1 Meeting the challenge

"It's going to be clear tonight," you think to yourself as you stare out of the window. "I can't wait for the Sun to go down!" Your mind immediately leaves whatever it is you're doing at the time, be it work, chores, school, or something else, and flies into the cosmos.

Shhh, did you hear that? That's the universe calling you.

As amateur astronomers, we aren't content to sit home at night, watch television, or drive to the local multiplex cinema to take in the latest movie. We won't have any of that. We're explorers. That's what drew us into astronomy in the first place: the idea that we can explore this marvelous universe of ours right from our backyards.

But then, hours later, as you're gathering your observing gear for a night under the stars, you stop dead in your tracks. "What am I going to look at?"

Has that ever been you? Probably. In fact, that may have been you just last night. Let's face it, if you've been involved with observational astronomy long enough, there is bound to come a time when you've seen "everything" your telescope can show you. All of a sudden, that show on television is beginning to sound tempting.

Okay, now stop right there! I'm not going to let you do it. You're an explorer. You're a pioneer. As amateur astronomers, we share a unique perspective on life. We enjoy searching for sights that few others in the entire course of human history have ever witnessed first hand. We blaze a trail that few have trod before. We won't miss a clear night just because "there's nothing new to observe."

That's where this book comes in. You and I are about to go observing together. No, not for the "same old stuff" that many observing guides run through time and again. We're hunting for bigger game. We're going to challenge our telescopes, our observing site, and our powers of observation.

Each object included in the later chapters has been selected not because it is easy, but because it is difficult to see in some way. The type of challenge posed will vary from one target to the next. An object might be very faint, or very small, or tough to spot for any of a number of other reasons.

Of course, what might be a challenge for one person could be an easy catch for another. So much depends on each observer's level of experience, clarity and darkness of the observing site, and the telescope used. A tough test for a 4-inch telescope, for instance, will probably prove easy for a 14-inch − although not necessarily.

To help level the playing field, each chapter will be segmented further into six instrument categories based on aperture: naked eye, binoculars, 3- to 5-inch telescopes, 6- to 9.25-inch telescopes, 10- to 14-inch telescopes, and 15-inchers and up. Although many of the included deep-sky objects require dark skies regardless of telescope size, each chapter also includes targets of interest to city dwellers. Many close-set double and multiple star systems are equally challenging regardless of the observing site.

Since many of those deep-sky objects will be unfamiliar to most readers, each listing is accompanied by an eyepiece field chart. These charts are not intended to supersede the need for a separate star atlas, however. In order to locate these objects, you will also need one of several star atlases that are currently in print (Appendix B lists some of the best). Use the atlas to find the target's general location, and then zero in on it using the eyepiece field chart.

Closer to home, we also try to see tough targets in the Solar System, visible through the year. For example, one challenge is to see several small craters within the prominent lunar crater Plato. Another is spying the major moons orbiting Uranus. Both of these tests are notoriously difficult, but can also be attempted with equal effort from within a city or out in the country, given the right equipment.

Each entry in the chapters to come is rated on a 1-to-4 star scale alongside the challenge header according to the level of the challenge that it presents. A "Challenge Factor" of 1 star represents the easiest level, while a rating of 4 stars means that extra effort will be needed.

You will find that some of the 4-star challenges are not doable unless all conditions are perfect. Consider those to be "hors catégorie," a term used in bicycle racing to designate an uphill climb that is "beyond categorization."

Okay, the stage is set, but before we can dive right into the challenges, we need to do a pre-check. In order to meet the Cosmic Challenge, your observing gear must be selected to eke out every photon possible from each target. Your observing site must also be matched to the test. Finally, you must be prepared, both mentally and physically. How do we go about ensuring these? Read on!

OPTIMIZING YOUR EQUIPMENT

Your eyes

Let's begin on common ground. Whether you own a telescope, binoculars, or no optical device at all, you have the greatest optical device on Earth: the human eye (Figure 1.1). Have you ever stopped and thought about it? Unless you are suffering from an eye-related malady, you probably take your sense of sight for granted. But consider that upwards of 90% of the information our brain receives and processes comes from just your two eyes.

As amateur astronomers, we are most interested in optimizing our so-called *night vision*, since that will allow us to push our observing skills to their greatest extent. To understand how to do that, it is important to understand just how the eye adapts to different lighting conditions.

We have all had occasion to wake up in the middle of the night and turn on a light, instantly blasting our eyes with a huge quantity of photons. It can be pretty painful at first, but slowly our eyes become accustomed to the bright light and our vision returns to normal.

