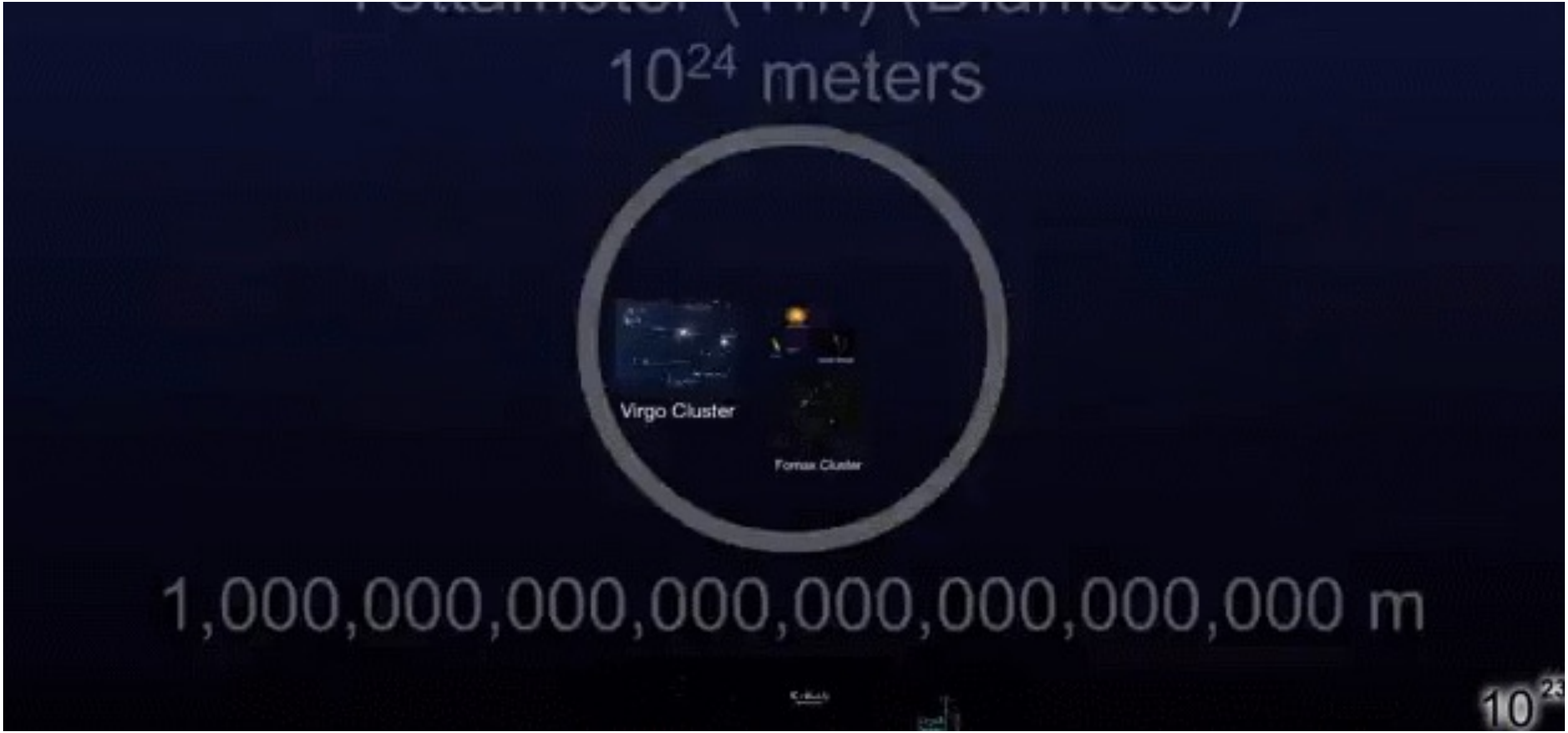
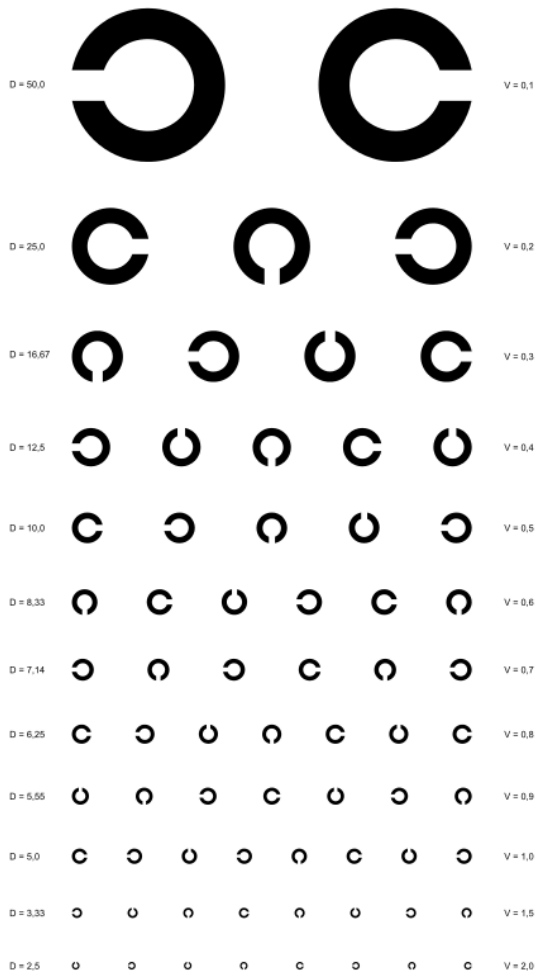
Designation of Microscopes and Telescopes

Mingquan He| College of physics

What is the smallest thing in universe?



Limit of naked-eye



~0.1 mm

明视距离 **Distance of distinct vision** 250 mm

How to observe things that are small or far away?

How to observe things that are small or far away?

Microscope and Telescope

Reproduction of **first compound microscope** made by Hans and Zacharias Janssen, circa 1590.
National Museum of Health and Medicine, Washington, D.C.

One of Galileo's first telescopes. He did not invent the telescope, but he did make several improvements and was the **first to aim one at the stars**.

Who invented Microscopes and Telescopes ?

