TELESCOPES

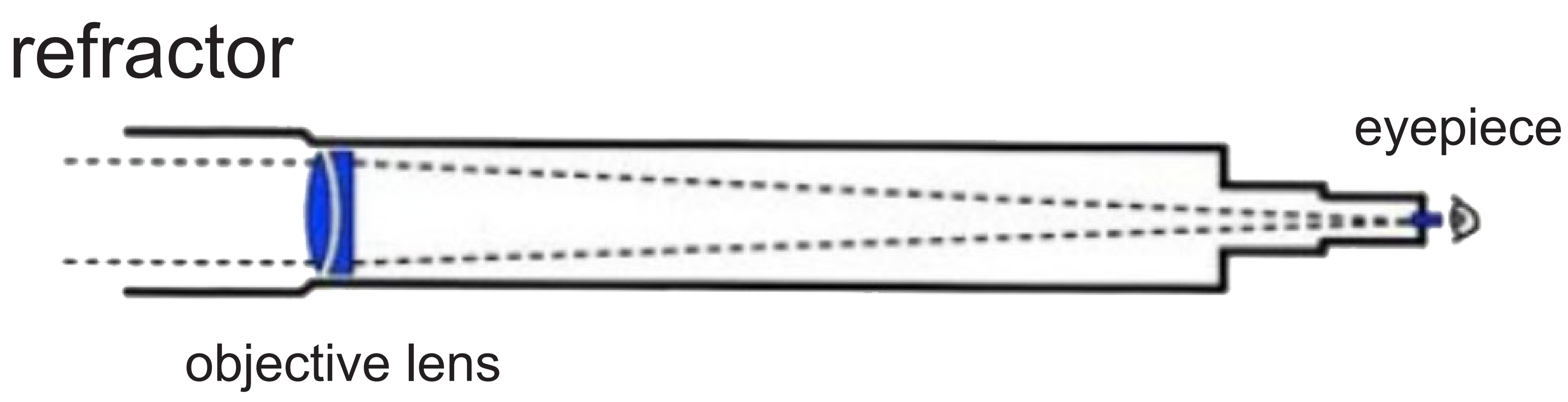
Telescopes are the most powerful but least versatile of the observation aids. The primary optics of amateur telescopes vary from 50 mm to 300 mm or more for the serious observer. Magnification is typically in the range of 40x to 400x, while the Field of View (FOV) is typically smaller than 1°.

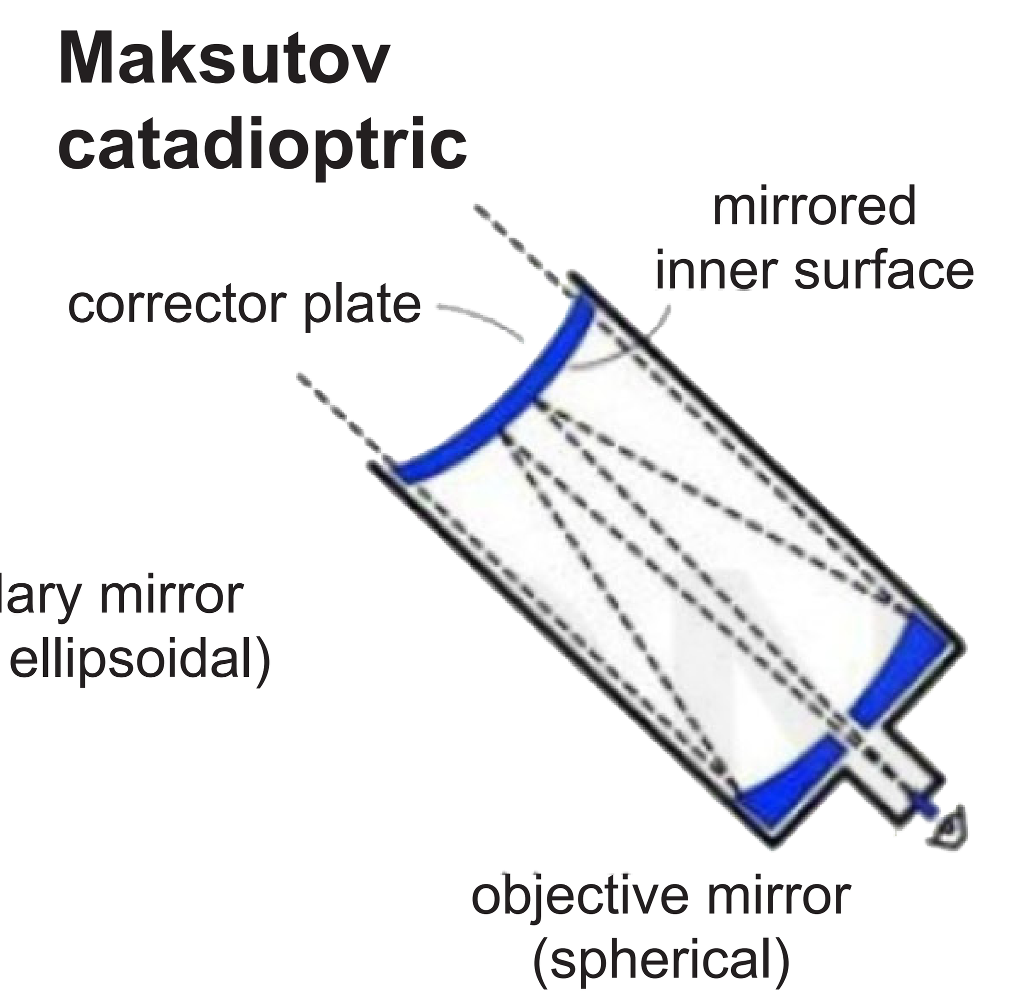
Telescope Designs
There are three optical telescope designs:

