GLEANINGS FOR ATM's

CONDUCTED BY ROBERT E. COX

Eliminating Stray Light in Cassegrain Telescopes

THE VARIOUS TYPES of Cassegrain telescopes, including Maksutov-Cassegrain and Schmidt-Cassegrain, can suffer greatly from stray light in the field of view, unless they are equipped with proper baffling or stops or both. Yet many amateurs build such telescopes without knowing how to install these essential features.

In a Cassegrain system, the focal plane is usually located behind a hole in the primary mirror. Fig. 1 shows the image-forming rays coming to focus after reflection from the secondary mirror, producing an image of whatever we are observing. However, light from some other celestial objects or from the sky itself may also reach the focal plane along paths indicated by the dashed lines.

This stray light is not focused and simply causes a general illumination in the focal plane that is well described by the word *fogging*. When we view stars on a very dark night, this effect is small, but if the moon is up or artificial lights brighten the sky, the illuminated field becomes quite objectionable. Daylight viewing of landscapes (or celestial objects) is almost impossible with a Cassegrain telescope not treated to reduce stray light.

There are three ways of preventing stray light from reaching the focal plane, without interfering with the image-forming rays. The first method is to place a stop at the Ramsden disk of each eyepiece to be used with the telescope. Figs. 2 and 3 illustrate the Ramsden disk in the simple case of a refractor and the more complicated one of a Cassegrain system.

In Fig. 2 the solid lines show how the focal-plane image formed by the objective is reimaged at "infinity" for viewing by the observer. In addition, to its right the eyepiece forms an image of the objective area itself. This image is the Ramsden disk or eyepoint of the system. Its size is inversely proportional to the magnification. It is simple to calculate, for it is equal to the objective diameter D divided by the magnification M, that is, D/M. In Fig. 2, this is Df/F, where F and f are the focal lengths of objective and eyepiece, respectively.

For example, in a 3-inch refractor, f/15, with a 1-inch eyepiece, the magnification is 45x; the Ramsden disk's diameter is 3/45 or 1/15 inch. In an 8-inch, f/8 Newtonian reflector, a 2-inch Erfle eyepiece gives 32x, so the eyepoint is ¼ inch across. Suggestions for measuring the size of the Ramsden disk in commercially made instruments, to determine their actual magnifications, were given in the July, 1960, Gleanings for ATM's.

In practice it may be complicated to calculate the actual stop, especially its position for a particular eyepiece used with your telescope. It is usually easier to measure the Ramsden disk by pointing the telescope, focused at infinity, at some illuminated area – a wall or the daylight sky. Look into the eyepiece from a distance of a foot or so, and the Ramsden disk will appear as a bright spot suspended in space. Its actual measurement may present problems, especially with high-power eyepieces, but in the July, 1960, article mentioned above, Robert E. Cox suggests using a pocket microscope with a graduated reticle.

It is evident that all of the light passing through the objective and the eyepiece will fall within the Ramsden disk. To see the entire field of view, the observer must place the pupil of his eye at this eyepoint. If his pupil is larger than the Ramsden disk for a particular ocular, however, his eye can be a small distance away from the eyepoint and still collect all the light. This is generally the case, since the Ramsden disk is usually small, which may explain why so few amateurs pay serious attention to it.

Yet, as Fig. 3 indicates, the problem is

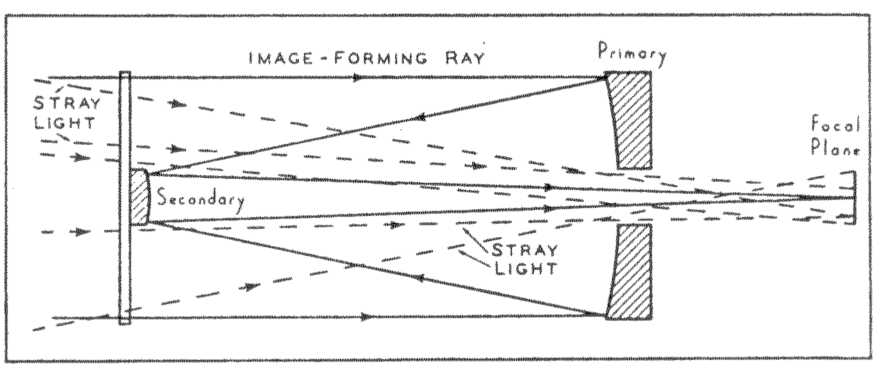

Fig. 1. The dashed lines show how light can pass the secondary mirror support and go directly through the primary mirror's perforation without being focused by the Cassegrain system's optical surfaces. Unless corrected, this floods the focal plane with unwanted stray light.