Hans Lippershey
1570 – buried 29 September 1619
German-Dutch spectacle-maker

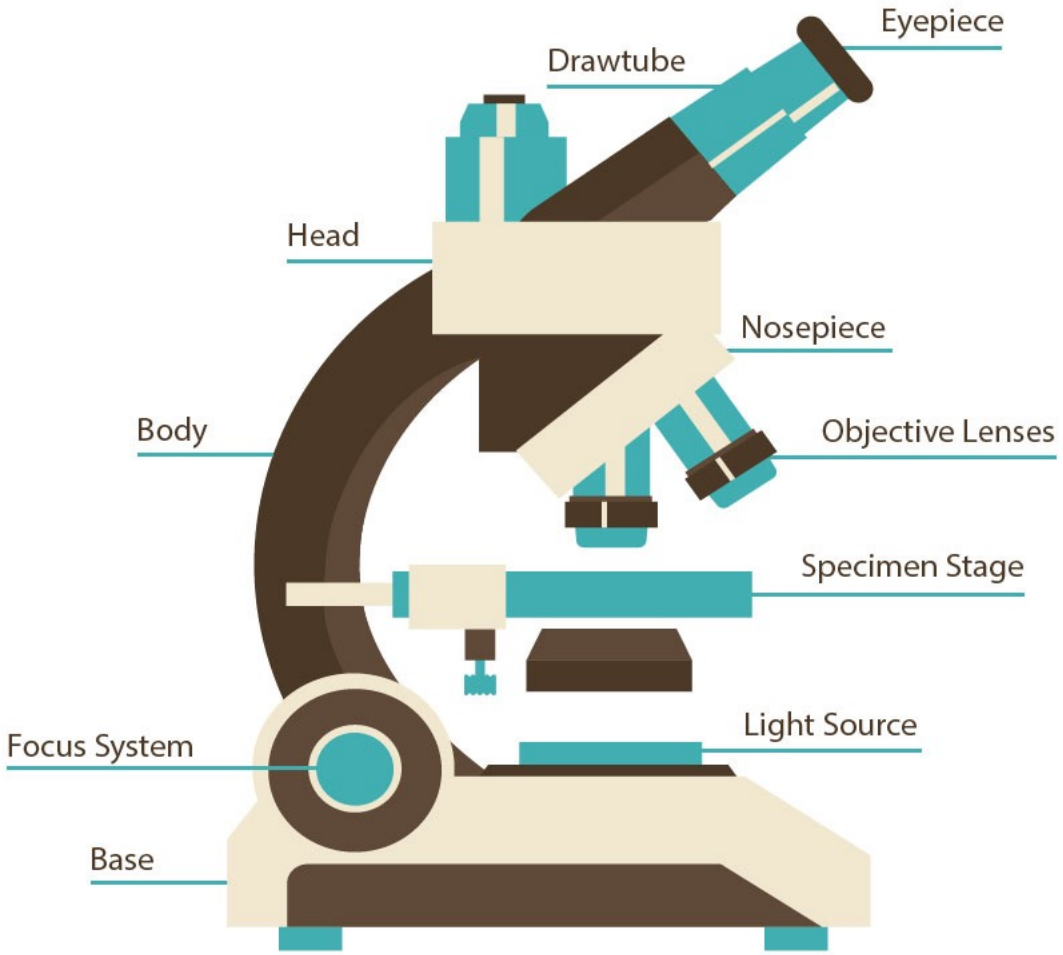
Microscope: ~1590

Telescope: Hans Lippershey applied patent in 1608.

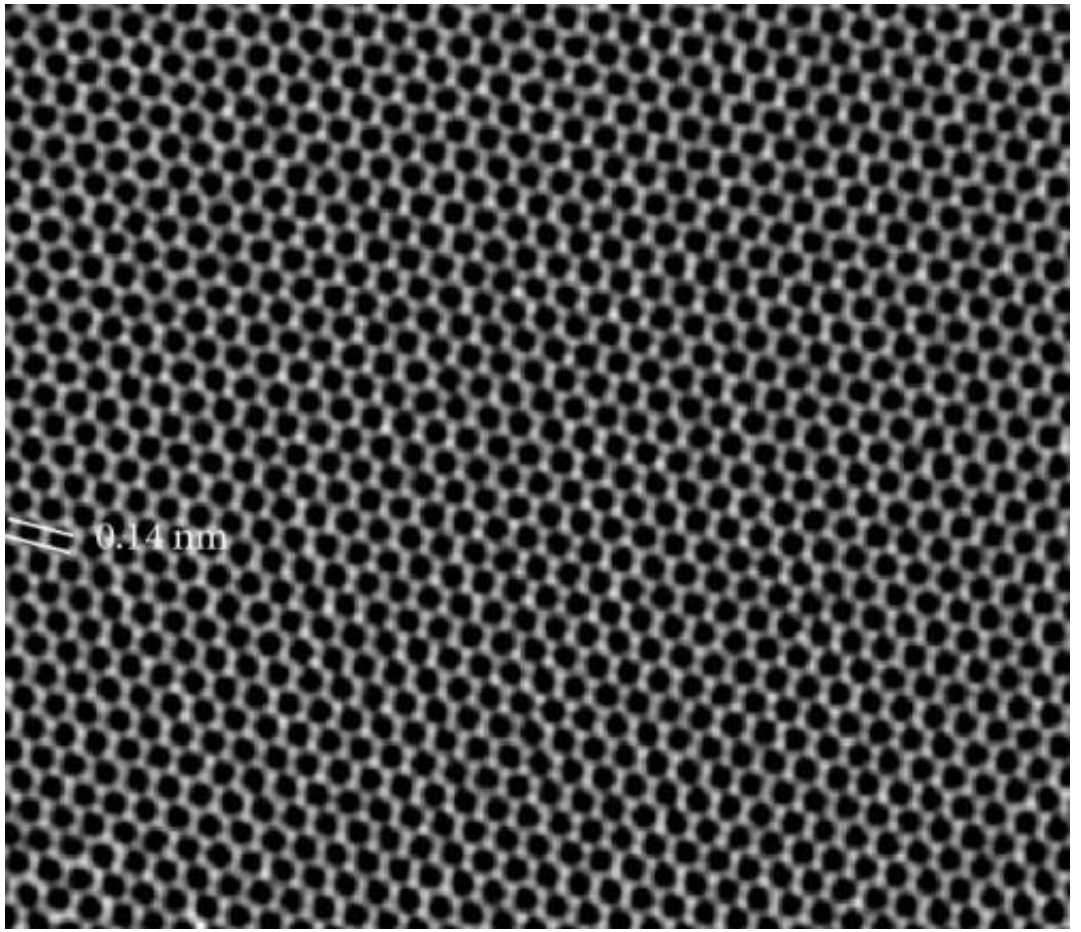
Zacharias Janssen
1585 –1632
Dutch spectacle-maker

