CHAPTER SEVEN

Accessories

Eyepieces

It’s a telescope’s *eyepiece* that does the actual magnifying of the image brought to a focus by the objective lens or primary mirror. It also happens to be the element in the optical train that is most often overlooked as the source of good or bad performance of the overall system. An eyepiece can literally make or break even the best of telescopes. Small imported refractors from the Far East are especially notorious for having poor-quality oculars. And since a telescope would not be able to function without an eyepiece (at least for visual observing), an eyepiece can really be considered a necessity, rather than an accessory as listed here.

There’s a multitude of eyepieces on the market today, ranging from inexpensive, basic two-element oculars to sophisticated multi-element designs containing seven or eight individual lenses and costing as much as do some telescopes themselves! A good eyepiece should be well-corrected for chromatic and other aberrations, have as wide and flat (curvature-free) a field as possible, and provide good eye relief. It is especially important that *all* glass surfaces have antireflective coatings to reduce internal reflections. (Some lower-grade eyepieces have so many “ghost” images that they are said to be “haunted”!) In premium eyepieces, the edges of all lens elements are ground and coated flat black in order to eliminate any possible scattering of light. And finally, rubber eyeguards to help position the eye at the correct distance from the eyepiece and also keep out stray light are supplied on most oculars today; if not, they are available separately from many dealers for a variety of ocular sizes, types, and styles.

Eyepieces come in several different sizes of barrel diameters. The 0.965-inch *subdiameter size* (sometimes referred to as the *Japanese size*) ocular is often

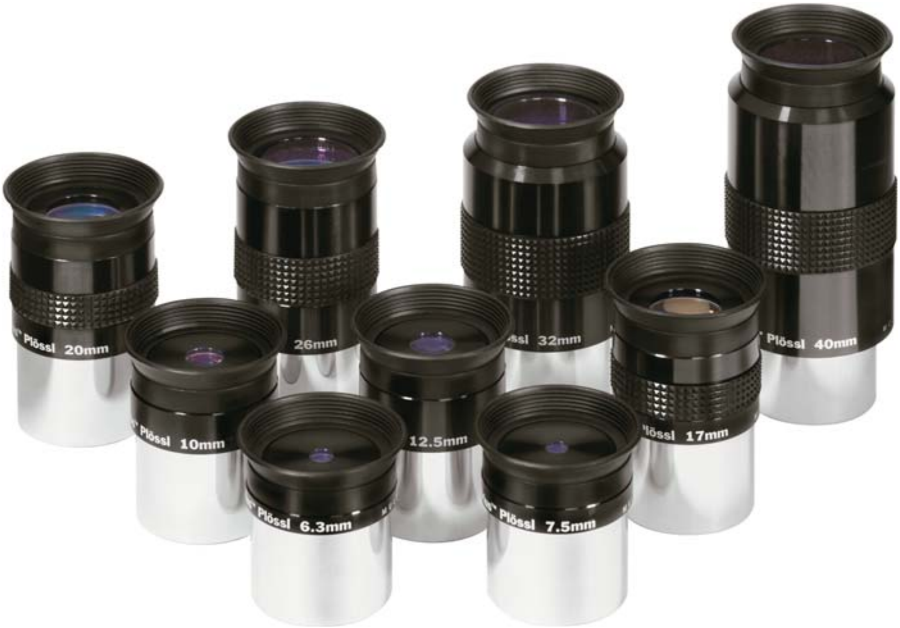

Figure 7.1. A fine example of a comprehensive set of quality 1.25″ eyepieces – in this case, Orion's Sirius Plössl collection, having focal lengths ranging from 40 mm to 6.3 mm. For all practical purposes, three eyepieces (providing low, medium, and high magnifications) will suffice for most viewing applications (at least initially!). Courtesy of Orion Telescopes & Binoculars.

found on inexpensive telescopes – especially the ubiquitous 2.4-inch (60-mm) refractor sold everywhere, imported from Japan and other countries in the Far East. They typically have very limited fields of view, poor eye relief, and inferior optical quality. The 1.25-inch *American standard size* is the one most widely used on telescopes, including on many imported scopes in recent years. The larger barrel diameter allows for big multi-element lenses that provide excellent eye relief, roomy fields of view, and good optical corrections. And finally, there's the huge *giant size* 2.0-inch-diameter barrel employed for some of today's most sophisticated, ultra-wide-angle eyepiece designs. They are so big and contain so much glass that they are sometimes referred to as "glass grenades". They also cost as much as do some telescopes!

Of the many types of eyepiece that have been developed over the years, the *Kellner* and the *Erfle* are two of the most common traditionally used by observers. Among the more popular forms today are the *orthoscopic* and the *Plössl*, which not only provide good optical performance and relatively wide fields of view, but are also very reasonably priced. And of the many modern, ultra-wide-field designs now available to stargazers, the *Nagler* series leads the pack with their incredible "space-walk" views (offering up to a whopping 82 degrees of apparent field – see below) and exquisite state-of-the-art optical corrections.

