be surprised if the streaking light of a satellite moves briskly through the field of view of your telescope some night. Also, there are many pieces of junk in orbit that flash on and off sporadically as they tumble through space: spent rocket boosters, lost communications satellites, and so on.

Deep Sky Objects: DSOs

Objects outside of our solar system are known collectively as deep sky objects, or DSOs. DSOs range from individual stars to cities of stars known as galaxies. Our own galaxy, the Milky Way, with its billions of stars is but one of the billions of galaxies in the universe. While the distances in our one solar system are immense – consider that it takes more than a year for our current spacecraft to travel from Earth to Mars – the distances we encounter when considering DSOs are almost unfathomable. When dealing with such distances, our Earth-bound units of kilometers and miles fail us. Instead, astronomers generally rely on a unit known as the light-year.

Deep Sky Object Catalogs

Most items in the sky are listed in one or more of the various "catalogs" that astronomers have created over the years. For example, the Andromeda Galaxy is known as M31 and NGC224. Some of the most useful catalogs for amateur astronomers are:

- Bayer designations for stars – a system of designating the brightest stars in each constellation by Greek alphabet – for example, the brightest star in Ursa Major (Dubhe) is known as α (alpha) Ursa Majoris.
- Flamsteed designation for stars – a system of designating the stars in each constellation by number – thus, Dubhe is also known as 1 Ursa Majoris.
- Various other star catalogs list stars as serialized numbers scattered all around the sky – Smithsonian Astrophysical Observatory (SAO), Henry Draper (HD), Hipparcos (HIP), and Hubble Guide Star (GSC) are common star catalogs.
- Messier Catalog – 110 DSOs of various types of objects. Most of the brighter deep sky objects visible in the Northern Hemisphere are listed in Charles Messier's catalog. Generally, these objects are the first DSO targets for beginning amateur astronomers. Messier 1 would be commonly referred to as "M1."
- Caldwell Catalog – 109 DSOs to expand beyond the Messier list. Some of these objects are only visible to observers in the Southern Hemisphere.
- New General Catalog (NGC) and Index Catalog (IC) – NGC consists of 7,840 objects and IC consists of 5,386 objects. NGC and IC are a large collection of DSOs cataloged by J.L.E. Dreyer. Other than stars, the majority of the DSOs of interest to amateur astronomers are found in these two catalogs.

Other catalogs will be of use to you after you gain experience, but these will provide many targets for your beginning years as an amateur astronomer.

Light travels at a constant speed of approximately 186,000 miles per second (300,000 kilometers per second). A light-year is the distant light travels in one year – about 5.9 trillion miles or 9.5 trillion kilometers. Thus, a light-year is not a measure of time, but rather of incredible distance. The closest Sun-like (main sequence) star is Alpha Centauri at a distance of 4.3 light-years. Thus, the light we see from Alpha Centauri has been traveling for a little more than 4 years, or a distance of about 25.4 trillion miles (40.9 trillion kilometers).

Galaxies are much farther away. The nearest major galaxy similar to our Milky Way Galaxy is the Andromeda Galaxy. Current calculations put it at about 2.2 million light-years away. You can do the math if you are interested in miles or kilometers, but consider that the light from the Andromeda Galaxy has been traveling for 2.2 million years before it reaches your eyes.

DSOs are the favorite targets of many observers, but most of them are very faint and therefore have a common nickname – faint fuzzies. Many of them require fairly large telescopes to show much detail or even to be detected in the eyepiece. Unlike the planets and the Moon, DSOs are easily washed out by light pollution, making them more difficult targets for the observer in the city. DSOs are a marvelously varied lot though, and a good number of them are readily visible even in smaller ‘scopes.

Stars, Variable Stars and Double Stars

Even in the largest telescopes, individual stars never present a disk like a planet. They are just tiny points of light, but all deep sky objects are visible to us due to the light and radiation produced in the nuclear furnaces of individual stars. Some stars are interesting in their own right, due to their vivid color. For example, Betelgeuse, the upper left star in the hourglass shape of the constellation Orion, is a brilliant red. All of the stars visible to us as individual points of light are inhabitants of our own galaxy.

Variable stars fluctuate in brightness, sometimes in a regular cycle, sometimes chaotically. Some amateur astronomers enjoy recording these variations, an interest that requires regular observations and a good eye for detail.

Double stars are perhaps the most interesting type of star for amateur astronomers. Double stars, when visible to the naked eye, generally appear to be a single star. But when magnified with binoculars or a telescope, they can be split into two or more individual stars. The closer those stars appear to each other, the larger the telescope required to split them. Sometimes these stars are binary or multiple star systems – stars that revolve around each other and travel through space as a group. Other double stars are simply optical doubles – they may be hundreds of light-years apart, but their chance alignment from our vantage point on Earth provides a view of what appears to be two closely placed stars.

Open Clusters

Open star clusters are groups of stars that were born together from the same cloud of gas. They are generally young, bright stars that are slowly drifting apart, but at a rate that won’t spoil our view of the cluster for hundreds of thousands or even millions of years. Many of the stars in the sky started their lives in a cluster, but have since drifted to their current locations after billions of years.

The open clusters we can readily observe are relatively close to Earth – almost all of them are less than 10,000 light-years distant. Smaller, wide-field telescopes provide some of the best views of many of the open clusters, particularly those that are closest to us. A larger ‘scope will help to bring out the fainter members of the cluster, especially when viewing from a light-polluted site.

Globular Clusters

Globular star clusters are immense balls of stars held tightly together by their mutual gravity. Almost all of the known globular clusters in our galaxy are very old, nearly as old as the galaxy itself, but astronomers have discovered younger globular clusters in some neighboring galaxies. Some of the largest globular clusters contain more than a million stars packed into an area of a few hundred light-years across. Imagine the night sky from the middle of such a cluster!

More than any other deep sky object, globular clusters produce their best views at high magnifications. A dark site, a large telescope, and a clear night can allow you to "pump up the power" and observe a nearly three-dimensional view of these jewels of the night sky. Larger telescopes will easily resolve stars from the general glow of the cluster, particularly if you use averted vision. The challenge with smaller 'scopes might be to simply detect the faint glowing "cotton ball" in the eyepiece (Fig. 2.11).

Nebulae

Nebulae (plural form of nebula) are a general category of DSOs that are faint, diffuse and, well, nebulous in appearance. A hundred years ago, when telescope quality did not provide the highly resolved views we enjoy today, almost all DSOs were referred to as nebulae. Today, we use the term to refer to clouds of gas and dust.

