TELESCOPES

The astronomical telescope

The **object lens** (or **objective**) forms a small, inverted real image of a distant object – in this case the Moon – just inside the principal focus of the **eye lens** (or **eyepiece**). This image acts as a close object to the eye lens which forms a virtual magnified image of it. The eye lens is being used as a magnifying glass, but it is magnifying an image of the object rather than the object itself. The final image is upside-down, but this doesn't matter in astronomical observations.

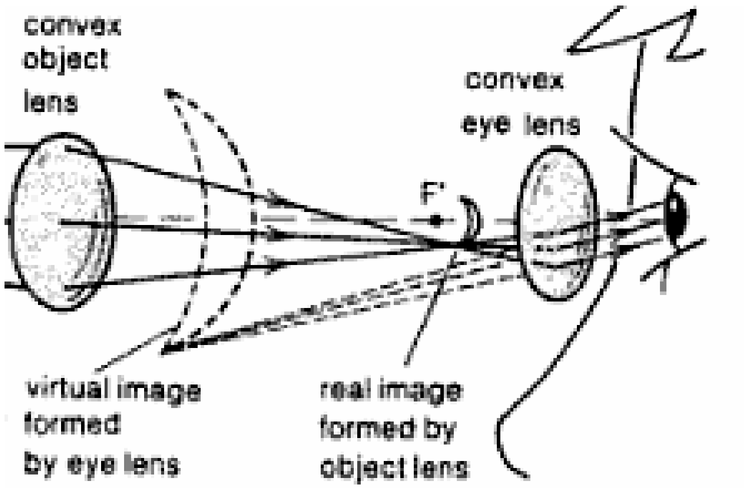

Figure 1 A simple telescope uses the small 'eye piece' lens to look at the real image formed by the large 'object' lens

Objective – objektív

Image of distant object:

- Smaller
- Real
- Inverted

Eyepiece – okulár (magnifying glass)

Image of close object:

- Upright
- Virtual
- Magnified image

Magnification The final image produced by the telescope is actually smaller than the original object. It looks larger because it is very much closer to the observer's eye. Figure 2 shows that the telescope increases the apparent **angular size** of the Moon, and it is this which causes the magnified image on the retina of the observer's eye.

The magnification produced by a telescope depends on the size of the real image formed by the object lens, and the extent to which this image is magnified by the eye lens. The two diagrams in figure 3 show that the object lens must have a long focal length to produce a relatively large real image. The eye lens on the other hand must have a short focal length if it is to act as a powerful magnifying glass.

To produce a high magnification, a telescope must have a long focal length object lens and a short focal length eye lens.

Light-gathering power For astronomers viewing very faint stars and galaxies, the light-gathering power of a telescope is as important as its magnification. The larger the diameter of the object lens, the greater is the light-gathering power, and the brighter and more detailed is the final image. In practice, the limit for the diameter of a glass object lens is about a metre. Above this, the lens would sag under its own weight.

