Chapter 2

Binocular Basics

Seeing Double

It's commonly recommended that before someone buys a telescope they should first get a good pair of binoculars. And with good reason! Not only are they much less expensive, and also are ultra-portable and always ready for immediate use, but they can provide views of the heavens unmatched by any telescope! This results primarily from their wonderfully wide fields of view—typically 5° or 6° (10- to 12 full-Moon diameters!) of sky in extent compared to the 1° fields of most telescopes even used at their lowest magnifications. There are also ultra-wide-field models that take in a staggering 10° of sky. Binoculars are ideal for learning your way around the heavens and for exploring what lurks beyond the naked-eye star patterns.

But there's another aspect of "seeing double" (as binocular observing is sometimes referred to) that makes these optical gems unsurpassed for stargazing. And that's the remarkable illusion of depth or 3-Dimensionality that results from viewing with both eyes. This is perhaps most striking in the case of observing the Moon, which looks like a huge globe suspended against the starry background—especially during an occultation, when it passes in front of a big bright star cluster like the Pleiades or Hyades. And see the discussion in Chap. 13 about apparent depth perception in viewing the Milky Way's massed starclouds. Finally, aesthetics aside, it's been repeatedly shown that using both eyes to view celestial objects improves image contrast, resolution and sensitivity to low light levels by as much as 40 %!

J. Mullaney, *A Buyer's and User's Guide to Astronomical Telescopes and Binoculars*,
The Patrick Moore Practical Astronomy Series, DOI 10.1007/978-1-4614-8733-3_2,

Specifications

A binocular consists essentially of two small refracting telescopes mounted side-by-side and in precise parallel optical alignment with each other. Between each of the objective lenses and eyepieces are internal prism assemblies that serve to not only fold and shorten the light path, but also to provide erect images. (Inexpensive "imitation binoculars" like opera and field glasses use negative eyepiece lenses instead of prisms to give an erect image, resulting in very small fields of view and inferior image quality.)

The spacing between the optical axes of the two halves of a binocular (known as the *interpupilary distance*) can be adjusted for different observer's eyes by rotating the tubes about the supporting connection between them. If this isn't properly set to match the separation between your eyes, two overlapping images will be seen. In this same area is a *central focusing* knob that changes the eyepiece focus for both eyes simultaneously. An additional *diopter focus* is provided on most binoculars (typically on the right eyepiece) to compensate for any differences in focus between your two eyes. Once this adjustment has been made, you need only use the main focus to get equally sharp images for both. Some lower-grade binoculars offer a rapid focusing lever; while allowing for quick changes in focus, the adjustment is too coarse for the critical focusing required in viewing celestial objects.

Two numbers are used for the specification of a binocular. The first is the *magnification* or power (×), followed by the *aperture* or size of the objective lenses in millimeters (mm). Thus, a 7×50 glass magnifies the image seven times and has objectives 50 mm (or 2-in.) in diameter. Another important parameter is the size of the *exit pupil* produced by a binocular, which is easily found by dividing the aperture by the magnification. This means that 7×50 binoculars produce bundles of light exiting the eyepieces just over 7 mm across. (These bundles can actually be seen by holding a binocular against the daytime sky at arm's length. You'll find two circles of light seemingly floating in the air before you.)

The pupil of the fully dark-adapted human eye dilates or opens to about 7 mm, so that in theory all the light a 7×50 collects can fit inside the eye. (This binocular is the famed "night glass" developed long ago by the military for optimum night vision.) But in practice, not only does the eye's ability to open fully decrease with age, but light pollution and/or any surrounding sources of illumination reduce dilation as well. Only under optimum conditions can the full light grasp of a 7×50 be utilized. Thus, a better choice for astronomical use is the 10×50, which gives a 5 mm exit pupil and slightly higher magnification (which also improves the amount of detail seen). A 7×35 or 6×30 binocular also provides a 5 mm pupil, but these smaller sizes have less light gathering power and resolution than does a larger glass.

Another feature of binoculars to look for is *eye relief*. This is the distance you need to hold your eyes from the eyepieces to see a fully illuminated field of view. This ranges from less than 12 mm for some models to over 24 mm for others. If the