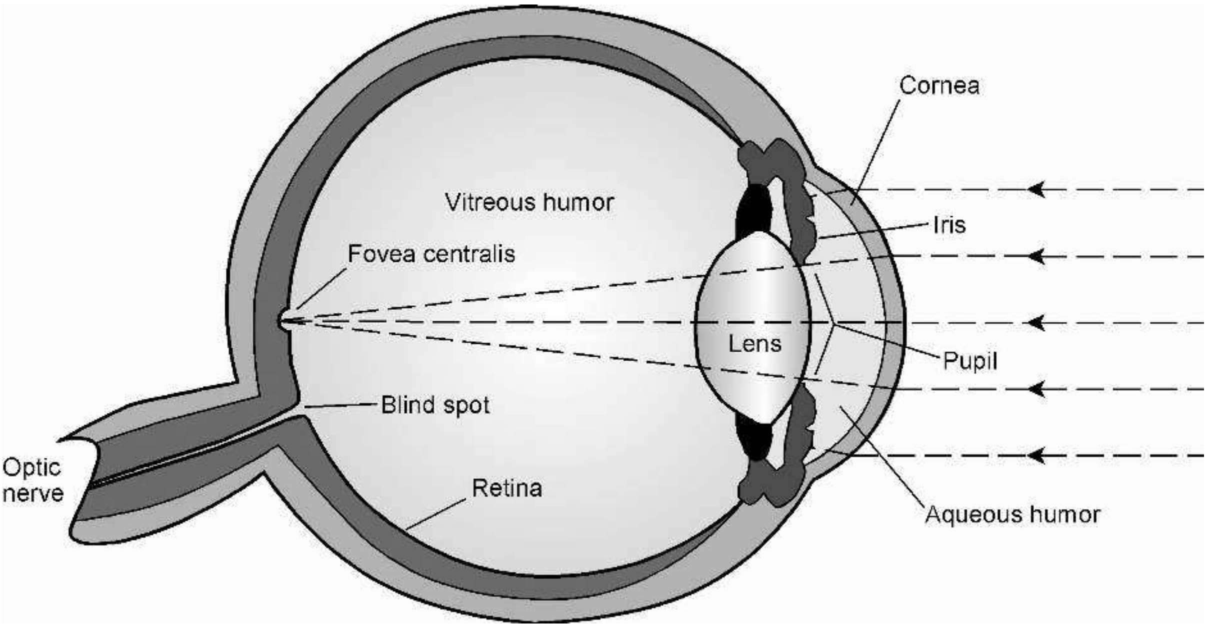

Figure 1.1 The human eye. The astronomer's most useful tool

Then, as we shut the light off again and our eyes plunge into darkness, we are once again blinded for a while until our eyes acclimate to the new conditions.

To appreciate our ability to perceive objects under varying lighting conditions, it is first important to have a basic understanding of how the human eye works. The human eye measures about an inch in diameter and is surrounded by a two-part protective layer: the transparent, colorless cornea and the white, opaque *sclera*. The *cornea* acts as a window to the eye and lies in front of a pocket of clear fluid called the *aqueous humor* and the eye's *iris*. Besides giving the eye its characteristic color, the iris regulates the amount of light entering the eye and, more importantly, varies its focal ratio. Under low-light conditions, the iris relaxes, dilating the pupil (the circular opening in the center of the iris), while, in bright light, the iris will tense, constricting the pupil, increasing the focal ratio, and masking lens aberrations to produce sharper views.

From the pupil, light passes through the eye's lens and across the eyeball's interior, which is filled with fluid called the *vitreous humor*. Both the lens and cornea act to focus the image onto the *retina*. The retina is composed of ten layers of nerve cells, including photo-sensitive receptors called *rods* and *cones*. Cones are concerned with brightly lit scenes, color vision, and resolution. Rods are low-level light receptors but cannot distinguish color. There are more cones towards the *fovea centralis* (the center of the retina and our perceived field of view), while rods are more numerous toward the edges. There are neither rods nor cones at the junction with the optic nerve, the eye's so-called *blind spot*.

In order to perceive images under dim lighting, the eye experiences a two-step process to adapt to the changing conditions. First, after being plunged into darkness, the eye's pupil quickly dilates to between 4 and 7 mm in diameter, doubling the pupil's normal, daytime aperture of approximately 2.5 mm. Of course, your numbers may vary, especially with age. While the irises of a 20-year-old may dilate to 7 mm, they may only expand to 4 or 5 mm for someone 50 or 60 years old.

A shift in the eye's chemical balance also occurs, but much more slowly. The build-up of a chemical substance called rhodopsin, or visual purple, increases the sensitivity of the rods. Most people's eyes become adjusted to the dark in 20 to 30 minutes, although some require as few as 10 minutes or as long as one hour.

The center of the retina, the *fovea centralis*, is only made up of bright-light receptors, or cones. As a result, apart from the blind spot itself, the center of our view turns out to be the least sensitive area of the eye to dim light. Knowing this is especially important when looking for faint, diffuse objects, like comets and many deep-sky objects. By averting our vision, looking a little to one side or the other, rather than staring directly at a faint object, the target's feeble light is directed onto the peripheral area of the retina, which is rich in dim-lighting sensing rods. Figure 1.2 shows just how big a difference averted vision can make.

There's more to averted vision than just looking to one side or the other. Studies show that the retina is most sensitive to dim light in the direction of your nose, and least sensitive toward your ear, in the direction of your eye's blind spot. The areas above and below your center of vision are also not quite as sensitive.

Have you ever caught yourself holding your breath as you search for a difficult target through your telescope? I know that I have. Oxygen deprivation, even if for only a few seconds, can actually desensitize your eyes, so keep breathing. In fact, some observers find that by breathing deeply for 10 to 15 seconds before peering into an eyepiece, and continuing to breathe normally once in position, actually accentuates faint objects. Be sure to keep this mind if you are observing at altitude.