Microscope

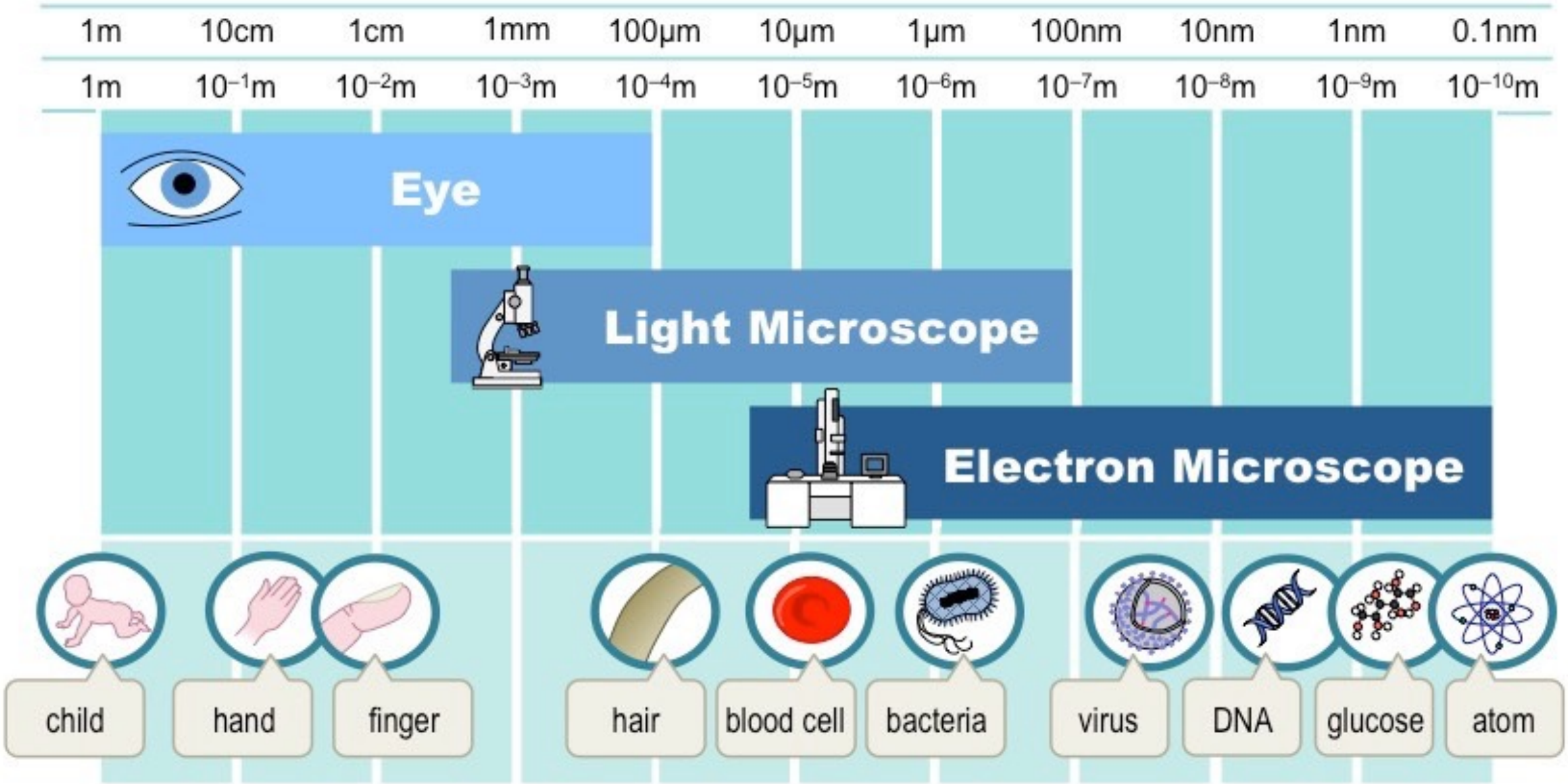
Optical microscope



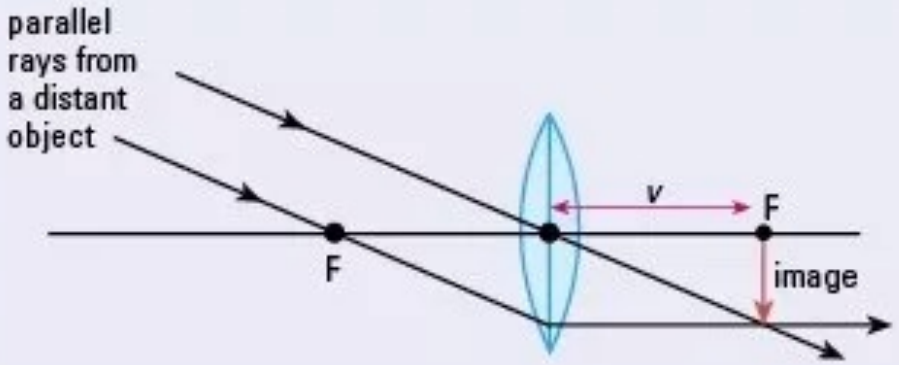
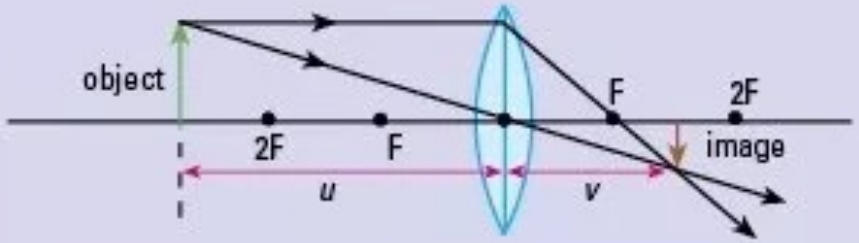
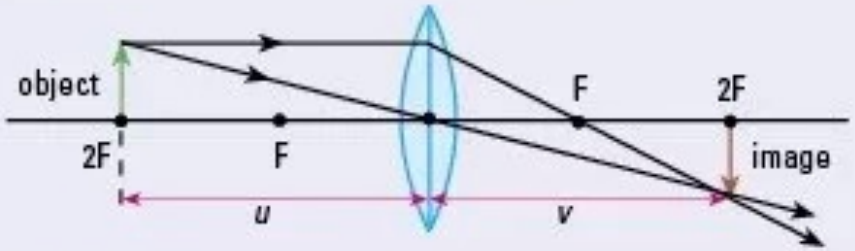
Electron microscope



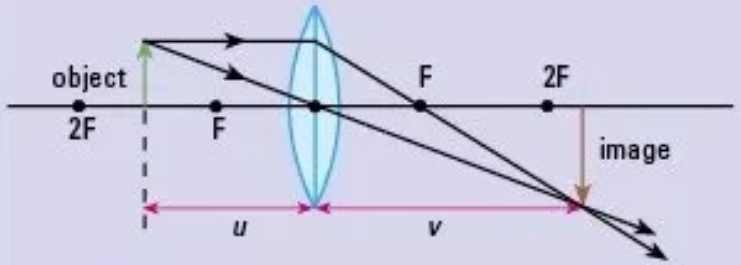
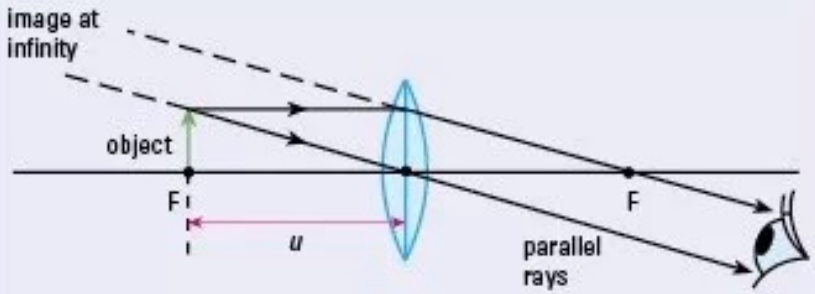
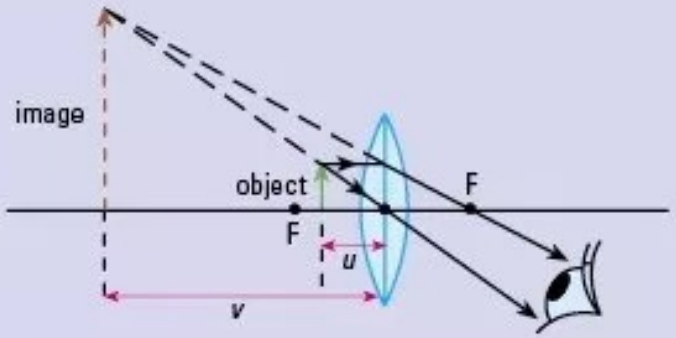
Microscopes