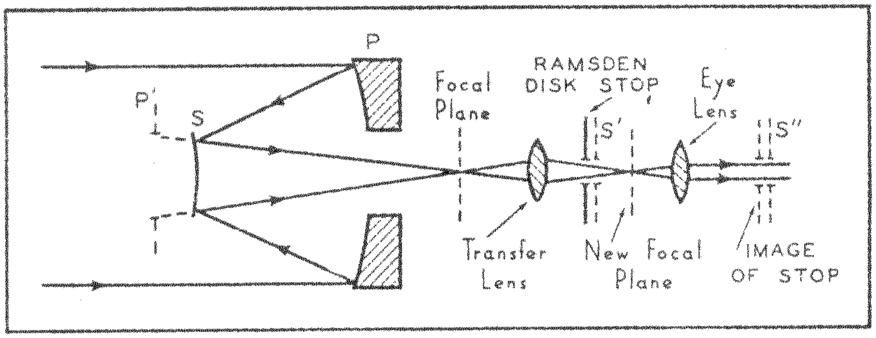

Fig. 4. The Dall system's transfer lens and stop eliminate stray light and give an erect image, making the telescope useful for terrestrial subjects.

maker Horace E. Dall, in this department in January and February, 1962, pages 48 and 109. The transfer-lens system in Fig. 4 might be thought of as a modification of the first method with the eye lens pulled out enough to form a real image of the object being observed (a form of eyepiece projection). This image is located a few inches beyond the rear of the eye lens instead of at infinity, and is then examined by another eye lens, which renders the rays parallel for observation.

An appropriate Ramsden disk stop can then be placed just behind the transfer lens, coinciding with the image P″ of the primary mirror. This stop's aperture will be imaged by the second eye lens as its Ramsden disk, but no stop is needed after this second lens because the stray light has already been eliminated. The arrangement provides good eye relief and allows the pupil of the eye to be placed right at the second Ramsden disk. Eyepieces can be interchanged at will, since the stop is associated with the first lens. Finally, with the eyepiece removed, photographs can be taken at the new focus, yet be free from stray light.

Of course, the transfer or erector lens is not an eye lens, but an element designed or chosen to have minimal aberrations in this application. The additional length of the optical train is absorbed into the telescope by having the focal plane, formed by the secondary mirror, come between the primary and secondary mirrors, so the telescope is no longer than the equivalent simple Cassegrain.

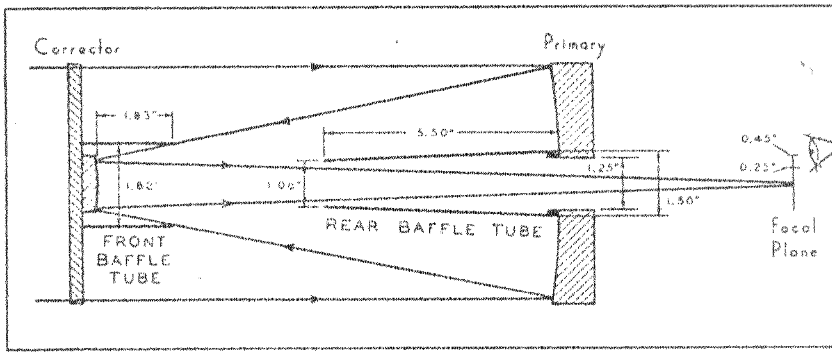

Fig. 5. This is the Schmidt-Cassegrain system tabulated by the author on page 227, April, 1962. The baffle system's dimensions are given here.

Further information on transfer lenses can be found in the November, 1959, SKY AND TELESCOPE, page 53. This method has much to recommend it, but it is often impractical to modify an existing Cassegrain to employ a transfer lens, unless the system has been designed with such a change in mind.

The **third method** uses one or two baffle tubes, the first projecting toward the secondary mirror from the hole in the primary, the other (if needed) extending from the secondary toward the primary (Fig. 5). Such a mechanical baffle is designed to cut off all the stray light without obstructing a significant portion of the useful image-forming light.