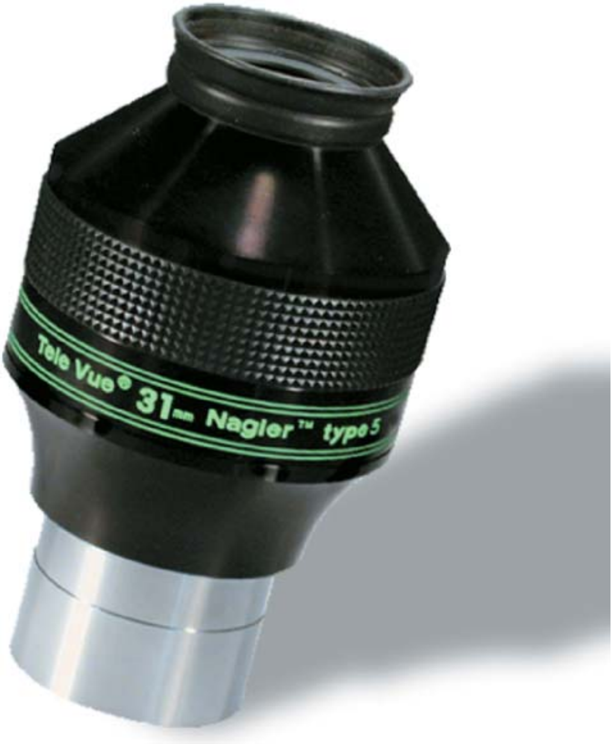

Figure 7.2. One of the legendary Nagler eyepieces having an amazing 82-degree apparent field and providing spectacular "space walk" views of the sky. Courtesy of Tele Vue Optics.

Two basic parameters describe the field of view of an eyepiece. One is its *apparent field* – the angular extent in degrees seen when looking through it at a bright surface such as the daytime sky. This can range from as little as 40 degrees up to as much as the 82 degrees mentioned above, depending on type, design, and brand. Most eyepieces in use today typically have pleasing apparent fields of 50 to 55 degrees. The other parameter is its *actual field* – the amount of sky it encompasses when used on a given telescope. It's quite easy to find what this is: simply divide the apparent field (which is a stated design value for the eyepiece type being used) by the magnification it produces (see below). Thus, an eyepiece having an apparent field of 50 degrees and magnifying 50 times (or 50×) on a particular telescope results in an actual field of 1 degree (or two full-Moon diameters in extent). At 100×, the field becomes $\frac{1}{2}$ degree, and at 200× it shrinks to only $\frac{1}{4}$ degree. Thus, *the higher the power, the smaller the amount of sky a given eyepiece will show.* It should be mentioned here that 1 degree (1°) equals 60 minutes (60′) of arc and that 1′ contains 60 seconds (60″) of arc. The Moon at its average distance has an apparent angular size in the sky of $\frac{1}{2}$ degree or 30′, providing a convenient yardstick for judging eyepiece fields of view.

Determining the magnification an eyepiece gives on a telescope is equally straightforward. The power (×) is found by simply dividing the focal length of the telescope by the focal length of the eyepiece. As already discussed in Chapter

3, the focal length is the distance from a lens or mirror to its focal point, specified in either inches or millimeters. A telescope having a focal length of 50 inches (or 1250 mm) used with a 1-inch (or 25-mm) eyepiece yields a magnification of 50×.

Changing the eyepiece to one with a $\frac{1}{2}$-inch (12.5-mm) focal length increases the power to 100×, while a $\frac{1}{4}$-inch (6-mm) eyepiece gives 200×. Therefore, *the shorter the eyepiece's focal length, the higher the magnification it provides* – and along with it, correspondingly smaller actual fields of view. Thus, it is important to use eyepieces with the largest possible apparent fields. While most telescopes today are typically supplied with one or two basic eyepieces of good quality and reasonable apparent fields of view, you may want to consider eventually upgrading to a premium wide-angle, low-power ocular – one having a focal length, say, between 26 mm and 32 mm.

Most of the major telescope manufacturers and suppliers have extensive lines of eyepiece sizes, types, and designs, ranging from basic oculars priced at under $50 to premium ones going for as much as $300 each! Among others, Orion offers a quality selection of sizes and types at affordable prices, while Meade and (especially) Tele Vue provide premium, multi-element designs in a variety of focal lengths and apparent field sizes at correspondingly higher costs.

Zoom eyepieces make possible a continuous range of magnifications using just a single ocular. These have traditionally been considered much inferior to single eyepieces of a given focal length, owing to the changes in field of view and focus with changes in power. Improved models have recently appeared on the market in an attempt to rectify this. Tele Vue's 8–24-mm Click-Stop Zoom priced at $210 is a definite step up optically over traditional zooms (although the apparent field still varies from 55 degrees to 40 degrees). Its 3–6-mm Nagler Zoom (obviously intended for high-power viewing) has a constant 50-degree apparent field through its short range and sells for around $380. Orion offers a 7–21-mm zoom whose apparent field varies from 43 degrees to 30 degrees; it costs about $60. But for those of us who enjoy wide, expansive eyepiece views, despite their convenience even these improved zooms still fall far short of the performance a high-quality single ocular can provide.

Finders

Another accessory that's often skimped on with a commercial telescope is its *finder*. This is a small auxiliary telescope or other sighting device mounted on the main instrument itself to aid in pointing it at celestial targets so they will appear in the field of a low-power eyepiece. Such an eyepiece typically provides an actual field of only a degree or so; optical finders, on the other hand, have fields of 5 or 6 degrees (similar to those of binoculars), making it easy to locate objects in the sky. Once the finder has been aligned with the main telescope using the provided adjusting screws, so that they're pointing at the same piece of sky, any target placed on the finder's crosshairs will then be in the scope's eyepiece. Magnifications generally range from 6× or 7× for small finders to 10× or 12× for large ones.