Ray diagram for convex lenses

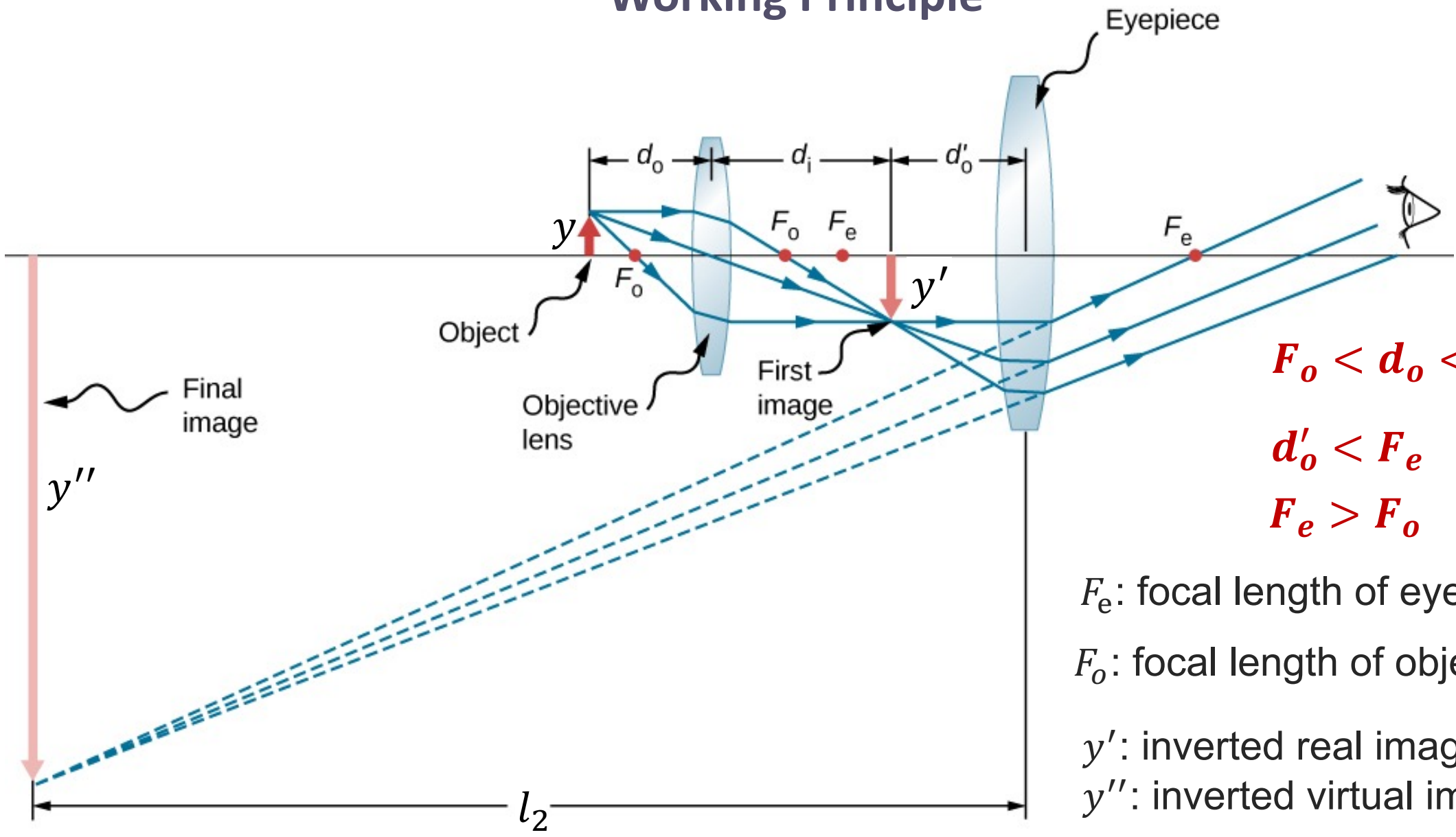
Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$u = \infty$		- inverted - real - diminished	$v = f$ - opposite side of the lens	- object lens of a telescope
$u > 2f$		- inverted - real - diminished	$f < v < 2f$ - opposite side of the lens	- camera - eye
$u = 2f$		- inverted - real - same size	$v = 2f$ - opposite side of the lens	- photocopier making same-sized copy

Ray diagram for convex lenses

Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$f < u < 2f$		- inverted - real - magnified	$v > 2f$ - opposite side of the lens	- projector - photograph enlarger
$u = f$		- upright - virtual - magnified	- image at infinity - same side of the lens	- to produce a parallel beam of light, e.g. a spotlight
$u < f$		- upright - virtual - magnified	- image is behind the object - same side of the lens	- magnifying glass

