IMAGE IN A REFRACTING TELESCOPE

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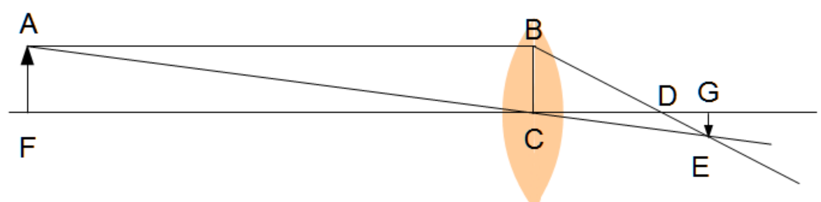
Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 6, Problem 6.2.

In a refracting telescope, the main imaging element is, of course, the primary lens. To get an idea of how a lens forms an image, look at the diagram:



The lens, shown in orange, focuses all light that comes in parallel to its axis (the axis is line FG) to the focal point at D. The focal length f is the distance from the centre of the lens to the focal point, so is the distance CD. Suppose we place an arrow FA a long way from the lens, oriented so that the arrow's tail lies on the axis and the arrow is perpendicular to the axis. To find where the head of the arrow shows up on the image behind the lens, we draw two lines. AB is parallel to the axis and is refracted by the lens so that passes through the focal point by following path BD. The line AC passes through the centre of the lens and, for a very thin lens, is not appreciably refracted so the light ray passes straight through. This ray intersects the BD ray at point E, which is where the image of the arrow's head will be.

Since the tail of the arrow is on the axis, light parallel to the axis passes straight through the lens and thus the image of the tail forms at point G. Note that the larger the distance of the arrow from the lens, the smaller is the angle between AB and AC, so the size GE of the image is also smaller (as you'd expect).

To summarize, the distance p from the arrow to the lens is AB $=$ FC, the focal length is $f=$ CD and the distance from the lens to the image plane is $q=$ CG.

To get a relation between p, q and f we can use similar triangles. Triangle ACF is similar to ECG so

$$\frac{\overline{AF}}{p}=\frac{\overline{GE}}{q} \tag{1}$$

Triangle BCD is similar to EGD so

$$\frac{\overline{BC}}{f}=\frac{\overline{GE}}{q-f} \tag{2}$$

However, $\overline{BC}=\overline{AF}$ so we can divide the first equation by the second to get

$$\begin{aligned}
\frac{f}{p} &= \frac{q-f}{q} && (3)\\
fq &= pq-fp && (4)\\
\frac{1}{p}+\frac{1}{q} &= \frac{1}{f} && (5)
\end{aligned}$$

where we divided the second equation by fpq on both sides to get the last equation.

In astronomy, the distance p is essentially infinite compared to f and q so the last equation tells us that for distant objects

$$q\approx f \tag{6}$$

That is, the image plane is the same as the focal plane of the lens.

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