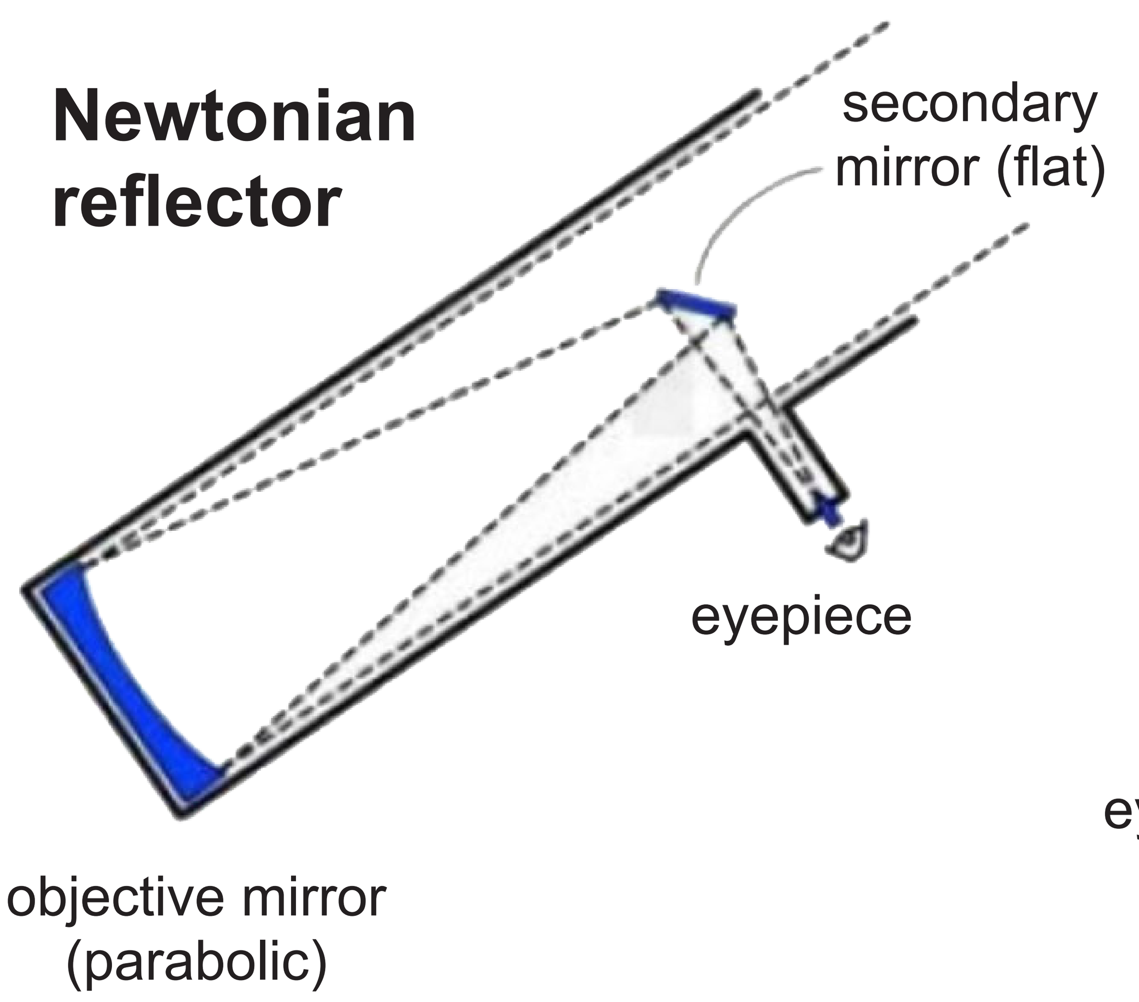
- **Refractors** use lenses throughout the optical path. The first refractor telescope was made by the Dutch eyeglass maker, Hans Lippershey. It was improved by Galileo, who was the first to turn a telescope to the night skies in 1609 and immediately made important discoveries.