We can break this category down into bright and dark nebulae. Bright nebulae are powered by stars embedded in them. Some are reflection nebulae – the dust and gas simply reflect the light of the nearby stars. Others are emission nebulae – gas

Fig. 2.11 The Hercules globular cluster (M13) imaged with a NexStar 130SLT and digital SLR (Image by Eric Cauble)

Fig. 2.12 The Orion Nebula (M42) imaged with a CPC Deluxe 800 HD and CCD camera (Image by Brent Sprinkle with processing by Don Walters)

in the nebula emits its own light due to the molecules of the gas being energized by radiation from the nearby stars. Dark nebulae are visible as dark patches where dust is blocking the light of background stars.

Most nebulae are very difficult to see without truly dark and clear skies. Take advantage of any trips to dark observation sites by preparing a list of nebulae. Look for details in the clouds of gas such as texture, lighter and darker structure (especially dark lanes), and background or embedded stars (Fig. 2.12).

Planetary Nebulae

Another type of faint fuzzy is the planetary nebula. The term planetary nebula came from some of the first astronomers with access to telescopes. The brighter planetary nebulae they were able to detect through the eyepiece were similar to planets in size and appearance, yet they were obviously gaseous in nature.

Planetary nebulae are the remains of old stars similar in size to our Sun. In fact, in a few billion years, if everything goes as expected, our Sun will become a planetary nebula. Due to changes in the nuclear reaction occurring in the star's core, it eventually becomes unstable and an explosive reaction blows off most of the gases in the outer portion of the star. The result is a small, hot white dwarf star with an expanding cloud of gas escaping away at high speed. Radiation from the star energizes the gas, causing it to glow.

Planetary nebulae come in a variety of shapes. Twin cones expanding out from the central star are well known. So are spheres of glowing gas around the parent star. Others are more intricate shapes, suggesting very complex circumstances at the time of the explosion, or perhaps that the star had a binary companion whose gravity helped create such a convoluted shape.

There are many planetary nebulae visible to amateur astronomers. A few even display noticeable color. Use higher magnification to see if you can detect additional detail.

Similar to planetary nebula are supernova remnants. Occasionally, a star explodes into an elaborate cloud of hydrogen, helium, and heavier elements. The supernova itself is extremely bright. Nearby supernovae would be visible even in the light of day. The remaining cloud of gas is usually very faint and difficult to see in a backyard telescope.

Galaxies

Containing as many as billions of stars, galaxies come in a wide variety of shapes and sizes. Spiral galaxies like our own Milky Way Galaxy are among the largest and most common. With their large, central bulge of stars and graceful, sweeping arms, spiral galaxies are one of the most majestic sights you will encounter in the sky. Elliptical galaxies are incredibly large, with many billions of stars amassed in an egg-like shape. Smaller dwarf galaxies are often classified as irregular galaxies – millions of stars seemingly dropped haphazardly like a child's jacks against the backdrop of the sky.

These huge collections of stars are visible from incredible distances. As noted earlier, the closest major galaxy to us is an incredible 2.2 million light-years distant. Other galaxies visible to the amateur astronomer are tens of millions of light-years from Earth. The light we see today left some of these galaxies when dinosaurs still ruled Earth!

Due to the extreme distances, most galaxies are very faint. While you might detect them with a large 'scope in the city, the views improve enormously under dark skies. You will also have a much better view when the sky is very transparent. Under such clear, dark skies, a larger telescope will show the arms of spiral galaxies, dust lanes that obscure the light from the billions of stars, and other subtle details (Fig. 2.13).

As incredibly large as galaxies are, they are not the largest structures in the universe. Typically, small numbers of galaxies are held together by their mutual gravity in a structure astronomers call galaxy clusters. Our Milky Way Galaxy is one of a few galaxies in the cluster known as the Local Group. Large backyard telescopes can show us other galaxy clusters scattered around the sky.

Furthermore, the billions of galaxies in the universe are organized into superclusters – tens of thousands of galaxies arranged in waves and knots through-

Fig. 2.13 Bode's Galaxy (M81) imaged with a CPC Deluxe 1100 HD and CCD camera (Image by Bruce A. Donzanti)

out the immense expanses of space. Superclusters are not visible directly, but rather, by mapping the location of millions of galaxies, astronomers have created a three-dimension model that reveals their existence.

Equipment Basics

Never before has such a wide variety of quality equipment been available to the amateur astronomer. With hundreds of models of telescopes to choose from, we need a basic understanding of the most common designs to make a wise purchase decision. Although there are so many models to choose from, as we will see, there are only a few common designs on the market.

Basic Terms

Before discussing equipment, there are a few terms we must understand.

Objective

This is the component of the optical system that collects the light from the sky, allowing us to see all those faint objects that our eye cannot detect on its own. In binoculars and some telescopes, this is the lens at the front of the optical tube. In other telescopes, it is a large, dish-shaped mirror at the back of the optical tube. We measure the diameter (distance across) of the objective and express this as the aperture of the instrument. Generally speaking, the larger the aperture, the more light the instrument collects, and thus, the more objects we can see. When we say the NexStar 8SE is an 8-inch ‘scope, we are referring to the diameter of the objective.

The relationship between aperture and light-gathering power is geometric, based on the area of the objective, not the diameter. When comparing two ‘scopes, simply square the diameter of their objectives and divide. For example, to compare 80-mm and 60-mm telescopes, we calculate 80 × 80 divided by 60 × 60. The resulting answer of 1.78 indicates that an 80-mm objective collects 78% more light than a 60-mm objective.

Additionally, larger apertures are capable of resolving finer detail in objects. Thus, a larger aperture can usually split closer double stars, show more detail on the Moon and planets, and show more detail in deep sky objects. More so than light-gathering power, resolution is greatly affected by the overall quality of the instrument’s optics.

There is a saying among astronomers that “aperture rules.” While this is certainly true, larger aperture comes at a price, both monetarily and practically. Larger aperture telescopes are more expensive than their smaller siblings. Also, larger aperture telescopes require much more effort to transport, setup, and store. Consider carefully the size of telescope you will purchase. The best telescope for you is not necessarily the most expensive or largest model you can buy. It is the one that you will use the most. An exquisite 14-inch telescope will provide incredible views, but if you only find the energy to set it up once every couple of months, perhaps you would more enjoy a 5-inch ‘scope that takes just minutes to carry outdoors and put into use.

Focal Length

While some optical designs do not lend themselves to this straightforward definition, focal length is the distance from the objective to the point where the image comes to focus. The focal length of a telescope is sometimes found on a label on the optical tube, otherwise you must refer to the manual. Generally speaking, longer focal lengths produce better high magnification views of the Moon, planets, and smaller deep sky objects, while shorter focal lengths allow for wide-field views of large objects like open clusters and large nebulae. Each eyepiece also has a measured focal length that is marked on the side of the eyepiece itself.

