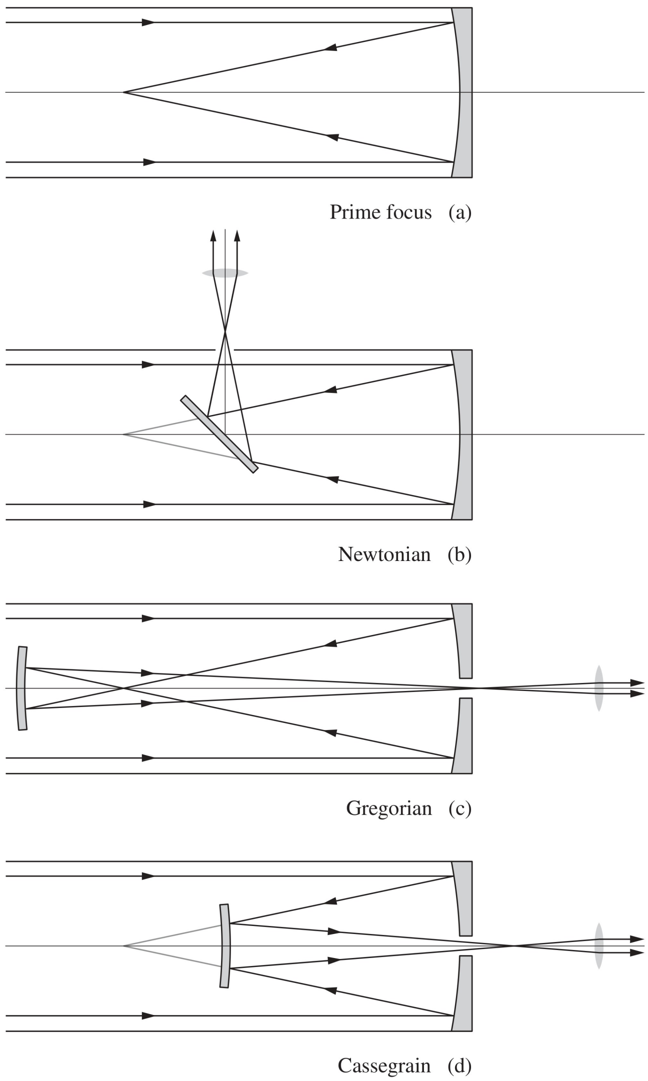
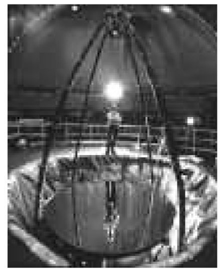


Figure 5.122 Reflecting telescopes.

The simple single-mirror paraboloidal telescope (Fig. 5.122*a*) was designed to function with rays entering along its optical axis. But there will always be objects of interest elsewhere in the field of view other than at its direct center. When a parallel bundle of off-axis rays are reflected by a paraboloid, they do not all meet at the same point. The image of a distant off-axis point (e.g., a star) is an off-axis asymmetric blur caused by the combined aberrations of *coma* (p. 263) and *astigmatism* (p. 266). This blurring becomes unacceptable rather quickly as the object moves off-axis; that's especially true for the contribution due to coma, and it ends up limiting the acceptable field of view to something quite narrow. Even for a slow $f/10$ system, the angular radius of the acceptable field of view is only about 9 arcminutes off-axis, and it drops to a mere 1.4 arcminutes at $f/4$. The classical two-mirror telescopes (Figs. 5.122*b*, *c*, and *d*) are similarly severely limited in their fields of view by coma.



The rotating 3-meter-diameter Liquid Mirror Telescope in New Mexico is used by NASA to detect chunks of low-Earth-orbit space debris as small as 5 cm. (NASA)

Incidentally, if we put a liquid such as mercury in a shallow horizontal basin and continuously rotate it about a vertical axis at a constant rate ω, the equilibrium configuration of the surface will be parabolic. The elevation (z) above the lowest point in the liquid at any location on the surface is given by

$$z = \frac{\omega^2 r^2}{2g} \tag{5.85}$$

Large (upwards of 3 meters in diameter), robust, diffraction limited, liquid mirrors have been produced. The main advantage of a liquid telescope mirror over a glass one is that it's very much less expensive. The main disadvantage is that it can only look straight up (see photo).

Aplanatic Reflectors

An optical system that has negligible amounts of both spherical aberration (p. 259) and coma is called an **aplanat**, and there are aplanatic versions of both the Cassegrain and the Gregorian scopes. The Ritchey-Chrétien telescope is an aplanatic Cassegrain having a hyperboloidal primary and secondary. In recent times, this configuration has become the leading choice for devices with apertures of 2 m or more. Perhaps the best known example of its kind is the 2.4-m Hubble Space Telescope (HST), pictured in Fig. 5.123. Only telescopes in space (i.e., above the absorbing atmosphere) can work efficiently in the ultraviolet—which, for example, is where one would like to examine hot young stars. With its updated charge-coupled-device (CCD) arrays, the HST could "see" from about 1 μm in the IR to 121.6 nm in the UV. This complements ground-based telescopes that can provide diffraction-limited imaging in the wavelength range greater than 10 μm. (Incidentally, CCDs have a sensitivity about 50 times greater than otherwise comparable photographic film; the era of dropping film packs out of spy satellites is long over.)

With little or no coma, the field of view of the Ritchey-Chrétien is limited by astigmatism. Thus an $f/10$ instrument will have an acceptable angular field radius of about 18 arcminutes, twice that of an equivalent paraboloidal telescope. In comparison to the aplanatic Gregorian, the Ritchey-Chrétien has a smaller secondary and therefore blocks less light, and is substantially shorter in length; both features make it much more desirable.