Image Formation and Optical Instruments

Chapter 34

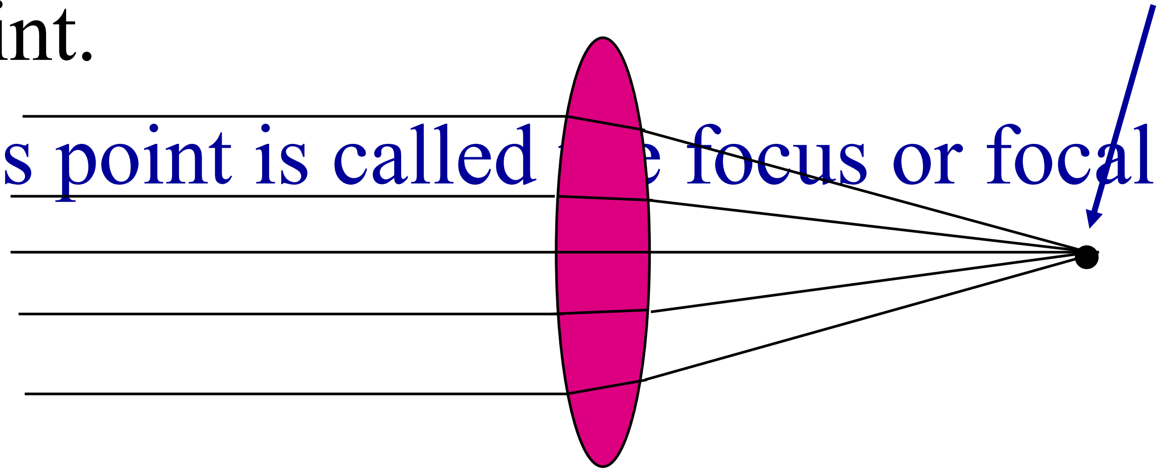
Mirrors

Lenses

The Simple Lens

A simple lens is an optical device which takes
parallel light rays and focuses them to a point.

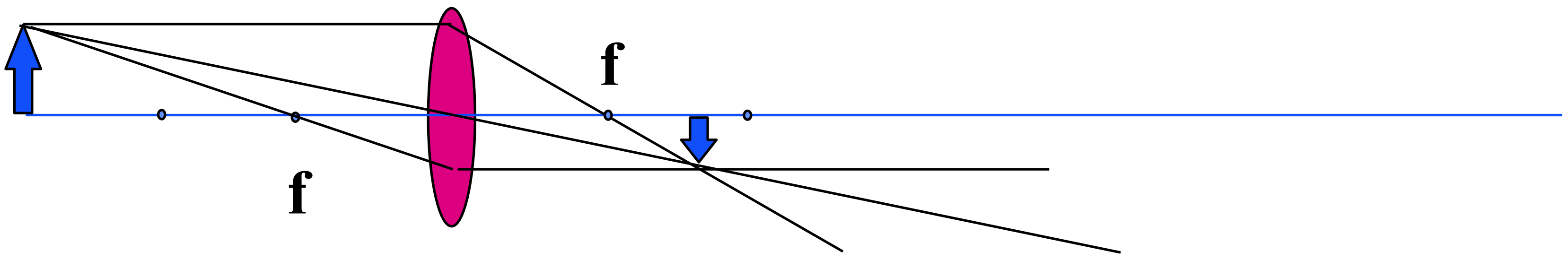
This point is called the focus or focal point



Snell's Law applied at each surface will show where the light comes to a focus.

Image Formation in a Lens

Each point in the image can be located using two rays.



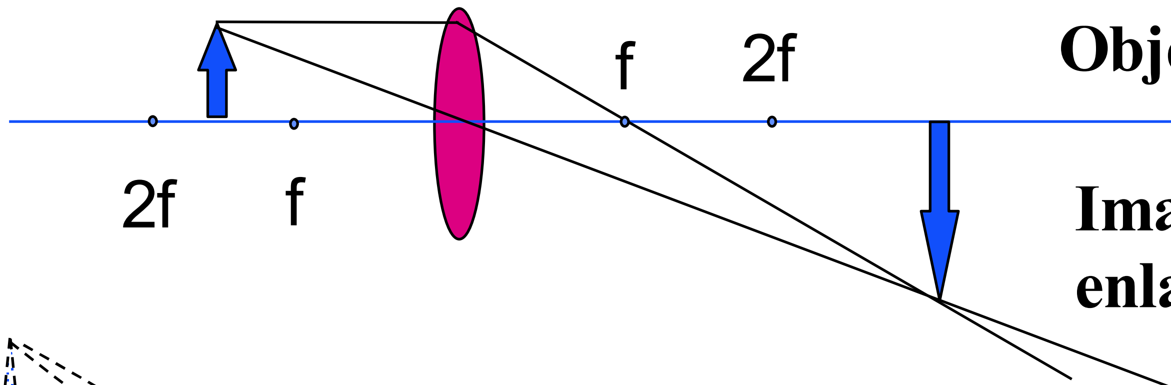
Ray tracing:

