Homebuilt Right-Angle Binoculars

One binocular user's cure for sore backs and stiff necks. | **By Glenn LeDrew**

Not long after receiving my first telescope as a Christmas gift at the age of 13, I came to resent squinting like a Cyclops through a single eyepiece. Even before I understood why, I felt that two-eyed viewing offered more. Much later, I learned that using both eyes allows one to see nearly 0.4 magnitude fainter. This may not sound like much, but the improvement is undeniable.

Binoculars eventually became my instrument of choice as I grew to appreciate the large-scale splendor of the sky. To overcome the various aches and pains induced by craning my neck to view the sky I tried a number of binocular supports, but this extra equipment negated one of the great benefits of binocular astronomy — extreme portability. It seemed to me that lightweight, right-angle binoculars could be the ideal solution, and so I set about building such an instrument.

Design Choices

Functional binoculars can be made from two finderscopes mounted side by side. The versatility of such an instrument is increased if it can accept 1¼-inch oculars to obtain a range of magnification, though unless the objective lenses are excellent, acceptable performance beyond two or three times the magnification of the original instruments is unlikely.

The design I settled upon consists of a pair of small telescopes equipped with Amici prisms to provide a correct, noninverted view. The specifics were largely determined by the components I already had, in particular, a pair of salvaged eyepieces. Most telescope builders and optical tinkerers have small collections of bits and pieces tucked away in boxes just waiting for a suitable project.

For me the Holy Grail of visual astronomy is a wide apparent field of view. For my binoculars, a high-end ocular like the Tele Vue Nagler would be ideal, but the cost for two is beyond my means. Fortunately, I already owned 7 × 32 Bushnell Xtra-Wide binoculars that I had bought for about $200 Canadian ($130 U.S.). The exciting feature of these binoculars is the 85° apparent field of their oculars. I measured their focal lengths to be 15 millimeters and their field-stop diameters an eye-popping 24 mm. While not even remotely near the quality of Naglers, these eyepieces (with built-in helical focusers) cost significant-

Glenn LeDrew is shown here using the 9 × 35 binoculars he built using salvaged optics and miscellaneous hardware. The right-angle configuration makes viewing a comfortable pleasure free of the back and neck strain induced by ordinary binoculars. Unless otherwise noted, all images are courtesy the author.

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LeDrew's binoculars consist of a pair of carefully aligned optical trains, each having an eyepiece, Amici prism, and objective lens.

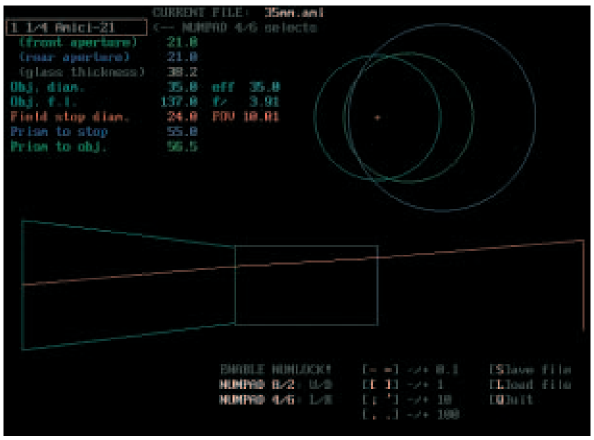
ly less than a single premium model.

If you choose to purchase oculars and are not as fanatical about wide apparent field as I am, Erfle eyepieces with 65° fields and focal lengths in the 25- to 16-mm range will provide nice views at a reasonable price. So will regular Plössls if you are willing to live with a standard 50° apparent field of view. Even oculars salvaged from regular binoculars will work — not surprising, considering their original use!

Prism Considerations

Not wanting mirror-reversed views, I bought two right-angle correct-image (Amici roof prism) star diagonals for 1¼-inch focusers, at a cost of $70 Canadian ($45 U.S.) each. These can be obtained from many astronomical-equipment suppliers. Alternatively, optical surplus stores often sell unmounted prisms for lower prices. These can be simply glued to supports during assembly. If you don't mind mirror-reversed views, a pair of prisms salvaged from old porro-prism binoculars will serve you well.

