Cambridge University Press
978-0-521-64441-9 - The 20-cm Schmidt-Cassegrain Telescope: A Practical Observing Guide
Peter L. Manly
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1

History and development of the 20-cm Schmidt–Cassegrain

The Cassegrain telescope was invented in about 1672 by Sieur Guillaume Cassegrain, a sculptor and metal founder employed by the King of France.[14] The mirrors were probably made of speculum or some similar metal which could take a polish. Cassegrain communicated his design to Monsieur de Bercè who took it to the French Academy and by May of that year the idea had appeared in *Journal des Sçavans* and *Philosophical Transactions*. Almost immediately a dispute erupted concerning the relative qualities of the Cassegrain and two English telescope types, the newly invented Newtonian telescope and the older Gregorian design. Battle lines among scholars and their scientific academies were drawn along national boundaries – in this case down the middle of the English Channel. Even Sir Isaac Newton himself joined the fray and published dissertations establishing his claims.

The Gregorian telescope is composed of a concave parabolic primary mirror with a concave elliptical secondary. The Cassegrain uses a similar concave parabolic primary with a convex hyperbolic secondary. The Newtonian has a concave parabolic primary with a plane secondary. All three designs had the advantage of no color aberration since they used mirrors instead of lenses. The invention of the achromatic lens was a half century in the future at the time. The Gregorian design was popular because it produced an erect image and it was free from spherical aberration – theoretically. The technology was not available, however, for grinding accurate aspherical surfaces. The Cassegrain was a more compact design but it, too, required aspherical surfaces. Newton's telescope used only one curved surface, the other being an easily generated plane. Newton generally used a higher

14 *The Telescope*, Louis Bell, Dover Publications, 1981 edition, p. 22. See also *The History of the Telescope*, Henry C. King, Dover Publications, 1955, p. 74, and *Lens Design Fundamentals*, Rudolf Kingslake, Academic Press, 1978, p. 322.

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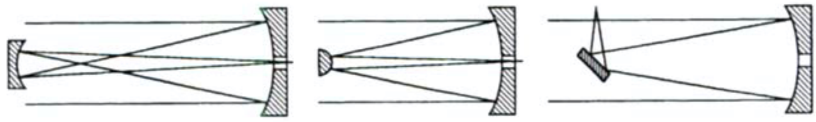

Figure 1.1. Two-mirror telescope designs.

f number (longer focal length) and thus the asphericalness of his parabola was much easier to grind than the other two models.

At least part of the confusion lay in the poor methods of optical testing in use at the time. Thus, surfaces intended to be parabolic or hyperbolic were probably not accurate. Further, comparison testing was generally performed by the designer and his results transmitted by letter to another observer who compared a verbal description of the view with a competing telescope using different astronomical objects, a different observer at a distant site several weeks later. Judging by the claims and discussions, telescope making in those days was much more an art than a science.[15]

Until optical manufacturing technology could improve, the Newtonian became the instrument of choice among reflecting types, chiefly due to the simpler manufacturing crafts required. While Cassegrain and bent Cassegrain telescopes[16] were produced for special purposes, the Newtonian and its close cousin the Herschellian telescope[17] design were used for almost all large telescopes for about two centuries.

15 Astronomy is largely a passive science. We observe but we do not touch our subject. There are those who try to simulate or calculate in a laboratory whatever goes on within the core of stars but that's theoretical astronomy. Only in the past two decades have we sent machines and humans to the Moon. We have also sent spacecraft to Venus and Mars to 'taste' the soil and farther to probe more distant planetary systems with radio waves and various sensors. Astronomy as an experimental science is still in its infancy.

16 The bent Cassegrain looks like the classical Cassegrain but a third mirror on a long rod is inserted up the baffle tube. This mirror sends the light out the declination axle to an instrument or eyepiece. It is popular in an alt-az mounting, allowing a heavy spectrograph to be placed nearer to the instrument's center of gravity rather than hanging it off the back end of the telescope.

17 A Herschellian telescope is composed of a parabolic primary mirror and an eyepiece situated at the edge of the upper end of the tube. The system thus works as an off-axis reflector. The aberrations induced by off-axis viewing are compensated for by the lack of a secondary mirror which, if it is made of speculum, could absorb about half the starlight.