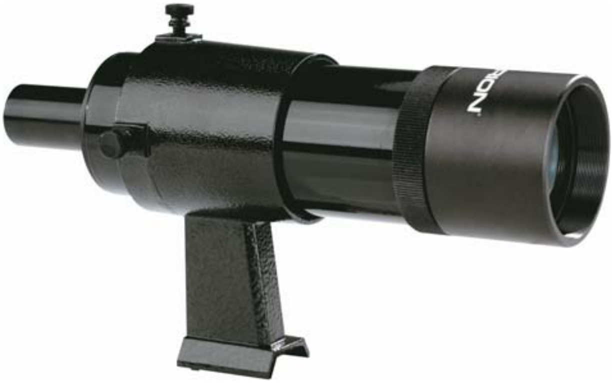

Figure 7.3. A conventional straight-through optical finder. Unlike this 9 × 50, finders on many small telescopes are greatly undersized and often are all but useless. Courtesy of Orion Telescopes & Binoculars.

An old rule of thumb states that a finder should have an aperture one-quarter that of the telescope itself. Thus, a 4-inch glass should have a 1-inch finder, an 8-inch a 2-inch one, and a 12-inch a 4-inch one. But this guideline is often ignored by manufacturers in larger-size scopes. And although the guideline may be followed for scopes in the 2–4-inch range, the optical quality is often very poor. A 1-inch (or 25-mm – finder sizes are typically given in millimeters) finder on a 4-inch telescope is hardly adequate. An ideal size for 4–8-inch telescopes is one with a 2-inch (50-mm) aperture and a magnification of 7 times (essentially half of a 7 × 50 binocular!), with correspondingly larger values for bigger scopes. Even a 2-inch glass can benefit from having a finder this size. While tiny finders may be adequate for sighting bright targets such as the Moon and planets, they are nearly useless for locating fainter targets such as nebulae and galaxies.

Having a good finder often requires upgrading the one supplied with the telescope as original equipment – either at the time the scope is ordered from the manufacturer, or as a later purchase from another source. Many of the telescope companies listed in Chapter 9 offer a selection of finders, with prices ranging from as low as $30 to well over $100, depending on aperture. Note that some of these may be equipped with right-angle *star diagonals* (see below) built into them, seemingly to make aiming easier. However, not only do you still have to sight along the tube for initial pointing, but the diagonal produces a mirror-reversed image of the sky that can be confusing to beginners. It should also be mentioned that many of the latest Go-To systems supplied with telescopes today (as discussed in Chapter 3) are so accurate that a finder is not needed. But for quick and ready aiming at bright naked-eye objects, one is still quite useful even so.

In recent years, a new type of finder has been increasingly supplied on telescopes in place of a traditional optical one. Known as the *zero-* or *unit-power finder* (it is actually 1-power – that of the human eye!), this is a sighting device that projects a red dot on the sky as you look through it – typically centered on a bull's-eye pattern. This makes going from a star atlas directly to the sky when aiming a telescope quick, easy, and surprisingly accurate. The original and still one of the best of many such devices now on the market is the famed Telrad, invented by the late Steve Kufeld. If not already included with the instrument you

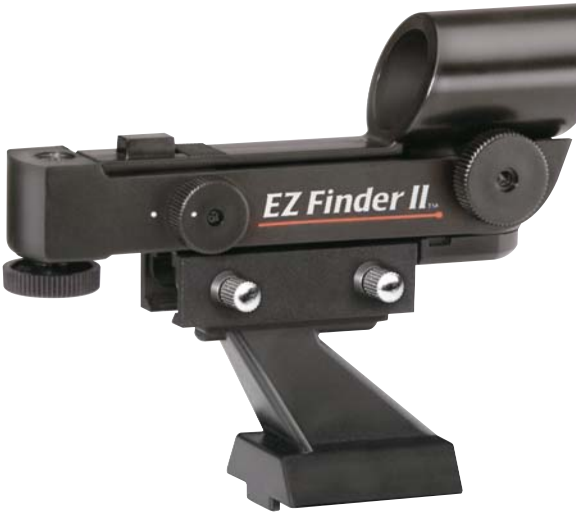

Figure 7.4. A unit-power (non-magnifying), reflex-sight finder like that now widely used on telescopes in place of (or in conjunction with) conventional optical finders. It works simply by superimposing a tiny LED red dot focused at infinity on a 10-degree view of the sky, showing exactly where the telescope is pointed. Courtesy of Orion Telescopes & Binoculars.

select, these finders can be ordered separately from such companies as Apogee, Celestron, Orion, Photon, Rigel, Stellarvue, Tele Vue, and Telrad itself. Prices range from under $50 to over $100. It turns out that many observers prefer to have *both* a unit-power and an optical finder on their telescopes – the former being used for rapid pointing to the position of a desired target, and the latter for positive identification and precision centering in the eyepiece.

Star Diagonals

Stargazers are typically pictured in cartoons and other media as peering at the heavens straight through a long refracting telescope. This image is quite misleading. For objects on the ground or low over the horizon, this set-up works satisfactorily; but most celestial objects are positioned high in the sky – even at the zenith (or overhead point) – and it's virtually impossible to bend the neck to view them straight through a refractor. This is also true with Cassegrain reflectors and catadioptric systems, where observing is done at the back end of the instrument, as in the case of refractors. (This isn't a concern with a Newtonian reflector, since the observer looks into the side of the tube.) To overcome this problem, a *star diagonal* is used.