Microscopes

Working Principle



$$F_o < d_o < 2F_o$$

$$d'_o < F_e$$

$$F_e > F_o$$

F_e: focal length of eye piece

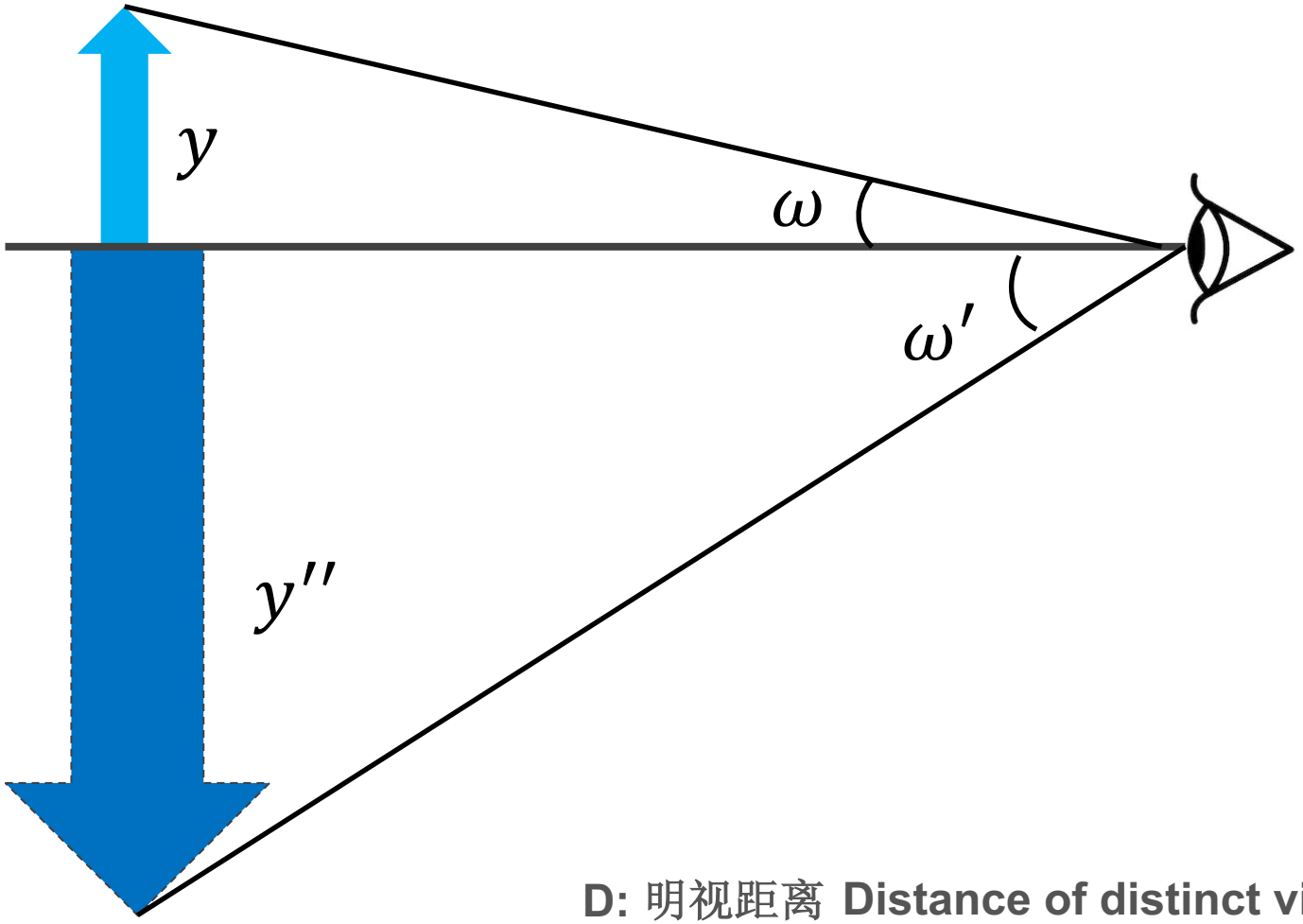
F_o: focal length of objective lens

y': inverted real image

y'': inverted virtual image

Microscopes

Magnification



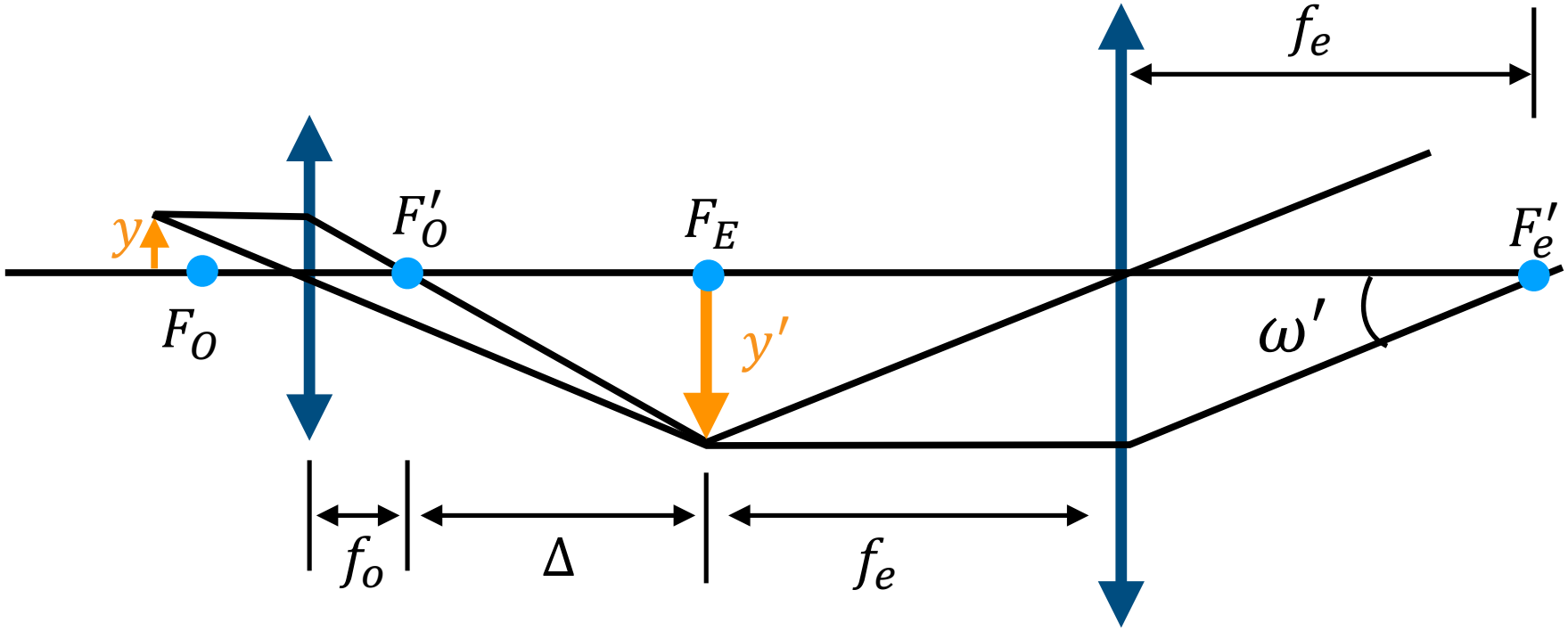
$$M = \frac{y''}{y} = \frac{tan\omega'}{tan\omega}$$

$$tan\omega = \frac{y}{D}$$

D: 明视距离 Distance of distinct vision =250 mm

Microscopes

How to calculate the Magnification?



$$tan\omega = \frac{y}{D}$$

$$tan\omega' = \frac{y'}{f_e}$$

Δ:optical tube length

$$M = \frac{tan\omega'}{tan\omega} = \frac{Dy'}{f_e y} = \frac{D\Delta}{f_e f_o} = M_o M_e$$

$$M_o = \frac{y'}{y} = \frac{\Delta}{f_o}$$

$$M_e = \frac{D}{f_e}$$

M: magnification D: distance of distinct vision=250 mm M_o: magnification of objective lens