1. **A ray which leaves the object parallel to the axis, is refracted to pass through the focal point.**

2. A ray which passes through the lens's center is undeflected.

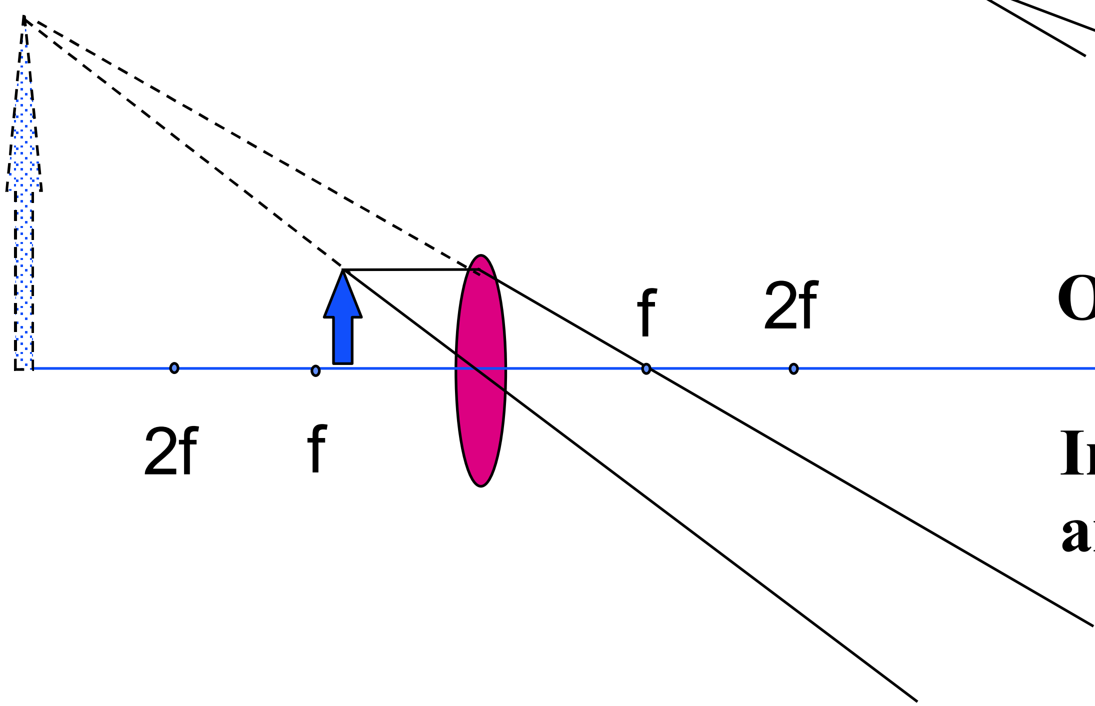
3. A ray passing through the focal point (on the object side) is refracted to end up parallel to the axis.

Some Simple Ray Traces



Object between 2f and f

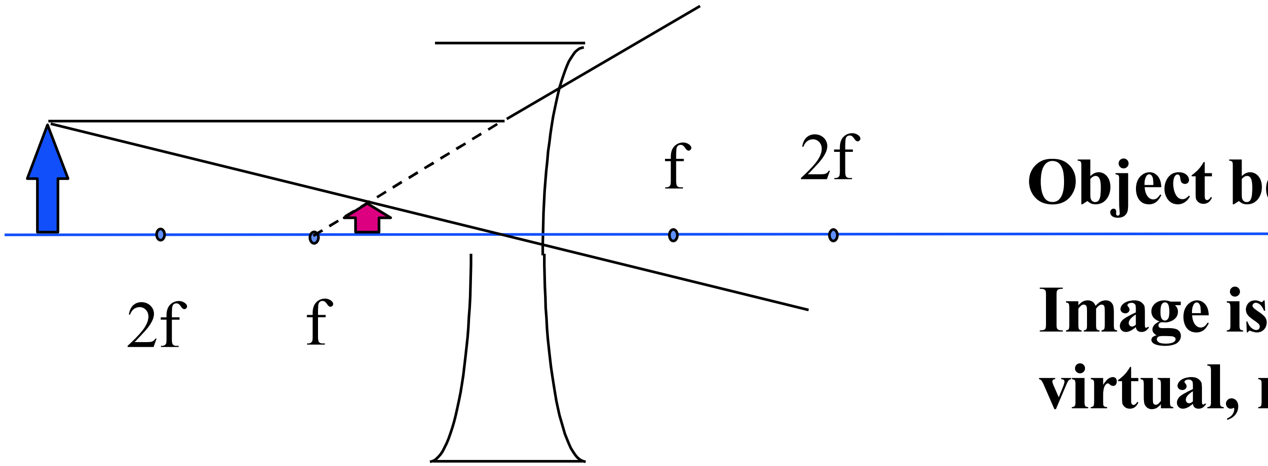
Image is inverted, real enlarged.



