A Bent Rich-Field Refractor

This twist on an old favorite provides new levels of viewing comfort. By Robert Ayers

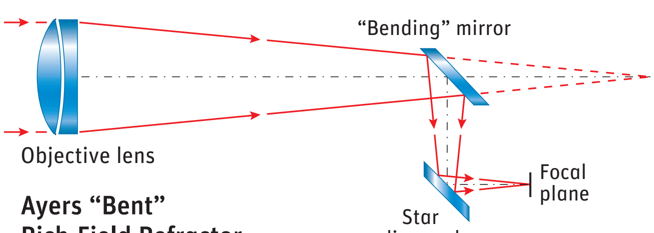
RICH-FIELD TELESCOPES (RFTs) have always been popular with amateur astronomers seeking expansive views of the heavens. When mated to a simple altazimuth mount and equipped with a modern nebula filter, such instruments really come into their own, displaying remarkable views of large objects like the Veil and North America Nebulae.

Short-focus refractors make good RFTs because they can deliver low magnification and a large exit pupil without the "missing-middle" problem that plagues compact reflectors with their typically large central obstructions. Thankfully, you don't need an expensive apochromatic objective lens either, since the chromatic aberration inherent in short-focus achromats isn't noticeable at the low magnifications typical of RFTs.

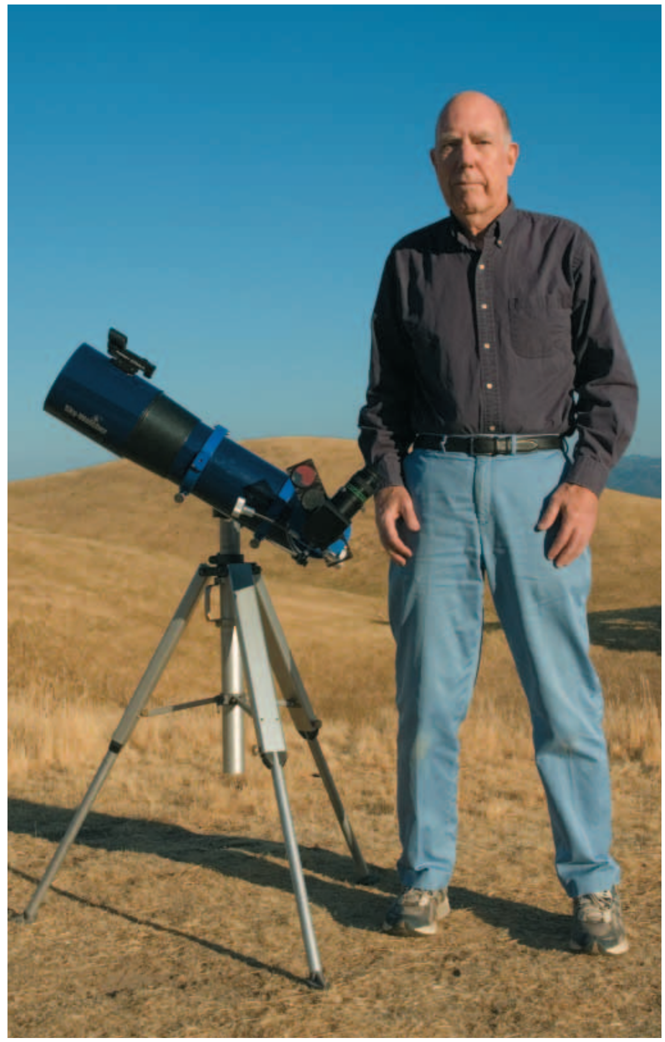
The Devil in the Details

All refractors — including compact, short-focus instruments on altazimuth mounts — have one major ease-of-use issue: the eyepiece position is often awkward, even for scopes equipped with a star diagonal. If you set the height of your tripod to accommodate viewing near the zenith, the eyepiece is too high when the scope is pointed toward the horizon. Conversely, a tripod configured for viewing objects low in the sky is poor for targets high overhead. The reason a refractor's eyepiece height varies so widely is because the focuser sits at the end of a lever arm positioned far from the altitude axis of the mount. This simple realization eventually led me to the "bent" refractor described here.

