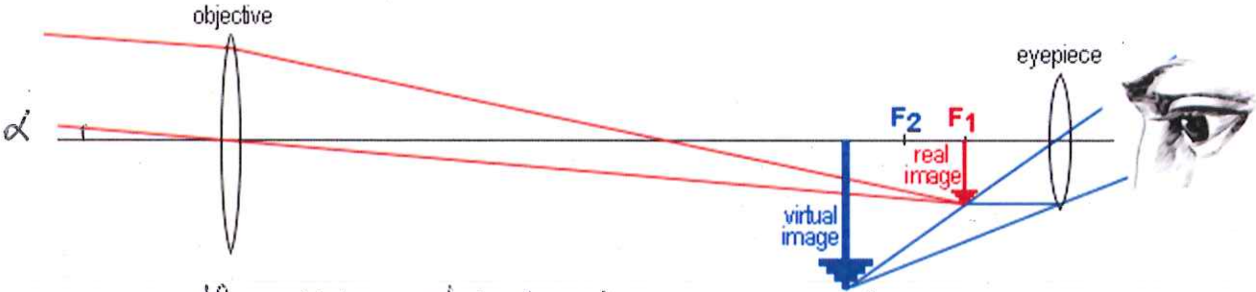
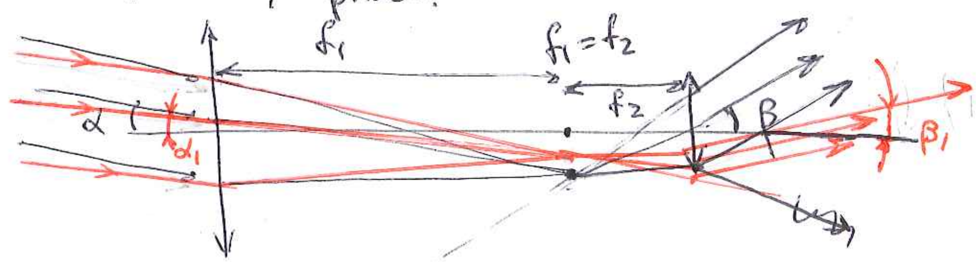
Telescope: to make a real image of a distant object, then make a magnified virtual image of it.



If our object is very far away

$$d_i = \frac{d_o \cdot f}{d_o - f} \overset{d_o \gg f}{\approx} \frac{d_o \cdot f}{d_o} \approx f$$

~~After~~ Intermediate real image is formed at the focal point of the 1st lens (objective)
After the second lens (eyepiece) the rays are almost parallel, so we need to place an eyepiece such that the real image of the objective is at the focal point of the eyepiece.



The difference b/w α and α_1 is much smaller than b/w β and β_1

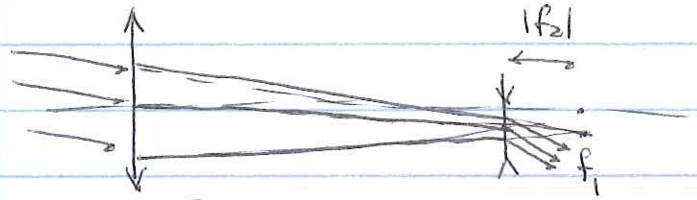
Astronomical telescope is an angular magnifier.

Telesope: two lenses at a distance $f_1 + f_2$

Angular magnification $M_\theta = \frac{\beta}{\alpha} = -\frac{f_1}{f_2}$ ← objective, ← eyepiece

for the refractive telescope with two converging lenses the image is inverted ($M_\theta < 0$)

Galelean telescope - one convergent + one divergent lens



$f_1 > 0$, $f_2 < 0$

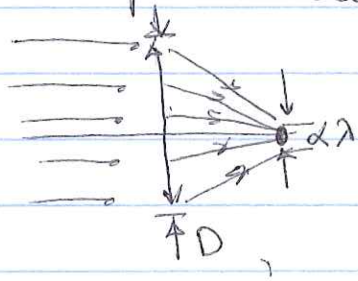
distance $d = f_1 + f_2 < f_1$

$M_\theta = - f_1 / f_2 > 0$

For the galelean telescope the image is not inverted

How well a telescope distinguish b/w two directions?
In ideal ray-tracing picture - any differences can be detected.
Two directions will be focussed into two infinitely small points at focus, and it should be possible to separate them,

However, it is impossible to focus light into a point. Because of the diffraction, the size of



the focal spot depends on the size of the lens, D, but it is roughly proportional to the wave length λ