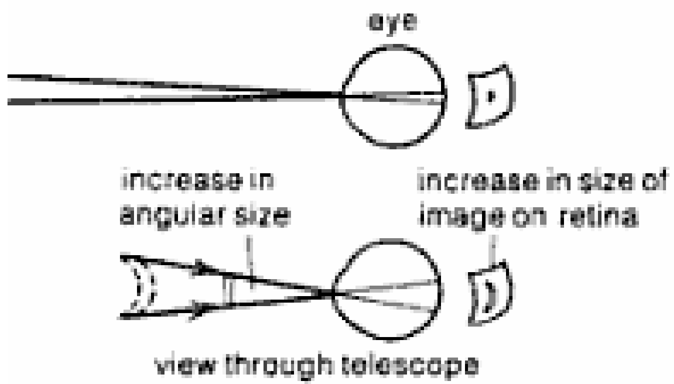

Figure 2 The telescope increases the apparent angular size of the object

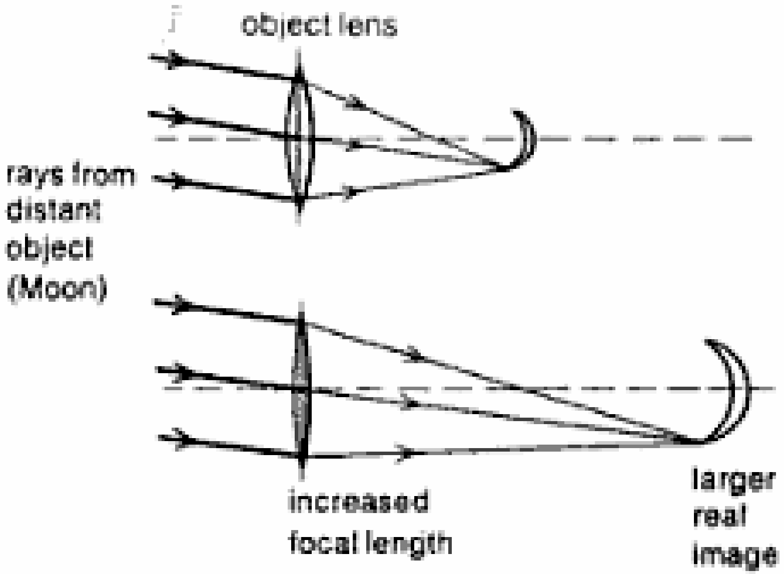

Figure 3 To get a high magnification you need a long focal-length 'object' lens (and therefore a long telescope!)

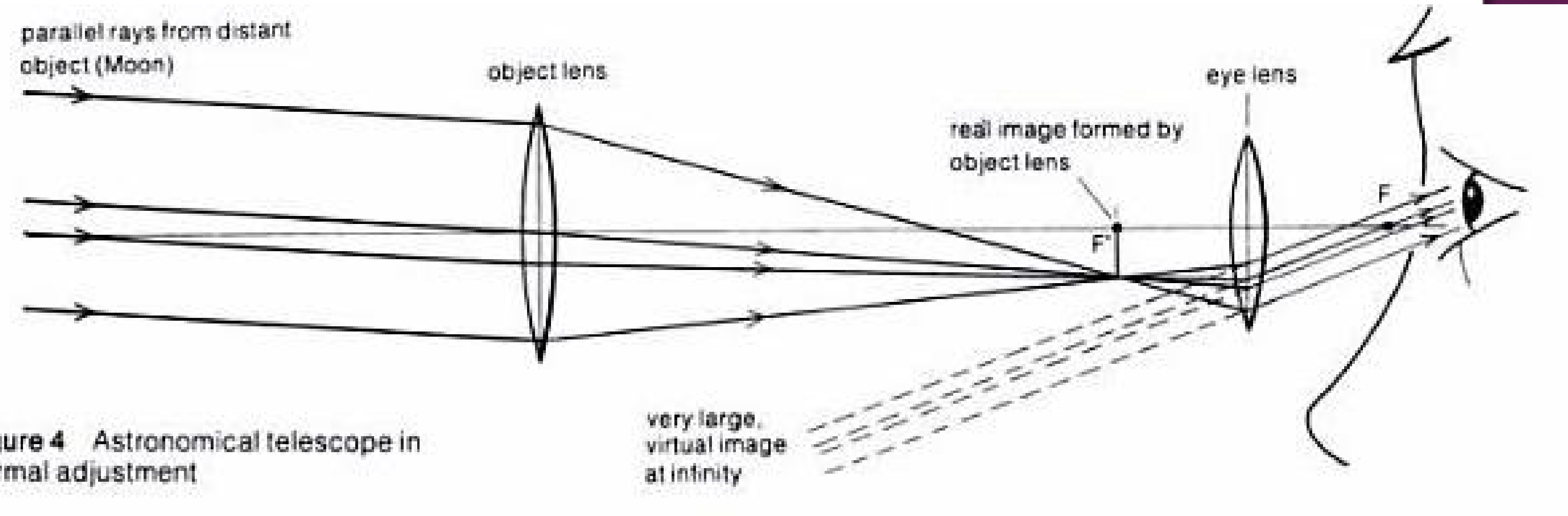

Figure 4 Astronomical telescope in normal adjustment

f_1 – focal length of objective

f_2 – focal length of eyepiece

Angular magnification: $\gamma = \mathrm{tg}\,\varphi' / \mathrm{tg}\,\varphi = f_1 / f_2$

- Calculate the focal length of objective and eyepiece, if the distance between them is 38 cm. Angular magnification of the telescope is 20.