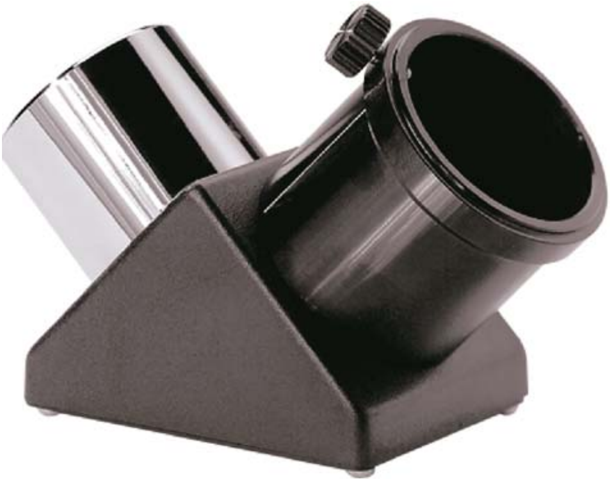

Figure 7.5. Shown here is a conventional prism-type star diagonal as commonly used on refractors, Cassegrain reflectors, and catadioptric telescopes. One end fits into the telescope's drawtube and the other end (with lock screw) accepts the eyepiece. Courtesy of Orion Telescopes & Binoculars.

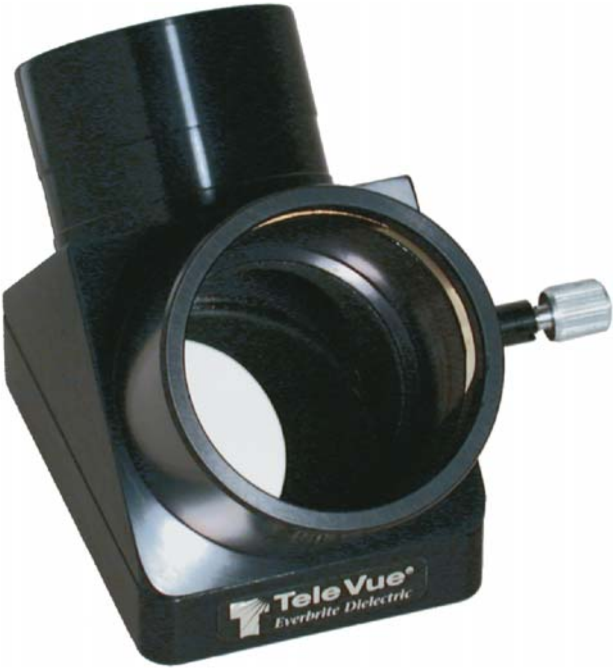

Figure 7.6. An optically perfect mirror star diagonal, which provides better image quality than standard prism diagonals, according to many discerning observers. Courtesy of Tele Vue Optics.

This device consists of two tubes joined at right angles to each other in a housing containing either a precision right-angled prism or a front-surface flat mirror, with one tube fitting into the focuser and the other accepting the eyepiece. The converging beam from the objective or primary mirror is turned 90 degrees to the optical axis by the star diagonal, where the image can be observed in comfort without contorting the neck and back. These are supplied as standard equipment on virtually all refractors and compound telescopes sold today, and are also available separately as accessories from many manufacturers. Prism star diagonals can be had for under $40, while mirror diagonals start as low as $60 and run up into the hundreds of dollars.

It should be mentioned that a star diagonal produces a mirror image of what is being viewed, so objects appear right-side-up but reversed left-to-right. This makes deciding which way to move the eyepiece somewhat confusing until you get used to it. To find your bearings, let the image drift through the eyepiece field (turning off the telescope's motor drive if it has one). Stars will enter the field from the east and leave it to the west. Nudging the scope toward Polaris, the North Star, will indicate which direction is north.

There is another type of diagonal, supplied on some telescopes intended mainly for terrestrial viewing, known as an *erecting prism diagonal*. These diagonals turn the image 45 degrees instead of 90 degrees and provide fully correct images. But not only are they awkward to use for sky viewing because of the angle the light is turned, but the roof prism that erects the image produces an obvious luminous line radiating through bright objects such as planets and first-magnitude stars. As a result, they are definitely not recommended for stargazing purposes!

Barlow Lenses

There exists a marvelous little optical device that effectively doubles or triples the focal length of any telescope, yet measures only a few inches long! Called a *Barlow lens* after the inventor of its optics, it consists of a negatively-curved achromatic lens (sometimes three elements are used instead of two) fitted into a short tube, one end of which accepts the eyepiece while the other goes into the telescope's focuser. With the proliferation of short-focus refractors and fast Dobsonian reflectors in such wide use today, these *focal extenders* are enjoying renewed popularity among observers.