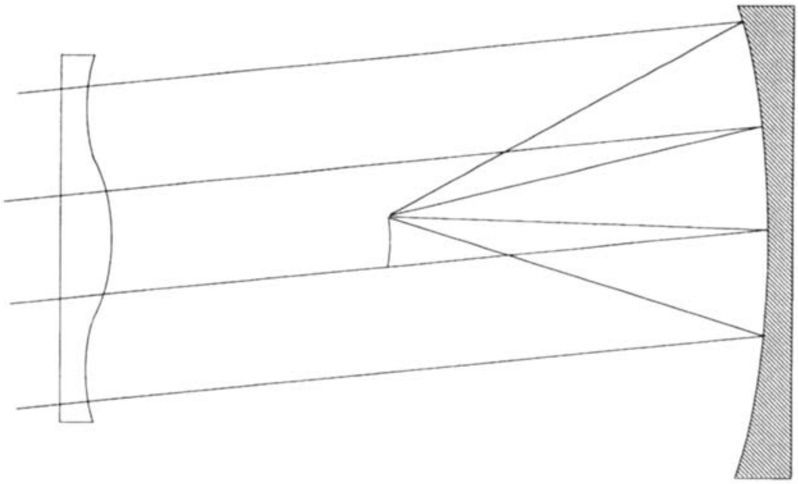

Figure 1.2. Classical Schmidt Camera. Note that the curve on the corrector plate has been greatly exaggerated.

By 1932 Bernhard Schmidt of the Hamburg Observatory was experimenting with manufacturing methods for highly aspheric surfaces. His intent was to produce a photographic telescope – more of a camera – with a wide field of view and a very low f number. The result, as shown in Fig. 1.2, is the classical Schmidt camera.

A thin lens – more of an optically weak correator plate – is placed in front of the mirror. The corrector plate also forms an aperture stop which is typically at the center of curvature of the spherical primary mirror. The corrector eliminates spherical aberrations, an optical defect normally seen in a spherical mirror. The image plane, about half way between the primary and the corrector, still has the defect of curvature of field but the radius is large enough that films could be warped into the proper shape for exposure. Thus, photographs can be made with pinpoint images all across the field.

The trick here is in producing the aspherical corrector plate. In 1936 after Schmidt's death, it was divulged as to how he produced such an unusual curve.[18] He had simply taken a thin optical flat, sealed it to the open end of a cylinder nearly the size of

[18] *The History of the Telescope*, Henry C. King, Dover Publications, 1955, p. 357.

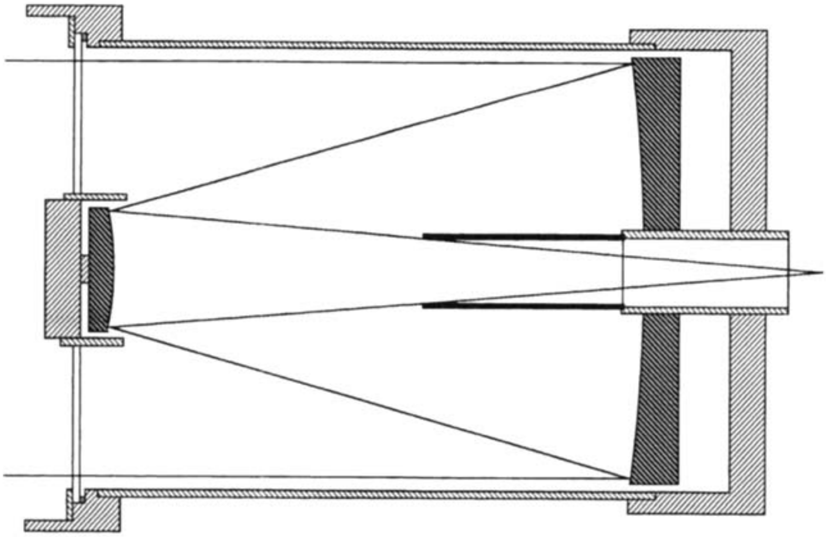

Figure 1.3. Schmidt–Cassegrain telescope cross-section

the corrector and partially pumped the air out of the cylinder, warping the thin plate. He ground the warped surface flat on the exposed side and then released the vacuum, allowing the glass to spring back into the correct shape. While this may seem simple, choosing the cylinder diameter and choosing the correct partial vacuum have remained the 'secret sauce' of Schmidt plate manufacture.

After the construction of several Schmidt cameras, it was realized by a few designers that a spherical mirror placed between the primary mirror and the image plane could redirect the beam through a hole in the primary, thus allowing easier access to the film plane. With the proper radius on the secondary, the image plane can also be made to be flat, making positional measurements of stars much simpler than on a curved film. This is technically a Schmidt–Cassegrain telescope but such designs are usually referred to as cameras rather than telescopes.