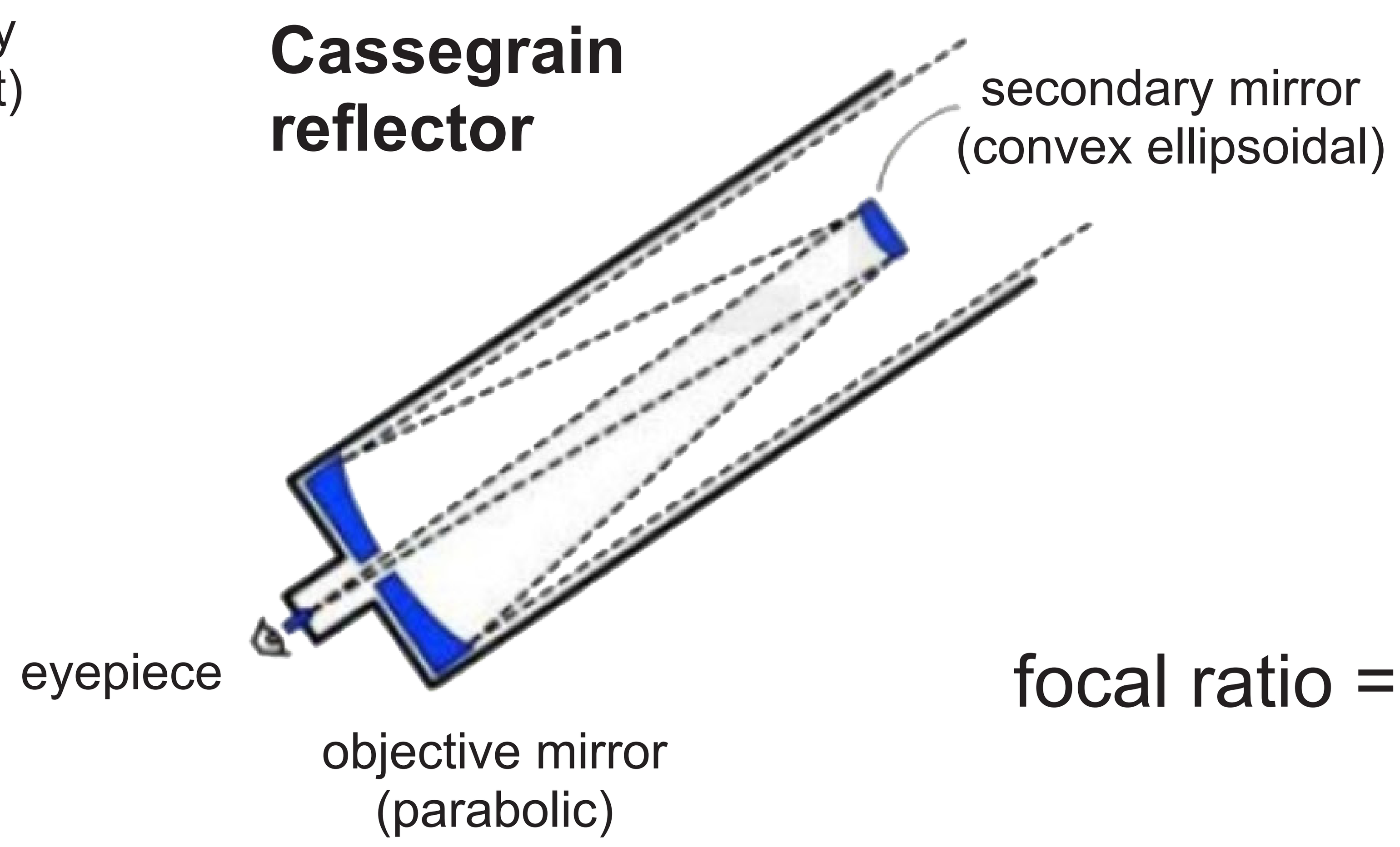
- **Reflectors** use parabolic mirrors for the objective optics. There are three main configurations:
  Classical Newtonian telescopes in which a secondary flat mirror is mounted at 45° at the open end of the tube to reflect the image through the side of the tube.
  Cassegrain telescopes have a spherical secondary mirror which reflects the image back to be viewed through a central hole in the primary mirror.
  Catadioptric telescopes which use spherical primary mirrors (easier and cheaper to make compared to parabolic primary mirrors) and an aspherical lens to correct the aberrations caused by the primary lens. Popular variations of catadioptric telescopes are Maksutov or Schmidt Cassegrains. Most large professional telescopes, such as the Hubble Space Telescope (HST), Keck and ESO VLT, are of Ritchey-Chrétien design, which has hyperbolic primary and secondary mirrors.