Sometimes, averted vision alone is not enough. Another way to detect difficult objects is to tap the side of the telescope tube very gently. The eye's peripheral vision is also very sensitive to motion, so a slight side-to-side motion will often reveal marginally visible objects, even if only for a moment.

Our ability to perceive color involves the complex interaction of the wavelengths across the visible spectrum and the human visual perception. If our visible window was restricted to only one particular wavelength, then our perception would be restricted to that one color. For example, if the human eye was only sensitive to energy at 550 nanometers ("nm" is the abbreviation for nanometer, a very small unit of measure: one nanometer is equal to 10^{-9} meters or 10 angstrom (Å) units), then our world would appear only as varying intensities of yellow. If it were stimulated only at 485 nm, then our world would appear blue, and so on. Our eyes' ability to perceive the wavelength composition of light is critical to the sensation of color perception.

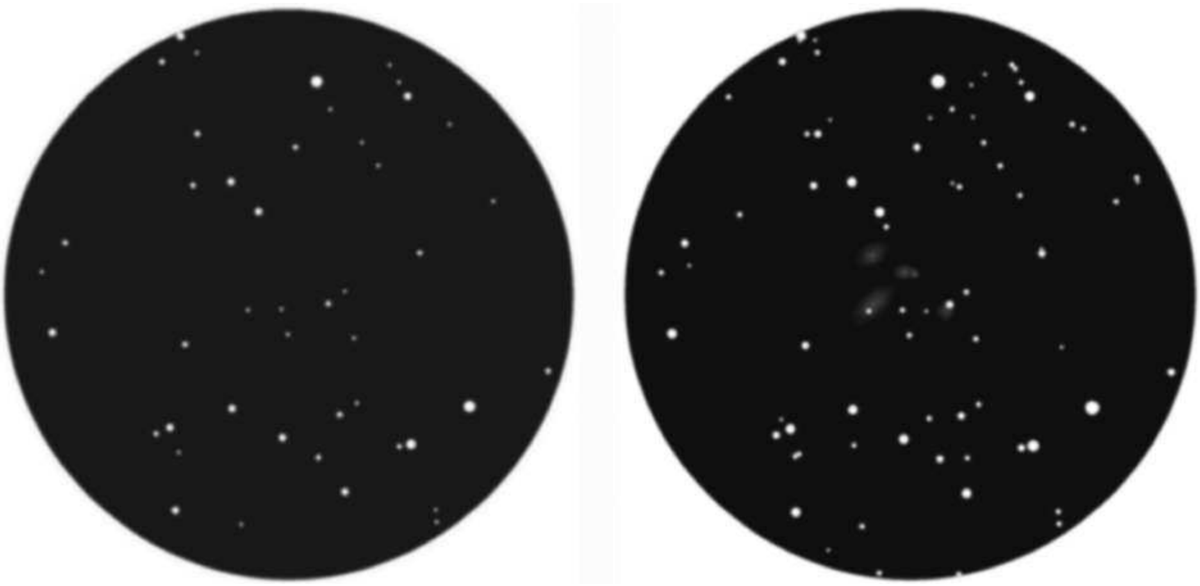

Figure 1.2 Direct vision (left) versus averted vision (right). Looking to one side rather than directly at a target can make all the difference in the world

While the eye's sensitivity to dim lighting increases dramatically during the dark adaptation process, it becomes nearly color-blind. That's why, at night, everything looks gray, varying only in light and dark intensity. Sadly, despite what some books and telescope promotional materials may imply, we visual observers will never enjoy the vibrant colors that are captured in astronomical photographs.

Most extended deep-sky objects display little color, apart from the greenish and bluish tints of some brighter planetary nebulae, and the blue, yellow, and reddish-orange tinges of some star clusters. The most notorious deep-sky objects to spot visually are emission nebulae. For instance, take a look at a photograph of M42, the Great Nebula in Orion, and you will immediately see a labyrinth of red filaments excited into fluorescence by a colorful brood of blue-white stars that are snared within. But when we look at M42 through our telescopes, all we see is a grayish image, perhaps with a hint of green through 8-inch and larger apertures.

Where's all that red? True, M42 will show the most subtle ruddy tinge along its fringe in 12-inchers and up, but that is about it. That's because, unfortunately, of all the colors in the visible portion of the electromagnetic spectrum, our eyes are least sensitive to red. Even the greenish tint to M42 is an exception to the rule. The vast majority of emission nebulae appear as vague grayish blurs to the eye, barely above the blackness of the surrounding sky. Cameras do not have the restricted color perception that plagues our eyes, and so can record nebulae in all of their colorful splendor given the proper exposure. So, while we can marvel at these glorious targets in books and magazines, we can only imagine their true magnificence when trying to spot them for ourselves.

Your binoculars

I've long preached that, when it comes to stargazing, two eyes are better than one. Using both eyes is not only more relaxing than squinting through a conventional telescope, it also has a more natural feel to it. Beyond the aesthetic appeal, ophthalmological studies prove that binocular vision increases the observer's perception of challenging objects. This effect is referred to as *binocular summation*. Depending on the type of object being viewed, the brain processes up to 40% more information using both eyes than just one.