Object between f and lens

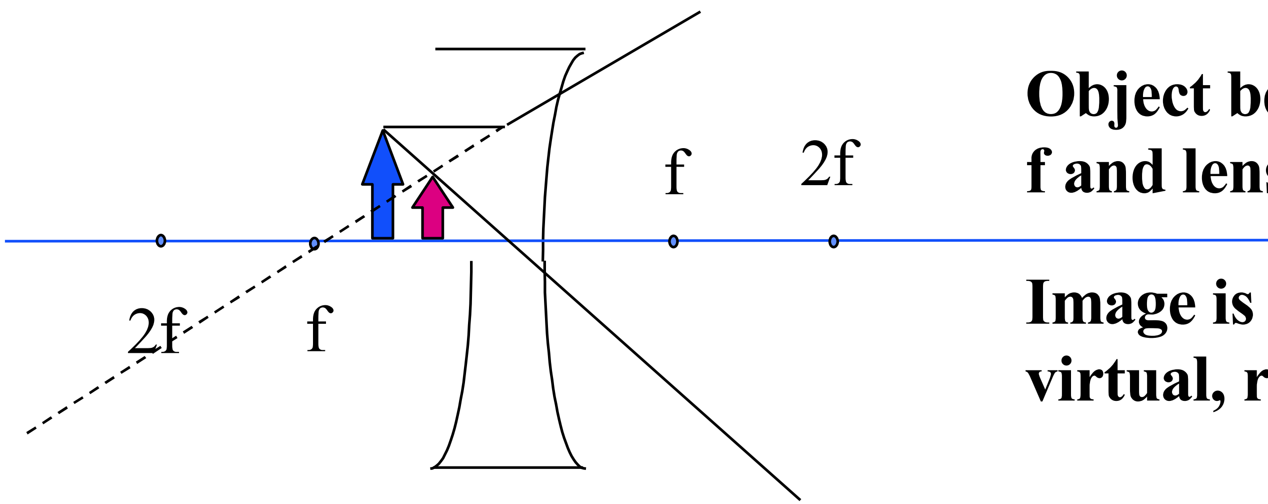
Image is upright, virtual, and enlarged.

Some Simple Ray Traces (diverging lens)



Object beyond 2f.

Image is upright, virtual, reduced.



Object between f and lens.

Image is upright, virtual, reduced.

A ray parallel to the axis diverges such that its extension passes through the focal point.