Normal adjustment In figure 4, the lens positions have been adjusted so that the image formed by the object lens lies exactly at the principal focus of the eye lens. The rays entering the observer's eye are parallel, and the telescope is said to be in **normal adjustment**. For prolonged viewing, this arrangement is less tiring for the eye as the focusing muscles are fully relaxed. To the observer, the view of the Moon seems little different than before, though he is actually looking at an infinitely large image of the Moon an infinite distance away from his eye!

Binoculars: two telescopes side by side, with prisms to turn the image the right way up

Astronomical reflecting telescopes

In a reflecting telescope, a concave mirror is used instead of a convex lens to form a real image in front of the eye lens. Figure 5 shows a typical arrangement; the eye lens is on the side of the telescope, and a small plane mirror is used to reflect light from the concave mirror towards it. The small mirror stops a little of the incoming light from reaching the concave mirror, but it doesn't block the observer's view in any way. A concave mirror (or a convex lens for that matter) forms a complete real image even when partly covered.

The main advantage of reflecting telescopes is that very large concave mirror diameters are possible. Unlike lenses, mirrors can be supported at the back. The world's largest reflecting telescope is sited on Mount Semirodriki in the USSR. It has a 6 metre diameter mirror and a light-gathering power which should enable it to detect a lighted candle more than 20 000 km away!

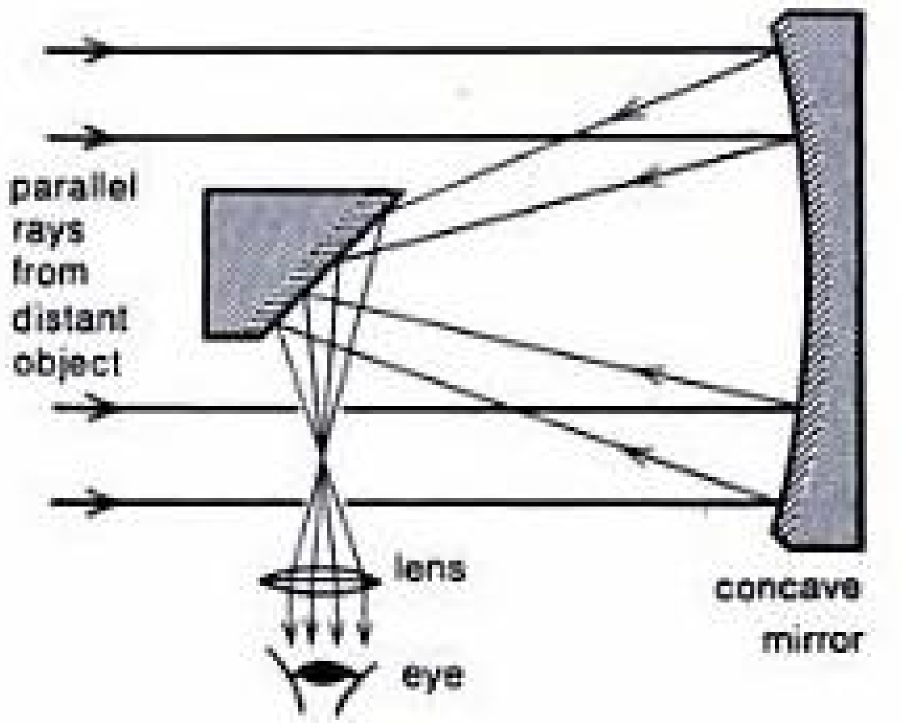

Figure 5 A reflecting telescope