The studies show that the improvement stems from how our brains process the information received from our eyes. The reason for this is actually two-fold. First, with two signals, any "noise" occurring along one stream will be canceled out by the second stream, thereby improving perception. The second advantage is that, when some of the cells in the brain's visual cortex receive two almost identical signals simultaneously,

Table 1.1 *Binocular versus monocular vision*

Binocular aperture	Equivalent telescope aperture
30	36
35	42
40	47
42	50
50	59
56	66
63	75
70	83
80	95
90	107
100	119
125	148
150	178

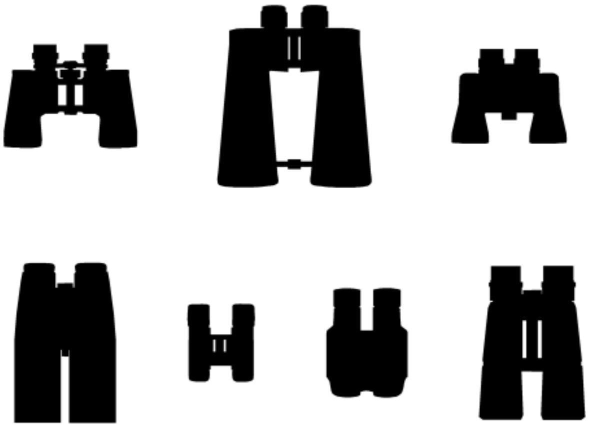

Figure 1.3 Binocular silhouettes. Binoculars come in different shapes and sizes, though all share one of two basic designs. The top three silhouettes show typical Porro-prism binoculars, while the bottom four illustrate the roof prism design

they show a greater level of activity than simply doubling that from one eye alone.

How much of an advantage does binocular vision offer over a one-eyed telescope? Despite the term, *binocular summation* does not simply mean adding the apertures of a pair of binoculars together. An 80-mm binocular is not equivalent to a 160-mm telescope. Instead, we must look at the total light-gathering area. To calculate the true advantage of using two eyes over one, plug the binocular's aperture (A) into the following formula:

$$\text{Equivalent telescope aperture} = \sqrt{(A^2 \times 1.41)}$$

Table 1.1 summarizes findings for most popular binocular apertures. Therefore, a pair of 80-mm binoculars is equivalent to a single 95-mm telescope operating at the same magnification. Magnification is key, since different values, and the different exit pupils that result, will affect performance greatly. The *exit pupil* is the circle of light exiting each eyepiece. This topic will be addressed in the section discussing eyepieces later in this chapter.

While it is true that just about any pair of binoculars (Figure 1.3) will show the night sky in greater depth than viewing by eye alone, some binoculars are more suitable to stargazing than others.

Let's begin with the optics. Are the lenses coated? Optical coatings reduce lens flare and improve light transmission, two desirable characteristics for astronomical binoculars. A plain, uncoated lens reflects about 4% of the light striking it, reducing image contrast and causing the black background to appear grayish. By applying a microscopically thin coating of magnesium fluoride (abbreviated MgFl) to both sides of a lens, reflection is reduced to about 1.5%. The optics in top-end binoculars receive multiple anti-reflection coatings. These reduce reflection to less than 0.5%, producing even finer views.

Manufacturers usually state on the binocular tailstock the type of optical coating, but don't just take their word for it. To check for yourself, hold your binoculars at arm's length and look into the objective lenses at a narrow angle. What color do you see? A lens coated with a single layer of magnesium fluoride will show a bluish or purplish tint, while multicoated lenses have a greenish tint. Uncoated lenses have a whitish glint.

Unfortunately, some low-end binoculars that state "fully multicoated optics" are not fully multicoated. Often, the outer surfaces of the objectives are multicoated, but internal optical surfaces are only single coated. Yes, this is false advertising, but unfortunately the only way to check for sure is to disassemble the binoculars and look for yourself. This is not recommended!

Next, let's talk about binocular prisms. Binoculars use one of two different types of prism assemblies to flip images right-side-up. Porro prisms are more common than roof prisms, especially for astronomical viewing. Low-end roof prisms usually generate dimmer images than similarly priced Porro prisms owing to their need to have one prism face aluminized.

The best Porro-prism binoculars use prisms made of BaK-4 glass, while less expensive models use BK-7 glass. The index of refraction of BaK-4 allows total internal reflection of all light entering the prisms. That is, all the light entering the prisms exits into the eyepieces. The reflection properties of BK-7 Porro prisms require that one face of the prisms be aluminized in order to reflect light. The result, as with inexpensive roof-prism binoculars, is dimmer images.

Again, the manufacturer should state the type of prism glass used on the binocular's tailpiece, but to see for yourself hold the binoculars at arm's length and look at the circle of light (the exit pupil) exiting each eyepiece. Do you see a clear circle, or is there a grayish diamond shape within? Clear circles indicate that the pair's prisms are made of BaK-4, while the diamond effect is caused by the light fall-off from using BK-7 glass.

While it is important to look for the right features when buying a pair of binoculars for stargazing, it is just as critical that the binoculars match the person using them. As was discussed earlier in this chapter, the amount of light entering the eye is controlled by the pupil's iris. To be perfectly matched to an observer for nighttime sky watching, the exit pupil should be no larger than the dilated diameter of the observer's eyes. Too large an exit pupil will diminish image contrast by washing out the background.