While there are already plenty of folded-refractor designs, I didn't want to build an entire telescope from scratch — my goal was to make my 6-inch f/5 Synta refractor more user friendly. Ideally I could accomplish this with only two folding mirrors so that light loss and costs would be minimized. The configuration I ultimately settled on is an altazimuth refractor whose light path is bent twice at 90° angles. As the diagram below shows, the first bend redirects the light path perpendicular to the optical tube assembly (OTA), while the second bend allows the eyepiece to be tilted to any elevation with respect to the tube. In addition, the two bends eat up enough of the scope's focal length that the focuser is closer to the altitude axis of the mount. As a result, the eyepiece is always at a convenient angle and at a relatively constant height.



Ayers "Bent" Rich-Field Refractor
(Not to scale)



The author stands next to his "bent" rich-field telescope (RFT) — a 6-inch f/5 refractor modified to provide comfortable views no matter where it is aimed in the sky. All photographs are courtesy the author.

Getting Bent

The basic bent-telescope design is quite simple. The only variable is the location of the first bend — you have to figure out how much of the objective's focal length should come after the first mirror. As this mirror is moved closer to the objective, the telescope gets shorter and easier to balance. However, the more you shorten the tube, the big-

The key to the scope's design is the ability to adjust the tilt of the eyepiece independent of the telescope tube's orientation. This is accomplished by adjusting the angle of the RFT's star diagonal.

ger (and more expensive) the diagonal mirror becomes, and the more ungainly the finished telescope looks.

I chose the bend location of my telescope by experimenting with a cardboard model to learn how far away the eyepiece had to be from the main telescope so that my head wouldn't bump into the tube, regardless of where the scope was pointing or which eye I was using.

Originally, I planned to configure the scope so that the focuser would be located at the altitude axis of the mount. This arrangement was particularly appealing since it meant the eyepiece would always be at the same height regardless of where the scope was aimed. Unfortunately, such a setup would make the instrument objective-heavy and require a substantial off-axis counterweight to compensate for the imbalance. After some experimentation, I found that so long as the eyepiece height varies by no more than a few inches, there is no need to complicate matters with a counterweighting system.

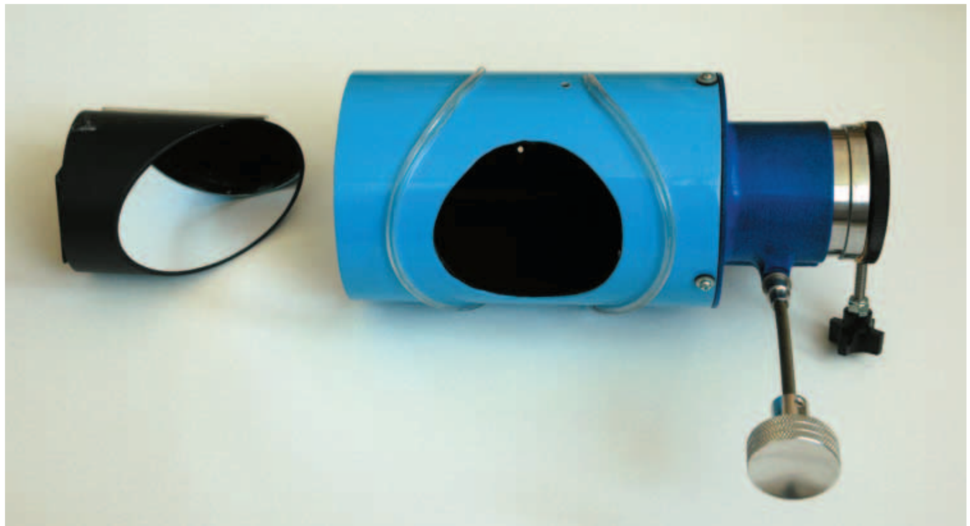
One design aspect that I studied carefully is how to minimize vignetting. RFTs are normally used with low-power eyepieces that typically have field stops in the range of 30 to 42 millimeters (1.2 to 1.6 inches) in diameter. To provide the illumination necessary for such eyepieces, you have to ensure that there are no choke points in the light path. The easiest way to do this is to make a scale drawing of your scope with all its baffles and accessories accounted for. Keep in mind that a 2-inch star diagonal typically has a 45-mm opening and that 2-inch filters (which I enjoy using) usually have clear apertures of only 43 mm. You will also have to take into account the inside diameter of your instrument's focuser. Although my scope's focuser is a 2.7-inch model, I do get some minor vignetting at the edge of the field because of my filter slide. In actual use though, I never notice it.