Focal Ratio

Focal ratio is the focal length of an objective divided by the diameter of the objective, expressed as f/ratio. For example, an 80-mm telescope with a 400-mm focal length has a focal ratio of f/5 (400/80 = 5). Smaller numbers are said to be “faster,” as they allow for shorter exposures when imaging, but it is a mistaken belief that faster focal ratios produce brighter views in the eyepiece. Only more aperture can produce brighter visual images.

Magnification in a Telescope

To calculate the magnification given by a telescope, divide the focal length of the telescope by the focal length of the eyepiece in use. For example, a 1000-mm telescope provides a magnification of 100 when we use a 10-mm eyepiece (1000/10 = 100). By changing to smaller focal length eyepieces, we increase the magnification. There is an accepted limit to the amount of magnification possible with a telescope. Two times the aperture in millimeters or 50 times the aperture in inches are good rules of thumb, although seeing conditions rarely allow us to exceed a magnification of 300. On most nights, a magnification limit of 200 or less is more practical.

Beware of purchasing a telescope that is advertised based on its maximum magnification. Many department store telescopes boast “575× Astronomical Telescope.” Upon closer inspection, we find that the aperture of the ‘scope is 60 mm, capable of a usable magnification of about 120×. Since magnification is varied simply by using an eyepiece of different focal length, magnification available with the provided eyepieces is one of the least important factors when considering a telescope. Focus on aperture, smooth movement when pointing the ‘scope, a sturdy mount and tripod, and overall quality of construction. When possible, test the telescope or binoculars out under the night sky. Stars should focus easily to sharp points of light. Center a bright star and defocus the image, both inside and outside of focus. The resulting bull’s-eye rings should appear nearly the same inside and outside of focus. Judging optics requires a bit of experience – something as simple as poor collimation (discussed in Chap. 11) or tube currents in an un-cooled ‘scope can make the best optics look terrible. But even a beginner can detect truly poor optical quality.

Eye Relief

Eye relief is the maximum distance you can position your eye away from the eyepiece and still take in the entire field of view. Shorter than 5 mm is very uncomfortable for most people, and if you must wear glasses to view (necessary if you have astigmatism), eye relief of about 20 mm is required. Eye relief is a characteristic of each eyepiece or binocular design.

Exit Pupil

Exit pupil is a measurement of the fully illuminated circle of light that comes from the eyepiece of a telescope or binoculars. To calculate the exit pupil in millimeters, divide the aperture of the objective (in millimeters) by the magnification of the view. For example, if a pair of binoculars has an aperture of 50 mm and a magnification of 10 (10 × 50 binoculars), it produces a 5-mm exit pupil. A telescope varies each time we change eyepieces, and a simpler formula is to divide the focal length of the eyepiece by the telescope's focal ratio. For example, if you use a 30-mm eyepiece in an f/10 telescope, the result is a 3-mm exit pupil.

With binoculars, it is best to use an exit pupil that does not exceed the size of your fully dilated pupil. Most observers under the age of 30 have a maximum pupil dilation of about 7 mm under very dark skies. As we age, the muscles in our irises stiffen, and it is common for older observers to have a maximum dilation of about 5 mm. With a telescope, we can experiment with various eyepieces to produce the best magnification and exit pupil for the object at hand.

Lens Coatings

As light passes through a piece of glass, some of the light is reflected rather than passing through the glass. If that glass is a lens in our telescope, the reflected light never makes it to our eyes, and thus, the image loses some of its brightness. If a lens surface is treated with a special coating, anti-reflective or AR coatings, it reduces the reflection and transmits more of the light. Many optical components are constructed of multiple lenses. For example, some eyepiece designs have eight lenses! To be fully effective, all air-to-glass surfaces must be coated. Light transmission can be improved with multiple layers of AR coatings.

Manufacturers use the term "coated" to designate that at least one of the air-to-glass surfaces, usually the side of the lens you can see, has been coated with a single layer of AR coating. The better version is "fully coated" – all air-to-glass surfaces have been treated with AR coatings. "Multi-coated" optics feature at least one surface with multiple layers of AR coatings, while "fully multi-coated" indicates that all air-to-glass surfaces have been treated with multiple layers of AR coatings.

Binoculars

How would you like two telescopes, one for each eye? In essence, that is what a pair of binoculars gives you. Our brain and optical system evolved to integrate input from both eyes, so it is not surprising that binoculars seem very natural when used. Binoculars feature a right-side-up, left-to-right-correct image and a wide field of view that makes them very easy to point at your target. Almost anyone can pick up a pair of binoculars and successfully point them at the Moon; the same cannot be said of a telescope.

Binoculars are labeled with designations like 7 × 35 and 10 × 50. The first number denotes the magnification the binoculars offer, while the second number is the diameter in millimeters of the objective (front) lenses. As mentioned earlier, the diameter of the objective is also known as the aperture of an instrument. The larger the aperture, the more light the instrument collects and the fainter the objects you will be able to see.

Higher magnifications do allow you to see smaller details in an object, but this comes at a cost. First, it is generally true that as the magnification increases, the field of view decreases. For example, a pair of 10 × 50 binoculars might show 5° of sky, while a pair 20 × 70 binoculars might only show 3°. For general sky "sweeping," a wider field of view is highly desirable.

Second, higher magnifications also magnify every little movement of your arms as you try to steady the binoculars. Most individuals cannot successfully steady binoculars higher than 10 × when holding by hand. Higher magnifications require a mount, such as a tripod, to steady the view. Image-stabilizing models are the exception. Equipped with computer-controlled prisms that move with every shake of your hand, they provide a steady view at high magnifications. Of course, image-stabilizing binoculars are more expensive than their traditional counterparts.

Although almost any binoculars will allows us to see many more stars as well as some of the brighter deep sky objects, the best general purpose binoculars for astronomy feature a minimum aperture of 50 mm and magnifications between 7 and 10 times. 7 × 50 and 10 × 50 models are quite popular and very reasonably priced. 7 × 50 produces an exit pupil of about 7 mm, fine for younger eyes under dark skies, while 10 × 50 produces an exit pupil of 5 mm, more useful in urban settings or for older observers.

When deciding on binoculars, consider the instrument's anti-reflective coatings, fully multi-coated being most desirable. If possible, take them out under the night sky and look at the Moon. Cheaper models will typically exhibit false color around the edge of the Moon, while better models will have less color and sharper images. Also, look at a sign off in the distance. Note if the words at the edge of the field of view are as sharply focused as those in the center. Don't panic if they are not, as most binoculars do not produce sharply focused images out towards the edge of the field, but there are notable differences, and the better a binocular performs in this respect, the more you will enjoy the view. Finally, consider the weight. Very heavy binoculars will not be comfortable for handheld viewing.

