Gleanings for ATM's

Conducted by Roger W. Sinnott

HOW I MADE A SCHMIDT CAMERA

MANY amateurs have built their own Newtonian and Cassegrain telescopes, even though these instruments need optics accurate to a fraction of a wavelength of light. Few, however, have attempted a Schmidt camera, perhaps being scared off by the aspheric corrector plate.

Yet the Schmidt camera represents the acme of perfection in medium-field astrophotography; its great speed and unparalleled crisp images make it a potent tool for exploring the universe. I have constructed such a camera, polishing the corrector plate by the same vacuum technique invented by Bernhard Schmidt himself.

Both the mirror and the corrector plate of my camera are made from common plate glass. This choice may shock the purists, but it's important to remember that a Schmidt camera isn't a high-resolution instrument. We won't use it to split a close double star or see Encke's division in Saturn's rings. The camera's resolving power need not be any better than that of the photographic emulsion.

For example, with my camera's aperture of 200 millimeters (8 inches) the theoretical resolving power would be about 0.5 arc second if the optics were perfect. This corresponds to 0.001 mm at its focal length of 500 mm. But a star image as large as 0.010 or 0.015 mm is considered very good photographically. So the optical tolerances in a Schmidt camera are much less stringent than in a high-resolution telescope.

I began by grinding the primary mirror from the thickest glass plate I could find. Its diameter is 250 mm and thickness 30 mm. I ground and polished the surface to a good sphere, checking the quality of the figure with both Foucault and Ronchi tests. Its radius of curvature is 1,000 mm to yield a focal length of 500 mm.

Next I completed the tube, mirror cell, and spider system to hold the filmholder,

The main telescope at Luciano Lai's Giordano Bruno Observatory is this fork-mounted 0.4-meter (16-inch) f/5 Newtonian reflector. The four piggyback instruments are 60-mm and 120-mm finders, a 150-mm f/15 guiding refractor, and the Schmidt camera (black tube) described in the text. All photographs are by the author.

To bring out details in this Schmidt-camera photograph of the great Andromeda galaxy, M31, the author printed the negative through an unsharp mask — a thin out-of-focus positive image made from the original. (For more on the technique, see *Sky & Telescope* for April, 1979, page 355.) Note the faint extensions of the galaxy's familiar oval. This is a 15-minute exposure on gas-hypered Kodak 2415 film.

making sure to provide these parts with all the adjustment screws that would be needed in the final optical collimation.

THE CORRECTOR PLATE

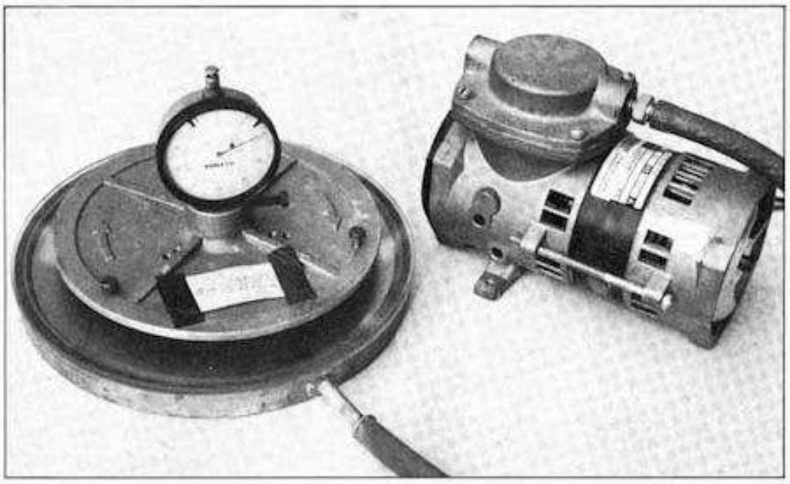
For the corrector I bought a piece of plate glass 1 by 0.5 meter across and 6 mm thick. It is the type of glass used for full-length wardrobe mirrors. By running it in front of the finished primary mirror while viewing the latter in a Ronchi test, I was able to find a section with almost no defects. From this area I cut a 200-mm disk.

First I ground one side of this disk against two others in turn, and each of them against the other, cycling through all possible combinations. This is the standard procedure for making an optical flat. After working my way from coarse to fine abrasives, I polished the would-be corrector as uniformly as possible but made no attempt to check the final figure.

During this polishing stage, the worked surface may have drifted away from perfect flatness and ended up as a concave or convex sphere of very large radius. But this is of no concern — it would only cause a slight shift of focus in the camera with no effect on performance.

Now for the other side of the corrector — the one that must carry the peculiar aspheric curve. As Schmidt found, if you subject a circular plane-parallel plate to pressure on one side by applying a partial vacuum to the other, and carefully control this pressure, the glass will deform as shown in the top diagram on page 669.

Keeping the glass deformed, we grind



Adopting the same approach used by Bernhard Schmidt in 1930, the author made his corrector blank with the equipment pictured here. At left the spherometer sits on the corrector blank, which in turn rests on the rim of a specially machined metal holder. The vacuum pump at right gradually removes air from the holder, causing the glass to bend inward. When the spherometer shows that the proper deformation has been reached, the pump is disconnected and grinding can begin.

and polish the exposed surface to a sphere. Upon releasing the vacuum, the glass springs flat again but the surface now has the special profile required.

