MAGNIFICATION IN AN ASTRONOMICAL TELESCOPE

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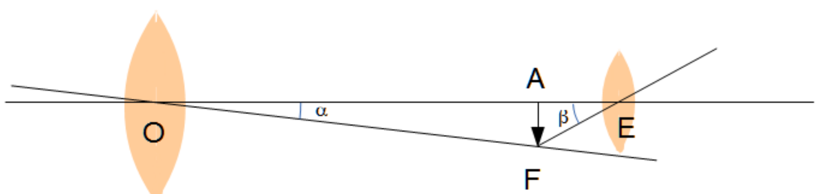
Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 6, Problem 6.5.

Anyone who has an astronomical telescope probably knows that the magnification you get from the telescope is the focal length of the main lens or mirror (the objective) divided by the focal length of the eyepiece. To see where this formula comes from, look at the following diagram:



Suppose we're observing a double star in which the two components are separated by an angle α. If we have one component exactly centred in the objective lens so that its light arrives parallel to the axis of the lens (along the line OA), then the light from the other component arrives at an angle α as shown. Since the image and focal planes are essentially the same for distant objects, the image of the double star (represented by the arrow AF) is formed in the focal plane of the objective lens O, so that the distance OA is the focal length f_O of lens O.

Now we place the eyepiece E so that it is at a distance equal to its focal length f_E from the image plane AF. The light ray from the star that is aligned with the axis of the lenses passes directly through E, but the light ray from the companion star passes from F through the centre of E as shown. [In reality, the ray that travels along FE would, of course, also have to have passed through the objective lens O, and in a real telescope, the distance between O and E is much larger than shown in the diagram, so that the rays OF and EF would be almost parallel, and EF would actually intersect the lens O. The angles α and β in an astronomical telescope are typically only seconds of arc.]

Because the focal length $f_E \ll f_O$ the angle β is correspondingly larger than α. As these angles are both very small, we can use the approximations $\tan\alpha \approx \alpha$ and $\tan\beta \approx \beta$, so

$$\alpha = \frac{\overline{AF}}{f_O} \tag{0.1}$$

$$\beta = \frac{\overline{AF}}{f_E} \tag{0.2}$$

The angular magnification is therefore

$$M = \frac{\beta}{\alpha} = \frac{f_O}{f_E} \tag{0.3}$$

For example, my telescope (which uses a mirror, but the principle is the same) has a mirror with focal length $f_O = 2800$ mm. A typical eyepiece giving a moderately wide view has a focal length of $f_E = 24$ mm so the magnification is about 117.