Comfort when using binoculars will generally require a reclined position; extended periods of looking up can definitely be a pain in the neck! A reclining lawn chair is an excellent solution, particularly if the arms of the chair are suitably positioned to support your arms as you hold the binoculars. A camping mattress or pad can also provide excellent portable comfort for binocular use.

Even after you own a telescope, a good pair of binoculars is a must. Binoculars are quick to set up (just take them out of the case) and are the ultimate in portability. The wide field of view they afford is wonderful for many extended objects and provides the best views of the star fields of our own Milky Way Galaxy. Binoculars are an essential piece of gear for the amateur astronomer.

Telescopes

Although some amateur astronomers start their observing career with binoculars, it isn't long before they are ready to move on to a telescope.

Telescopes differ greatly from binoculars. Telescopes have a much narrower field of view, especially at higher magnifications. As mentioned earlier, while a pair of binoculars generally has a fixed magnification, we can change the magnification offered in a telescope by simply changing the eyepiece. The orientation of the view provided by a telescope is also different. Almost all astronomical telescopes present a mirror image view (backwards from left to right), upside-down view, or both! While this makes little difference when viewing celestial objects (in space there is no "up"), it presents unique challenges when attempting to match the view in the eyepiece to a diagram or star chart. And perhaps most importantly, a telescope requires a stable mount that makes easy work of tracking objects as they drift across the sky.

The higher cost and added complexity of a telescope makes the purchase decision much more difficult. Advertisements and store displays don't provide much help, nor do the wonderful color pictures that adorn the packaging of most telescopes. But the situation is not as confusing as it first seems. Most telescopes sold are one of four designs: refractors, Newtonian reflectors, Schmidt-Cassegrain, or Maksutov-Cassegrain.

Refractors (Fig. 2.14)

Refractors match most people's image of what a telescope should look like – a long tube with a lens at the front and eyepiece at the back. The lens at the front of the telescope is the objective in a refractor 'scope. The lens collects the light and focuses it towards the back, where the eyepiece magnifies the view. The first telescopes designed, at least as early as the seventeenth century, were refractors.

While high-quality refractors are prized for their crisp, clear views of the Moon and planets, they are not ideal for faint deep sky objects. The high cost of creating large objective lenses limits the most commonly available refractors to about 6 inches. The most popular high-quality refractors are in the 4-inch range, which limits their ability to detect faint, deep sky objects.

One of the biggest drawbacks to the refractor design is the lens itself. A single lens acts like a prism splitting white light into a rainbow of colors, an effect known as chromatic aberration. On bright objects such as the Moon and planets, this can be quite visible. To combat this effect, achromatic designs use two lenses of different shape and glass composition to reduce chromatic aberration. This can be very effective, particularly if the refractor has a long focal length. But it was the long focal length of traditional refractors, coupled with the expense of creating large aperture lenses, which caused the refractor to fall in popularity in the 195's and 60's.

Refractors saw a great resurgence in the 1990s as short-tube refractors became widely available. Short-tube achromatic designs are quite popular but do exhibit

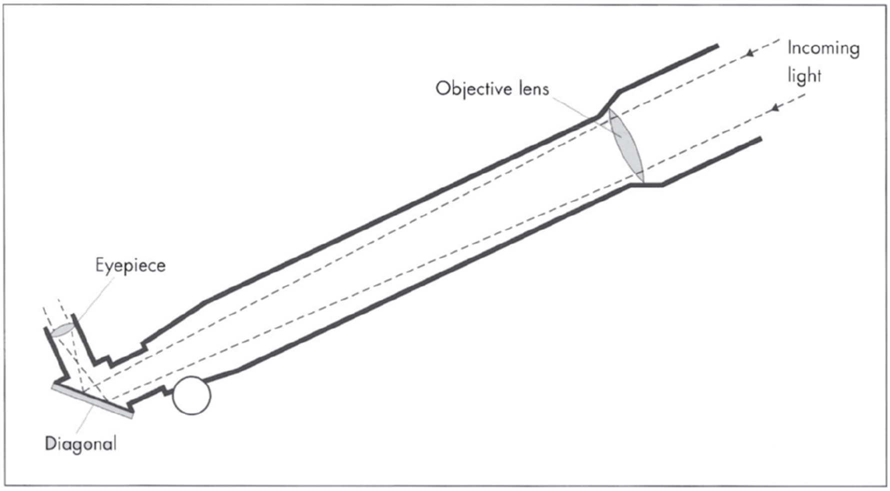


Fig. 2.14 The refractor telescope design

levels of chromatic aberration that some find distracting. Wide-field apochromatic (color-free) designs are very popular and widely used. Apochromatic refractors often sport as many as 4 lens elements in the objective and provide excellent views of brighter objects. The disadvantage is a price tag generally 3–6 times higher than achromatic models of the same aperture.

Refractors are equipped with a diagonal at the eyepiece end to reflect the light at a 90° angle in order to provide a more comfortable viewing position. The diagonal is inserted into the focusing tube and the eyepiece is inserted into the diagonal. Without the diagonal, we would find ourselves contorting into various uncomfortable positions to position ourselves near the eyepiece.

Perhaps the greatest strengths of the refractor design are its durability and maintenance-free operation. With reasonable care, a refractor will provide the same high-quality views for many years. The optical components are often permanently collimated (aligned) and require no fine-tuning to produce the best image possible. If your time under the stars is limited, or you find you are not mechanically inclined, a refractor might be best for you.

Newtonian Reflectors (Fig. 2.15)

To combat the effects of chromatic aberration found in refractor telescopes, Sir Isaac Newton created an optical design using two mirrors – a design that now bears his name. In a Newtonian reflector, a dish-shaped mirror is placed at the back of the optical tube. Incoming light reflects off the primary mirror and is focused back towards a small, flat secondary mirror that diverts the light out the side of the tube towards the eyepiece. To create a correctly focused image, the primary mirror

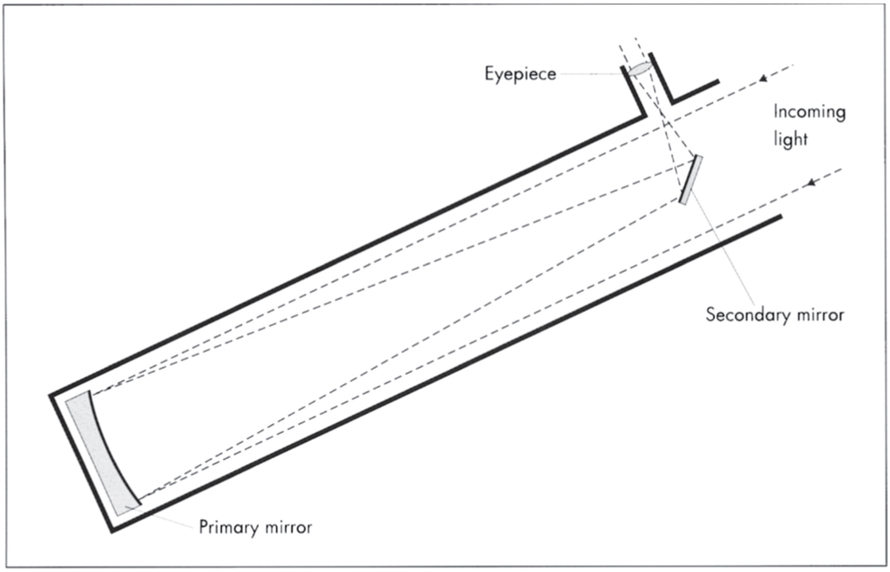


Fig. 2.15 The Newtonian reflector telescope design

should be parabolic in shape. Creating a parabolic mirror is more expensive than creating a simple spherical mirror, so cheaper Newtonians often utilize the lower-cost mirror at the expense of image quality.