The exit pupil for a particular pair of binoculars is determined by dividing the objective's diameter by the power. For example, a 7×50 binocular has a 7.1-mm exit pupil, while 10×50 glasses have a 5-mm exit pupil.

The binoculars' objective diameter and resulting exit pupil should closely match the conditions under which they will most frequently be used. If you spend most of your observing time under dark rural skies, then your eyes' pupils should dilate fully to about 7 mm. Therefore, a diameter/power combination producing a matching 7-mm exit pupil should be chosen.

Depending on your age as well as the level of light pollution at your observing site, your pupils may never dilate beyond 4 or 5 mm. In these instances, 10×50 binoculars, with their 5-mm exit pupils, will produce superior results than similar quality 7×50s, even though their apertures are the same.

Even the mythical "finest binocular in the world" is of little value if the user cannot hold it steadily. That is why, when trying to get the most out of any binocular (even those that are image-stabilized), always place it on some sort of external support. Not only will this steady the view, it will also allow the observer to go back and forth between binocular and star chart when hunting for a particularly challenging target.

The traditional choice has always been a conventional camera tripod, but not all tripods are suitable for the task at hand. Tripods are typically designed to aim a camera toward a subject that is, more or less, the same height above the horizon as the camera itself. As binocular astronomers, however, we have higher aspirations than that. Because we spend most of our time looking skyward, most tripods prove too short to view the sky comfortably, especially when aiming near the zenith.

Instead of, or perhaps in combination with, a tripod, use a mount that offsets the binoculars away from the tripod legs. The favorite design, called a "flexible parallelogram" mount, works on the same basic principle as swing-arm desk lamps. The binoculars are attached to the end of a pivoting beam that allows the glasses to be pointed anywhere between horizon and zenith. Once the binoculars are aimed toward a target, the height of the eyepieces is raised or lowered to a comfortable position without affecting aim.

Many binocularists prefer mirror-based mounts. With these, the binoculars are mounted on a tabletop bracket that is tilted down toward a large flat mirror. The mirror is angled skyward, allowing it to be aimed toward any part of the sky without the observer craning his or her neck. While I admit the design has some attractiveness, these binocular mounts are compromises at best. For one, all commercial mirror-style binocular mounts that I know of use only standard aluminizing, which reflects between 85% and 88% of the light striking them. This effectively reduces the binoculars' aperture. They also flip images around, negating one of the greatest appeals of binocular astronomy: that the binoculars act as direct extensions of our eyes. They are prone to dewing over in damp environments.

Your telescope

Telescopes are like some children. Both need to be coddled and fussed over all the time. You have to spoil them if you want to get the most out of them. That goes for when you are viewing through them as well as when you are not. In fact, the latter is actually more important than the former.

Unless a telescope is stored correctly, dust, grime, and other contaminants will impair (indeed, ruin) the telescope in surprisingly little time. Unless a telescope is stored in a cool, dry place, with its optics dry and properly sealed, its optics will quickly turn into an expensive Petri dish cultivating all sorts of biological activity. On the other hand, a telescope that is properly cared for between uses can easily outlast its owner.

It sounds obvious, but when you are not using your telescope, keep it sealed. This is usually just a matter of putting the dust cap that came with the telescope over the front of the tube and capping the focuser. If your telescope's dust cap is long gone, use a plastic shower cap. Further, if your telescope or binoculars came with a case, use it as a second seal against dust as well as a cushion against bumps.

Never cap and seal a telescope, however, before it has had time to dry. If you live in a humid environment, remember that a dark, dank telescope is the perfect breeding ground for mold and mildew. If the outside of the tube is damp after a night under the stars, then the insides probably are, as well. To help the telescope dry without condensation puddling on the mirror or lens, tilt the tube at about 45° and leave it that way, uncapped, until the morning.

The same advice applies to eyepieces. I recently received an email from a new amateur astronomer named Terry, who was concerned that his eyepieces were damaged. He wrote, "I was looking at the Moon the other night when I noticed what appeared to be something on or in the eyepiece. After careful examination, I found what I can only describe as something growing on one of the glass surfaces. I always keep them capped in 'bolt cases' and inside a carrying case. Do I need to let them dry out more before I put them away?" The quick answer to Terry's question is "yes!" Never store a telescope, binoculars, eyepieces, or any other optical equipment unless you know that it is dry. Even then, it's not a bad idea to keep a small pouch of desiccant in your eyepiece or binocular case.

Even if you are diligent about storing your optics correctly, dust is bound to accumulate. Many amateurs are surprised to learn that even a moderate amount of dust will have very little effect on a telescope's performance. Mildew, however, will result in dimmer, hazier images.

Collimation

Many amateurs complain that their telescope optics just don't have what it takes. Instead, they curse the manufacturer for selling them a lemon. But I have found that, more often than not, the optics are perfectly fine. The only thing that is wrong is that they are out of collimation.

Some telescope designs are more easily knocked out of collimation than others. Refractors should never go out of collimation unless the telescope tube has become bent or warped, usually as a result of mishandling by the user. Catadioptric telescopes should also stand up well, but reflectors should be checked before each session.