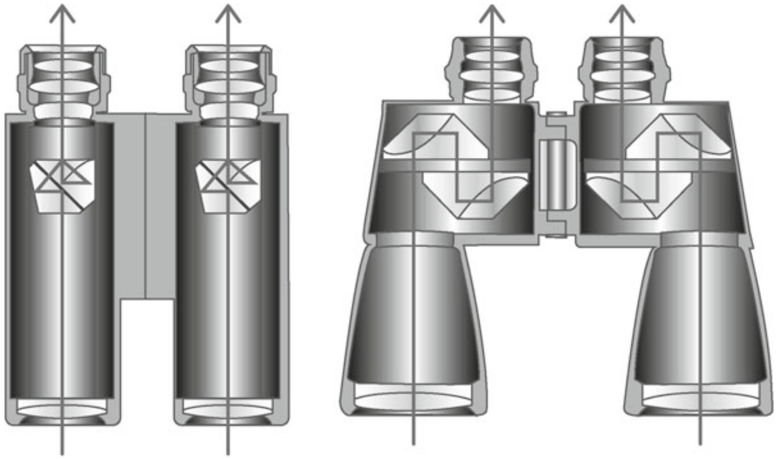

Fig. 2.1 Optical light path through a roof prism binocular (*left*) and a Porro prism binocular (*right*). Although bulkier than the former, the latter is preferred for astronomical viewing due to its superior image quality

relief is too short, you'll have to "hug" the eyepieces to get a full field of view and if too long you may have difficulty centering the binoculars over your eyes. A good value is around 15–20 mm, especially if you wear glasses. If you do, longer eye reliefs are preferred over shorter ones. Note here that if you do wear glasses to simply correct for near or far sightedness (rather than for astigmatism), you can remove them and adjust the focus to compensate. Most binoculars have fold-down rubber eyecups to allow getting closer to the eyepieces if necessary; these also keep the eyes from touching the glass surfaces and (depending on style) help keep out stray light.

While just about any size binocular can be and has been used for stargazing, the 7×50 and 10×50 are the most popular choices among observers. (See also the section below on giant binoculars.) Note too that 10× and 50 mm are about the highest magnification and largest aperture that can be conveniently held by hand; more power and/or bigger sizes require tripod mounting the binocular in order to hold it steady. (It should be mentioned here that *zoom binoculars* are also widely available. While offering a range of magnifications with the flick of a lever, these generally have inferior image quality and fields of view that change as the power changes.) Good stargazing binoculars in the above size range are available for around $100 from a number of companies, including Bushnell, Celestron, Eagle Optics, Nikon, Oberwerk, Orion, Pentax and Swift. (See Chap. 8 for contact information on these and many other manufacturers.) Prices for premium astronomical glasses typically run between two and three times this amount (Fig. 2.1).

Prism Types and Optical Coatings

There are two basic types of prism assemblies used in quality binoculars today—the more modern and compact *roof prism* style, and the traditional *Porro prism* design. The latter yields brighter, sharper and more contrasty images than does the former, but at the expense of more bulk and weight. Porro's give binoculars their well-known "zig-zag" shape while roof's have a "straight through" streamlined appearance to them. For a variety of optical imaging reasons, Porro prism binoculars are preferred for astronomical use. But roof prism glasses can certainly be turned skyward as well.

Another factor here is the type of glass used to make the prisms themselves. Better quality binoculars use *BaK-4 barium crown glass*, while less expensive models use *BK-7 borosilicate glass*. BaK-4 prisms transmit more light, producing brighter and sharper images, while BK-7 prisms suffer from light "fall-off" resulting in somewhat dimmer images. If not stated on the binocular housing itself (where the size, magnification and field of view are printed), it's easy to check which kind of glass has been used. Hold the binocular against the daytime sky at arm's length and look at the circles of light (exit pupils) floating behind the eyepieces. BaK-4 prisms produce perfectly round disks while BK-7 prisms give diamond-shaped ones (squares with rounded corners) having grayish shadows around the edges.

While discussing prism types, mention should also be made of optical coatings. Untreated glass normally reflects 4 % of the light falling on it at each surface. By applying *antireflection coatings* (typically magnesium fluoride) to the objective lenses, eyepieces and prisms, light transmission through the binocular can be increased significantly. Less expensive binoculars state that they have "coated optics," which typically means that only the outer surfaces of the objective and eyepiece lenses are coated; their inner surfaces and the prism assemblies are not. This can easily be checked by looking into the objective end of a binocular and catching the reflection of a bright light or the daytime sky on the glass surfaces. Coated optics typically have a bluish-purple cast to them (this may appear pink if the coating is too thin and green if too thick), while untreated surfaces will give off white reflections. Quality binoculars specify that they have "fully coated optics," meaning that *all* glass surfaces have antireflection coatings on them. The term "fully multicoated optics" will be found on premium glasses, indicating that several different coating layers have been applied on all glass surfaces to reduce light loss even further. Note that the reflections from such coatings seen looking into the front of the binocular typically have a greenish cast to them, mimicking those seen in overly thick coatings mentioned above (Fig. 2.2).

