Chapter 15

Focal Extenders and Reducers

15.1 Focal Extenders

A focal extender is a system of lenses with negative power placed in the converging light cone of an objective to increase the effective focal length of this objective. Focal extenders—or "tele-X-tenders"—are often used in combination with photographic objectives as an easy and cheap way to produce a greater focal length. Those focal extenders typically consist of three or more lenses in order to maintain good off-axis sharpness.

The focal extenders used by amateur astronomers with telescopes are, in contrast, simpler. Most consist of two lens elements, and are called Barlow lenses. The focal length amplification factor usually lies between 1.5 and 3.0. A Barlow lens is an extremely useful accessory for the following reasons:

1. when it is used with a fast objective, for instance an *f*/5 Newtonian, high powers can be obtained without resorting to eyepieces having extremely short focal length and low eye relief;
2. when it is used for photographing lunar and planetary details, an increase of the image scale is easily attained; and,
3. the application of a Barlow lens usually improves the off-axis sharpness of the eyepiece used.

This last occurs because the image surface of most telescope objectives is inward curving; the Barlow tends to flatten the focal plane. (This is explained in greater detail in section 14.2, on field flatteners.) In addition, the greater focal ratio of the system reduces astigmatism present in the eyepiece.

Some manufacturers supply a set of eyepieces with a matched Barlow lens. The Barlow may be designed so that its inherent astigmatism partially compensates the eyepiece astigmatism, thus providing considerable improvement in the off-axis definition of the eyepieces used with it. Furthermore, a Barlow lens often permits the use of relatively poorly corrected eyepieces with Newtonians and other telescopes with fast focal ratios. These eyepieces are normally rejected by users of fast Newtonians because of the intolerable off-axis aberrations.

An important point that should be kept in mind is that the Barlow's amplification factor depends on the position of this lens with respect to the original focal

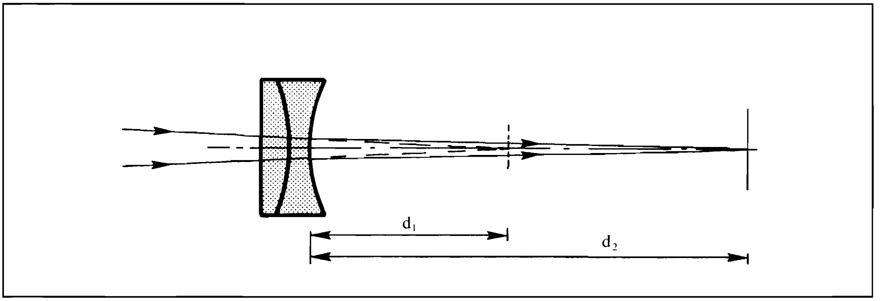

Fig. 15.1 *Barlow Lens for a 200 mm f/10 Schmidt-Cassegrain Telescope.*

plane. The amplification factor, M_B, and the effective focal length of the system used with a Barlow, F_{comb}, are computed from:

$$F_{\text{comb}} = \frac{F_o \cdot F_B}{F_B - d_1} \tag{15.1.1}$$

$$M_B = \frac{F_{\text{comb}}}{F_o} = \frac{F_B}{F_B - d_1} \tag{15.1.2}$$

where F_o is the focal length of the objective, F_B is the focal length of the Barlow lens, and d is distance the Barlow lens lies inside the original focus. In developing these equations, the thickness of the Barlow was ignored. The image height and the position of the new focal surface are thus:

$$h_2 = M_B \cdot h_1$$

and

$$d_2 = M_B \cdot d_1 .$$

Thus the amplification factor is independent of the focal length and focal ratio of the objective. When $d_1 = 0$, then $M_B = 1$, meaning that the Barlow has no effect. This phenomenon, in fact, also happens with a single-lens field flattener. When $d_1 = F_B$, the magnification goes to infinity, meaning that the Barlow has converted the converging beam into a parallel beam, and the telescope becomes a Galilean, or Dutch, telescope.

However, in the design of a Barlow, the optical characteristics of the objective must be taken into account in order to obtain optimum performance. Because coma, astigmatism, and field curvature are different in Newtonians, Cassegrains, and refractors, Barlow designs should be different too. Unfortunately, this is often ignored in practice. Few Barlow lens construction data have been published in the literature. In table 15.1, we give data for a Barlow designed for use with the 200 mm *f*/10 Schmidt-Cassegrain described in section 9.3. This Barlow design is shown in fig. 15.1.