

The Baseline Telescope Optics

The author provides a brief historical and technological review of different types of telescopes, and how they were developed and improved.

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When you stop and think about it, virtually all of astronomy is applied spectroscopy. As the happy recipient of a new Meade ETX-125AT telescope on a recent birthday, I thought this installment of “The Baseline” might address a fundamental spectroscopic issue in telescopes: their basic optics.

The telescope was invented around 1608, apparently by the Flemish spectacle maker Hans Lipperhey. One person who seized upon the capabilities of this new instrument was Italian mathematician Galileo Galilei. By grinding his own lenses, Galileo was able to make superior instruments that he used to observe craters and mountains on the moon, the phases of Venus, the rings of Saturn, and the four largest moons of Jupiter (now called the Galilean moons). Because Galileo’s telescopes used lenses to refract and magnify light, they are (and are still) referred to as refracting telescopes.

Refracting and Reflecting

Although refracting telescopes still are available, their sizes are limited because of the inherent difficulties in constructing large lenses. Popular in the late 19th and early 20th centuries, the largest refracting telescope was built for the 1900 Paris Exposition/World’s Fair. At 1.25 meters wide, it was intentionally constructed so that it would sag under its own weight into the correct shape. Unfortunately, it did not work very well, and was destroyed not long after the exposition. The largest refracting telescope currently operating, with a 40-inch lens, is at the Yerkes Observatory in Williams Bay, Wisconsin. It was built in 1897. Modern refracting tele-

scopes can do a good job because of the production of high-quality lenses.

Reflecting telescopes use mirrors instead of lenses to manipulate the incoming light. Although Scottish mathematician James Gregory designed the first reflecting telescope, the ability to construct good parabolic mirrors at the time was too poor to produce a good working instrument. The first practical reflecting telescope was invented by Isaac Newton around 1670. Because all wavelengths of visible light follow the same law of reflection, reflecting telescopes do not suffer from the chromatic aberration found in refracting telescopes (caused by the difference in refractive index for different light wavelengths). Figure 1 shows the optics of a Newtonian, or reflecting, telescope. The large primary mirror is parabolic, which sends light to a smaller secondary mirror and to an ultimate focus outside of the telescope body, where it can be viewed by an observer.

Done with Mirrors

Because of the presence of the secondary mirror and its support in the path of the incoming light, interference and contrast problems can plague Newtonian telescopes. Also, magnification is related directly to the focal length of the primary mirror, so telescopes of increasing power also were increasingly long and unwieldy. In 1672, a man named Cassegrain (details of whom are historically sketchy; references differ on details of the person) described a different type of reflecting telescope. Figure 2 shows the basic optics of a Cassegrain telescope. The primary mirror is parabolic, with a hole in its center. The primary mirror sends light to a convex hyperbolic secondary mirror, which reflects the light to a focus behind the primary mirror. It is more compact than a Newtonian reflector, and its focal plane is coincident with the optical axis. However, the Cassegrain optics did suffer from spherical aberration, which is when light reflected from different points on a mirror focus at different points. Spherical aberration causes blurry images. A variant of the Cassegrain telescope, the Ritchey–Chrétien reflecting telescope, uses two hyperbolic mirrors. This configuration eliminates the presence of coma, an aberration caused by an object being off of the exact optical axis of a parabolic mirror. Most professional observatories use Ritchey–Chrétien op-

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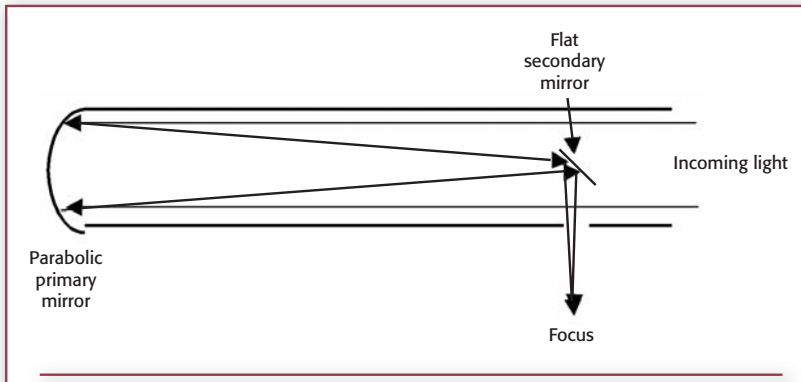


Figure 1. Newtonian reflecting telescope.