Sign Conventions

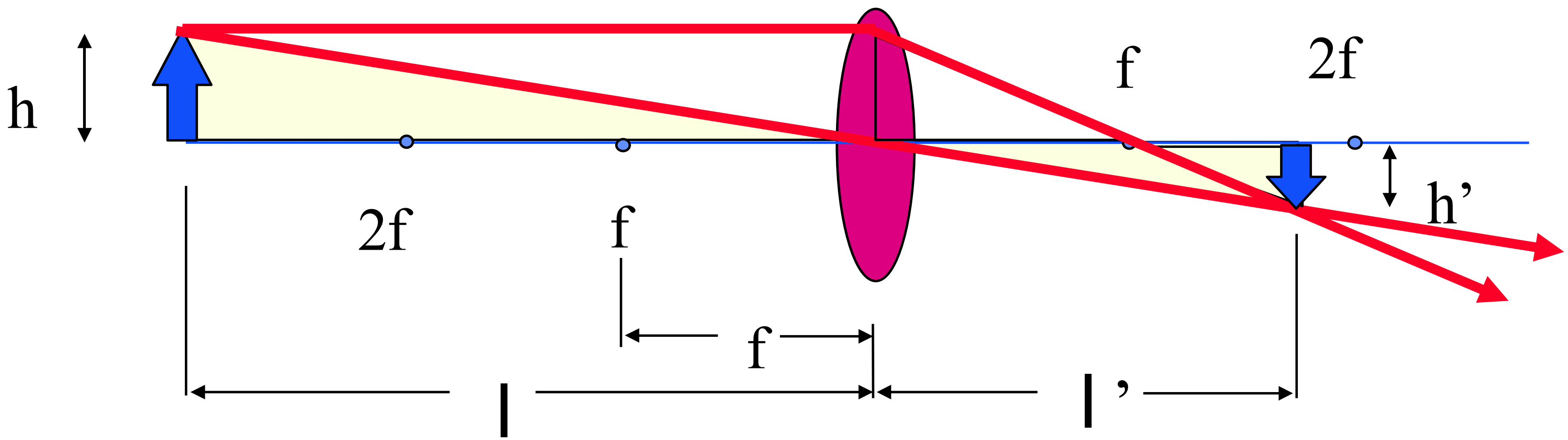
1. Converging or convex lens

focal length is positive
image distance is positive when on the other side of the lens (with respect to object)
height upright is positive, inverted is negative

2. Diverging or concave lens

focal length is negative
image distance is always virtual and negative (on the same side of the lens as the object)
height upright is positive, inverted is negative

The Thin Lens Equation



$M = h'/h = -l'/l$ Magnification

$1/l + 1/l' = 1/f$ The thin lens equation

About the Thin Lens Formula

$$1/l + 1/l' = 1/f$$

- When $l = f$, $l' =$ infinity
- When $l = 2f$, $l' = 2f$ and the magnification is 1.
- When $f > l > 0$, l' is negative
  - This means that the image is virtual, and so it is on the same side of the lens as the object.
- If $f < 0$, l' is always negative
  - A negative lens can not produce a real image. It always produces a virtual image.

The Lensmaker's Formula

The lens formula gives the image distance as a function of the object distance and the focal distance [1/f -1/l = 1/l']

The lensmaker's formula gives the focal distance f as a function of R_1 and R_2, the radii of curvature of the two surfaces of the lens.

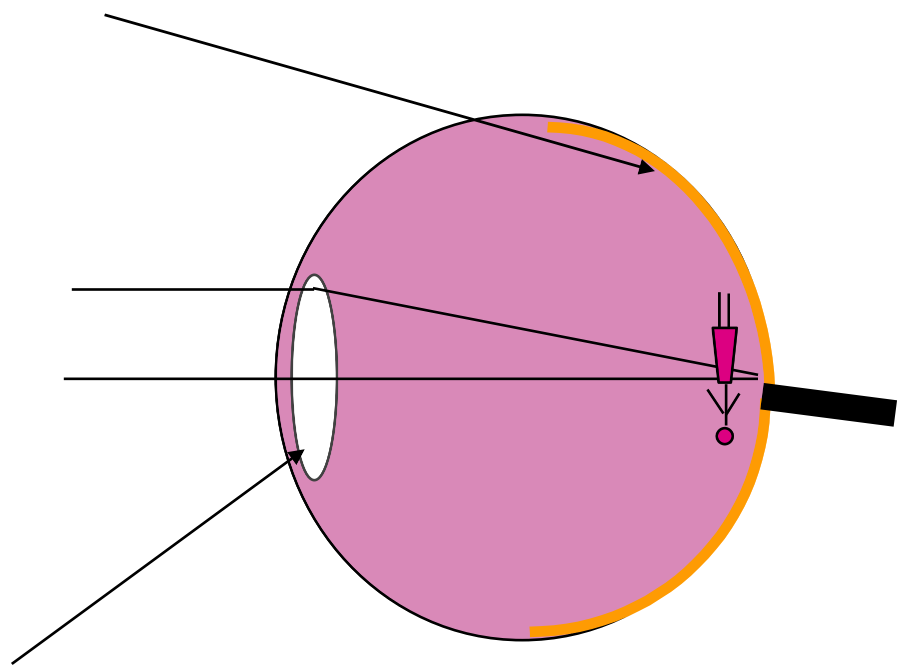
Lensmaker's Formula

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

The Eye: A Simple Imager

- A simple lens focuses the light onto the retina -- the photosensor
- The retina sends signals to the brain about which sensor is illuminated, what color the light is, and how much of it there is.
- The brain interprets.