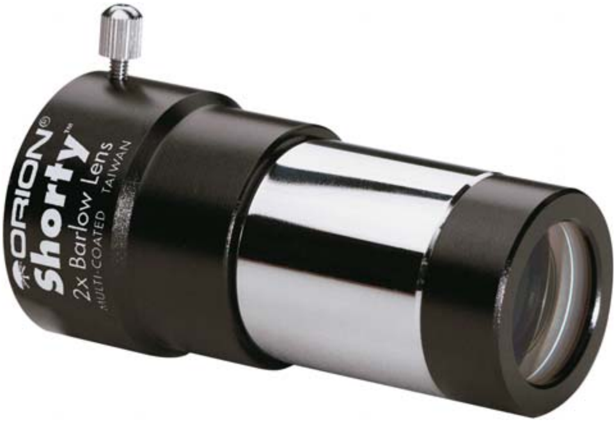

Figure 7.7. This 2× Barlow lens is just 3 inches long and effectively doubles the magnification of any eyepiece used with it. Other models provide amplifications of 2.5× and 3× (or even more, using extender tubes, as mentioned in the text). Courtesy of Orion Telescopes & Binoculars.

The Barlow's negative-lens element decreases the angle of convergence of the light being brought to focus by a telescope's objective lens or primary mirror – causing the latter to appear to be at a much greater distance from the focus than it actually is. This effectively increases the original focal ratio/focal length of the system. Barlows are typically made to amplify between two and three times (2× to 3×). The actual stated *power* is based upon the eyepiece being placed into the drawtube at a set distance from the negative lens; the further the eyepiece is pulled back from this lens, the greater the amplification factor. (Some adjustable Barlows use this very principle to provide a range of powers.) By adding extender tubes, many observers have pushed their 2×- or 3×-rated Barlows to 6× and more! Also note here that the eyepiece–Barlow combination is normally placed into a star diagonal as a unit. But if instead the eyepiece itself is placed into the diagonal and the Barlow inserted ahead of it in the telescope, the extra optical-path length though the diagonal to the eyepiece will also greatly increase its effective amplification.

Solar, lunar, planetary, and double-star observers have long used Barlow lenses to increase the image scale and magnification of the objects they are viewing. The great advantage of these devices to the casual stargazer is that they make it possible to achieve high powers using eyepieces of longer focal length than would normally be required to do so. Such oculars have bigger lenses, wider apparent fields of view, and more comfortable eye relief than do ones of shorter focal length. Thus, an eyepiece having a 25-mm (1-inch) focal length and combined with a 3× Barlow used on a telescope having a 1250-mm (50-inch) focal length would result in a magnification of 150× (3 times 50×). To achieve the same power with an eyepiece alone would require one with a focal length of about 8 mm.

Barlow lenses are not normally supplied as standard equipment on commercially available telescopes (except for imported 2.4-inch/60-mm refractors, which are notoriously already way overpowered without using one!). But they are widely available from many of the companies listed in Chapter 9, at prices from under $50 up to more than $200 for premium units. Here's a great way to effectively double or triple the number of eyepieces in your collection for a very modest investment!

Dew Caps/Light Shields

Reflectors have their own built-in versions of *dew caps/light shields*, since their primary mirrors are located at the bottom ends of their tubes. But refractors and catadioptric telescopes need to have extensions added to their tubes to prevent dew from forming on their front optical elements, and also to help prevent stray light from entering the system. Although refractors are generally provided with a dew cap/light shield, these are typically much too short to offer any real protection. And, surprisingly, virtually every catadioptric telescope sold on the market today comes without one at all! In any case, the observer can (and definitely should) either fashion one out of some black, opaque, flexible material such as common posterboard, or purchase one from the manufacturer at the time the telescope is ordered. They are very affordable (well under $100, depending on size) and are an absolute "must" for anyone using a refracting or catadioptric telescope. (A useful rule of thumb is that a dew cap/light shield should be at least 1.5 times as long as the aperture of the telescope, and to be fully effective 2.5 times as long. The main concern here is that it does not extend out so far as to reduce the effective aperture itself. This can readily be checked by looking up through the instrument without the eyepiece in place at the daytime sky.)

Miscellaneous Items

The following additional accessory items are mentioned here for the sake of completeness. Few are ever supplied as standard equipment with a telescope purchase, and in many cases they have relatively limited utility (especially for beginning observers). In addition to the primary resource listing in Chapter 9, the advertisements in *Sky & Telescope*, *Astronomy* and other magazines provide sources for most of these items.

Binocular viewers make it possible to use both eyes at the telescope instead of one. While some light-loss is involved in splitting the incoming light into two separate beams, as with binoculars image contrast, resolution, color perception, and sensitivity to low light levels are all increased over viewing with one eye only. And there's also the wonderful illusion of depth perception in looking at objects such as, for example, the Moon, where the observer feels suspended in orbit above its vast globe! A downside is the matter of cost. Not only are these devices quite expensive in themselves (ranging anywhere from $300 to $1,600), but two precisely matched eyepieces are needed for each magnification that's used. In other words, a double set of eyepieces is required for the telescope! The binocular viewer fits directly into the drawtube of a Newtonian reflector (it's vital here to make sure the telescope has enough "back-focus" to accommodate the light path through the viewer to the eyepieces; if not, a Barlow lens inserted ahead of the viewer itself can be used to extend the focus), and into the star diagonal of a refractor or catadioptric (which typically have ample back-focus).

Rotary eyepiece holders offer the convenience of having anywhere from three to six eyepieces (depending on model) at your fingertips ready to rotate into position for rapid changes in power. The holder itself is a prism star diagonal and fits directly into the telescope drawtube just as a standard one does. Unitron, with their Unihex rotary eyepiece selector, was the first to market such a device and is still among the few companies offering one. Prices begin around $125. Note that those eyepieces not actually in use often tend to dew up (see below).

