

Optical Telescopes

Introduction

The night sky always attracted people by its charming mystery. Observers had been using naked eyes for their explorations for many centuries. Obviously, they could not achieve a lot due to eyesight limitations. It cannot be estimated, how important the invention of telescopes was for astronomers. It opened an enormous field for visual observations, which had led to many brilliant discoveries.

That happened in 1608, when the German-born Dutch eyeglass maker had guessed to combine several lenses and created the first telescope [PRAS]. This occasion is now almost forgotten, because no inventions were made but a Dutchman. His device was not used for astronomical purposes, and it found its application in military use. The event, which remains in people memories, is the Galilean invention of his first telescope in 1609. The first Galilean optical tube was very simple, it could only magnify objects three times. After several modifications, the scientist achieved higher optical power. This helped him to observe the venusian phases, lunar craters and four jovian satellites.

The main tasks of a telescope are the following:

- Gathering as much light radiation as possible
- Increasing an angular separation between objects
- Creating a focused image of an object

We have now achieved high technical level, which enables us to create colossal telescopes, reaching distant regions of the Universe and making great discoveries.

Telescope components

The main parts of which any telescope consists with are the following:

- Primary lens (for refracting telescopes), which is the main component of a device. Bigger the lens, more light a telescope can gather and fainter objects can be viewed.
- Primary mirror (for reflecting telescopes), which carries the same role as the primary lens in a refracting telescopes.
- Eyepiece, which magnifies the image.
- Mounting, which supports the tube, enabling it to be rotated.

Telescopes can be divided into two main categories: refractors and reflectors.

Refracting telescopes

The history of refractor's invention was discussed in the introduction part. Refractor is the simplest type of telescopes, which combines two lenses at the ends of a tube. As mentioned above, the main component of this type of

telescope is the primary lens – the objective. A concave lens is used as an objective of a refractor. It defines how faint objects can be viewed. The eyepiece, another concave lens, is placed at the other end of the tube. It defines the magnification of an object observed. The appearance and a schematic view of refracting telescope are shown in Figure 1.

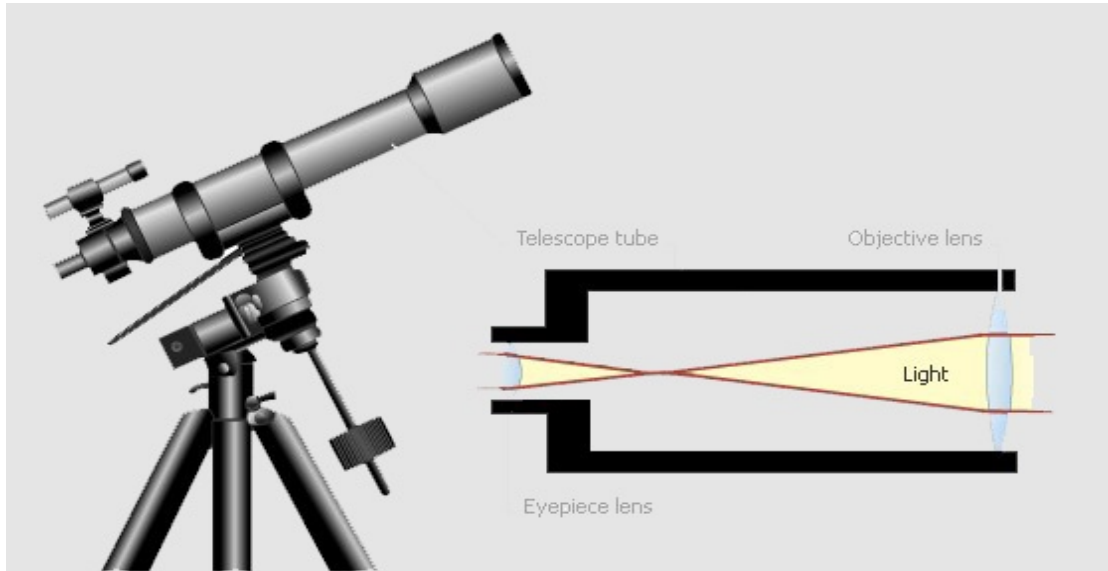


Figure 1. The refracting telescope.

Reflecting telescope

This is a later type of telescopes, firstly proposed by Giovanni Francesco Sagredo (1571 – 1620) who suggested that a curved mirror could be used instead of a lens. [WIKI] The first reflecting prototype was created by Isaac Newton in 1669. [WIKI]. These telescopes employ parabolic mirror to gather light from distant space sources and several auxiliary mirrors which direct path to the eyepiece. The appearance and a schematic view of reflecting telescope (Newtonian design) are shown in Figure 2.

