TOPICS

- Recap of PHYS110 *- 1 lecture*
- Physical Optics *- 4 lectures*
  - EM spectrum and colour
  - Light sources
  - Interference and diffraction
  - Polarization
- Lens Aberrations *- 3 lectures*
  - Spherical aberrations
  - Coma, astigmatism, field curvature, distortion
  - Chromatic aberrations
- **Instrumental Optics** *- 4 lectures*
  - **Telescope, microscope**
  - Stops, eyepieces
  - Instruments for the anterior eye
  - Instruments for the posterior eye

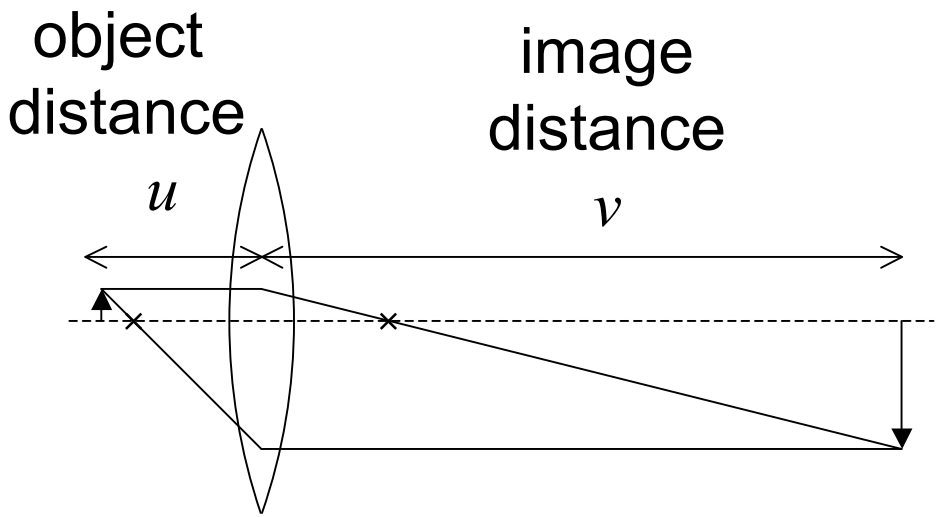
Lecture 9

- Magnification
- The magnifying glass
- The compound microscope
- The astronomical telescope
- The Galilean telescope

Magnification

- For an optical system that produces a **real** image, the magnification M is defined as:

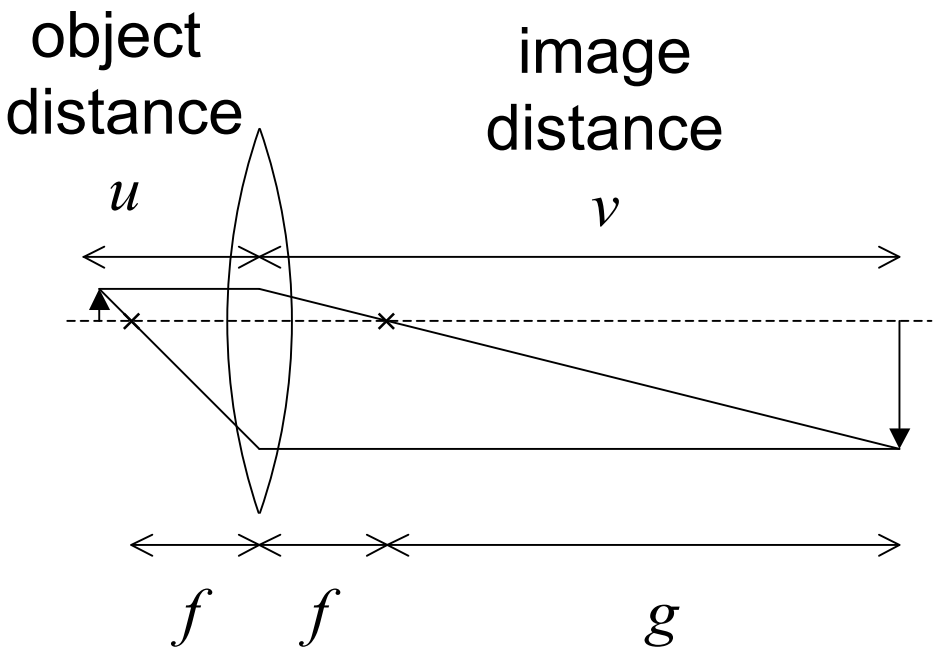
$$M = \frac{image\ size}{object\ size} = \frac{v}{u}$$



