CHAPTER FOUR

Refracting Telescopes

Achromatic

The earliest of telescopes was the *refracting* or *lens* type. Initial versions used a single objective lens to collect and focus the image and a simple eyepiece to magnify it. Single lenses by their very nature have a number of optical shortcomings, chief among these being *chromatic* (or color) *aberration*. This results in light of different colors coming to focus at different points, producing image-degrading prismatic haloes appearing around the Moon, planets, and brighter stars. Another serious problem is that of *spherical aberration* – the inability of a single lens to bring all light rays to the same focus. However, as focal length increases, these aberrations tend to decrease. Attempting to take advantage of this, telescopes became ever longer, reaching unwieldy lengths of up to more than 200 feet in one case! (Galileo made his historic discoveries using small, primitive refractors. And while he did not invent the telescope itself, he's credited with being the first person to apply it to celestial observation – and to publish what he saw.)

It was eventually discovered that color aberrations could be considerably minimized by combining two different kinds of glass in the objective, leading to the independent invention of the *achromatic refractor* by Chester Hall and John Dolland. This form is still in wide use to this very day; all the refractors in the world's major observatories (the largest being the 40-inch Clark at Yerkes Observatory) and most of the instruments in amateur hands are basic achromats.

Most common in the latter category is the famed "two point four" or 2.4-inch (60-mm) refractor, with which so many stargazers over the years have begun their celestial explorations. These "department store" telescopes, as they are

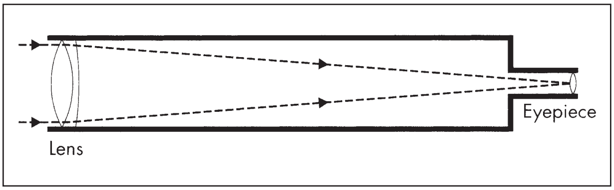

Figure 4.1. The optical configuration and light-path of the classical achromatic refracting telescope, which employs a double-lens objective. (Apochromatic refractors having objectives composed of three or more elements are also widely used by observers today as discossed in the next section.)

sometimes referred to, are mostly imported from Japan (and more recently from China and Taiwan) and typically have optical quality ranging from good to dismal. Even those with good optics often have subdiameter-size eyepieces of poor quality, along with useless finders and shaky mountings. But there are exceptions; the optically and mechanically superb Unitron refractors mentioned in Chapter 1 were and still are made in Japan. If the reader contemplating a first telescope can find a good 2.4-inch or 3-inch Unitron, it can't be beaten for "quick and ready" stargazing at a minimal investment. Among others, Celestron, Edmund, Meade, and Orion offer entry-level 60-mm to 90-mm refractors in the $100 to $300 price range. And fortunately, most companies have at long last switched from the Japanese subdiameter eyepiece size typically found on these imported scopes to the larger and optically superior American standard size (see the section on eyepieces in Chapter 7). Premium-grade achromatic refractors in 4- to 7-inch apertures are offered by Apogee, Borg, D&G, Goto, Helios, Konus, Meade, Murnaghan, Orion, Pacific Telescope, Stellarvue, Unitron, Vixen, Zeiss, and others, with prices ranging from around $500 to more than $2,000.

As is well known, refractors offer the highest resolution (sharpest image) and contrast per unit aperture of all the various types of telescopes. This is because light has an unobstructed path through the system (i.e., there is no image-degrading secondary mirror in the way, as is the case with reflecting and compound systems). They also have very stable images, owing to their closed tube design (eliminating thermal currents within the light path) and rapid cool-down times resulting from their relatively thin objective-lens elements. This has long made them the instrument of choice for high-definition study of the Sun, Moon, planets, and close double stars.

It should be mentioned here that, whatever level of refractor you eventually select, be sure that it has internal *glare stops*. These are concentric flat black rings with a graded series of openings in them, with the largest ones near the front end of the tube and progressively smaller ones toward the eyepiece end as they match the converging cone of light formed by the objective. Their purpose is to eliminate stray light from entering the telescope and reaching the eyepiece. Entry-level refractors generally have two or three glare stops, while premium ones may have five or more. You can check this for yourself by looking into the telescope from the objective end, tilting the tube slightly so you can see down the optical path.

Figure 4.2. This 70-mm StarSeeker achromatic refractor by Orion is typical of the many small telescopes now on the market offering Go-To finding technology (note the keypad controller) at very affordable prices. Courtesy of Orion Telescopes & Binoculars.

Apochromatic

After more than two centuries of widespread use, the traditional achromatic refractor is now giving way to an advanced form called the *apochomatic refractor*. A relatively recent advance that makes use of the latest optical glasses and computerized designs, such an instrument offers excellent correction of all aberrations, including color, by employing three (and in some cases even more) elements in its objective instead of the traditional two. There are also a number of *semi-apochromatic doublets* on the market; these hybrids make use of highly sophisticated rare-earth glasses and optical designs to achieve three-element performance. And while traditional achromats operate at focal ratios around f/11 to f/15 or more in order to control aberrations (making them rather unwieldy in large sizes), apochromats typically work at f/4 to f/6 (and some up to f/9). This results in very compact and highly portable systems. But this superior optical performance and portability come at a hefty price; apochromatic refractors typically begin at around $500 for optical-tube assemblies alone and run into many thousands of dollars for a complete 4- to 7-inch telescope. Among the major

Figure 4.3. The Tele Vue 101-mm apochromatic refractor, seen here equipped with a mirror star-diagonal and Nagler eyepiece. This is one of the finest refracting telescopes ever made, offering superb correction of all possible optical aberrations. These highly color-corrected systems with short focal ratios are mainly available in apertures under 6-inch and are much more costly than a traditional refractor. Courtesy of Tele Vue Optics.

sources for these optically superb instruments are Astro-Physics, Meade, Stellarvue, Takahashi, Tele Vue, and Williams.