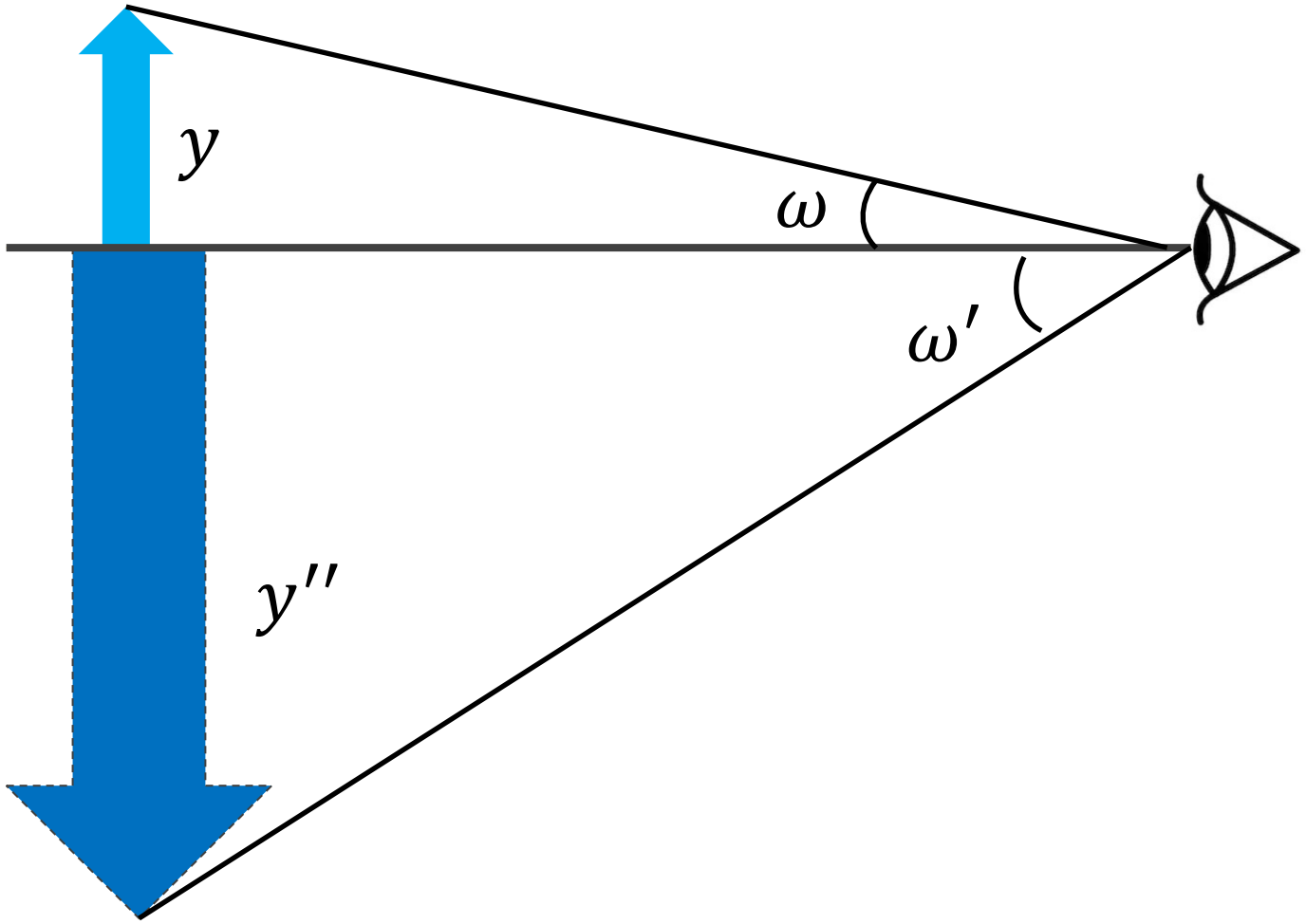
f_e: focal length of eye piece f_o: focal length of objective lens M_e: magnification of eye piece

Microscopes

Magnification

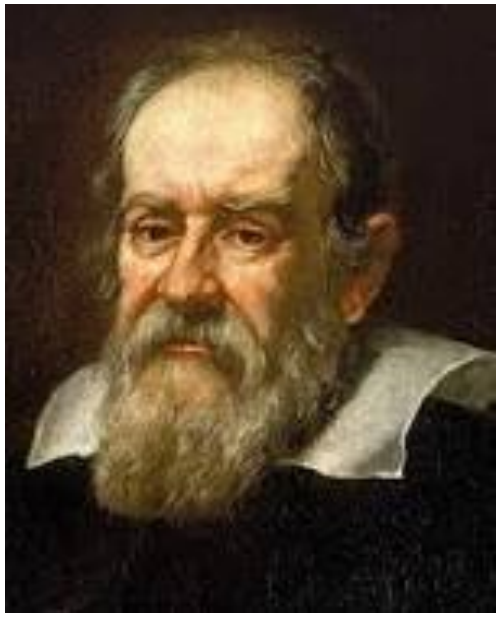
Theoretical value： $M_t = \frac{D\Delta}{f_e f_o} = M_o M_e$