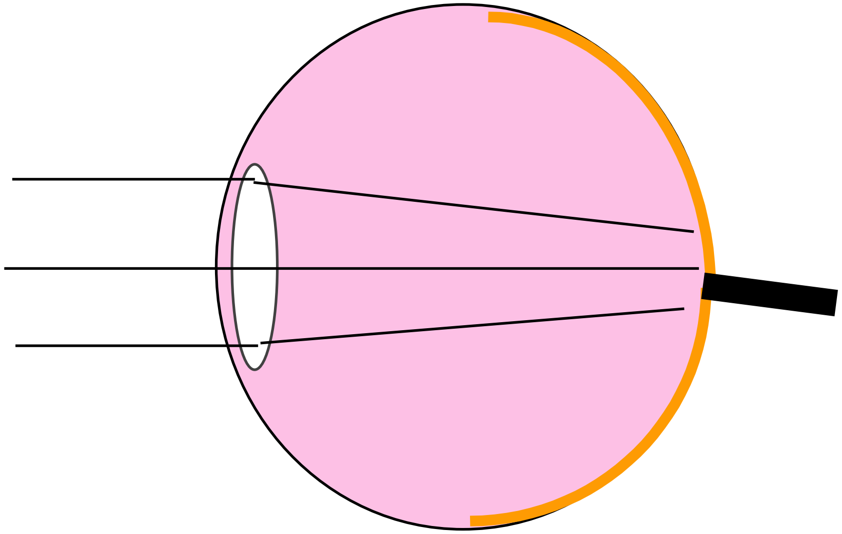
The retina senses the light.



Your eye's lens is a simple refracting lens which you can deform to change focus.

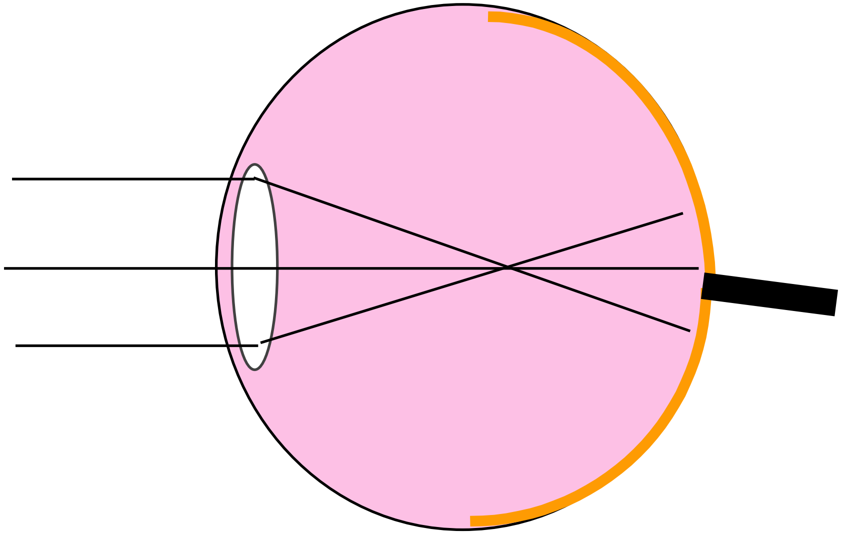
The Eye: Near & Farsightedness

Far-sighted:



Eye too short: correct with a converging lens

Near-sighted:



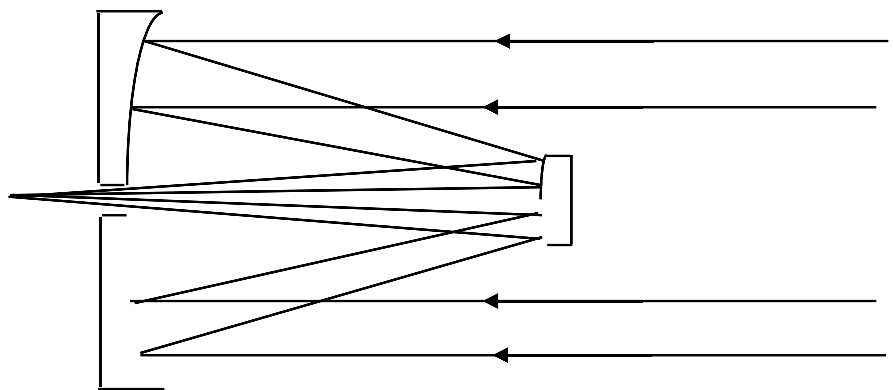
Eye too long: correct with a diverging lens

Image Forming Instruments

- Cameras are much like the eye except for having a shutter and better lenses.
- Binoculars and telescopes create magnified images of distant objects.
- Microscopes create magnified images of very small objects.