The diagrams below illustrate refractor, reflector, Maksutov, Schmidt Cassegrain and Ritchey-Chrétien designs:

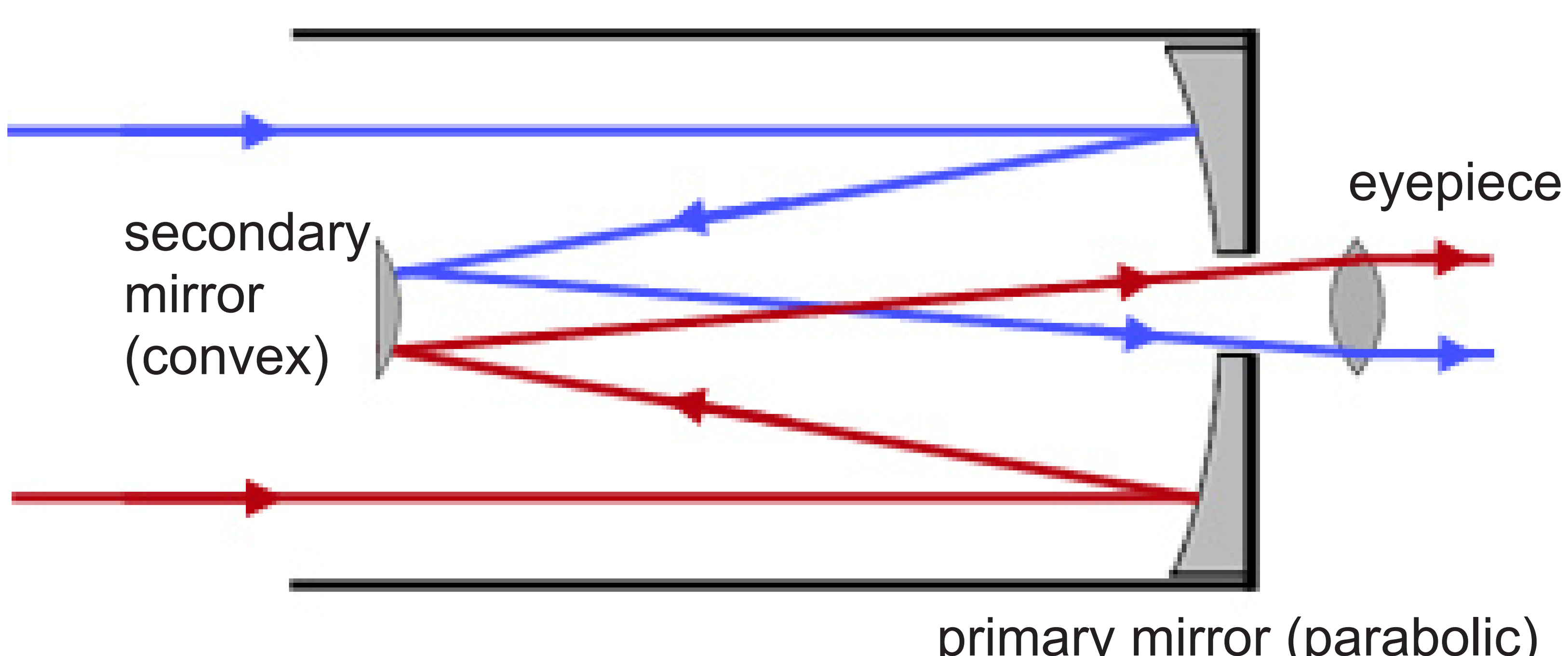




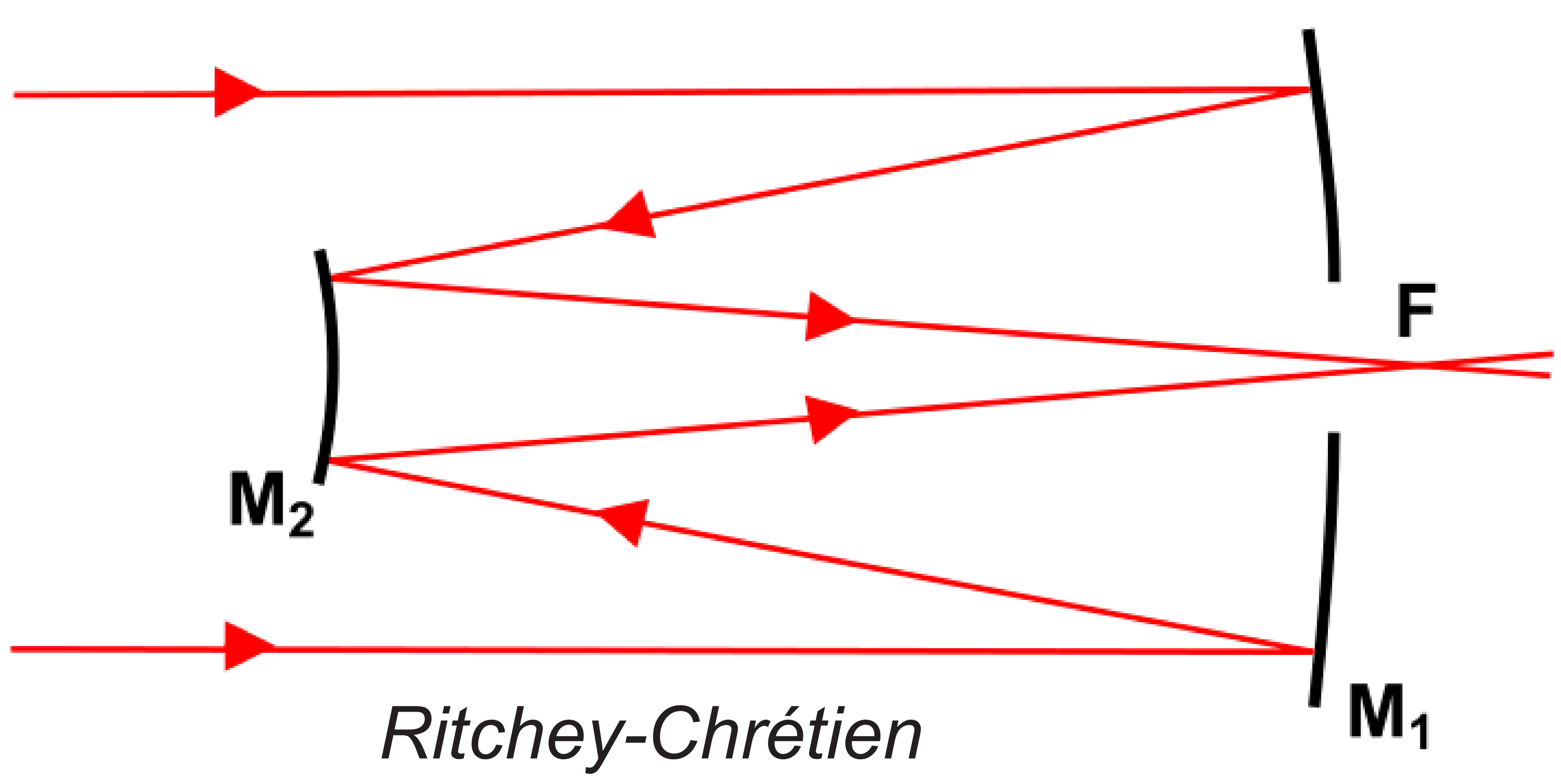




$$\text{focal ratio} = \frac{\text{focal length}}{\text{diameter of objective}}$$



Schmidt Cassegrain



Ritchey-Chrétien

Telescope parameters
The two important parameters of any telescope are its Focal Length and Primary Objective Diameter. The