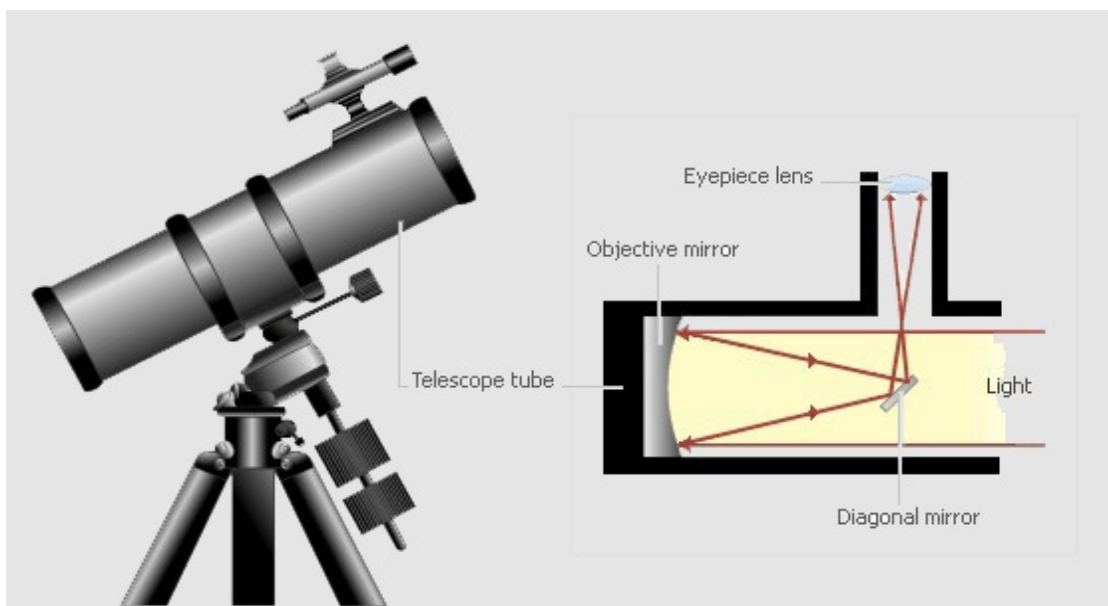


Figure 2. The reflecting telescope

Principle of working and main parameters

The light from a source reaches the primary lens (or primary mirror), converging at a focal point of a system. Depending on the design, the light either enters the eyepiece (refractors) or is reflected outside a main tube towards the ocular lens (reflectors).

The angular resolution is defined by the diameter of the main lens or mirror, which is referred to as an aperture D , measured in millimeters. For the visible light this limit is described by the following formula:

$$\sin \alpha = \frac{138}{D}$$

Where α is the limit resolution measured in arcseconds.

Each lens or mirror have their special feature known as focal length. If the focal length of the objective is F and the focal length of the eyepiece is f , then the magnification of the image produced by the optics is described by the following simple formula:

$$M = \frac{F}{f}$$

As mentioned before, the bigger the aperture, more light the optics can gather. More light enters the telescope, the fainter objects can be viewed. Limiting magnitude of a telescope can be found according the following formula:

$$M_L \approx 2.7 + 5 \log d$$

Where d is the aperture diameter in millimeters.

Another important parameter of a telescope is the focal ratio. It is defined as the focal length of the objective divided by its diameter. The smaller the ratio, the “faster” the optical system is and the better and brighter image can be produced.

Mountings

There are two main classes of mount: altitude-azimuth and equatorial. Telescopes with the first mount are aligned with the local zenith. Experiencing symmetrical gravity forces, the telescopes are normally less massive. The disadvantage is that the device should be moved in two directions simultaneously in order to track the object.

Equatorial mount is aligned with the polar axis. It requires a heavy counter-weight to balance the telescope. The advantage of this mount is that the tube has to be rotated along one polar axis only for following the sky. This configuration is much more convenient for tracking objects.

Optical defects

The quality of the views produced by optical telescopes is limited by optical defects - aberrations. Refractors suffer from chromatic aberration more than from other deviations. This is the result of the difference of the speed of light of various wavelengths in medium. Red light is refracted more than blue one.

As the consequence of this effect, a star is rounded by colorful concentric rings of light. A corrective lens is placed on top of the primary objective to reduce chromatic aberration.

Other types of aberrations are monochromatic. They are spherical, coma, astigmatism, distortion and field curvature. Spherical aberration results from the special spherical surface feature – it focuses on a line, not a point. Therefore, rays from the center of a mirror focus farther from it than rays from the edges. This is fixed by employing parabolic mirrors.

The rest of aberrations are off-axis, they depend on the field angle.

Conclusion

Telescopes are more the achievement of eyeglass makers than the invention of scientists. We can now see, how important opticians' device became for the astronomers. Telescope observations proved that the Earth is not the center of the Universe, and that the Solar System consists of several planets and their satellites. The optics is constantly modified and better telescopes are being produced for better views.

References

- [1] Observational Astronomy, Second edition, by D. S. Birney, G. Gonzalez, D. Oesper.