The final steps in the evolution of the Schmidt–Cassegrain start with moving the secondary mirror closer to the corrector plate. This results in a smaller secondary with less obscuration of the aperture. Finally, the corrector plate is moved toward the primary which results in a very compact package. One side effect is

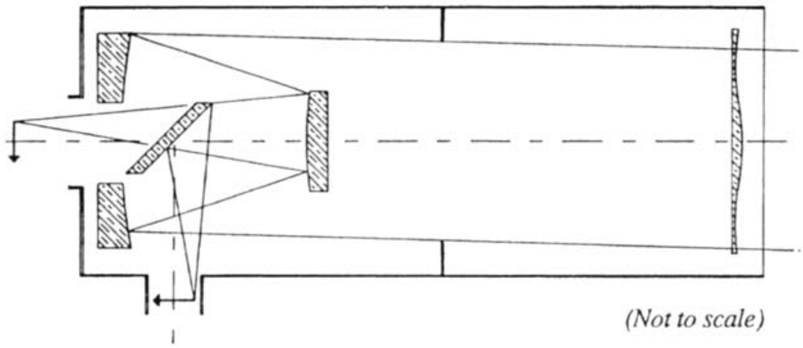

Figure 1.4. Bent–Schmidt–Cassegrain showing the placement of an optional tertiary mirror. Illustration courtesy of Coyotè Enterprises.

that the overall focal length of the system becomes a strong function of the radius of curvature of the secondary. Thus, when a secondary of high curvature is used, a relatively long effective focal length can be folded into a short tube. This is especially handy for portable observations or when an observatory would like a larger instrument without constructing a new and larger dome.

While established optical manufacturers would occasionally custom make a single Schmidt–Cassegrain telescope for some special purpose, it was an electronics company that first produced this type in quantity. Tom Johnson and Alan Hale of Valor Electronics had made several telescopes of various sizes and designs starting in about 1954. The first 20-cm f/10 S–C by them appeared in 1966. The reason for settling on that design centered on the portability and ease of use inherent in the type.[19] The company changed its name to Celestronics, then Celestron Pacific and finally Celestron International, reflecting more emphasis on their optical business and less on electronics.

Then in 1971 competition appeared with the introduction of the Dynamax telescope from Criterion Manufacturing Company.[20] Criterion had been making Newtonian telescopes for the amateur market for many years and was expanding its product line. A lawsuit ensued over manufacturing trade secrets, chiefly concerning the method of making the corrector plate.

19 Private conversation with Alan Hale.
20 The company later changed its name to Criterion Scientific Instruments.

Figure 1.5. Production of 20-cm S–C Telescopes. Each of the 350–500 parts of the instrument is inspected and tested prior to assembly and then the overall system is checked before shipping. Photo courtesy of the Meale Instruments Corporation.

While the suit was eventually settled out of court, ten years of legal briefs piled up before it was over. The Dynamax production facility was later bought by Bausch and Lomb and in 1987 the company stopped making S–C telescopes.

In 1980 Meade Instruments Corporation, long a manufacturer of Newtonian telescopes, started making 20-cm S–C telescopes, providing competition in a lively market. In Japan, JSO and Takahashi have produced S–C telescopes in the 20-cm aperture range.[21] In England, Orion Optics, and in Belgium, Lichtenknecker Optics, have produced the type.

The Lichtenknecker design and one made by Coyotè Enterprises of Des Moines, New Mexico, are interesting in that they are not fixed to one f number or optical configuration. By interchanging corrector plates and secondary mirrors, the tele-

[21] The Takahashi instrument actually has a 22.5-cm aperture.

scope can be used either visually or photographically at several different effective focal lengths. This is similar to a system used by Celestron two decades ago to make some of their telescopes more versatile. The corrector plate and secondary mirror were removable as a single assembly. Then a new corrector, tube extender and a film holder were bolted on the front of the telescope, changing it into a classical Schmidt camera.

It is estimated that between 75 000 and 100 000 telescopes of the 20-cm S–C variety have been made to date by the several manufacturers. About 10 000 more are produced each year. While the majority of 20-cm S–C telescopes wind up looking at the night sky, I have seen them used as collimators on optical benches, as sub-millimeter microwave receivers, for artillery spotting purposes, as a boresight camera for a large experimental radar system and for terrestrial viewing as described in Chapter 5. On at least two occasions a 20-cm S–C telescope has gone into space. Once for visual use by the astronauts and once as the optical system for an experiment mounted in the Space Shuttle payload bay. Two of the manufacturers suspect that there have been more uses in space, judging from custom modifications ordered with some telescopes, but the experiments are usually classified. And finally, the type has been used several times as a prop in motion pictures.[22]

[22] The only environment I have not heard of a 20-cm S–C working is underwater. It would not surprise me, however, to learn of some aquatic application.