Magnification

Using $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, it follows that

$$M = \frac{v}{u} = v\left(\frac{1}{v} - \frac{1}{f}\right) = 1 - \frac{v}{f} = \frac{f - v}{f} = \frac{-g}{f}$$



Magnification is the ratio of the distance g from the second focal point to the image and the focal distance f of the lens

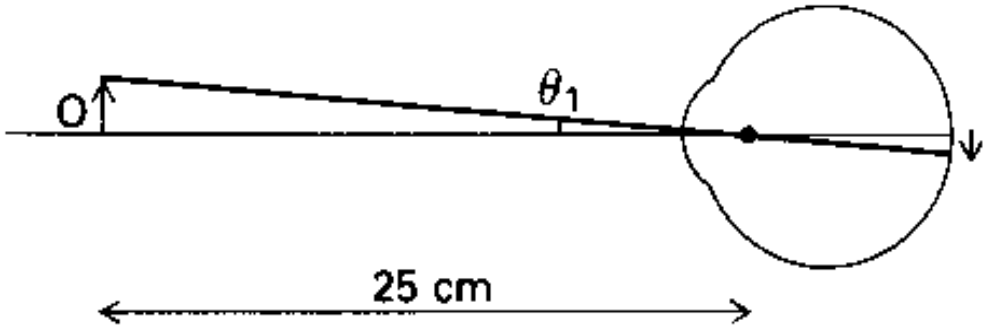
Magnification

- Most optical instruments make a **virtual** image that the observer needs to look at
- The eye becomes integral part of the optical system
- Definition of magnification:

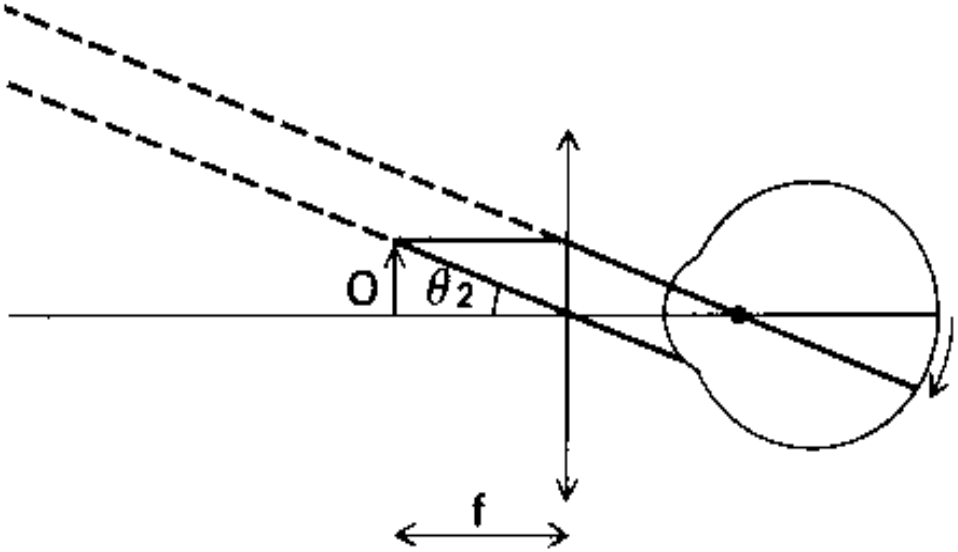
$$M = \frac{\text{retinal image size with the instrument}}{\text{retinal image size without the instrument}}$$