Besides virtually eliminating chromatic aberration, Newtonians also prove to be the least expensive design per inch of aperture. Virtually all really large amateur ‘scopes, 18 inches and larger, are Newtonian reflectors. When considering “bang for the buck,” nothing beats a Newt.

Newtonians do have some drawbacks. One is the open tube design. When in use, a Newtonian exposes the surface of its mirrors to the elements. Unlike the mirror in your bathroom, the reflective coating of a telescope mirror is on the front of the glass. This coating is typically aluminum, covered with a thin, protective layer to retard corrosion. But eventually, the elements win out and the mirror becomes tarnished. At this time, it becomes necessary to have the mirror professionally re-coated or, for inexpensive instruments, replaced. Higher quality coatings can last for years.

Larger aperture Newtonians can be very long and heavy. Truly large Newts usually sport a frame of thin tubes to support the primary and secondary mirrors as well as the eyepiece holder and focuser. This frame can be disassembled for transportation and storage. The size and weight of even a moderately sized Newtonian can prove taxing for a mount, particularly a GoTo mount.

Collimation (precise alignment of the optical path) of a Newtonian reflector is a challenge for a beginner and must be performed regularly to ensure quality performance. Having access to an experienced friend or local astronomy club is almost required for the new owner of a Newtonian reflector.

Newtonian reflectors excel at deep sky viewing in larger apertures, but the longer tube lengths required for larger apertures, and the added weight this entails, do not make them well suited to most GoTo mounts. Thus, the Newtonians offered on Celestron's computerized mounts are modest in aperture.

Schmidt-Cassegrain Catadioptric (Fig. 2.16)

Schmidt-Cassegrain telescopes, or SCTs as they are commonly referred to, combine the best elements of refractor and reflector designs to produce the most compact optical tubes available for any given aperture. Catadioptric or compound 'scopes refer to that combination of lenses and mirrors. The SCT design is the most popular line of serious amateur telescopes sold today. Celestron perfected the process of mass-producing the Schmidt-Cassegrain design in the late 1960s, and popularized the design through the 70s.

At the front of the tube is a lens known as the corrector plate. The corrector plate allows for improved performance from a spherical primary mirror, reducing the cost of producing a high-quality instrument. Mounted in the center of the corrector plate is the secondary mirror that directs the light to the back of the tube, through a hole in the primary mirror, towards the eyepiece. Like refractors, SCTs use diagonals to provide convenient positioning of the eyepiece. Due to the compact size of the SCT design, the placement of the eyepiece at the rear of the 'scope provides comfortable viewing for most orientations of the optical tube. Additionally, the corrector plate protects the mirrors from corrosion, increasing the longevity of their coatings.

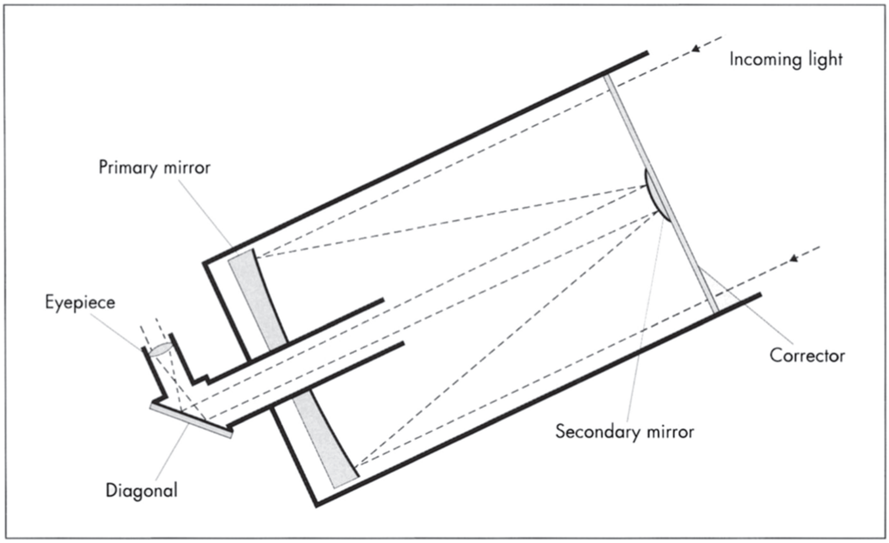


Fig. 2.16 The Schmidt-Cassegrain telescope design

The folded light path provided by the corrector plate and mirrors allows the focal length of the ‘scope to be about five times the length of the optical tube. In refractors and most Newtonians, the optical tube is about the same length as the focal length. As a comparison, the focal length of the NexStar 8 SE (an SCT design) is about 80 inches (200 cm), while its optical tube is about 16 inches (40 cm) long. A refractor or Newtonian with a similar focal length would sport a tube nearly 7 feet (2 meters) in length!

There are some tradeoffs, though. SCTs are more expensive than similar aperture Newtonian reflectors, although lower in cost than comparable refractors. They do require precise collimation, but fortunately, the process is much less complicated than with a Newtonian. The closed-tube design incorporating the corrector plate increases cooldown time, particularly in larger models. Some models also exhibit excessive image shift when focusing. That is to say that focusing will actually cause the object in the field of view to move up, down, left or right. This is due to the method that focus is achieved with most SCTs – the primary mirror slides up and down to move the focal plane. While some manufacturer’s ‘scopes exhibit a good deal of mirror shift, Celestron’s focusing mechanism minimizes this dramatically.

More recently, the two primary manufacturers of SCTs have introduced modified SCTs with improved optical performance: the EdgeHD from Celestron and ACF from Meade. These advanced optical tubes improve the optical performance near the edge of the field of view by reducing coma and field curvature. Coma causes stars towards the edge of a wide field of view to have short, wispy trails extending out towards the edge of the field. Field curvature means the focus point for the center and the edge of the field are not the same. Thus, objects in the center of a wide field of view will be in focus, while objects towards the edge will be progressively out of focus.