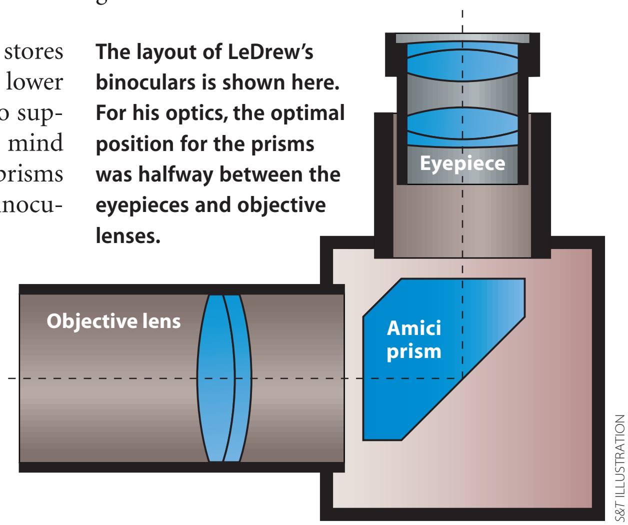
To avoid vignetting (edge-of-field dimming), typical binocular eyepieces have field stops no larger than the clear aperture of the rear prism. If the eyepiece can be placed farther back, this restriction can be eased somewhat. Like most Amici prisms designed for use in telescopes, mine have rather restricted clear apertures of 21 mm — significantly smaller than the field stops in my chosen eyepieces. But correctly spaced, this prism-eyepiece combination should still work. To find the optimum separation between prism and field stop, I wrote a computer program to graphically lay out the entire optical arrangement and show edge-of-field vignetting. This software, and instructions for use, is available for downloading at SkyandTelescope.com/resources/software/article_328_1.asp.



A schematic of the author's optics is shown in this screen grab. The program calculates the relative spacing of the optical components for homebuilt binoculars.

Before running the program you have to choose a pair of objective lenses. Those in my Xtra-Wide binoculars were not suitable due to their extremely short focal ratios, which would have delivered sharp views only in the center of the field of view. Luckily, I had a pair of 35-mm objectives from other binoculars left over from an earlier project. At f/4 they proved to be a good choice, since my software calculated that the edge-of-field illumination would be decent — about 60 percent (many commercial binoculars have even more vignetting than this). The best position for the prisms turned out to be almost exactly midway between the objectives and eyepieces — a strange-looking configuration at first glance.

Once I had made my choices, I built a crude mockup held together with tape. Even then the performance was noticeably superior to the original Xtra-Wide binoculars! Encouraged, I proceeded with greater confidence.



The layout of LeDrew's binoculars is shown here. For his optics, the optimal position for the prisms was halfway between the eyepieces and objective lenses.

Construction Details

The "body" of my binoculars consists of pieces of 3-inch-square aluminum tubing cut to 2-inch lengths. Each prism is supported and positioned so that the center of the prism is exactly in the center of the aluminum body (see the diagram above), thus simplifying the overall layout. As shown in the photographs on the bottom of the next page, the prisms are secured in their supports (⅛-inch-thick angle aluminum) by shortened lengths of the star diagonal's original 1¼-inch barrels, which now serve as locking

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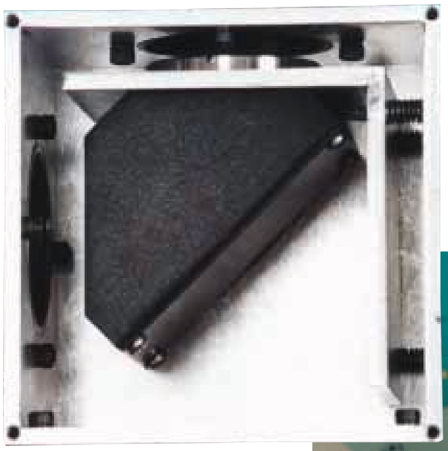
LeDrew equipped his binoculars with a simple mechanism for adjusting interocular spacing. The hand bolt passes through the slotted hole in the mounting plate and threads into the underside of the right-hand binocular half. When the bolt is loosened, the right half can slide from side to side within the bracket while maintaining collimation with the left half. (Note the six ¼-20 holes on the bottom plate; these are for mounting the binoculars on a photographic tripod.)

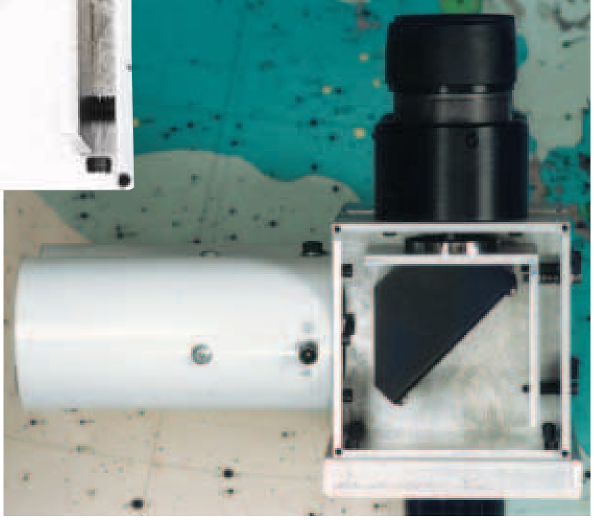
rings. Each prism support floats on three spring-loaded screws arranged in an L configuration that provides easy left-right and up-down collimation adjustment. It was not necessary to blacken the body interiors because the prism apertures themselves function as very effective baffles. I used machined black Delrin plastic to couple each eyepiece to its respective binocular half.