Rich-Field

Technically, a *rich-field telescope* (or RFT, as it's referred to) is one that gives the widest possible view of the heavens for its aperture. This occurs at a magnification of about 4× per inch of aperture (so 16× for a 4-inch scope). Because of the relatively long focal lengths of typical non-RFTs, their maximum fields of view are only a degree or so in extent (or two full-Moon diameters of sky) – even when used at their lowest possible powers. But RFTs, with their short focal ratios of typically f/4 to f/5, can easily reach a low magnification, resulting in fields a whopping 3 to 4 degrees across. Sweeping the heavens – particularly the massed starclouds of the Milky Way – with one of these gems is truly an exhilarating experience! RFTs are also wonderful for viewing conjunctions of the planets, big naked-eye star clusters such as the Pleiades (M45), and eclipses of the Moon and (with proper filters!) the Sun. They provide truly amazing low-power views of the Moon itself – especially when it's passing in front of (or occulting) objects behind it, at which times it seems suspended three-dimensionally in space.

Short-focus achromatic refractors are available in apertures ranging from 3 to 6 inches from Apogee, Borg, Celestron, Helios, Konus, Meade, Orion (an especially popular RFT being its little ShortTube 80-mm f/5, priced at $200 without mounting), Pacific Telescope, Stellarvue, and Vixen among others, at prices up to more than $2,000. Many of the shorter aprochromatic refractors offered by several of these same companies, as well as those by Astro-Physics, Takahashi, TBM, Tele Vue, and Williams, also make superb rich-field telescopes – but at prices ranging from under $2,000 to well over $4,000. As with the ShortTube, many RFTs come without a mounting. The achromats are typically lightweight, and at least in the smaller sizes can be supported on a camera tripod, while the apochromats are usually much heavier and require an actual telescope mount. (See also the discussion on rich-field reflecting telescopes in Chapter 5.)

Figure 4.4. Orion's Express Rich-Field 80-mm semi-apochromatic refractor offers stunning wide, bright views of the sky. Like many premium refractors today, it's available either as an optical-tube assembly only or fully mounted as seen here. Courtesy of Orion Telescopes & Binoculars.

Long-Focus

At the opposite extreme from rich-field telescopes are *long-focus refractors*. These are basic achromatic scopes, but have focal ratios from around f/14 to f/20 and sometimes even longer. This results in very large image-scales and high magnifications. These instruments are truly superb for high-definition solar, lunar, and planetary observing, as well as for splitting close double and multiple stars. The views through them when the atmosphere is steady are simply exquisite! (The finest images I have ever seen through *any* telescope have come with the historic 13-inch Fitz–Clark f/14 refractor at the Allegheny Observatory in Pittsburgh,

Figure 4.5. Orion's SkyView Pro 100 mm (4-inch) apochomatic refractor on a conventional German equatorial mount. At a focal ratio of f/9, it's one of the longer focal length apos on the market and as such makes an excellent instrument for lunar and planetary observing. Courtesy of Orion Telescopes & Binoculars.

Pennsylvania. In 1870, Samuel Pierpont Langley saw and drew detail in sunspots so fine that it could never be confirmed until balloon-borne telescopes flying in the stratosphere photographed it nearly a century later!)

Unfortunately, these views come with several disadvantages. Long focal lengths and high magnifications bring with them correspondingly limited fields of view – normally much less than a degree, even using wide-angle eyepieces. More of an issue is that these long instruments can become quite unwieldy, requiring very sturdy mountings (and larger structures, if being housed in some type of observatory). Also, with the trend today towards shorter and more portable refractors, sources for such telescopes are relatively limited. A traditional one is Unitron, which offers a 4-inch f/15 achromatic refractor at prices beginning well over $1,000. Another is D&G Optical, which makes 5-inch to 10-inch f/15 scopes on order, with prices running into many thousands of dollars for the larger sizes. Yet-longer focal ratios (ideal for high-resolution lunar, planetary, and double-star observing) must be custom-made, typically at a much higher cost than for a production-line instrument. One solution to the great tube lengths of such refractors is to compress the optical system into only a half or even a third of its original size. This is done by slightly tilting the objective and using one or more optically flat mirrors to fold the light path. While many amateur telescope makers have constructed folded long-focus refractors, to date there have been no commercial versions – or at least ones that have remained on the market for very long! (The ultra-long-focus 24-inch planetary refractor of France's famed Pic du Midi Observatory is an outstanding professional example of folding a telescope's light path.)

It should be mentioned here that, with the use of a 2× or 3× Barlow lens (essentially doubling or tripling the existing focal length – see Chapter 7), a telescope of normal or even short focal ratio can be converted into a much longer one. However, I have never found the image quality to be quite the same as in a true long-focus instrument (owing to a number of subtle optical factors).

Solar

While almost any telescope – but particularly a refractor – can be used for viewing the Sun once equipped with a safe, full- or partial-aperture solar filter placed *over its objective* (*never over its eyepiece!*), there is a type of refractor especially made for solar observation. Not only do these instruments properly filter the Sun, but they also have built-in narrow-bandpass filters tuned to the hydrogen-alpha wavelength. This makes it possible to look into the deeper levels of the Sun's churning atmosphere and also to see graceful prominences dancing in real time off its limb. The premier source here is Coronado, which a few years ago introduced to much acclaim its PST (Personal Solar Telescope) line with apertures ranging from 40 mm to 140 mm in size. These superb instruments provide views of our nearest star that are nothing short of amazing. Prices for the 40 mm begin at about $500. A calcium-light model is now available too. (Coronado also offers its BinoMite 10 × 25 and 12 × 60 filtered binoculars for viewing the Sun in ordinary white light using both eyes.)