The UCF Robinson Observatory

The telescope here is a 66 cm (26 in) dia.
Schmidt-Cassegrain reflecting telescope.

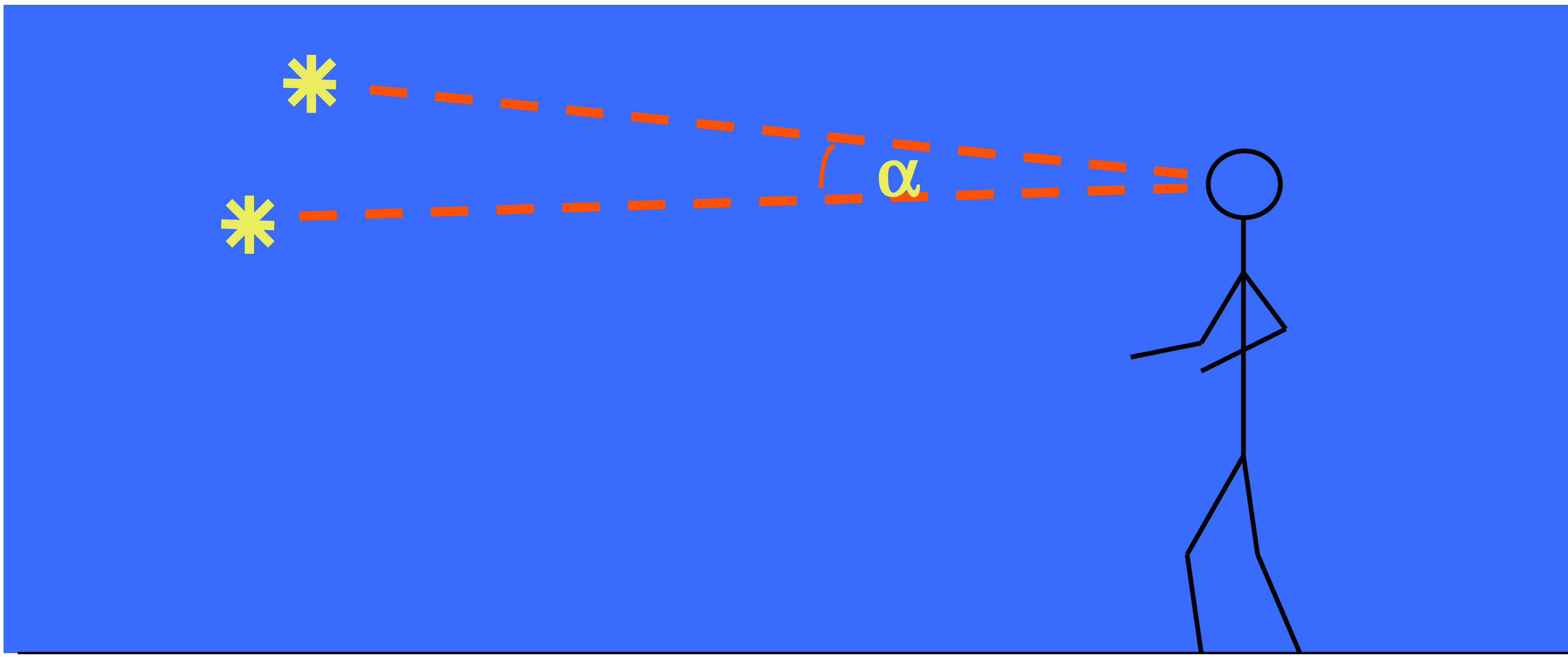


Telescopes are described by their diameter since that describes its ability to collect light from distant stars and glaxies; and that's more important than magnification.

Florida is not ideal for most observational astronomy. Why?