Focal Ratio *f* (defined in the diagram) gives an indication of how 'fast' a telescope is. A low *f*-value is a fast telescope with a relatively bright image, smaller magnification and wider FOV, whereas a high f-value implies a dimmer image, larger magnification and narrower FOV.

The *magnification* of a telescope/eyepiece combination equals the ratio of the telescope's Focal Length to that of the eyepiece used. For example, a 20 mm eyepiece on a 1 000 mm telescope gives a magnification of 1000/20 = 50. This happens to be the sweet spot for many telescope/eyepiece combinations.

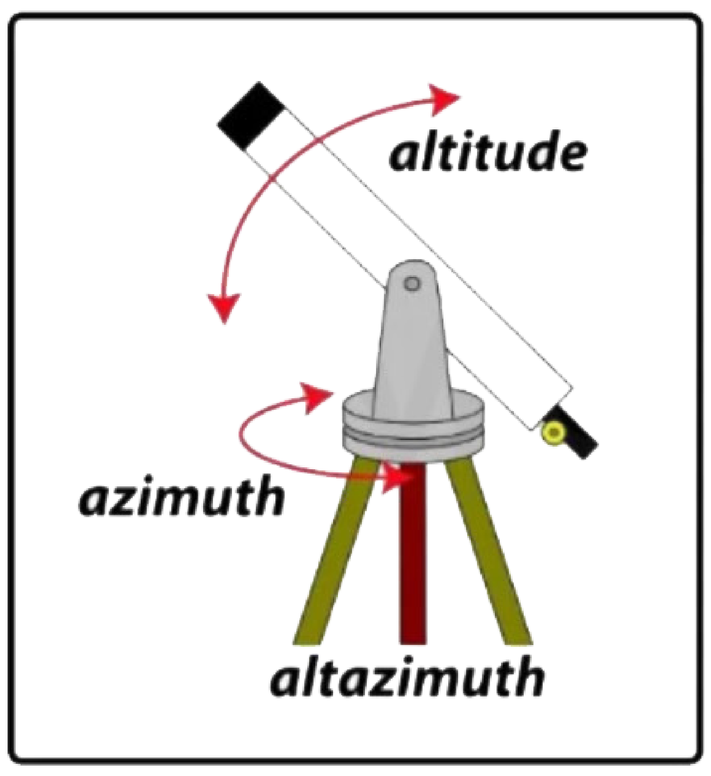
The *maximum* conservatively recommended magnification is 10x the tube diameter in mm, beyond which the image becomes dim and grainy. This is dependent on the surface brightness of the object and is typically half or less than half the manufacturer's recommendation.

