Observing the universe

Observing from Earth

The modern astronomer's traditional instrument is the telescope, and this can take two forms – the refractor and the reflector. In both the basic principle is the same: to collect radiation from a distance and bring it to a focus where it can be examined by eye, camera or other equipment.

The refractor

Here light collection and focus are carried out by a lens or **object-glass** at the front end of the telescope tube. Such an object-glass now always has two components, one of 'crown' glass and the other of 'flint' (a denser type than crown glass), to form an image with an acceptable minimum of spherical and chromatic aberration (Fig. 9·1). Yet such a two component object-glass has four lens surfaces which have to be figured, while the lenses themselves must be thick enough to support their own weight and be made of clear homogenous glass, free from bubbles or strains. Object-glasses are, therefore, very expensive, difficult to construct, and at large apertures absorption of light by the necessarily thick lenses becomes a problem. In consequence, an aperture of 1 m seems the maximum practicable.

The light-grasping power of a telescope – its ability to detect faint objects and thus probe far out into space – depends on the square of its aperture. Thus, the light-grasp of a 2-m aperture instrument is not twice but four times that of a 1-m, and with the present desire for large apertures, the refractor has given place to the reflector for all professional work.

The reflector

The reflector collects and focuses incoming radiation by using a concave mirror, on the surface of which is a highly reflective coating, usually of aluminium (Fig. 9·2). The film has a thickness of only some 300 nm and gives a reflecting surface that mirrors accurately the carefully ground and polished surface beneath it. The glass now most used for mirrors (whose optical quality has only to be retained on one surface) is one of the new zero-expansion, glass-ceramic materials which, over the temperature range at which the telescope is used, keeps its shape within very close tolerances – typically one part in 10^7 for each degree Celsius (C) change in temperature.

The aluminium film does not remain permanently highly reflective. When freshly applied it reflects about 90 per cent of the light falling on it, but after one or two years, this has dropped to 85 per cent, and realuminizing is called for. Like the original aluminizing, this has to be done in a vacuum, but observatories carry the necessary equipment for this since it is impracticable to send the mirror away for this purpose.

The basic optical layout of a modern telescope makes use of a number of different focal lengths (Fig. 9·3). For photographing or detecting very distant objects the **prime focus** is used; here radiation suffers only one reflection and so there is the least loss of the incoming signals. In large optical telescopes an observer's cage is built at the prime focus but in smaller instruments, where such a large obstruction would be impracticable, the light receives a second reflection bringing the focus to the side of the tube. This is the method adopted originally by Newton, and such a **Newtonian focus** is commonly used by amateur astronomers (Fig. 9·4).

Modern observing techniques often require the use of ancillary equipment that is unsuitable for use at the prime focus, and alternative foci are provided. One, the **Cassegrain** (named after the seventeenth century Frenchman Cassegrain), lies below the primary mirror, light being reflected by a convex mirror shaped to a HYPERBOLA, below the prime focus back down the telescope tube and through a hole in the centre of the primary. The other is the elbow or **coudé focus**: here additional reflections bend the light beam from a small secondary mirror below the prime focus to a room below the telescope where very massive ancillary equipment is situated. The additional mirrors rotate to compensate for movement of the telescope, with the result that the coudé focus always remains fixed.

The normal optical arrangements of a reflector use a primary mirror whose concave surface is curved in the shape of a PARABOLA, but some variations are used, and in particular a number of modern professional telescopes are of the Ritchey-Chrétien design (originally devised in the 1920s by George Ritchey and Henri Chrétien). Here the primary has a hyperbolic curve and the telescope not only gives a good optical performance but also a short tube length, which is also an advantage since it leads to a greater rigidity of the whole assembly, which is of particular importance in research fields such as astrometry – the determination of stellar positions to a high degree of precision.