To see if your telescope's optics are properly collimated, place a bright star in the exact center of a high-power eyepiece (say, 200× or more). Defocus the image so that the star expands into a disk. If the telescope is properly collimated, then the disk should appear perfectly round. The silhouette of the secondary mirror should be smack dab in the middle of things through reflectors and catadioptric instruments.

If, however, the defocused star appears oval or lop-sided – and it is perfectly centered in view – then the instrument is in need of adjustment.

Collimating a Newtonian

To collimate a telescope accurately, you're going to need the proper tools. At a minimum, you will need a sight tube, which consists of a long empty tube with a set of crosshairs at one end and a peephole at the other.

Check your Newtonian's collimation by aiming the telescope toward a brightly lit wall or the daytime sky (far from the Sun, please). Rack the focuser in as far as it will go, insert the sight tube, and take a look. Ideally, you should see the secondary mirror centered in the crosshairs. If you do, skip to the next step; if not, then the secondary must be adjusted. Move to the front of the telescope tube and loosen the nut holding the secondary's central bolt in place. Slide the secondary assembly in and out along the telescope's optical axis until it appears centered[1] in the sight tube. Before

[1] Technically, the secondary should be offset ever-so-slightly toward the primary, rather than centered directly under the focuser. To learn more about this fine point of Newtonian collimation, review the discussion in D. Kriege and R. Berry, *The Dobsonian Telescope* (Willmann-Bell, 1997).

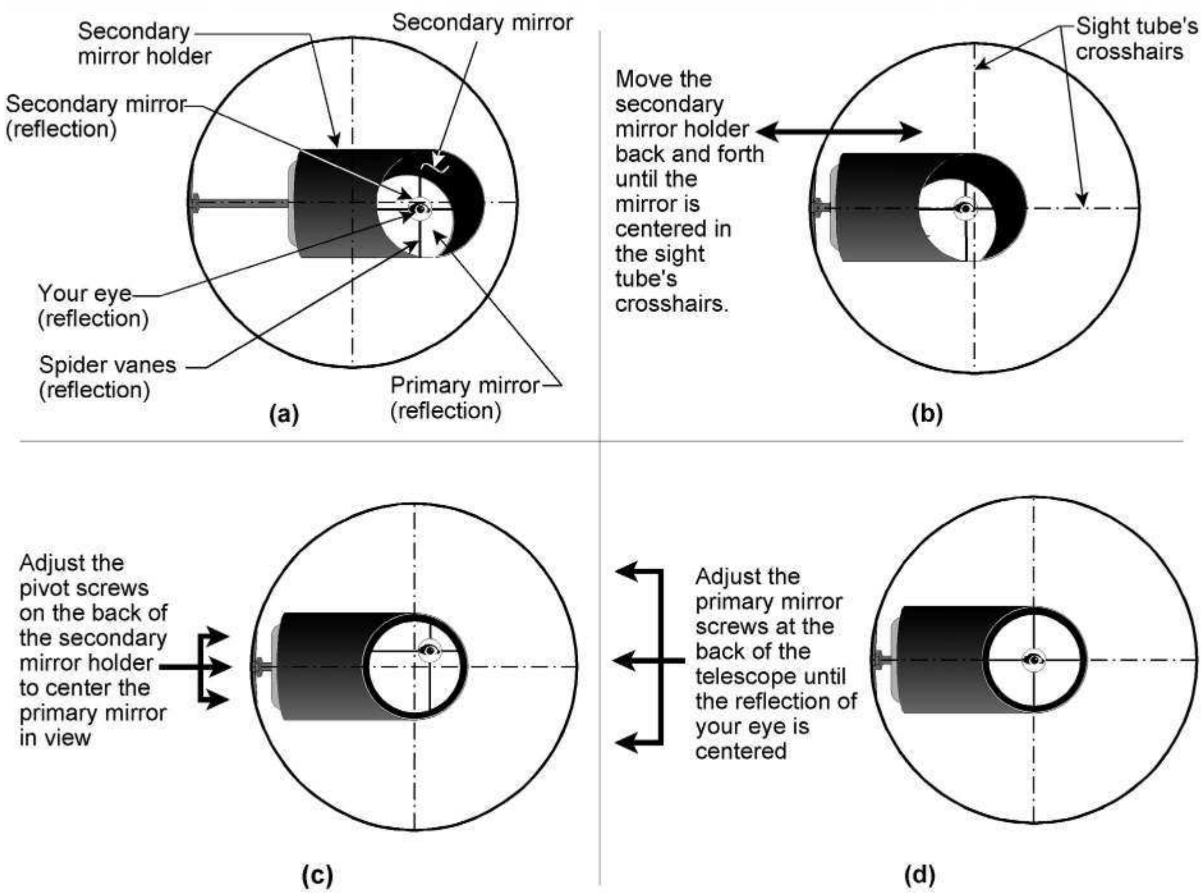

Figure 1.4 Newtonian collimation. Collimating a Newtonian reflector is as easy as 1–2–3. (a) The view through an uncollimated telescope. (b) Adjust the secondary mirror's central post until the mirror is centered under the focuser tube. (c) Turn the secondary mirror's three (possibly four) adjustment screws until the reflection of the primary mirror is centered. (d) Finally, adjust the primary mirror until the reflected image of your eye is centered in view

tightening the nut, check to make sure that the diagonal is not rotated left or right; it should appear perfectly circular. When done with this step, the view through the sight tube should look like Figure 1.4b.