Measured value： $M_m = \frac{y''}{y}$

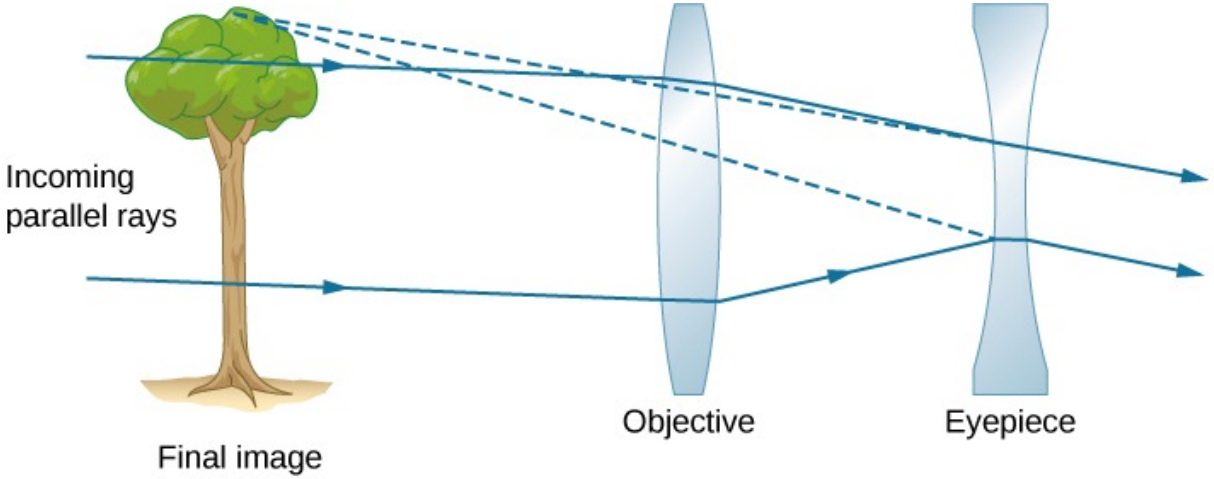


Telescopes

Galileo's Telescope



Galileo Galilei
15.02.1564– 08.01.1642



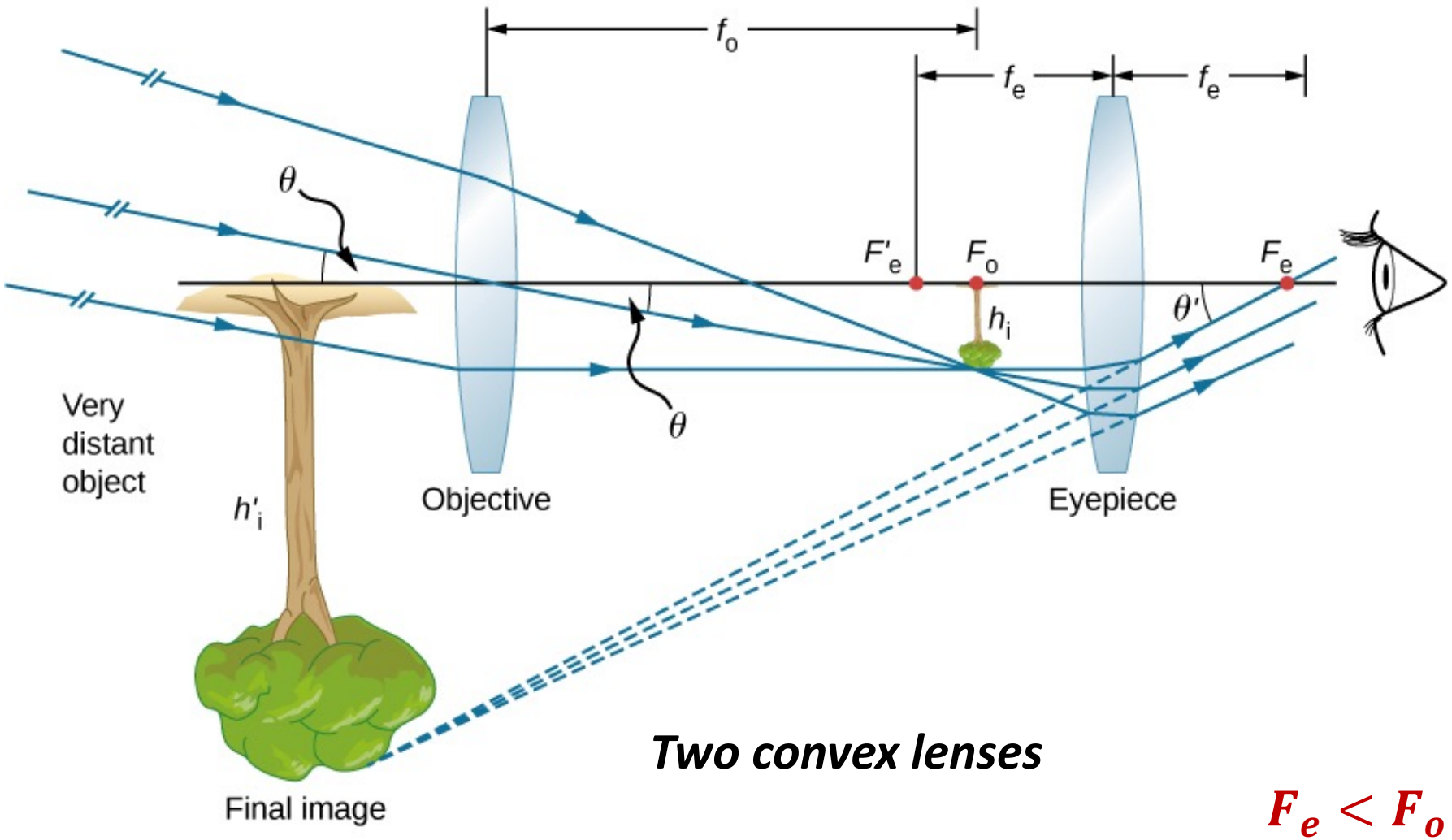
One convex lense + One concave lense
Upright images

Galileo was the first to point a telescope skyward. He was able to make out mountains and craters on the moon, as well as a ribbon of diffuse light arching across the sky — the Milky Way. He also discovered the rings of Saturn, sunspots and four of Jupiter's moons.

Galileo's ink renderings of the moon: the first telescopic observations of a celestial object.