Magnifying glass

Without magnifying glass:
Object can be brought as close as the near point, nominally $0.25\ \mathrm{m}$



With magnifying glass:
Object can be seen *without accommodation* when placed at the first focal point, at a distance of f



$$M = \frac{\tan\theta_2}{\tan\theta_1} = \frac{O/f}{O/0.25\mathrm{m}} = \frac{0.25\mathrm{m}}{f} = 0.25F$$

Magnifying glass

- A magnifying glass smaller than the pupil of the eye is not practical
- This limits practical magnifying glasses to

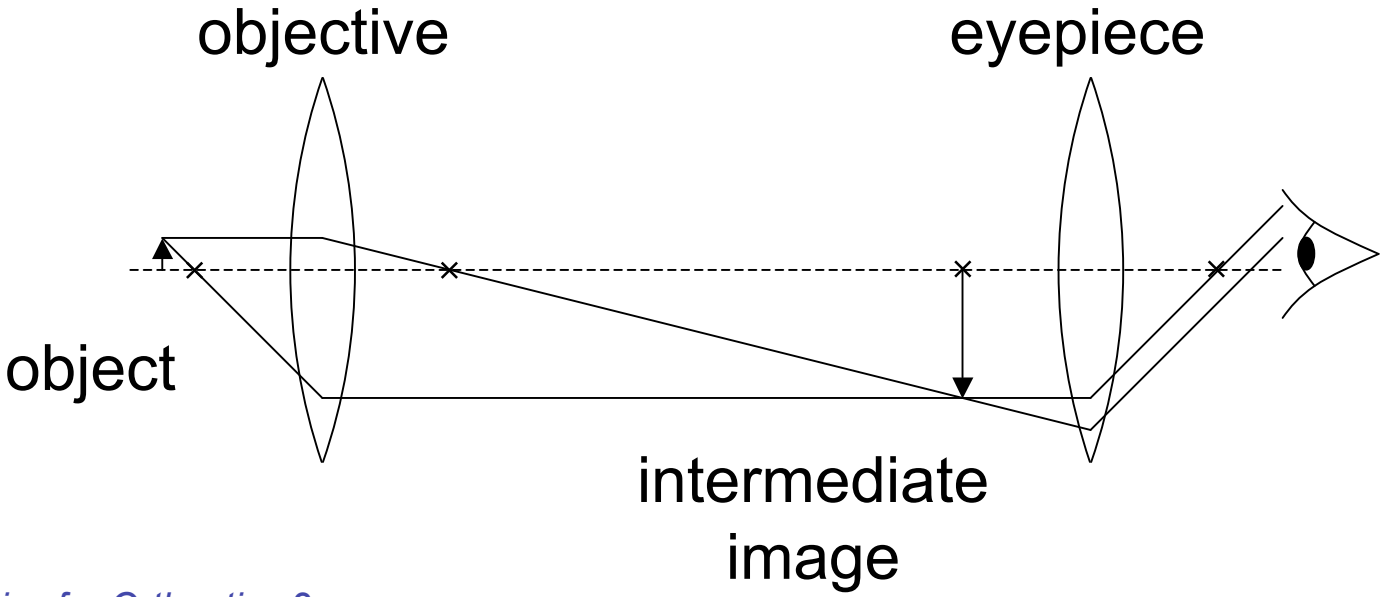
  $f \approx 1\text{cm}$ ($F = 100\text{D}$)