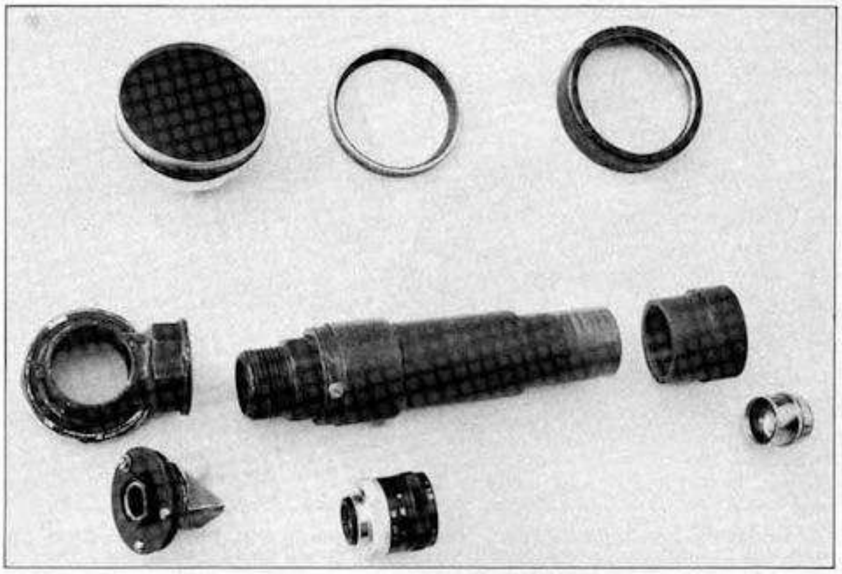
It is important, of course, to achieve the proper deformation. For a telescope of focal length F and a corrector plate of diameter D, the vacuum should bend the glass to a radius of curvature R given very nearly by the following formula:

$$R = 8(F/D)^3 D.$$

The result will be a Schmidt corrector with minimum thickness 70 percent of the way from the center to the edge. (For a detailed discussion of the corrector's profile and related matters, see pages 323-375 of Albert G. Ingalls' *Amateur Telescope Making — Book Three.*)

In the case of my Schmidt camera, with F = 500 mm and D = 200 mm, the formula gives an R value of 25,000 mm, or 25 meters. Such a weak curvature is hard to measure in a knife-edge test but is easily done with a spherometer graduated to 0.01 mm. The sagitta or curve depth equals $r^2/2R$, where r is the distance from the spherometer plunger to each leg. The

Huge objects like the California nebula in Perseus are easy targets for the Schmidt. Also called NGC 1499, this magnificent emission nebula spans almost 3° near the 4th-magnitude star Xi Persei to its right. Though dim visually, details in the nebula stand out clearly with the red-sensitive 2415 emulsion (hypered). The author exposed the film 15 minutes.

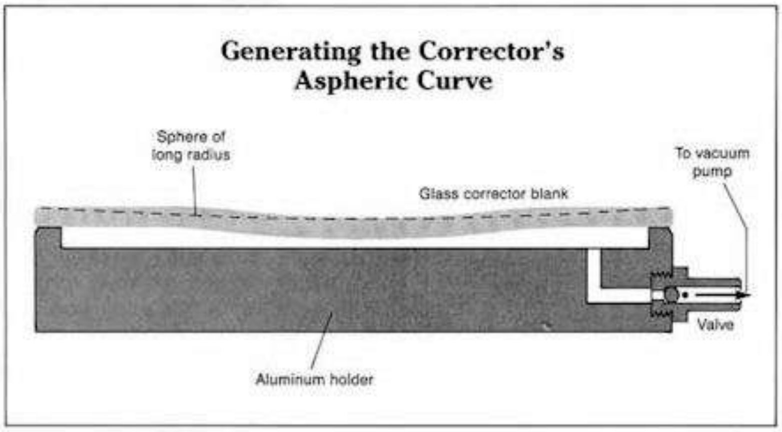


A Schmidt camera requires the film to be bent gently convex to a radius of curvature equal to the focal length (500 mm here). Across the top, from left, are the filmholder itself, the fixed ring placed on each disk of film, and the rotating ring that screws down to hold the assembly together. Without the fixed ring, the film might turn with the rotating ring and become scratched when loaded or unloaded. Along the bottom are the focuser parts: bayonet adapter at left, knife-edge with prism, pipe and relay lens (below pipe), and viewing eyepiece with sleeve at far right.