The SCT design is a great all-around performer and is well suited for use on a GoTo telescope mount. The compact and robust design results in a fine instrument that can provide exhilarating views for many years to come.

Maksutov-Cassegrain Catadioptric (Fig. 2.17)

Similar in physical design to SCTs, Maksutov-Cassegrain telescopes, or Maks as they are commonly known, use a lens and mirrors to focus gathered light. The main difference you will note is the shape of the lens, typically called the corrector or meniscus lens. In a Mak, the meniscus is a curved shape rather than the flat corrector plate found in an SCT. In most Maks, the secondary mirror is a reflective coating applied directly to the back of the meniscus.

Generally, Maks are designed with a long focal length and slow focal ratio of f/12 or higher. This makes them well suited to viewing the planets and fine details on the Moon. The resulting narrow field of view does exhibit some limitations when viewing deep sky objects, particularly extended open clusters and galaxies. Also, their slow focal ratio results in very long exposure times for photographs of deep sky objects. In addition to their long focal length, the relatively small size of

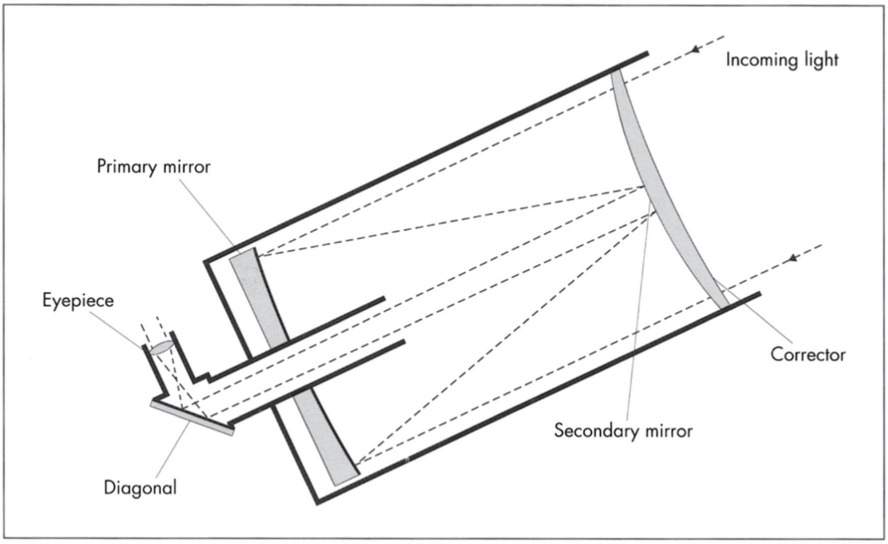


Fig. 2.17 The Maksutov-Cassegrain telescope design

the secondary mirror (spot) provides slightly higher-contrast views of the Moon and planets when compared to SCTs.

Maks are generally more expensive than similar aperture SCTs, falling somewhere between SCTs and refractors. Also, larger Maks are rare, as most models are 5 inches or smaller. The meniscus is thicker than the corrector plate on SCTs, so cool-down time is increased.

Maks are generally very low maintenance. Most models do not provide for user collimation and are expected to keep their alignment indefinitely. Like all reflector-type 'scopes, they exhibit no noticeable chromatic aberration. These factors, coupled with excellent planetary views and very compact design, make the Maksutov-Cassegrain a good choice for someone looking for the advantages of a fine refractor, in a less expensive, more convenient package.

Finderscopes

The narrow field of view of a telescope makes it very difficult to aim accurately at a desired location in the sky. To overcome this problem, a finderscope, or finder, is mounted on the side of the main telescope. When correctly aligned, the finderscope and the main 'scope both point at the same place in the sky. The lower magnification and wider field of view of the finder make it easier to locate and point the 'scope at any given point in the sky. When you look in the eyepiece of the main 'scope, your target should be visible.

There are two basic types of finders. Traditional finders are small refractor ‘scopes with crosshairs in the eyepiece. The alternatives are “zero-power” or “unity” finders. Unity finders project a red dot or bull’s-eye onto a small window. By looking through the window, you can easily aim the ‘scope with the dot or bull’s-eye.

The common refractor-style finder is designated similarly to binoculars. A 6 × 30 finder has an aperture of 30 mm and magnifies 6 times. Larger aperture makes it easier to find fainter objects, although 50 mm is a practical limit for most uses. There are two basic types of refractor finders. The most common is a straight-through finder where the eyepiece points straight back from the tube of the finder. Most straight-through finders produce an image that is upside-down. Moving the telescope in the right direction to aim with the finder can be a little confusing at first, but after a little while, it becomes second nature. To match the view in the finder to your star charts, simply turn the chart upside-down. Alternatively, there are correct-image straight-through finders that simplify matters further. While providing a more natural right-side-up view, straight-through finders are slightly disadvantaged with reduced light throughput (dimmer images) and added expense.

The second type of refractor-style finder uses a diagonal and is known as a right-angle finder. While a right-angle finder provides more comfortable positioning of the eyepiece, most models produce a left-to-right mirror image that is difficult to match to printed star charts. A few more expensive models do provide a correct-image.

Unity finders are particularly easy to use, since they simply project a target on your naked-eye view of the sky. Aiming the ‘scope could not be easier. However, they do present some disadvantages. First, since they do not collect light or magnify the view, you are limited to stars you can see with the naked eye. Second, the lack of magnification can make it difficult to precisely aim at a star and have it show in a narrow-field, high-magnification view in the main ‘scope. But unity finders are well suited to use with GoTo telescopes, since typically we only manually point at two or three bright stars during the initial setup, and the computerized hand control takes it from there.

With any type of finder, aligning it with the telescope is a simple task best performed during the day. Looking through the main ‘scope with a moderately powered eyepiece, aim your telescope at a distant object such as a ceramic insulator on an electric pole. Then simply turn the adjustment screws on the finderscope until it is also aimed precisely at the same point. Check to be certain that the finder is well secured.

Telescope Mounts

The mount is generally comprised of two sections – the part that holds the telescope and allows it to be pointed in any direction, and the tripod. The section that holds the ‘scope and moves is referred to as the mount, while the tripod is considered separately. In some cases, there is no tripod, or the tripod is optional, but in many cases, the mount and tripod are sold as a single unit.

It is absolutely critical that the mount provides excellent stability for the telescope in use. An unstable or undersized mount will make the view in the eyepiece shake terribly at the slightest touch or in the lightest wind. When trying out a telescope, perform the “rap test:” using a high-power eyepiece, focus on a distant object and tap the eyepiece end of the ‘scope. All vibration should dampen within no more than 2 or 3 seconds; less would be ideal.