  with a magnification of

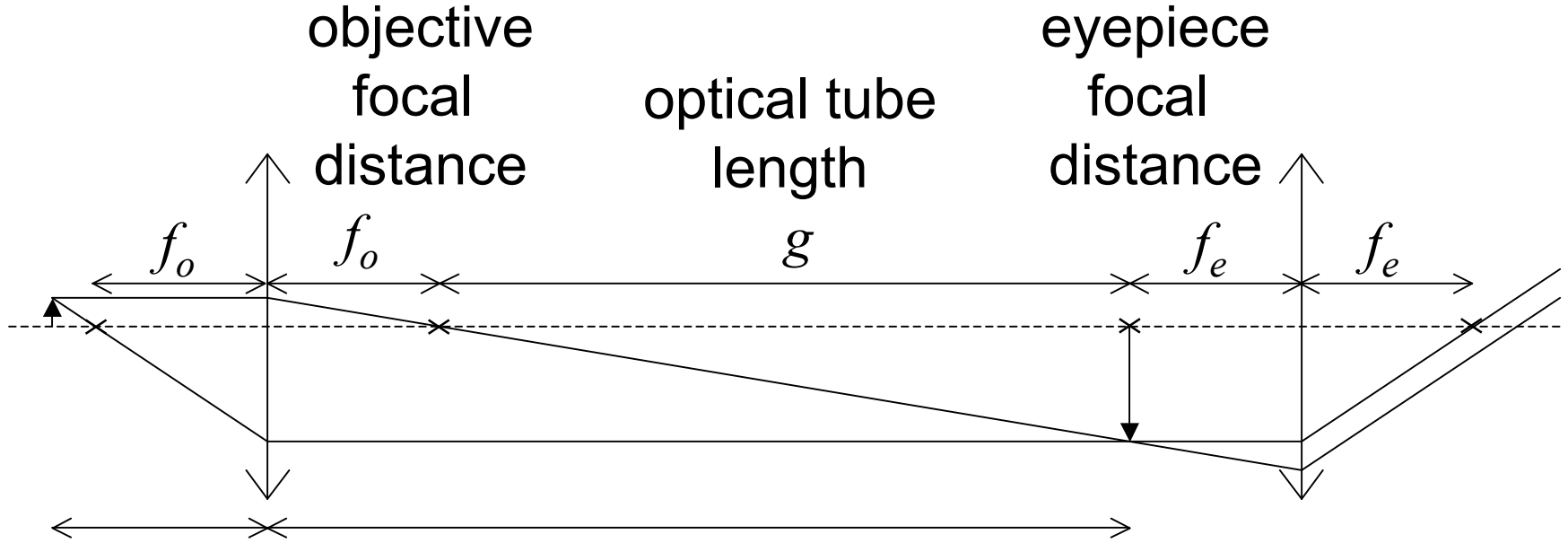
  $25\text{cm}/1\text{cm} = 25$
- For stronger magnification, the compound microscope is used

The compound microscope

- To magnify close objects
- Consists of two converging lens systems
- The **objective** forms a magnified real image of the object
- The **eyepiece** is used to examine this image
  - works as a magnifying glass



Magnification of microscope



magnification of objective

$M_o = v/u = -g/f_o = -gF_o$

magnification of eyepiece:

$M_e = 25\text{cm}/f_e = 0.25F_e$

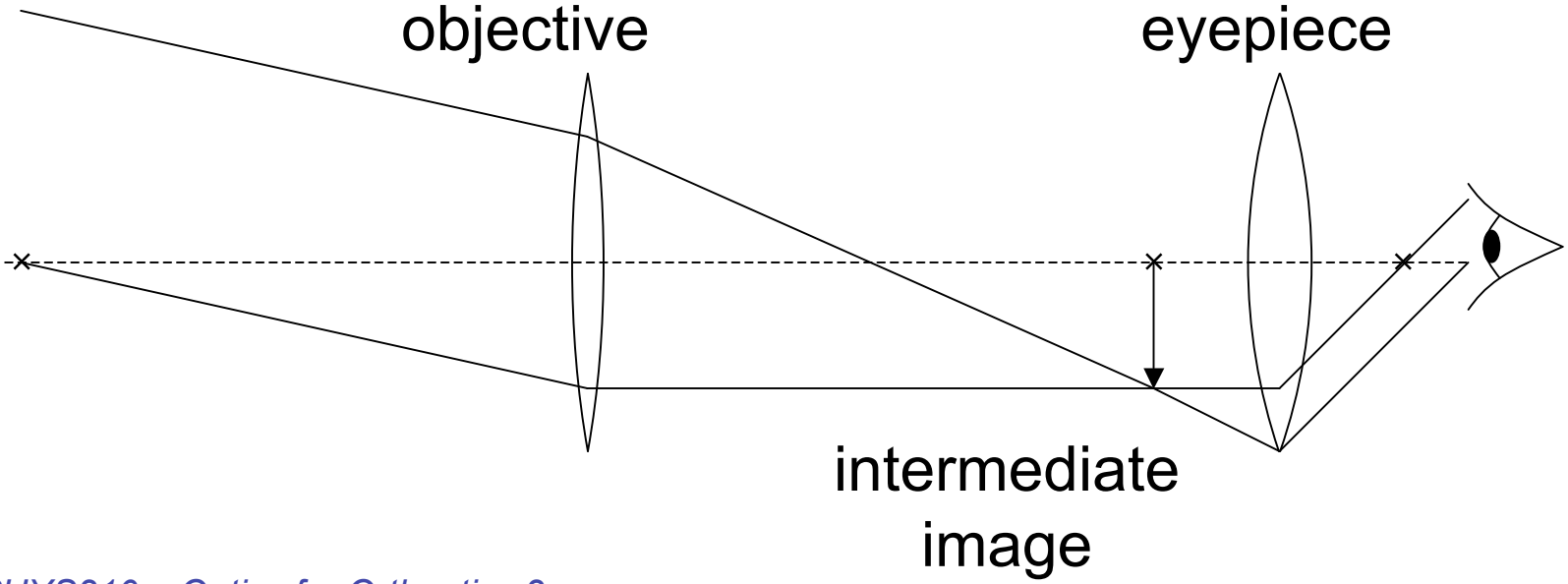
Total magnification $M = M_o \times M_e$

Compound microscope

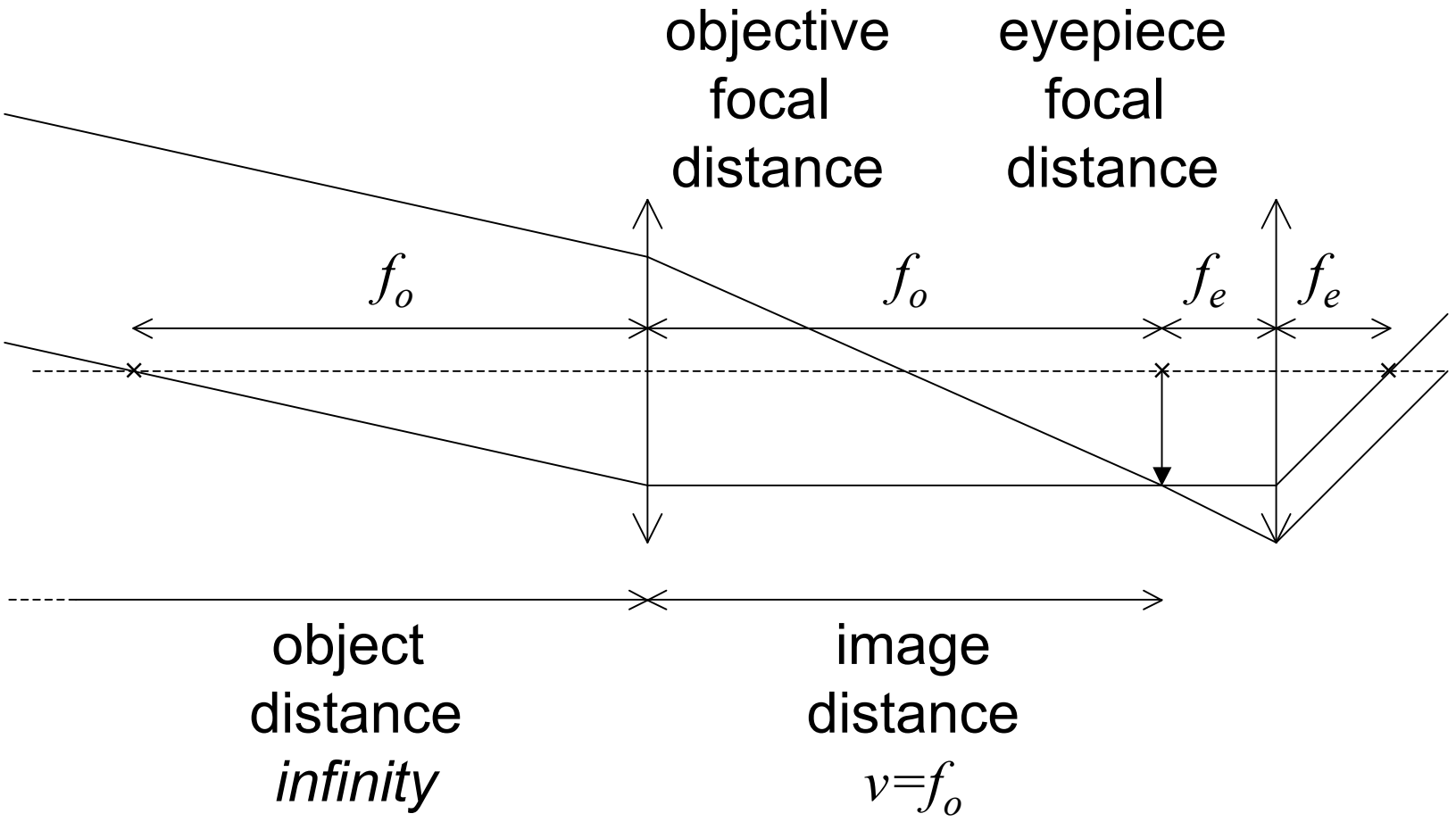
- The microscope image is inverted
- Prisms can be used to produce an erect image.
  - can also help to shorten the instrument
- The light intensity of the image is poor for high-power objectives
- Strong light sources needed for surface illumination microscope
- High-power transmission microscopes use specialized condenser systems to guide the light efficiently through the sample into the microscope