With the diagonal centered under the focuser, look through the sight tube at the reflection of the primary mirror. You should see the end of the telescope tube and at least part of the mirror. Most secondary mirror mounts have three equally spaced screws that, when turned, pivot the secondary's angle. Alternately loosen and tighten these three screws until you see the end of the telescope tube perfectly centered in the secondary. Don't worry if the primary isn't centered; we will take care of that in a moment. When properly aligned, the view after this step should look like Figure 1.4c.

Finally, it is time to adjust the primary mirror's tilt, as in Figure 1.4d. Look at the back of the primary mirror's cell. There should be three, sometimes six, screws. These adjust the tilt of the primary. Go back and forth between the sight tube and these adjustment screws, turning only one at a time slowly, until the primary's reflection is centered in the sight tube's crosshairs. Many companies place a center dot or ring in the exact middle of the primary to make this step easier. (If your primary mirror mount has three sets of two screws, one in each pair adjusts the mirror, while the other presses against the mirror's cell to keep it from rocking. If your telescope uses this type of mirror mount, the three locking screws must be loosened slightly before any adjustment can be made.)

If your Newtonian's focal ratio is *f*/7 or slower (that is, has a higher *f* number), you're done. If, however, your Newtonian is faster than *f*/7, a second tool, called a Cheshire eyepiece, is strongly recommended for more precise alignment. Like a sight tube, a Cheshire eyepiece contains no optics. Instead, a hole in the side of the Cheshire's barrel reveals a polished metal surface cut at a 45° angle. A small hole centered in that surface opens to a peephole at the top of the tool.

To understand how a Cheshire eyepiece works, insert it into your telescope's focuser and shine a flashlight beam into the eyepiece's side opening while you look through the peephole. Centered in the dark silhouette of the diagonal, you should see a bright donut of light. That's the reflection of the Cheshire's polished surface off the primary mirror. The dark center is actually the hole in that surface. Adjust the primary's tilt until its black reference spot is centered in the Cheshire eyepiece's donut. That's it.

Collimating a Schmidt–Cassegrain

Unlike a Newtonian reflector, where both the primary and secondary mirrors can be readily accessed for collimation, commercially made Schmidt–Cassegrain telescopes (SCTs) have their primary mirrors set at the factory. Fortunately, SCTs are rugged enough to put up with the minor bumps that might occur during set-up without affecting collimation. The secondary mirror, however, should be checked often to see if all is well.

The best way to check an SCT for collimation is to aim at a star and slightly defocus the image. Ideally, the diffraction rings surrounding the defocused star should be perfectly centered with the star perfectly centered in view, as in Figure 1.5a. If not, then something needs to be done.

A Schmidt–Cassegrain's secondary mirror floats in the middle of the telescope's corrector plate, held in place by three equally spaced adjustment screws. (Some models hide the adjustment screws with a plastic cover. You'll need to remove this cover, very carefully, to find the screws.) You change the tilt of the secondary by turning those screws in and out.

Slowly turn one of the adjustment screws no more than a quarter turn. Return the star to the center of view and take a look. Are the rings centered? If not, check which direction they are off and turn the corresponding screw slightly in or out, then recheck. Did that help or hurt? If collimation is still off, return and try turning another screw. Keep going back and forth until everything is centered, but do not just work one screw. Turn two, possibly all three, to avoid loosening or tightening one screw too much.

If the image is still not correctly aligned even after repeated attempts, then there is a distinct possibility that the primary is not square to the secondary. Focus on a rich star field. If any coma (ellipticity) is evident around the stars at the center of view, then chances are good that the primary is angled incorrectly. In this case, your only alternative is to contact either the dealer where the telescope was purchased or the manufacturer.

Baffling/flocking

While ensuring that a telescope's optics are collimated correctly is the single best thing that an observer can do to get optimal performance out of an instrument, it's really just the beginning. Most commercial telescopes can be made to outperform themselves by adding a few enhancements.

First, let's talk baffling. By baffling your telescope properly, you can enhance image contrast greatly, improving the odds of seeing dim, low-contrast objects. Most refractors and catadioptric telescopes have internal baffles (Figure 1.6) that are designed to keep stray light from washing out the in-view target. The dew shield that sticks out in front of a refractor's objective does double duty as a shield against lens fogging as well as a baffle to keep errant light from a foreign source off the objective. The vast majority of catadioptric scopes do not come supplied with a dew shield, even though they need one just as much as any refractor. Newtonian and Cassegrain reflectors do not come with these as standard equipment either, but both would benefit from one, as well.

To be of maximum benefit, an external dew/light shield should extend in front of a telescope a distance equal to the aperture, as in Figure 1.7. For example, an 8-inch telescope should have an 8-inch long dew/light shield protruding in front of it in order to block stray light properly. Let's say that 8-inch telescope is a Schmidt–Cassegrain, with its corrector plate set back just a few millimeters from the front edge of the tube. That telescope's dew/light shield needs to measure a full 8 inches in length, plus enough extra material for the shield to slip over the tube and be held in place.