A fair idea of what baffle tubes are appropriate can be gained by laying out the optical system in two dimensions on a drawing board, but the seriousness of light blockage or vignetting may be improperly estimated. It is preferable to work toward drawing a diagram to represent the eye's view looking into the telescope. The sources of stray light and the obstructions become immediately apparent. Basically, we must find the images of all apertures as they finally appear in the secondary mirror when viewed from the focal plane.

Such a "stop analysis" is more generally applicable than just to Cassegrain systems. The methods that I have used can be found in Max Herzberger's *Modern Geometrical Optics* (Interscience Pub-

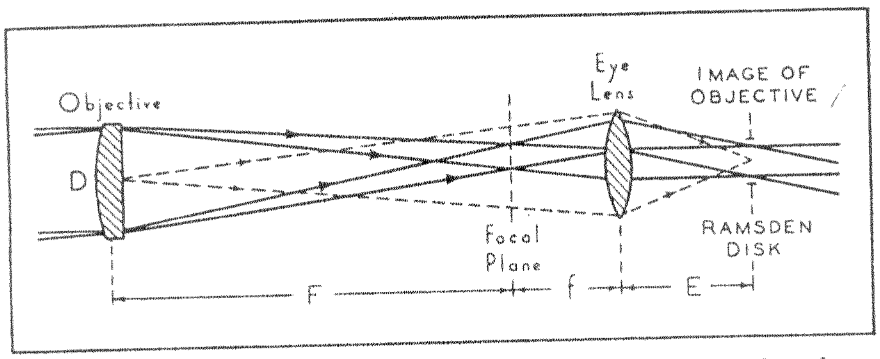

Fig. 2. For the central point of the objective, the dashed lines show how the eye lens images the aperture at the location of the Ramsden disk.

important in Cassegrain systems. The same principle applies as in Fig. 2, but there are a few more apertures to consider. First, the telescope should be constructed with its main tube sufficiently larger than the primary mirror that the latter is the limiting aperture or *entrance pupil* of the system, unless vignetting of the field of view can be tolerated.

The virtual image of the primary mirror is formed by the secondary at **P′**. Provided that the secondary is somewhat larger than this image, the limiting aperture is still the primary. If primary and secondary were the only elements of the system, **P′** would be referred to as the *exit pupil*, because light from an object entering through entrance pupil **P** would seem to leave through **P′**. In the case of the simple refractor (without eyepiece), the entrance and exit pupils are essentially the same size and at the same place, the objective itself.

When an eyepiece is added to the telescope of Fig. 3, images of **P′** and **S** are formed at **P″** and **S′** by the eyepiece. The twice-imaged primary at **P″** is actually the Ramsden disk for this arrangement, but **P″** and **S′** are close and almost the same size in most cases, so the latter is a sufficiently good approximation of the disk.

Use the formula $R = D/M$, where M is the effective focal length of the compound system divided by the ocular's focal length. Suppose an 8-inch Cassegrain telescope has an f/4 primary and a secondary amplifying four times, so the effective focal length is 128 inches. The Ramsden disk is 8/128 inch with a 1-inch eyepiece, or 1/16 inch. Since Cassegrain systems have high magnification in general, R is quite small, with the result that the observer's dark-adapted eye (pupil size as large as $\frac{1}{3}$ inch) may see a much larger field than the small Ramsden disk itself, and this area may be filled with stray light.

Knowing size and position of the Ramsden disk, we can eliminate the stray light by cutting a small hole in an opaque sheet of material and fixing it to the eyepiece. This was pointed out many years ago by John H. Hindle in his chapter on compound telescopes in *Amateur Telescope Making — Book One*. He wrote, "The eye lens should be covered with an eye plate perforated the exact diameter of the Ramsden disk. . . . It is advisable to have the eyepiece mount at the secondary focus adjustable on three screws, so as to bring the Ramsden disk precisely in the center of the hole in the eyeplate for the very finest performance."

Although a Ramsden disk stop is an excellent way of eliminating stray light, there are a few drawbacks. As mentioned earlier, to get a full field of view the observer's eye should also be at the eyepoint, but the stop now is in the way. This is not too objectionable, unless the Ramsden disk is nearly as large as the pupil of the eye or unless the observer must wear glasses.

Another drawback is that each eyepiece must have its own stop, which usually will work only with one telescope. The stop for an f/15 Gregory-Maksutov is not likely to be correct when the eyepiece is used on an f/23. Lastly, it is evident that such a stop does no good at all when the eyepiece is removed for photography at the focal plane.