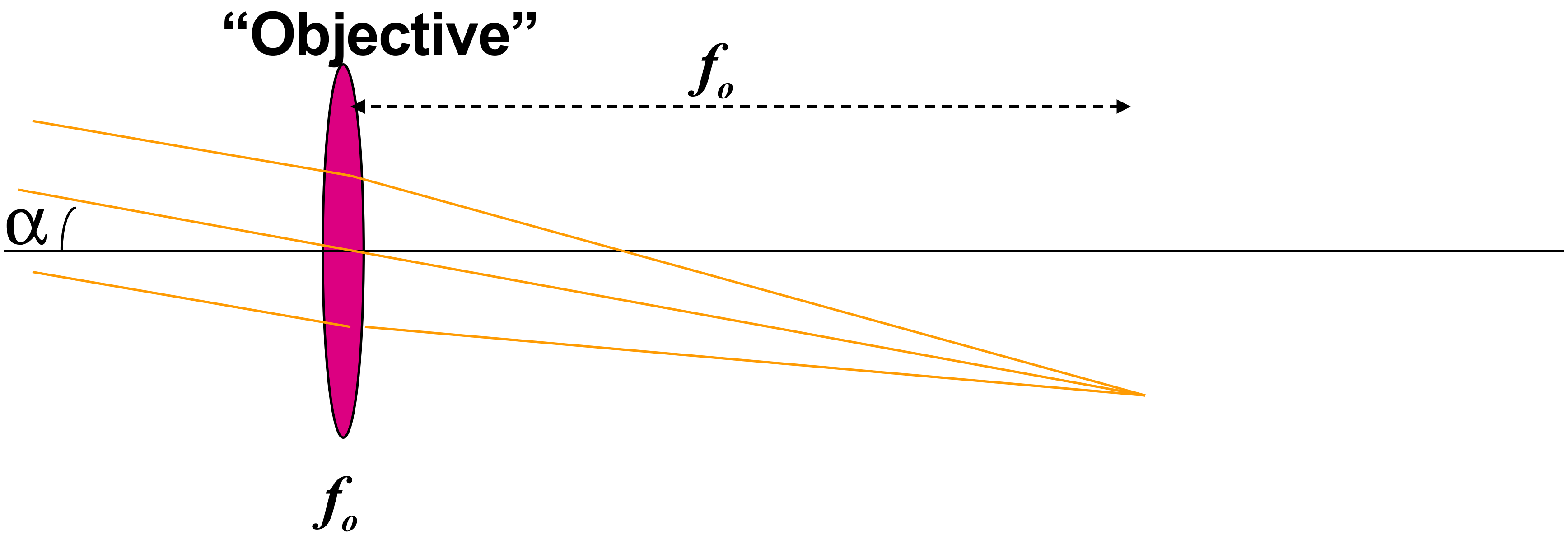
Image-Forming Instruments: the Telescope

When we look at distant objects, we judge their sizes from their angular size. In the case of stars, what we observe is their angular separation.



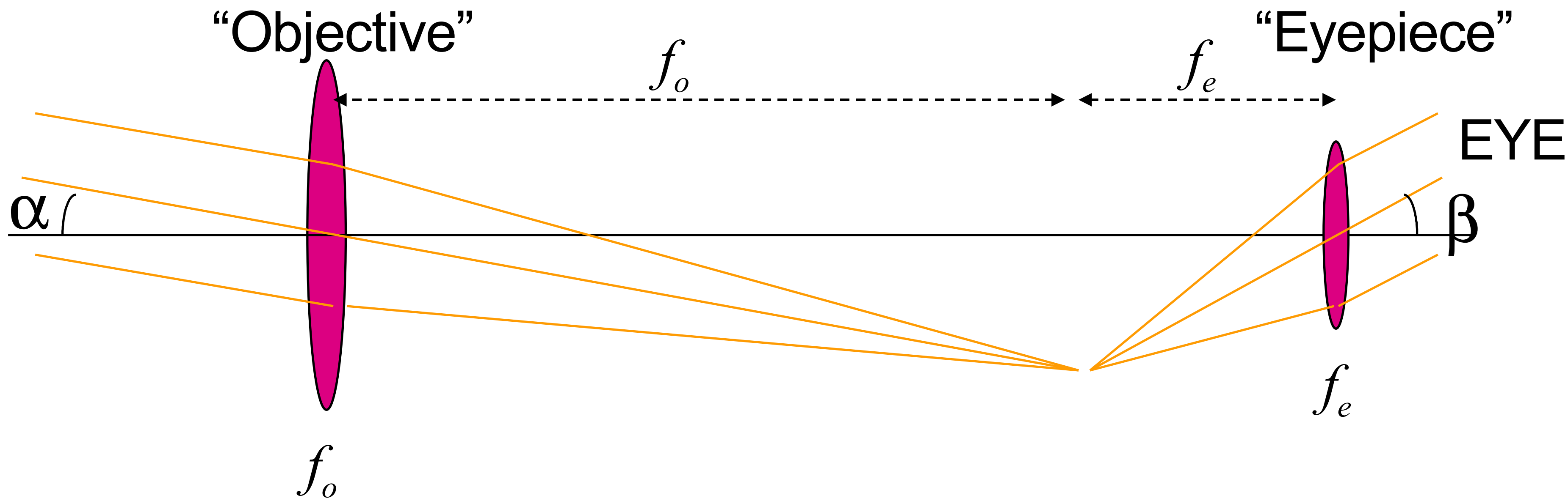
A telescope magnifies the angular size (or separation) of objects.