Image-Stabilized

A fairly recent development first introduced by Canon, the well-known camera manufacturer, is that of *image-stabilized* (or IS) *binoculars*. Anyone who has looked through a typical binocular knows firsthand how difficult it is to hold it

Fig. 2.2 This wide-field 10×50 Porro prism binocular is an ideal instrument for general stargazing purposes. Note the coated objective lenses and the cap covering the tripod adapter receptacle located on the bridge joining the two optical barrels. Craters on the Moon, Venus' crescent, Jupiter's four bright Galilean satellites, and awesome views of the Milky Way are just some of the wonders visible through such glasses. Courtesy of Orion Telescopes & Binoculars

steady. Even reclining on a lawnchair and supporting both arms, a person's breathing is enough to make the image dance around. (And just imagine attempting to use binoculars on a rocking boat at sea!). Here, roof prism assemblies are essentially "floating" in sealed oil-filled housings. Microprocessors located within each barrel detect any movement of the observer and send a correcting signal to the prism assemblies to compensate, keeping the image stationary. Available models typically range from10×30 mm to 18×50 mm in size and are quite costly, with prices beginning around $500 (that of a decent telescope itself!). Fujinon has also introduced an image-stabilized binocular into its extensive line of high-end glasses. Called the Techno-Stabi, this 14×40 glass is priced at over $1,000. Nikon and Zeiss are also among the companies now offering image-stabilized binoculars. (The latter actually advertises a 20×60 glass priced at $6,000!)

Minis and Giants

Binoculars are available in an amazing range of sizes. At the small end are *mini binoculars*—miniature roof prism glasses compact enough to fit in your shirt pocket! Obviously apertures here are quite limited (typically 25 mm or less in size); while they will show the Moon's surface features, they are not at all suited for viewing fainter celestial wonders. At the other extreme are *giant binoculars*, with apertures ranging all the way up to 150 mm (6-in.) in size! A giant is generally taken to

Fig. 2.3 A 15×80 giant binocular for serious two-eyed stargazing! Note, as seen here, that such large glasses must be tripod-mounted since they are much too heavy to hold steady by hand. Jupiter's disk, the egg-shaped outline of Saturn and its rings, plus hundreds of spectacular deep-sky objects (including the brighter galaxies) lie within reach of giant binoculars. Courtesy of Orion Telescopes & Binoculars

mean any glass 60 mm or larger in aperture. Among the most common and popular of these are 80 mm binoculars, having magnifications ranging from 11× to 30×. Prices here are much higher than for standard binoculars, running from around $200 to nearly $500. There are exceptions however. Celestron offers a 15×70 glass $90, and Oberwerk 8×56 and 11×56 ones (nearly "giants") for $100. The latter's true giant 25×100 binoculars run between $400 and $600.

There's also the important issue of weight, which for an 80 mm binocular is typically 5 lb or more. This makes giant glasses all but impossible to hold by hand, requiring them to be mounted on a sturdy tripod. Virtually all binoculars—not just giants—have a provision for adapting them to a tripod mounting. There's typically a cap located at the objective-end of the central pivot support covering a standard ¼-20 screw receptacle. This takes an "L-shaped" or "finger" clamp (available from most binocular suppliers) that attaches the binocular directly to the tripod head for support. Before purchasing any binocular, you should carefully check the manufacturer's specifications to see if it is tripod adaptable. In recent years, sophisticated cantilevered or "parallelogram-style" binocular mounts have also become commercially available, but these can cost as much as a giant glass itself (Fig. 2.3).

Binocular Telescopes

Perhaps the ultimate in giant glasses is the advent of *binocular telescopes*. These hybrids are essentially two full-sized such instruments mounted in parallel side by side, with special transfer optics to bring their individual images close enough together to view with both eyes as for conventional binoculars. Initially appearing as homemade curiosities at star parties and telescope-making gatherings (in sizes up to a whopping 17.5-in. in aperture!), they were soon followed by commercial units introduced by JMI (Jim's Mobile, Inc.) called "Reverse Binoculars" having apertures ranging from 6- to 16-in.. As might be expected since two telescopes are involved, prices here are truly astronomical. Their 6-in. binocular telescope currently goes for around $3,000 and the 16-in. for $13,000. Anyone who has looked through one of these optical marvels will tell you that the views are definitely worth the price! (Figs. 2.4 and 2.5).

Fig. 2.4 A 6-in. binocular telescope. The eyepieces and controls are located between the top ends of the tubes, as seen here. Viewing the sky through two 6-in. reflectors (one for each eye!) is an experience never to be forgotten. Courtesy of JMI Telescopes

Fig. 2.5 A 16-in. giant binocular telescope. The views through dual big reflectors of this aperture must be seen to be believed! Many celestial objects appear dramatically suspended three-dimensionally in space (as is the case with binocular viewing in general). Courtesy of JMI Telescopes

Sources for all of the various types of binoculars discussed above (and others) will be found in the comprehensive listing of manufacturers and suppliers given in Chap. 8. Their sites should be carefully studied (or their latest print catalogs), which provide detailed specifications and current pricing for all available models. And in conclusion, if you're looking for a good guide devoted entirely to binoculars and their use, an excellent choice is Philip Harrington's *Touring the Universe through Binoculars* (John Wiley, 1990).