Dew heating strips (sometimes called "dew zappers") avoid the annoying formation of moisture on the eye-lens of oculars left exposed to the night air, as well as on objective lenses, corrector plates, and even secondary mirrors. The heating element is typically encased in an elastic nylon strip with Velcro for attaching it around the various optical surfaces and is operated from a 12-volt DC source such as a car battery or power supply. Prices average under $100. While the dew caps discussed above generally provide adequate protection for objective lenses and corrector plates themselves without recourse to heating strips, eyepieces are

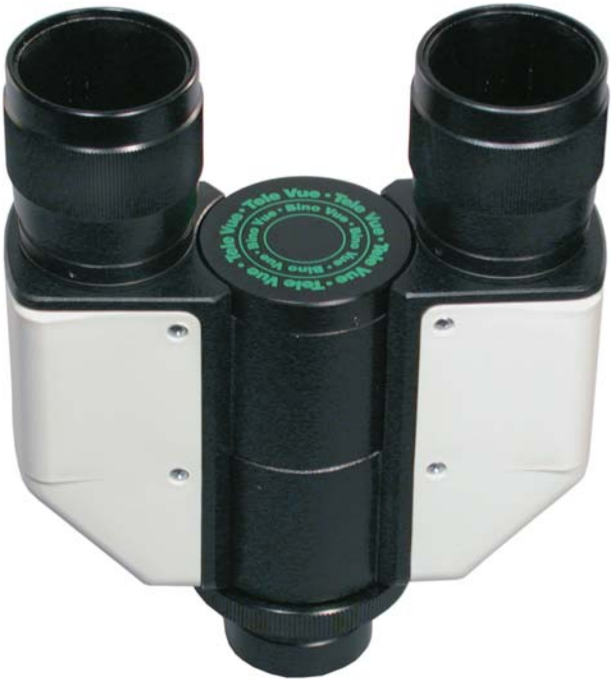

Figure 7.8. A binocular eyepiece holder, allowing use of both eyes at the telescope. Note that two oculars of identical focal lengths are required by these units. Some observers actually have a complete double set of eyepieces for use with their bino-viewers! Courtesy of Tele Vue Optics.

particularly vulnerable to dewing up. (So too are the lenses on finders.) They should never be left exposed to the night air in an open eyepiece box, for example. Except for the ocular that's in use on the scope at the time, they should be kept covered. Note that rotary eyepiece holders do leave their eyepieces exposed to the air, often requiring that they be capped until positioned into place for viewing. (Many observers today also employ ordinary hairdryers to remove dew from the various optical surfaces of their telescopes, but care must be taken not to overheat them! In this case, dew is dealt with after it forms on the optics – heating strips prevent it from forming in the first place.)

Image erectors are typically supplied with small imported refractors for use in terrestrial viewing. Their long tubes make them awkward to use on a telescope and their optics often leave much to be desired. An image-erecting star diagonal (mentioned above) offers a much more convenient and optically superior way to achieve a fully corrected image for land-gazing.

Focal reducers can be thought of as "reverse Barlows" in that they reduce the effective focal length of a telescope rather than extend it. Originally developed for use on catadioptric systems with their long focal ratios (typically f/10 to f/14), they're intended primarily for increasing the photographic speed of these slow telescopes for astroimaging purposes by reducing their effective ratios by as much as half the original values. This correspondingly both reduces the lowest achievable magnification and increases the maximum actual field of view that can be obtained with a given telescope. However, focal reducers have seemingly found only limited use for visual work among stargazers.

Aperture masks are used to reduce the effective aperture of a telescope, which many observers feel improves the visual image quality and reduces image motion under conditions of less than ideal atmospheric seeing. This goes along with the claim that small apertures are less affected by poor seeing – supposedly because the turbulence "cells" average around 4–6 inches in width, so that only one or two are over a small telescope at any given instant, whereas many may be over the light-collecting area of a large telescope. Although reducing the aperture can indeed often improve image quality on the Sun, Moon, planets, and double stars in poor seeing, it reduces the resolution and light-gathering power of the telescope as well. The masks can be made from a piece of cardboard simply by cutting a hole smaller than the original aperture itself.

Note that the opening should be on-axis in the case of refractors, and off-axis for reflectors or catadioptrics in order to avoid their central obstructions (which limit the mask's clear aperture to less than the radius of the primary mirror). They are placed over the front of the telescope itself.

Coma correctors do just what the name implies – reduce the amount of coma in fast (f/3 to f/6) short-focus Newtonian telescopes. This is especially useful for the immensely popular large Dobsonian reflectors in use today, most of whose parabolic mirrors operate at f/4.5 and exhibit noticeable flaring of images a short distance from the center of the eyepiece field. Few of these devices are found commercially at present – Tele Vue's Paracorr corrector is one of them and probably the best ever made. As with some of this company's famed wide-angle Nagler series of eyepieces discussed above, its coma corrector costs as much as a small introductory telescope itself! But the improvement in image quality and useable field of view are well worth the price for those who can afford this accessory.

Photographer's cloths are simply dark, opaque pieces of fabric that are thrown over the observer's head and the eyepiece area of the telescope to eliminate stay light and preserve dark adaptation (see Chapter 10). They are available commercially from camera stores and some telescope dealers, and are also easily made. In practice, these can prove a bit suffocating, especially on warm muggy nights, and are sure to raise the eyebrows of any neighbor who happens to see you lurking in the dark!