The Telescope



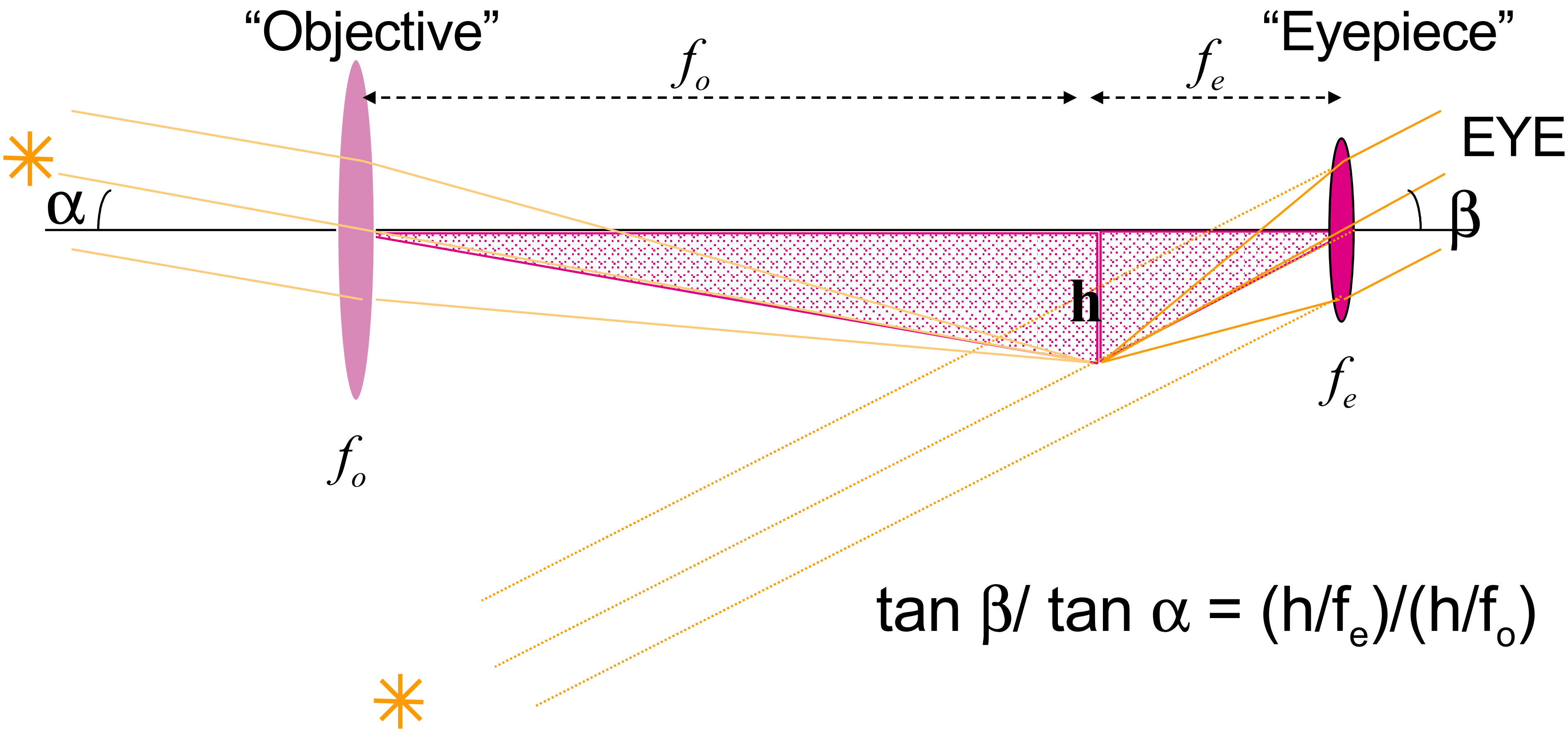
The "objective" lens first creates an image, in the focal plane, of a point at infinity.

The Telescope



The "objective" lens first creates an image, in the focal plane, of a point at infinity. The "eypiece" is placed $f_o + f_e$ from the objective, so that it produces parallel rays into the eye, at angle β.

The Telescope



tan β/ tan α = $(h/f_e)/(h/f_o)$

The eye sees an image at infinity, but at an angle of β instead of α.

The magnification is therefore: $M = \beta/\alpha = f_o/f_e$