Also, check that the movement of the mount is smooth and responsive. As Earth is turning, all objects move across the sky. The mount must be continually adjusted to keep an object in the field of view. A mount with jerky movement will prove difficult, if not impossible, when tracking the sky.

Finally, consider complexity and portability. Some mounts require just a few minutes to set up, while others might require a half-hour or more. Collapsible tripods are common and provide good portability, while large Dobsonian mounts may require a van or truck to transport. If you want a ‘scope that can be set up on a whim and is ready for service in minutes, choose accordingly. If ultimate stability or an extremely large optical tube requires a more heavy-duty mount, portability might take a backseat.

Mounts can be categorized into two basic types: altitude-azimuth (alt-az) or equatorial.

Altitude-Azimuth Mounts (Fig. 2.18)

The alt-az mount allows the optical tube to be pointed up/down and left/right. This arrangement is very simple to use and well suited for beginners, but it generally has one major drawback: objects in the sky don’t move up/down or left/right. As discussed earlier, they follow an arc from east to west as Earth turns on its axis at sidereal rate. To track an object with an alt-az mount, we must periodically move the altitude and azimuth axis to keep the object in the field of view. If the field of view in the eyepiece is several degrees, we will be adjusting every couple of minutes. If we are examining the Moon or a planet at high magnification, a small field of view, we will be adjusting every couple of seconds.

Generally, an alt-az mount cannot be motor driven with much success, unless a computer controls the motors to provide the correct movement in both axes and allow tracking the sky at sidereal rate. We find such computerized control in today’s GoTo telescopes.

Dobsonian mounts, or Dobs as they are commonly called, are a variation on the alt-az mount. Created by John Dobson in the 1970s, they are the most popular mounts for moderate to large-sized Newtonian reflectors. The low center of gravity of a Dob makes for a very stable platform for even the largest ‘scope. They are rarely motorized, but their smooth motion allows for easy tracking by simply nudging the end of the ‘scope.

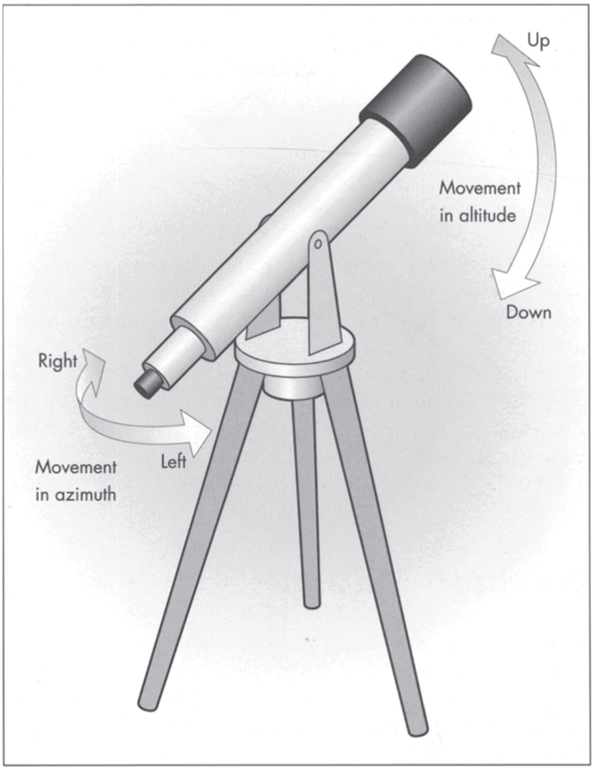


Fig. 2.18 The altitude-azimuth mount design

Equatorial Mounts (Fig. 2.19)

An equatorial mount takes a different approach to providing motion for the optical tube. One of the axes is aligned with the axis of Earth and can be turned opposite the motion of Earth to keep an object in the field of view. This axis is known as the right ascension (RA) axis since it allows us to point at any right ascension in the sky. The second axis is known as the declination (Dec) axis and allows us to point towards any declination above or below the celestial equator.

Tracking the sky at sidereal rate is relatively easy with an equatorial mount; we simply adjust the RA axis periodically. Many equatorial mounts can be equipped with a motor to drive the RA axis at sidereal rate, providing automatic tracking of any object in the sky. In this fashion, visual observations become much more convenient, and long exposure astrophotography becomes possible.

This convenience does come at the price of added complication. While we can take an alt-az ‘scope out, extend the legs, and start observing, with an equatorial mount, we need to align the RA axis with Earth’s axis. For observers in the Northern Hemisphere, we simply point the RA axis at Polaris, the North Star, for an approximate alignment. Some equatorial mounts even include a small telescope

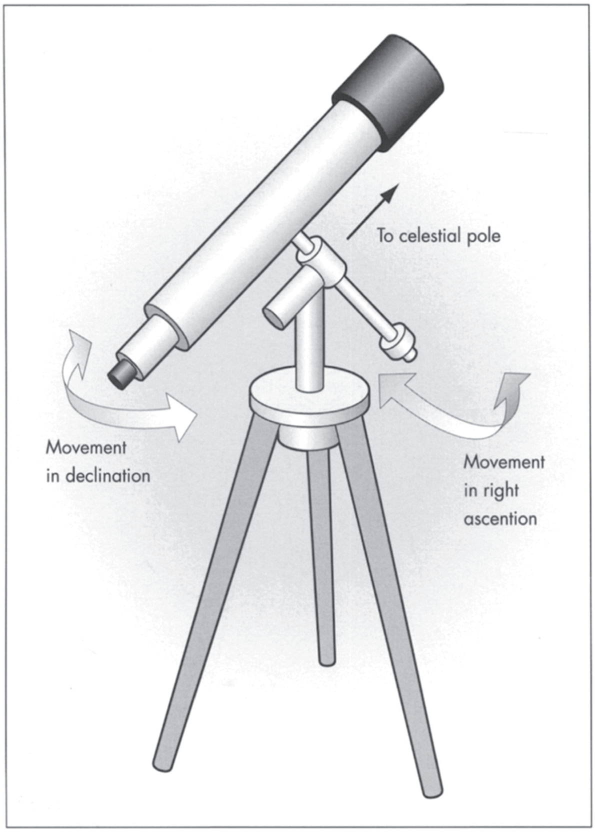


Fig. 2.19 The German equatorial mount design

in the center of the RA axis to make short work of this. Observers in the Southern Hemisphere have a much harder time of this, as there are no bright stars near the south celestial pole. A rough alignment using just the sighting method is sufficient for visual work, but astrophotography requires much more exact alignment to prevent drifting that will turn pinpoint stars into little dashes in the final exposure.

Fork-mounted alt-az ‘scopes can be equatorially mounted for astrophotography. Using a wedge (Fig. 2.20), the forks are tilted so that the azimuth axis is pointed at the celestial pole, thus becoming the RA axis. A wedge is commonly used with fork-mounted SCT ‘scopes to allow for long-exposure astrophotographs.