2

First observation – the Moon

Before you set up your telescope you might ask where the Moon is. After a few months of observing you'll have a sense of where the Moon is just as you know, at any time, roughly where the Sun is in your sky. For now, you may have to look it up in one of the popular astronomy magazines. Most newspapers also list the times of Sunrise, Sunset, Moonrise and Moonset in the section with local weather predictions.

Select a site for your telescope which doesn't have trees or streetlamps in the way. After reading your telescope manual, set up the telescope. Now you must align the polar axis to the Pole Star. There are many methods for accomplishing this and your telescope manual probably describes at least one. Another method is described in Appendix 2. Don't let anybody tell you that there is only one 'proper' procedure for polar alignment. The varying procedures differ in accuracy of alignment and time to accomplish.

If you are going to casually visually observe the Moon and bright planets then you don't need to have the polar axis aligned any closer than about three to five degrees. If you are going to look for faint galaxies and nebulae, especially ones which you've never seen before then you need an accuracy of about one degree. This is crucial if you intend to use the setting circles on your mount. It will take three to five minutes to align your telescope this accurately. If you're going to make long-duration photographic exposures of faint galaxies then the error between the polar axis and the true pole must be less than a tenth of a degree. An hour or more may be spent for this alignment. The alignment procedure in Appendix 2 describes the most precise method but it also tells which steps to omit for a quicker, less accurate alignment.

Why observe the Moon first? Well, it's easy to find, easy to focus on and your telescope will reveal a wealth of detail which gives you some understanding of the power of the instrument.

Figure 2.1. Southern highlands of the Moon and the crater Tycho, 1/2-second exposure with tele-extender and 25-mm eyepiece on Kodak #2415 film. Photo courtesy of Meade Instruments Corporation.

Try several eyepieces and see which one works best for you. Most important, observing the Moon provides a basic exercise in getting familiar with the mechanical operation of the telescope. If you should accidentally bump the mount, it's not going to be difficult to reacquire the Moon. You will learn not to lean on the telescope. You will learn how to gently move the field of view from one area of interest to another. You will learn just how sensitive the focus control of your telescope is. You will also discover a new world.

At some point you may come to hate the Moon, for it floods the sky with unwanted light, preventing observations of faint objects. For now, however, enjoy Earth's nearest neighbor. It isn't like most moons, whose diameters are usually 1% or less than the diameters of the planets they circle. The Earth–Moon system, with only a factor of four between their diameters, might more properly be considered a double planet.

Ask most people to envision a Lunar landscape and they won't picture in their minds the classical downward looking 'bird's eye' view of the surface as seen through a telescope.

They'll remember one of the Apollo photographs, for on 20 Jul 1969 the Moon ceased to be an astronomical object and became a real place. Now go back and see it as an astronomical object once more, just as generations of earlier observers discovered it.

You can gaze for hours at the mountains, plains, craters and rills of the Moon. Go ahead and drink your fill at the eyepiece while exploring a whole new world in minute detail. Each night, as the dark shadow of the terminator slowly works its way across the face of the Moon, the shadows lengthen or shorten. Low-contrast shadings appear and disappear. Craters with central peaks loom on the alien landscape. You may even want to compare the view with a good Lunar map in order to learn the names of some prominent features. As a suggestion, find the Sea of Tranquility and see if you can identify the area around Tranquility Base where Apollo 11, the Eagle, landed. You won't be able to resolve the lower section of the Lunar Excursion Module which was left there but you will view a historical site.

While the Moon is best viewed during its partial phases, if you find it near full phase there are a couple of interesting things to look for. First, note the differentiated aspects of Lunar features. There are large, darker areas surrounded by lighter regions with many craters and mountains. Note that the dark areas have significantly fewer craters. The darker features can be seen easily with the naked eye and before the invention of the telescope they were thought to be oceans and seas. Thus, they carry names like Oceanus Procellarum and Mare Imbrium. While we now know that there are no open bodies of water on the Moon, at one time the seas did flow, for they are made up of frozen lava which seeped into the basins, probably after large meteor impacts. These plains are the most recent Lunar surfaces formed and thus they have fewer meteor craters.

When the Moon is full, find the crater Tycho near the South Lunar Pole. There is a system of lighter-colored rays emanating from Tycho stretching across seas and mountains. This is probably material splashed from the crater when the meteor which formed Tycho struck the Moon. Try different eyepieces to see if the contrast between the rays and surrounding terrain is improved. Similarly, around the crater Copernicus there is a smaller system of rays. Look at other large craters under a variety of lighting conditions to see if you can find more ray systems.