The second method, which overcomes these objections, is the erector-lens system described by the English telescope

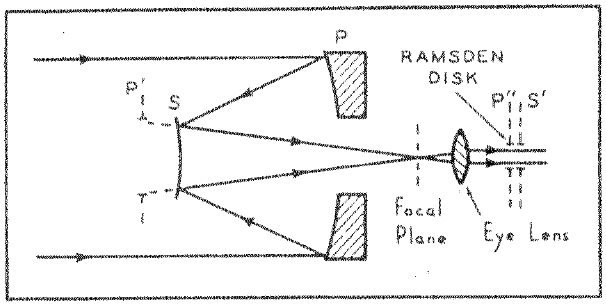

Fig. 3. The Ramsden disk of a typical Cassegrain system. The eye lens forms two images close together, one of the secondary mirror, the other of the virtual image of the primary.

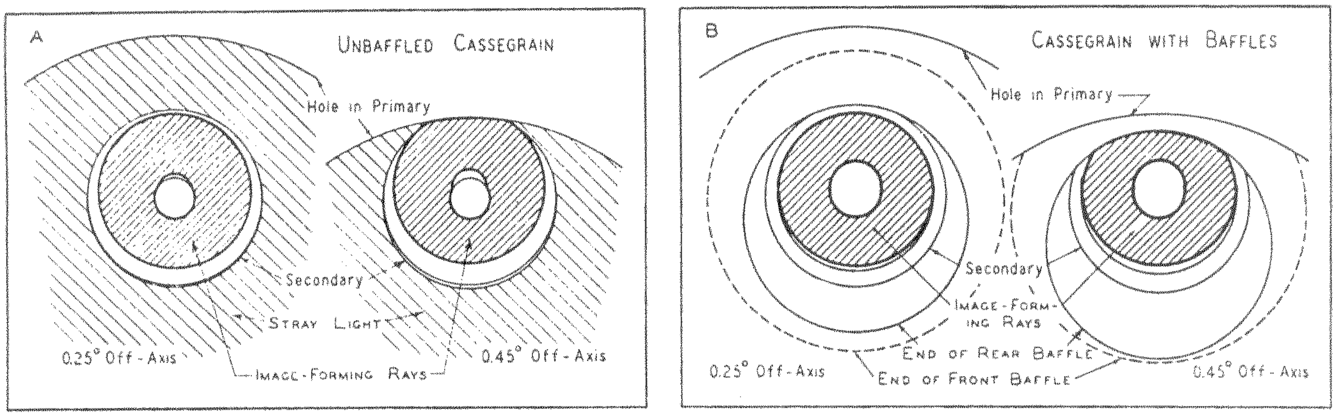

Fig. 6. The view from the focal plane of the Schmidt-Cassegrain system sketched in Fig. 5, seen at left with no provision to eliminate stray light, and at right with the system of baffle tubes in place. All diagrams are by the author.

lishers, New York, 1958) pages 101-105, and Hardy and Perrin's *Principles of Optics* (McGraw-Hill, New York, 1932). Only simple algebra is required and slide-rule accuracy is usually sufficient. The basic equation involved is known as the Gaussian approximation.

Fig. 6 shows the results for the f/15 Schmidt-Cassegrain system I described in this department a year ago (April issue, pages 193 and 227). The two baffles have been designed for minimum vignetting at 0.45-degree off axis, with a central obstruction one-third the diameter of the clear aperture. Fig. 6A shows what would be seen from the focal plane if no baffles were present, and in 6B the baffles are in position. This is not the only baffle design that can be used. If a smaller central obstruction were desired and if more vignetting were acceptable at the given field angles, a different set of baffles would be better.

Baffle tubes can be made of any opaque material, such as sheet metal, heavy paper, or plastic. The surfaces should be as flat black as possible *at grazing incidence*. Beware of some flat black paints that are glossy when viewed at a large angle. At the suggestion of Edgar Everhart, I have found a surface of black velvet the best yet.

A system of baffle tubes can have all the advantages of a transfer-lens arrangement, except that some vignetting and obstruction must be introduced. Furthermore, baffles can be easily inserted into any existing telescope, and no additional optical surfaces are involved.

Any Cassegrain-type instrument is incomplete without sky-fog elimination by one of the three methods we have considered. I have found examples of each of the systems to be satisfactory. Each is well worth the effort, and should remove much of the disappointment that some builders have had with Cassegrain telescopes.

R. R. WILLEY, JR.
117 Farmington Ave.
Farmington, Conn.