Construction Details

My bent RFT is based on a modified 6-inch f/5 refractor OTA. I utilized a short length of spare tubing (the "cross tube") to house the bending mirror and to attach the focuser — an item from a 5-inch refractor tube assembly that I had lying in my parts bin. The bending mirror is a 4-inch (minor axis) Newtonian diagonal in a diagonal cell. The support for this mirror can be simple and robust because, unlike in a Newtonian reflector, only the mirror itself is in the light path. I used an angle iron attached to the cross tube with a bolt and a wing nut to hold the diagonal-mirror assembly in place. This bending mirror directs light to a standard 2-inch mirror star diagonal inserted into the focuser.

The only challenging aspect of the construction was mating the two tube segments at right angles — the cutout in the main tube where it attaches to the cross tube isn't even easy to draw! Luckily, I have a friend with a milling machine

As this series of photos demonstrate, the eyepiece of Ayers's telescope remains at a comfortable height and angle, regardless of where the instrument is aimed.



Housed in a short length of tubing is the refractor's "bending mirror" — a Newtonian-reflector diagonal that directs light from the objective lens to a star diagonal (not shown) inserted into the focuser.

who cut the required arcs at the end of the refractor tube. I cut the hole in the side of the cross tube with a nibbler. Two lengths of plastic tubing (slit lengthwise) cover the edges of the rough-cut arcs in the main tube and provide the cross tube something with a little give to seat against. The two tubes are attached with bolts at the top and bottom (as seen in the picture on page 114).

If you don't have a short length of suitable tubing, or if you think cutting the necessary curves is beyond your abilities, you can house the bending mirror in a wooden cube mounted to the end of the OTA. It might not look as elegant, but it will work and is simple to make.

Variations and Limitations

Although my design solves a good number of problems, there are practical limits to its utility. For example, this telescope works well only on an altazimuth mount. An equatorial mount will place the eyepiece at uncomfortable positions regardless of how you configure the star diagonal — which undermines the whole point of the design. Furthermore, this kind of scope is impractical unless you use a short-focus instrument. A long tube would require counterbalancing to keep the focuser near the altitude axis, which would significantly diminish the design's ease of use.

Some readers will look at the optical layout and wonder if something similar can be accomplished with a Newtonian reflector. It *could* be done, but because so much of the light path must be diverted out the side of the tube to accommodate the extra bend and the observer's head, you would need to install a very large secondary mirror. This would produce an unacceptable central obstruction; for example, a 6 inch f/5 would need at least a 3.5-inch diagonal!

One modification that does strike me as potentially worthwhile is a Questar-like built-in finder utilizing a second, smaller finderscope objective. If you placed the finder objective (with its own bending mirror either in front or behind it) opposite the focuser, you could then engage the finder by switching the main bending mirror out of the way and allowing the finder objective to feed the eyepiece.

Conclusions

Observing with my bent RFT is a joy. After aiming the scope at my desired target, I sit down, and with a simple adjustment, place the eyepiece at a comfortable viewing position. I observe looking somewhat downward, as I would if I were reading or using a microscope. I also appreciate that since there are two reflections, the telescopic view now matches my star charts. My observing fatigue is minimized, and I can comfortably use the RFT to study challenging "fat faint fuzzies" for extended periods, regardless of their altitude. ✴

An amateur astronomer for more than 50 years, Robert Ayers *majored in astronomy at Harvard University but was attracted to a career in the nascent field of computing. Recently retired, he devotes his time to observing and to supporting astronomical education and research through his Robert Martin Ayers Sciences Fund. He can be reached at astroayers@gmail.com.*