Telescope covers are used to protect a telescope's sensitive optics (and its mounting) from dust, pollen, moisture, and other airborne contaminants at all times when the telescope is not in use. While they may simply consist of plastic sheeting thrown over the entire instrument, more typically they consist of a fitted plastic cap supplied with the telescope for covering both ends of the tube, in the case of a reflector, or the objective lens or correcting plate for refractors and catadioptrics, as well as eyepieces and finders. The best way to keep a telescope clean is not to let it get dirty! If a cover is not already supplied as standard equipment, a plastic-bowl cover or a heavy-duty shower cap can also be used for this purpose.

Filters of many different types and intended purposes are offered commercially for use on telescopes today. Among these are solar, lunar, planetary, nebula, and light-pollution filters.

With the exception of solar filters, which are placed over the front of the telescope (*never* over an eyepiece, as implied with those supplied on many small imported refractors), the other types screw into the front end of standard eyepiece barrels – virtually all of which today are specifically threaded to take them. I have never been a big fan of filters (except, of course, ones for viewing the Sun!), but they do serve a purpose. Planetary observers have long used them to enhance surface or atmospheric features, and an entire set of them can be purchased for as little as $50. Many deep-sky observers today routinely use nebula and light-pollution filters to increase the visibility of faint objects. These are much more specialized and difficult to manufacture than are planetary filters, with single units beginning at $50 and up. It's perhaps best to use your new telescope for a while to see where your interests lie before investing in them. Full-aperture optical-glass solar filters run from about $60 to nearly $150, depending on aperture, and are an absolute *must* for observing the Sun. Less expensive but still safe Mylar® versions are also widely used.

Micrometers are devices for measuring the angular size or separation of celestial objects (usually in arc-seconds) and their relative positions (or position angle) on the compass heading in degrees with a telescope. Of the many different types in use, the filar micrometer is the traditional such device. The few available commercial models run from around $600 to several thousand dollars, depending on features (such as digital readouts). Another form that's becoming more popular today and is much more affordable is the reticle eyepiece micrometer, which costs about the same as a good eyepiece. Micrometers are most often used in measuring the separations and position angles of double stars (especially binary systems), an activity ideally suited to amateurs looking for a useful observing program to pursue. For more information about micrometers and their application to double stars, see *Observing and Measuring Visual Double Stars* by Bob Argyle (2004) and my own *Double and Multiple Stars and How to Observe Them* (2005), both published by Springer.

Photometers measure the apparent brightness or magnitude of celestial objects (particularly stars) in visual or other wavelengths, generally employing sensitive photocells and electronic circuitry. For the amateur astronomer, they find most application in following the changes in brightness of variable stars. Commercial units are few and far between, and as a result many observers have built their own devices.

Spectroscopes use one or more prisms or a finely ruled diffraction grating to separate the light from celestial objects into its component colors or wavelengths. This makes it possible to glean such amazing physical information about them as their temperatures, compositions, sizes, and rotational and space velocities. For amateur use, the fun is seeing the absorption lines and bands in the various spectral classes of stars. In years past, Edmund marketed an imported eyepiece spectroscope that became very popular and is still to be found on the used market. Today, Rainbow Optics among a few others offers a visual star spectroscope that fits over a standard eyepiece – one capable of showing not only the absorption lines and bands in the brighter stars but also emission lines if present. The visual model sells for $200 while one that includes photographic and CCD imaging capability as well goes for $250. Readers interested in learning more about visual spectroscopes and stellar spectroscopy should consult Mike Inglis' excellent book *Observer's Guide to Stellar Evolution* (Springer, 2003).

Astrocameras come in many different types and varieties, ranging from basic 35-mm film cameras riding piggyback on telescopes for wide-angle shots of the sky to special cameras designed for prime-focus or eyepiece-projection photography through the telescope itself. (Unitron in its early days offered a superb astrocamera for these latter forms, which can still occasionally be found on the used market.) This is a vast and complex field – yet one that can be very rewarding, given lots of patience and practice. Amateur astronomers today are routinely taking spectacular color images of celestial wonders that rival those from the large professional observatories themselves. Even common digital cameras are now being widely used to do astro-imaging through telescopes. But film photography itself is a field that's rapidly declining in favor of CCD and video imaging (see below). A plethora of practical guides covering both conventional and electronic astroimaging are available today for the amateur astronomer. An excellent source for many of these is Sky Publishing Corporation's catalog, available by mail or on-line at www.skyandtelescope.com. Pricing for cameras intended for sky-shooting is about the same as for those used in conventional ground-based photography, since they are essentially the same equipment. But here I should like to offer a word of advice. If you are new to astronomy, before plunging into astroimaging of whatever type, spend the better part of a year seeing the real sky – that of all four seasons – with your own eyes rather than that of a camera! (And in this regard, see the discussion concerning the "photon connection" in Chapter 14.)

CCD and video imagers use charge-coupled devices (CCDs) and either eyepiece video cameras or common webcams, respectively, to photograph the heavens through telescopes. CCD imaging in particular has virtually replaced conventional film photography at most of the world's major research observatories today owing to its immensely faster speed (or "quantum efficiency") and dynamic range, and the fact that the images collected can be immediately viewed and processed electronically using sophisticated computer software. Exposure times of minutes or even seconds now show what previously took hours employing the fastest films. And these devices have now become widely available to amateurs as well. Basic units are surprisingly affordable; Orion offers a black and white Electronic Imaging Eyepiece camera that displays pictures from the telescope directly onto a TV screen, VCR, or camcorder for $65 and a color version for $120.