The astronomical telescope

- To magnify far-away objects
- Consist of two convex lens systems
- The **objective** forms an intermediate image
- The **eyepiece** is used to examine this image
  - works as a magnifying glass



Magnification of astronomical telescope

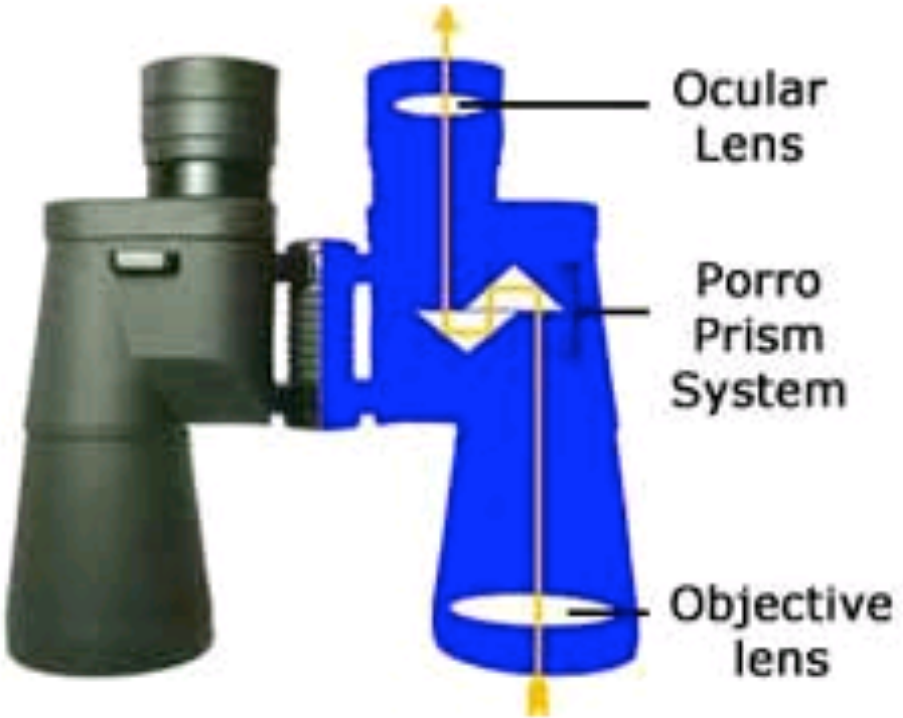


Magnification $M = -f_o/f_e = -F_e/F_o$

Distance between the two lenses is f_o+f_e

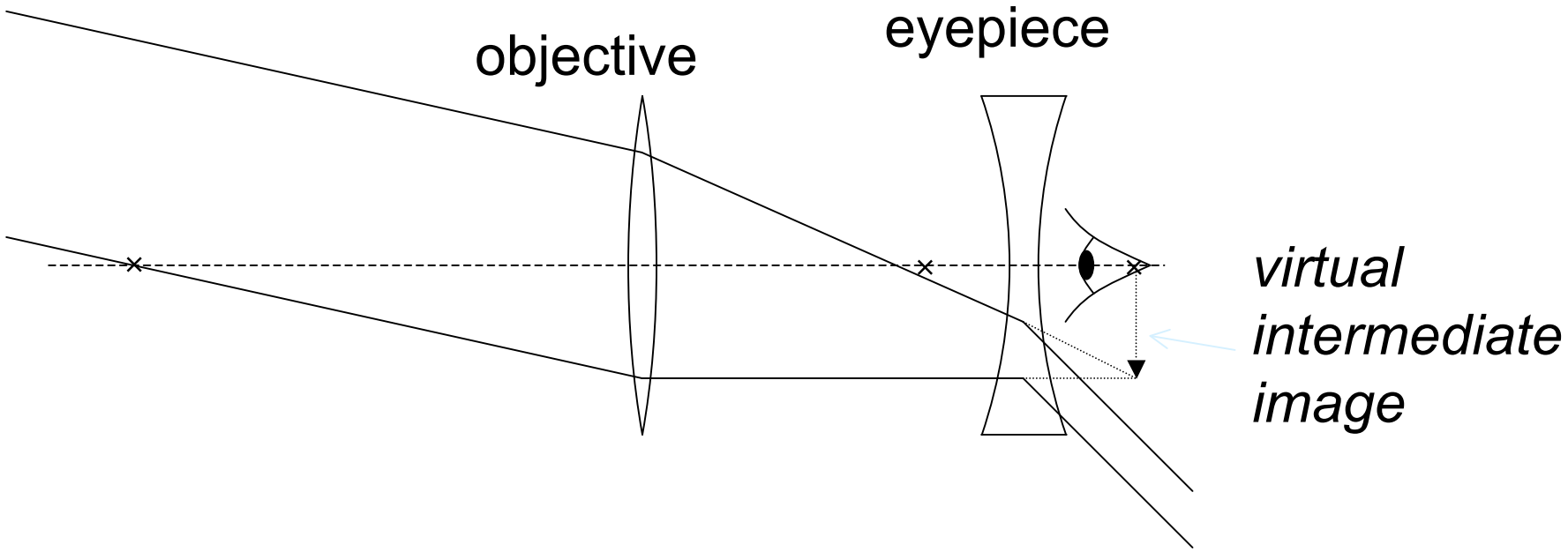
The astronomical telescope

- The image of the astronomical telescope is inverted
- Prisms or extra lens systems can be used to produce an erect image.
  - Can also help to shorten the instrument
  - Example: binoculars