Piers

A pier is not a complete mount, but rather takes the place of the tripod. Generally, we then attach an equatorial mount on top of the pier. Most piers are permanent fixtures, either in the owner’s backyard or in their home observatory. By perma-

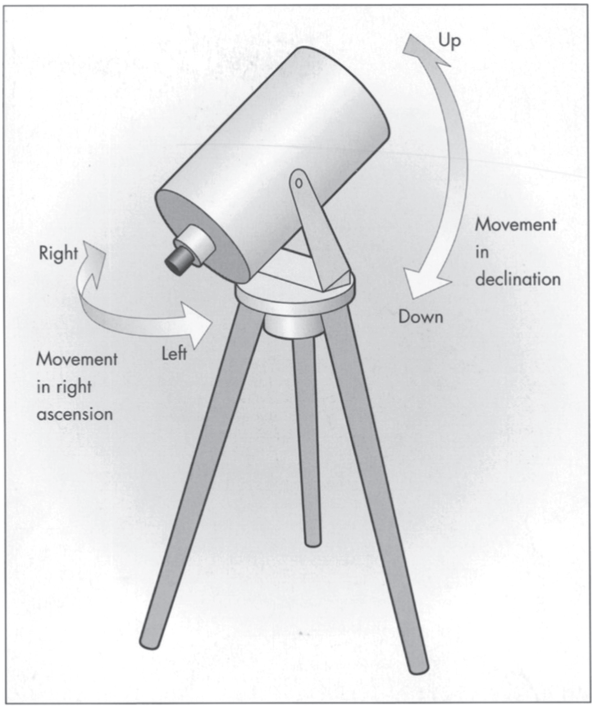


Fig. 2.20 A wedge-mounted fork

nently mounting the pier in the ground, we have an extremely stable mount that provides very accurate alignment of the RA axis. The ‘scope can be removed and stored indoors when not in use.

Some piers are portable, providing added stability for large telescope when used in the field. In most cases, they are lighter than similarly stable tripods.

The Eyepiece End of Things

While initially, the telescope gets most of the attention, before long you will be out shopping for additional eyepieces. We will cover eyepiece design and selection in more detail in Chap. 9, but here, we will discuss what the eyepiece does and its key characteristics.

The purpose of the main telescope is to gather light and bring it to a focal point, presumably without altering the image in any way. It is then the job of the eyepiece to magnify the image to a suitable scale. For this purpose, eyepieces are available in a variety of focal lengths, usually displayed on the outside of the barrel. As discussed earlier, we calculate the magnification an eyepiece gives by dividing the focal length of the main ‘scope by the focal length of the eyepiece. For a telescope with a focal length of 1000 mm, a 20-mm eyepiece yields 50×, while a 10-mm eyepiece yields 100×. Thus, shorter focal length eyepieces provide higher magnifications.

Besides focal length, eyepieces have other vital statistics. Eye relief, or the distance your eye may be from the eyepiece and still take in the entire view, is one. With some eyepiece designs, the shorter the focal length, the shorter the eye relief. Some short focal length eyepieces require you to position your eye uncomfortably close to see the object in the field of view. If you must wear or prefer to wear eyeglasses when viewing, you would do well to choose eyepieces with longer eye relief.

Another characteristic of eyepieces is apparent field of view, or AFOV. AFOV of less than about 50° results in a view that resembles looking through a straw. Wider AFOV provides a panoramic view that is preferred by most observers. The actual width of sky seen through a given eyepiece/telescope combination is referred to as the true field of view, or TFOV. The approximate TFOV can be calculated by dividing the AFOV of the eyepiece by the magnification given with that eyepiece. Taking our 1000-mm telescope and 10-mm eyepiece, we have a magnification of 100×. If the 10-mm eyepiece has an AFOV of 50°, then the TFOV will be 50 divided by 100, or 1/2°.

A common accessory known as a Barlow lens is used to increase the magnification given by any eyepiece. The typical Barlow doubles the magnification when used directly in front of the eyepiece and triples the magnification if used between the telescope and the diagonal. When used as shown in Fig. 2.21, the magnification for a 10-mm eyepiece is doubled; in a 1000-mm telescope this results in 200×. In addition to effectively doubling your eyepiece collection, higher magnifications are achieved without resorting to short focal length eyepieces and their often shorter eye relief. An additional trick with a Barlow is to insert it in front of the diagonal on a refractor, SCT, or Maksutov – the resulting magnification is 3 times the eyepiece alone, although some ‘scopes may not come to focus in this arrangement.

In the 1990s, amateur astronomers started experimenting with live video feeds from their telescopes. Using camcorders, they projected the view from their telescopes onto small video monitors to display the Moon and brighter planets for public outreach events. Equipment progressed as imaging sensors became much more sensitive, and electronics were developed to integrate short exposures in near real-time, which allowed fainter and fainter objects to be observed. This technique was originally called video astronomy and is referred to today as electronically assisted astronomy (EAA). Besides the obvious advantage of sharing the view simultaneously with several people, there are other benefits to this method. First and foremost, imaging sensors are much more sensitive than the human eye, allowing observation of faint objects in even moderate-aperture instruments. Additionally, while the human eye perceives almost no color when observing faint objects, many cameras used in EAA are able to produce colorful images of brighter deep sky objects. Also of note, the connection from the camera to the display can be fairly distant, allowing the observers to stay warm on a cold night or even to share their view around the world via the Internet.

Fig. 2.21 Inserting an eyepiece into a Barlow mounted in a diagonal (Photo courtesy Tommy McGee)

To explore this topic further, I suggest you join the discussions in the EAA forum at Cloudy Nights (https://www.cloudynights.com).

Conclusion

These may have been the first steps on your journey of learning about the cosmos and the equipment that will let you observe it. There are many additional books that can take you further, as well as experienced amateur astronomers in your local astronomy club that can help guide you in your endeavors.

Part of the enjoyment of viewing astronomical objects is understanding a little about the objects we observe. Astronomy is part intellectual and part visual. Knowing that the light that you are seeing now has traveled for tens of millions of years to reach you adds to the excitement of detecting that faint smudge in the eyepiece. The humbling realization that we live on such a small little speck in just one corner of the universe seems to make our daily troubles fade in comparison. And yet, as insignificant as we may seem, just the fact that we can begin to understand our place in the cosmos is truly unique. Welcome to a special crowd.

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The NexStar User's Guide II
For the LCM, SLT, SE, CPC, SkyProdigy, and Astro Fi
Swanson, M.
2017, IX, 274 p. 67 illus., 45 illus. in color., Softcover
ISBN: 978-3-319-64932-0