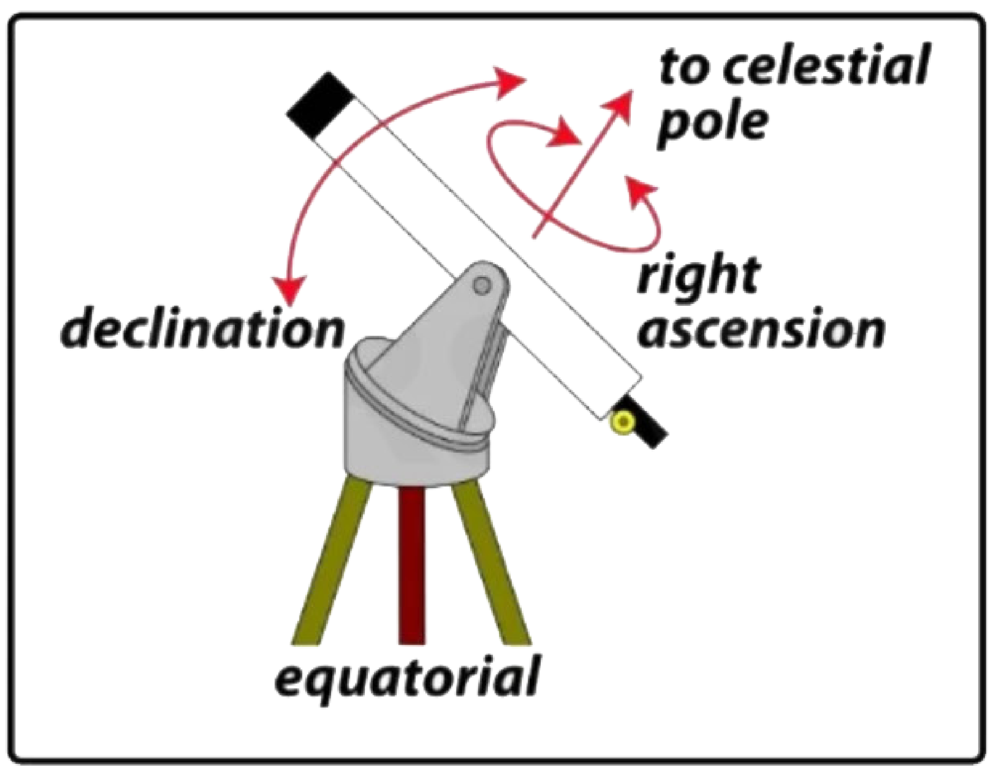
Finderscopes
Telescopes are fitted with finder scopes, typically 10 x 50 mm with a 7° FOV and a reticle or crosshairs to centralize on targets. Finderscopes must be aligned with the main telescope, which is best done during the day. Some telescopes are fitted with Red Dot finders instead of finderscopes.

Telescope mounts
There are two basic mount designs:

- *Altazimuth* (Alt-Az), the simplest design with two independent motions – horizontally in azimuth and vertically in altitude. A Dobsonian mount (pictured) is very popular and easy to use but it must be manually moved to follow celestial objects.

- *Equatorial* mounts have two axes, a polar axis that must be raised by the observer's latitude to point to the South Celestial Pole and must point North-South, which allows East-West rotation around the polar axis. The declination axis allows North-South rotation around the polar axis by mounting the telescope to one side of the polar axis and balancing it with a counterweight on the opposite side. The main advantage of a German equatorial mount (pictured) is that it only needs to be rotated around the polar axis to track a star if it is accurately polar aligned.





GoTo Mounts
GoTo mounts have built-in software that can automatically point the mount (and attached telescope) to any celestial object selected from its pre-programmed database. Both axes are motor-driven and controlled by a microprocessor or an external laptop or PC. GoTo mounts are extremely convenient but are also expensive.

Large optical telescopes

• Large Binocular Telescope	2x8.4m ≈ 11.9m	Mt Graham Obs, Arizona	2004
• Gran Telescopio Canarias	10.4m, 36 segments	Canary Islands	2006
• Hobby-Eberly Telescope	10.0m, 91 segments	McDonald Obs, Texas	1997
• Keck Telescopes	2x10.0m, 36 segments	Mauna Kea, Hawaii	1993
• SALT	9.2m, 91 segments	Sutherland, South Africa	2005
• Subaru Telescope	8.2m single mirror	Mauna Kea, Hawaii	1999
• Very Large Telescopes (3)	8.2m single mirror	Paranal Obs, Chile	1998

The Vera Rubin Telescope will be the world's largest optical telescope with a 39.3 m diameter segmented primary mirror. Designed by the European Southern Observatory, it will be located at the ESO Observatory in Chile and is intended to see first light in 2027. This telescope will have 256 times the light gathering capability, and images sixteen times sharper, than those of the Hubble Space Telescope.