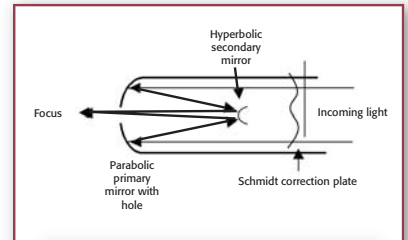


Figure 3. Schmidt-Cassegrain telescope

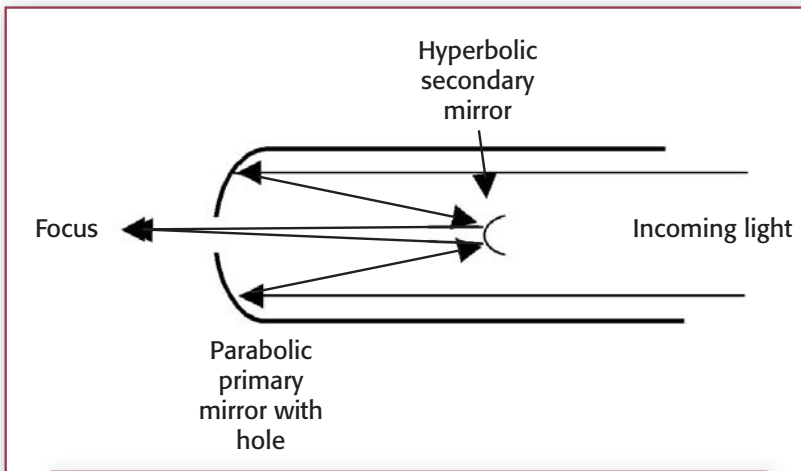


Figure 2. Cassegrain reflecting telescope

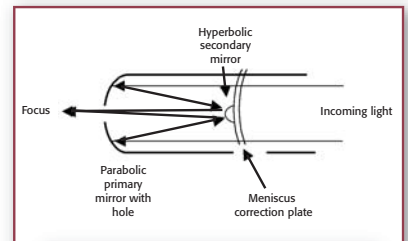


Figure 4. Maksutov-Cassegrain telescope with secondary mirror mounted on correction plate.

tics; the Hubble space telescope is also a Ritchey-Chrétien telescope.

Further Design Enhancements

Most modern telescopes used by amateur astronomers (like yours truly) rely on modifications to the Cassegrain optical configuration. Most of the modifications are lenses that serve to correct the spherical aberration inherent in Cassegrain’s original design. In 1930, Estonian astronomer Bernard Schmidt devised a glass corrector plate (see Figure 3) that reduced the spherical aberration of a Cassegrain telescope. This configuration is known as the Schmidt-Cassegrain telescope. Schmidt-Cassegrain telescopes combine the advantages of reflecting telescopes with the corrective power of

lenses. Telescopes that use both lenses and mirrors are called compound or catadioptric telescopes.

The corrector plate can have a variety of possible shapes. In 1941, two astronomers suggested that a meniscus-shaped plate be used as the corrector plate. Telescopes that use this are called Maksutov-Cassegrain telescopes, after one of the astronomers. (My Meade ETX is a Maksutov-Cassegrain telescope.) In 1957, engineer John Gregory (no known relation to James Gregory, who invented the refracting telescope) put the secondary mirror on the corrector plate itself (Figure 4).

All telescopes have additional optics that help focus the image into the eye. The optics of eyepieces can be more

complicated than the optics of the telescope itself. Another column, perhaps...

Beyond the Visible

All of the telescope designs discussed so far are for the visible range of the electromagnetic spectrum, of course. Newtonian and simple Cassegrain reflectors can also be used for IR or UV ranges, because those regions of the spectrum also can be reflected off of the mirrors. Reflecting telescopes that have a corrector plate are more limited, because the collector plate itself might not transmit light in the IR or UV ranges. Radio “telescopes” actually are directional antennas; their “optics” are based upon different principles. Again, perhaps a topic for a future column ...

Telescopes are fascinating optical instruments, and the amateur and professional astronomers that use them can be thought of as applied spectroscopists of a sort. Perhaps future columns will delve into other astronomical topics of a spectroscopic nature. ■