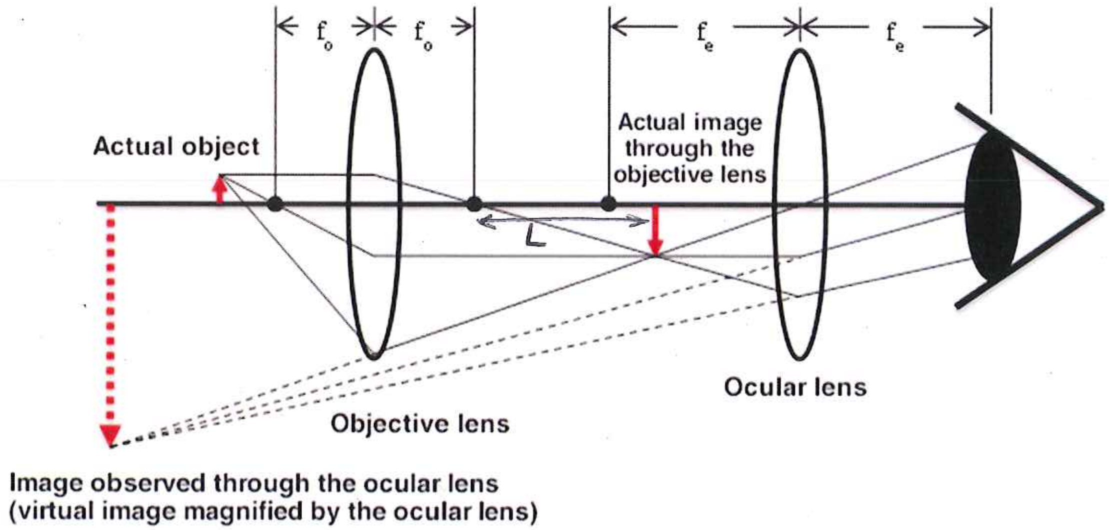
Angular resolution for a single lens

$$\Delta\theta_{res} = 1.22 \; \lambda / D$$

For a two-lens system

$$\Delta\theta_{tel} = \Delta\theta_{res \, objective} \cdot M_\theta$$

Microscope



It designed to first magnify a very small ~~[illegible]~~ object, to a real image, and then again magnify more by the second lens.

The distance b/w the lenses are usually closed because of the convenience (because normally one has to fiddle with the object)

Magnification $M = -\frac{L \cdot d_{near}}{f_e f_o}$

L - distance b/w the image focus of the objective and the real image, $d_{near} \approx 25cm$ is a "comfortable" imaging distance of an eye.

Clearly, the higher magnification requires smaller focal lengths for both objective and ocular.

ocular lens combination

Since it is hard to have a high-quality short-focus lens, usually a combination of several lenses are used.

objective lens assembly

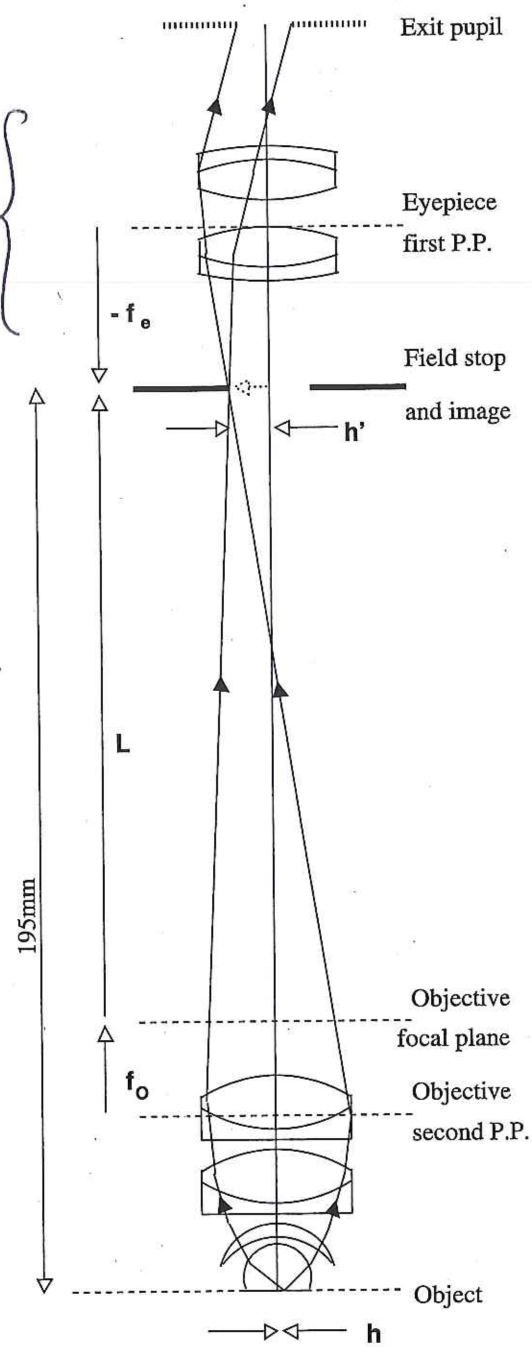


Fig. 4.9 Microscope construction showing the ray cone collected from an off-axis object point.