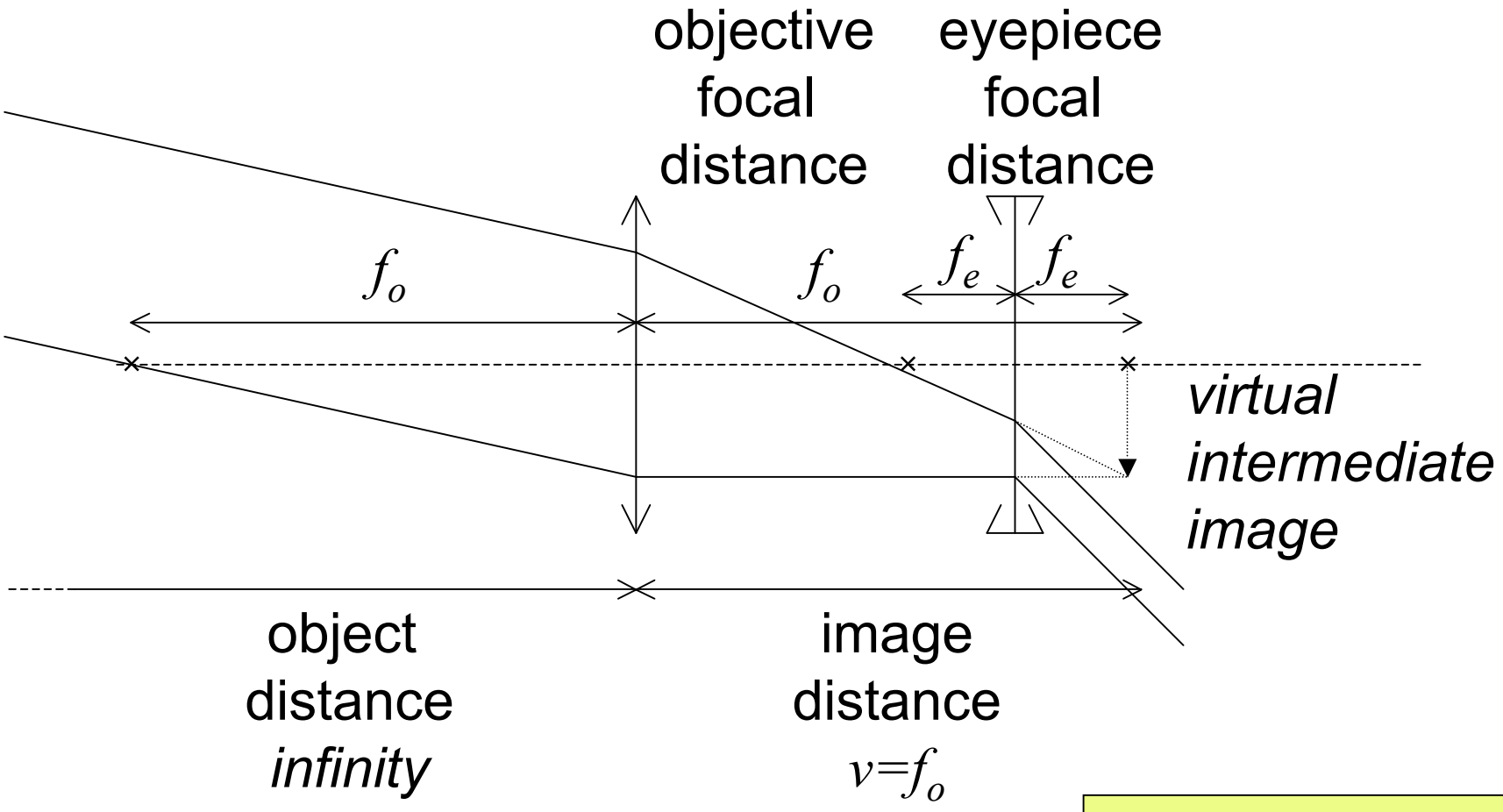


The Galilean telescope

- A convex lens as an objective plus a concave lens as an eyepiece.



Magnification of Galilean telescope



Magnification $M = -f_o/f_e = -F_e/F_o$

Distance between the two lenses is f_o+f_e

Same formulas as astronomical telescope, but now f_e is negative!

The Galilean telescope

+ Cheap, compact, light
+ Produces an erect, non-inverted image
– Limited field of view, must be held close to the eye

Best for low magnification applications:

- surgical loupe
- opera glasses