The barrels for my binoculars were cut from an old 50-mm refractor telescope tube. Two pairs of adapter collars were turned on a lathe — one to support the objective cells in the tubes and the other to attach the tubes to the binocular body. The tubes extend well beyond the objectives to provide a good measure of protection from dewing. To prevent internally scattered light, I cut threads to act as baffles on the inside surfaces of the objective-tube coupling adapters and in the Delrin eyepiece-assembly adapters.

I could have simplified the binoculars if I had a fixed interpupillary spacing set for my eyes only, but I wanted to be able to share the views. To accommodate this desire, the left half of the binoculars is permanently attached to the base plate, while the right half can slide from side to side but is constrained from lateral rotation by a pair of small vertical plates. A slotted hole in the base plate passes a screw with a knob that fixes the right telescope in position when tightened. Even with frequent interpupillary adjustment the binoculars hold collimation quite well. For tripod mounting, I also drilled and tapped several ¼-20 holes into the base plate.

The minimum interocular spacing is equal to the maximum width of each telescope — in my case 52 mm. The maximum spacing is, of course, up to the designer. I eventually plan to utilize the objectives from 20 × 60 binoculars, which should work out fine since my eye spacing is 67 mm.





With the side cover removed, the configuration of the prism assembly becomes obvious. A modified correct-view star diagonal directs the light from the objective to the eyepiece. *Close-up:* The star diagonal is mounted in a spring-loaded bracket for collimation adjustment.

Collimation Matters

Proper collimation in binoculars is critical. Poorly collimated units produce eye fatigue and headaches. There are three factors in successfully merging a pair of images:

1. Both binocular halves must be within 2 percent of the same magnification.
2. The optical axes emerging from the oculars should be as close to parallel as possible.
3. Neither image should be rotated about the optical axis with respect to the other by more than ½°.

These three conditions are addressed by the use of optics salvaged from a single pair of binoculars (or same-model components, such as telescope eyepiece pairs), a provision for user-adjustable

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collimation, and accurate machining of the various parts. Unless it has very large errors, a single Amici prism will not by itself introduce image rotation — a significant advantage over normal multi-prism binocular designs. As long as the bodies are made square and true and the prisms are mounted carefully on their supports, good collimation should be easy to attain.

As with a Newtonian reflector, proper diagonal alignment must be achieved. For my binoculars I did this for one side and then adjusted the other relative to it. I simply eyeballed the position and orientation of the left prism while adjusting its collimation screws. Later, I viewed a starry field and made fine adjustments to ensure that there was no on-axis flaring and that off-axis aberrations were symmetrical about the center of the field. Once the left side was set up, it was time to align the right side with respect to it.

In daylight, I mounted the binoculars on a steady tripod and aimed them at a house several hundred meters away. Looking through the binoculars with my eyes positioned some 20 centimeters (about 8 inches) from the eyepieces, I viewed the house through the now-constricted field of view. Slightly tweaking the collimation screws of the right prism quickly fused the pair of images into good rough alignment.

To ensure absolute collimation I interposed a piece of glass from a small picture frame between my eyes and the oculars to act much like a beamsplitter. So positioned, the flat glass would provide a collimated reference image of the distant target. Resting the glass motionless against the oculars and tilted at 45°, I could simultaneously see a dim reflection of the house (at naked-eye magnification) superimposed against the magnified view in the binoculars. Because the reflection in the glass is absolutely collimated with itself, it provides a perfect reference for the binocular view. In other words, if I adjust the collimation until I see a fused image in the binoculars *and* from the glass at the same time, the binoculars must be collimated. Once the collimation is set, future adjustments need be made only for the right half of the instrument.

Viewing Pleasure

My current combination of objective and eyepiece yields 9 × 35-mm binoculars with 4-mm-diameter exit pupils. The measured field of view is a whopping 10°. Compare this to the more typical 5° to 7° fields of regular binoculars! Granted, the edge-of-field sharpness produced by the eyepieces I chose is not very good, but I consider this unimportant in low power, ultrawide-field instruments, particularly ones that are hand-held. As long as one is looking toward the center of the field, the eye's off-axis resolution is poor enough that most aberrations will not be intrusive.

Over the years I've come to prefer smaller exit pupils too. Besides reducing the effects of astigmatism in my eyes, exit pupils smaller than 5 mm give the sky a pleasing, dark shade, which is even more desirable when light pollution is present.

With porthole-like views, my binoculars rule supreme for observing the very large and subtle dust clouds located well away from the bright band of the Milky Way. Some of these structures extend for 15° to 20°; a neat swath of sky laced with many such clouds lies just north of the Milky Way in Camelopardalis, Cassiopeia, and Cepheus. Of course, simply scanning the Milky Way itself is an endlessly rewarding, wondrous experience.

Thanks to these right-angle binoculars, an aching back, stiff neck, and tired arms are things of the past. Exploring the sky is now wondrously comfortable and doesn't require a single piece of ancillary equipment. Has it been worth the cost and effort? Absolutely!

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