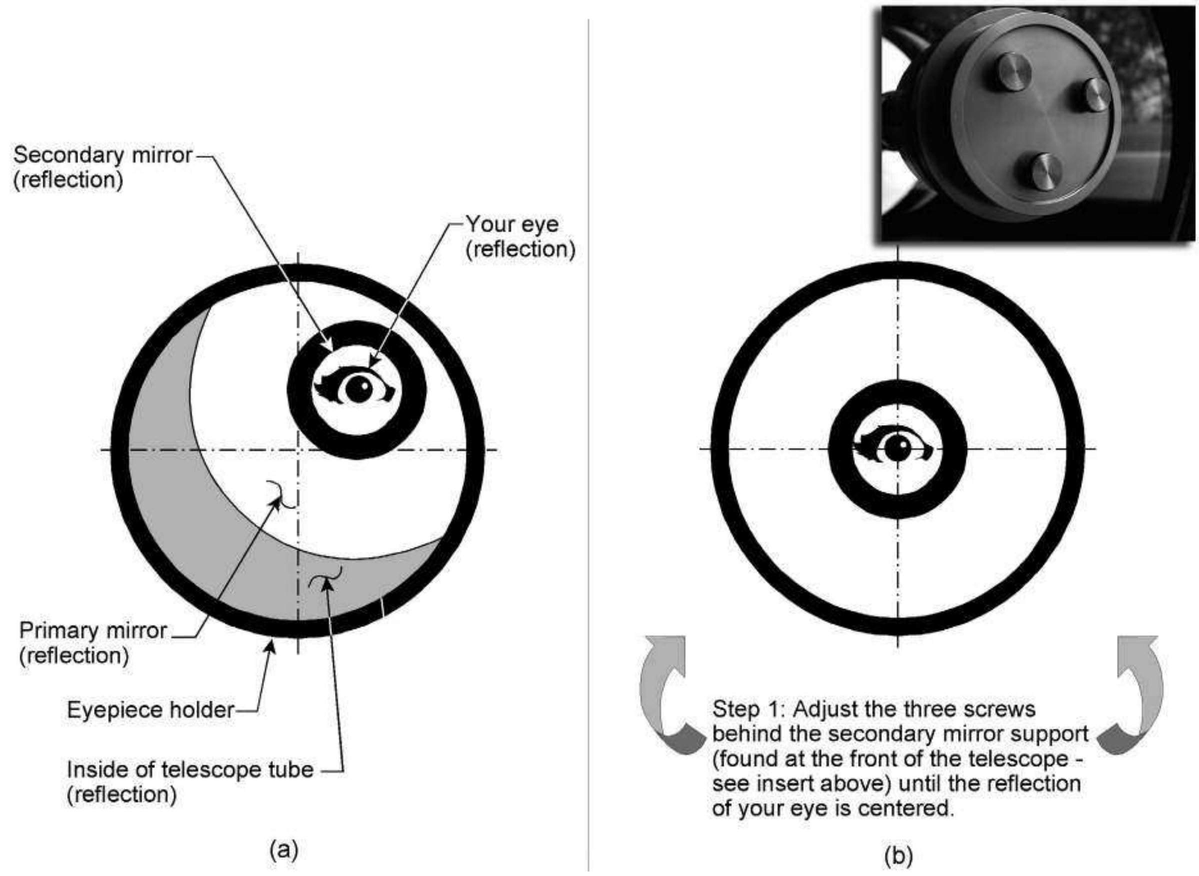

Figure 1.5 SCT collimation. Collimating a Schmidt–Cassegrain involves adjusting the secondary mirror (a) until its reflection appears centered in the primary as you look through the empty focuser (b). The insert at upper right shows an example of the secondary mirror's three adjustment knobs. Insert photo courtesy of Bob's Knobs

Now, let's say the 8-inch telescope is a Newtonian reflector. Measure how far back the focuser is located behind the front edge of the tube. For this example, let's say that it is located 2 inches back from the front of the tube. The light/dew shield here only needs to project 6 inches in front of the tube to meet our criterion.

There are many aftermarket light shields available for sale. The most convenient models are foldable for easy storage when not in use. Alternatively, you can make your own from several readily available materials. I have a shield on my own 18-inch Newtonian made from Kydex, a plasticized material commonly used for upper cage assemblies of truss-style Newtonian reflectors. Strips of adhesive-backed Velcro® hook-and-loop material holds the shield in place.

Just as light can sneak into a Newtonian's focal plane from the front, it can also enter through the tail end of the instrument as well, around the primary mirror. To combat this problem, some Newtonians come with a metal plate sealing the end of the tube. While this certainly blocks light, the plate also blocks air from entering, slowing the time it takes the mirror to acclimate to the cool night air. Instead, I recommend fashioning a cover of opaque black cloth, such as nylon, that fits over the tube. Nylon will allow the tube to breathe while effectively preventing light from entering.

Most refractors, Cassegrain reflectors, and catadioptric telescopes have internal light baffles in order to maximize image contrast, which is crucial to seeing dim objects. Surprisingly few observers realize that Newtonian reflectors can also benefit from internal baffling.

To evaluate your own Newtonian, take a look at the inside of the optical tube assembly. Every mechanical