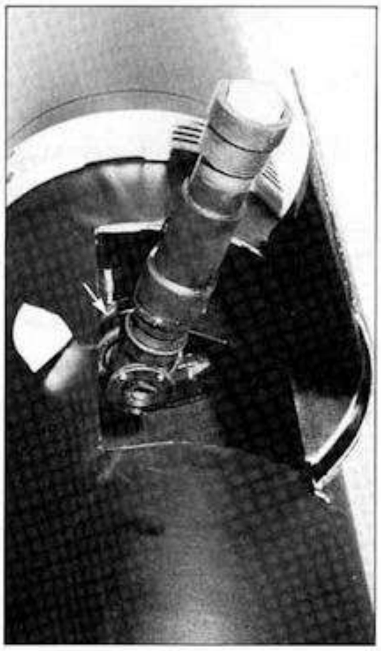
vacuum-induced curve depth, when a straightedge is laid across the corrector's full diameter, should be 0.20 mm for a camera like mine.

First I made a glass tool of the same diameter as the corrector and gave it a convex radius of curvature of 25 meters. I also machined an aluminum plate to carry the corrector and maintain the partial vacuum required during grinding and polishing. This holder is 5 mm thick across the middle and has a narrow rim raised another 2 mm. So as to support the corrector plate as evenly as possible, I carefully ground the top of this rim flat using the same three-disk method mentioned earlier.

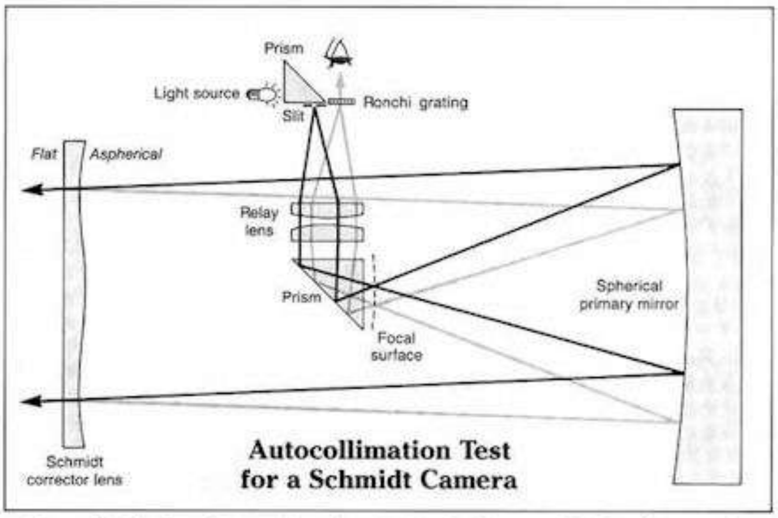
A valve on the edge of the aluminum holder allows air to be sucked out. I oiled the holder's rim and placed the finished flat side of the corrector in contact with it. Then I used a small electric pump to



This cross-sectional diagram shows, in exaggerated fashion, how the vacuum method of making a Schmidt corrector works. Under air pressure the glass deforms inward with a complex curve. Grinding and polishing the upper surface to a sphere (indicated by the dashed line), then releasing the vacuum, leaves the corrector with almost exactly the desired profile. This beautifully simple technique works well for f/2 and slower cameras, but a corrector made this way for a faster camera may need further retouching.



The focal plane of a Schmidt camera is not accessible with an ordinary eyepiece. So how can the filmholder be focused? The author removes it from its bayonet mount and attaches this right-angle viewer, which contains a knife-edge (just inside the round opening at bottom), a prism, and a relay lens. A portion of the focusing ring (arrowed) is visible between the focuser and the spider.



To test his Schmidt optics as an integral unit, Lai took advantage of the fact that one side of the corrector plate is optically flat. Light from the slit is reimaged at the telescope's curved focal surface, continues on to the aluminized primary mirror, and finally passes outward through the corrector. Most of the parallel light rays leave the camera and are lost, but a small fraction is reflected backward through the system to the Ronchi grating. Lai adjusted the optics until he saw straight bands, proof that the optics were correctly figured and aligned. The same prism and relay lens are now used to focus the camera before taking pictures (see the photograph at left).

evacuate the chamber until the curve depth, as measured with the spherometer, reached 0.20 mm. During these operations, it is very important to wear goggles for eye protection in case the glass should break. Finally I taped the rim and checked that it was airtight.

As I began to work the corrector against the tool with water and No. 600 abrasive (very fine), the first part of the surface to become ground was a ring near the 70-percent zone — exactly as expected. The work continued until this ground area had spread all the way to the disk's center and edge. Polishing on a pitch lap went normally. Once again, I made no attempt to test the corrector's figure separately, but I did try to polish as gently and uniformly as possible.

With the polishing complete I released the valve, cleaned the glass, and installed the finished corrector in the telescope for an autocollimation test (see the diagram above). The flat side of the corrector must face outward for this test to work. As desired, the Ronchi lines appeared quite parallel! Then I attached the instrument to the main telescope in my observatory and performed a star test, again with excellent results.

Because of this Schmidt camera's short focal ratio, f/2.5, the photographic focus is very critical. So I retain the same prism and relay lens used in the autocollimation test to check the focus before taking photographs.

So far, deep-sky photographs with the Schmidt camera have exceeded all expectations. My success is perhaps all the more surprising when you consider that I undertook this project more for fun than for any serious scientific purpose!

LUCIANO LAI
Via Mantovana 130 E
37062 Dossobuono
Verona, Italy