Meade pioneered affordable CCD imaging systems for their telescopes, including the very popular and easy-to-use Deep Sky Imager with Autostar Suite processing software that sells for just $300 and promises successful images the first night out! But here again, see the advice given in the section above on astrocameras.

Computers have become important tools in observational astronomy, as in almost every other area of modern life. While they can hardly be considered an "accessory" for the telescope in the normal sense of the word, they are used for such tasks as helping to find and track celestial objects, and in making, processing, and displaying observations by electronic imaging – all typically done remotely from the observer's living room, den, or office. While all this certainly has its place, such "robotic" remote observing, however satisfying and comfortable (especially in muggy or frigid weather), is *not* seeing the real sky – and is often not even being out *under* the real sky! Once more, to gain a perspective on this issue, please see the discussion concerning the "photon connection" in Chapter 14.

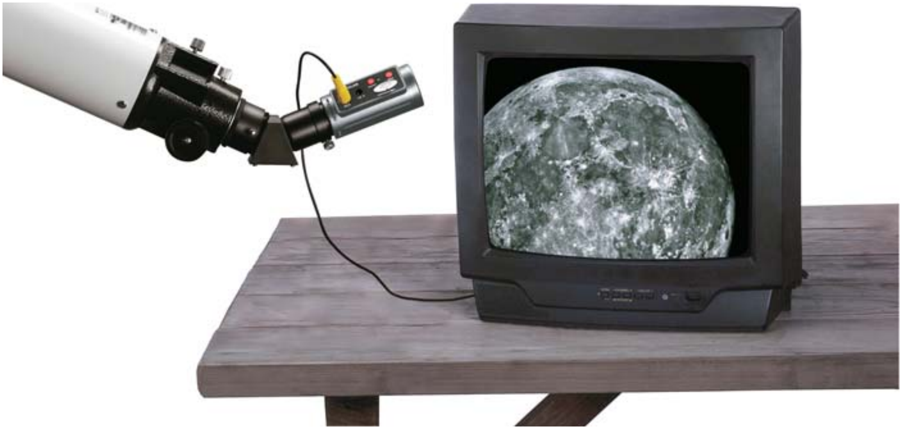

Figure 7.9. Electronic eyepiece cameras (both black & white, and color) like that seen here make video imaging easy and affordable today. The camera output can be displayed in real time on a monitor, or recorded on a VCR or camcorder for viewing later. Courtesy of Orion Telescopes & Binoculars.

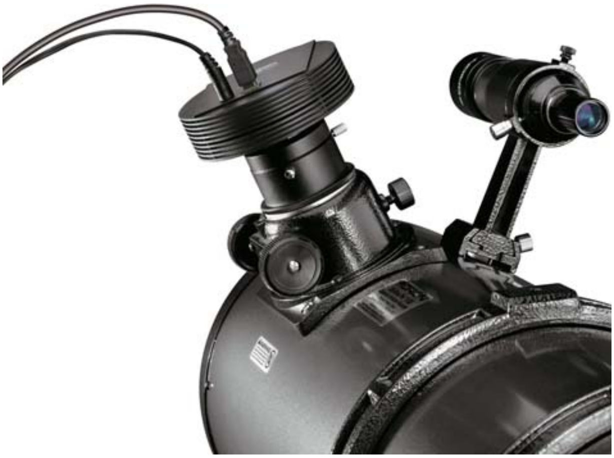

Figure 7.10. Shown here is a CCD color imaging camera attached to the focuser of a Newtonian reflector. This one is intended primarily for use on deep-sky objects, while other models are available for imaging solar system targets such as the Moon and planets. In either case, the output is fed into a PC for viewing and processing. These state-of-the-art devices make it possible for amateur astronomers to routinely take pictures rivaling those of professional observatories! Courtesy of Orion telescopes & Binoculars.

Setting circles/Go-To/Push-Pull-To/GPS systems are all devices designed to help the observer find celestial objects, employing various levels of sophistication. Some are included on certain telescopes as standard equipment, while in other cases they are add-ons to be ordered along with the telescope itself. As already mentioned in Chapter 3, the traditional use of mechanical setting circles (and subsequently digital ones) on equatorial mountings displaying Right Ascension and Declination to find celestial targets is rapidly disappearing in favor of these state-of-the-art computerized systems. These make it possible (after initial setting on two or three bright alignment stars) to locate thousands of objects essentially at the touch of a few buttons while at the same time providing excellent tracking capabilities. In the case of Push-Pull-To systems (as offered by Orion on its IntelliScope series of Dobsonian reflectors), after the target name or designation is entered on the keypad, the observer moves the telescope by hand (instead of with drive motors) until a "null" or zero reading is displayed on the LCD display. The object will then be in the eyepiece's field of view. These devices make finding things relatively easy and are especially helpful under light-polluted skies or when there's little time available to search for elusive targets. They certainly do serve a purpose and are firmly entrenched in modern-day amateur astronomy. Again, however, for us purists, automated acquisition takes much of the fun out of celestial exploration and typically leaves the observer not knowing the sky. We prefer old-fashioned, leisurely star-hopping from bright naked-eye stars to the object sought after using a good star atlas – enjoying the many delightful and unexpected sights encountered along the way!