Telescopes

Kepler's Telescope



Two convex lenses

$F_e < F_o$

Virtual inverted images

Telescopes

Kepler's Telescope

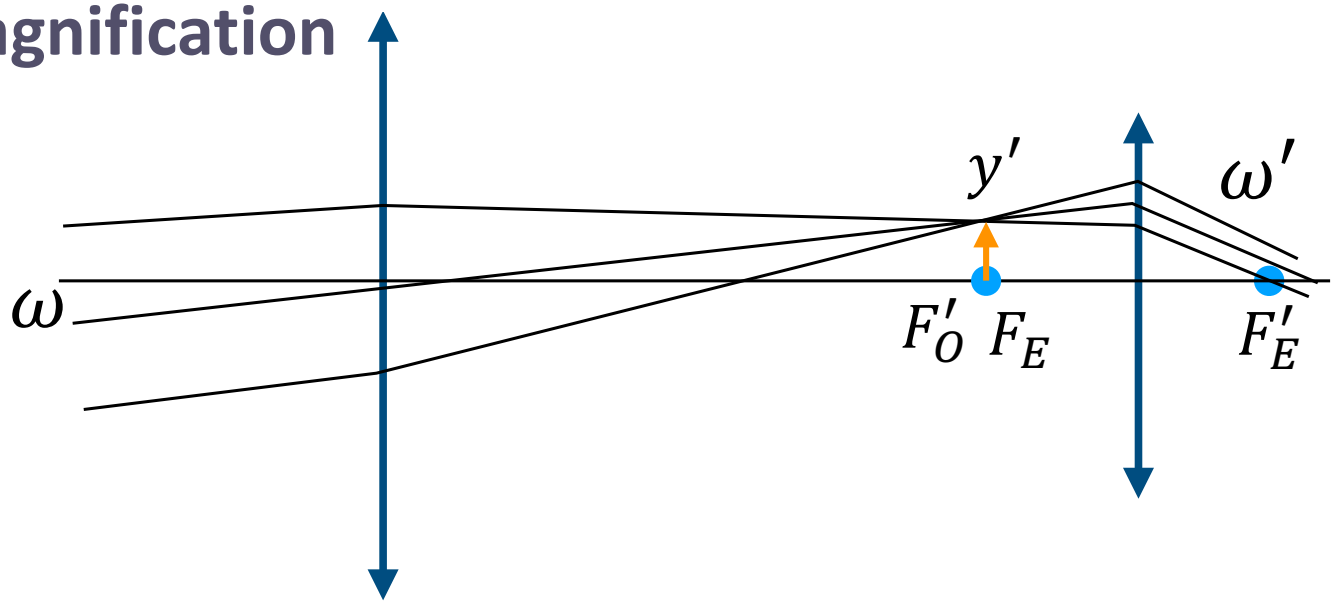
At infinity

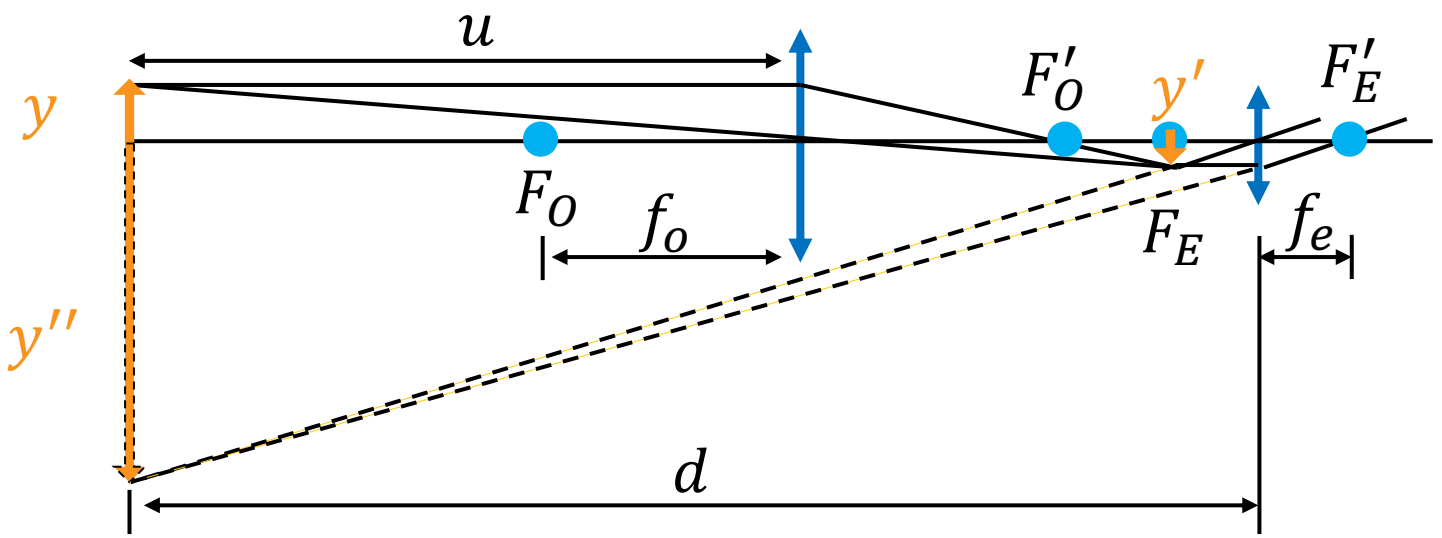
$$M = \frac{tan\omega'}{tan\omega} = \frac{y'/f_e}{y'/f_o} = \frac{f_o}{f_e}$$

At finite distance

$$M = \frac{f_o}{f_e}\frac{d + f_e}{u - f_o}$$

Magnification





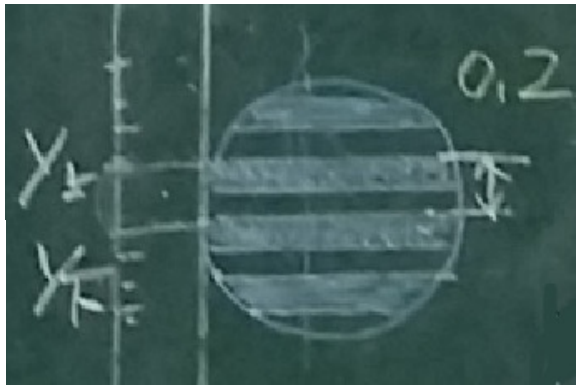
u: distance between the object and the objective lens
d: distance between the object and the eye piece

Microscopes and Telescopes

Time for fun!

1.Coaxial 等轴共高

2.Microscopes object: stripes with period of 0.2 mm



Appendix Table I: Experimental Raw Data for Microscopes

Types of Microscopes	f_e(mm)	f_o(mm)	Δ(mm)	y(mm)	y''(mm)	M_m	M_t
$f_e > f_o$	30	25	160	0.2			
$f_e < f_o$	25	30	160	0.2			

$$M_t = \frac{D\Delta}{f_e f_o}$$

3.Telescopes object: rainbow

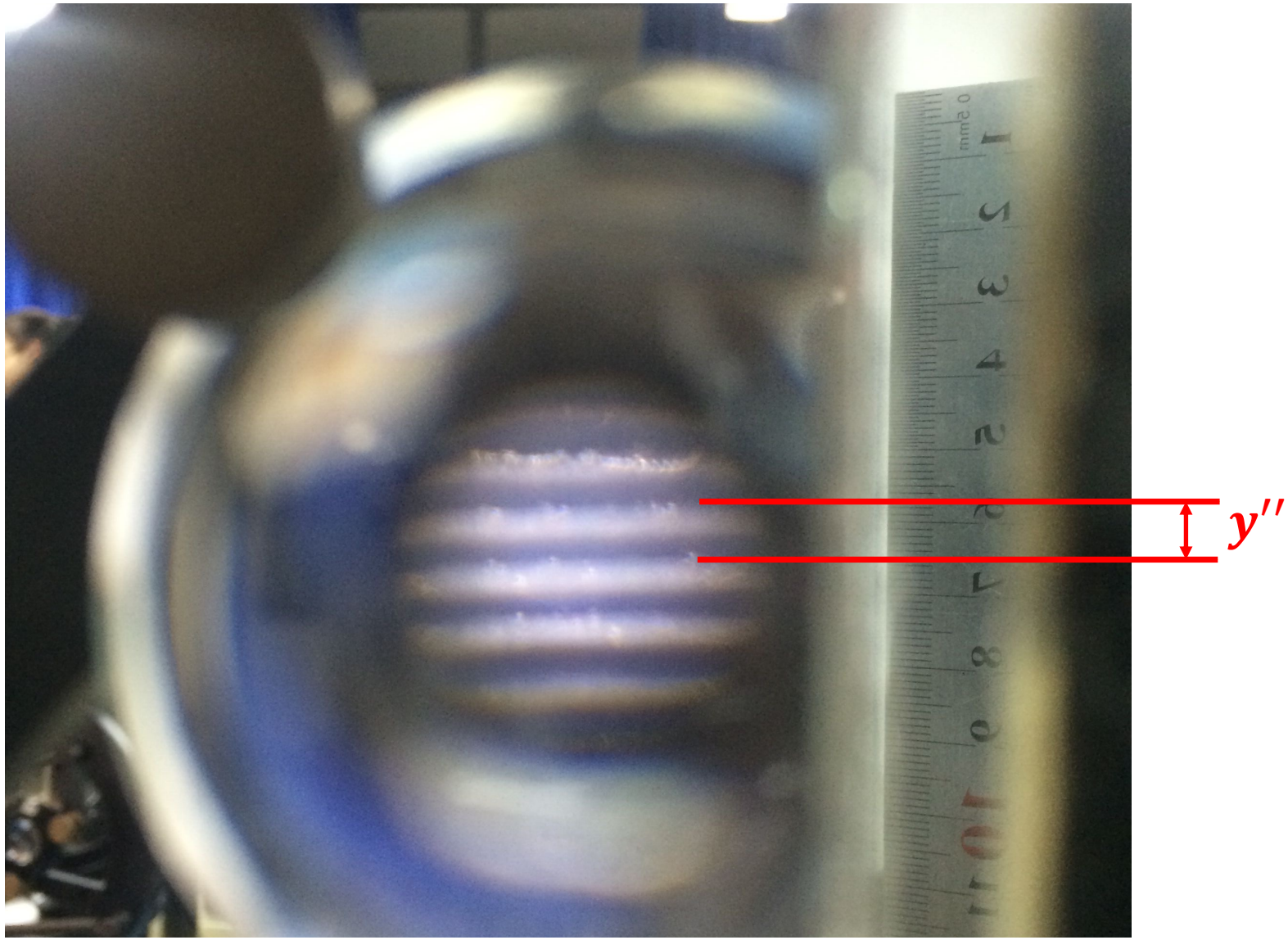
Appendix Table II: Experimental Raw Data for Telescopes

Types of Telescopes	f_e(mm)	f_o(mm)	u(mm)	d(mm)	y	y''	Image feature	M_m	M_t
Kepler	30	200			1				
Galileo	-30	200			1				

$$M_t = \frac{f_o}{f_e}\frac{d + f_e}{u - f_o}$$

Estimate the relative error between M_t and M_m!

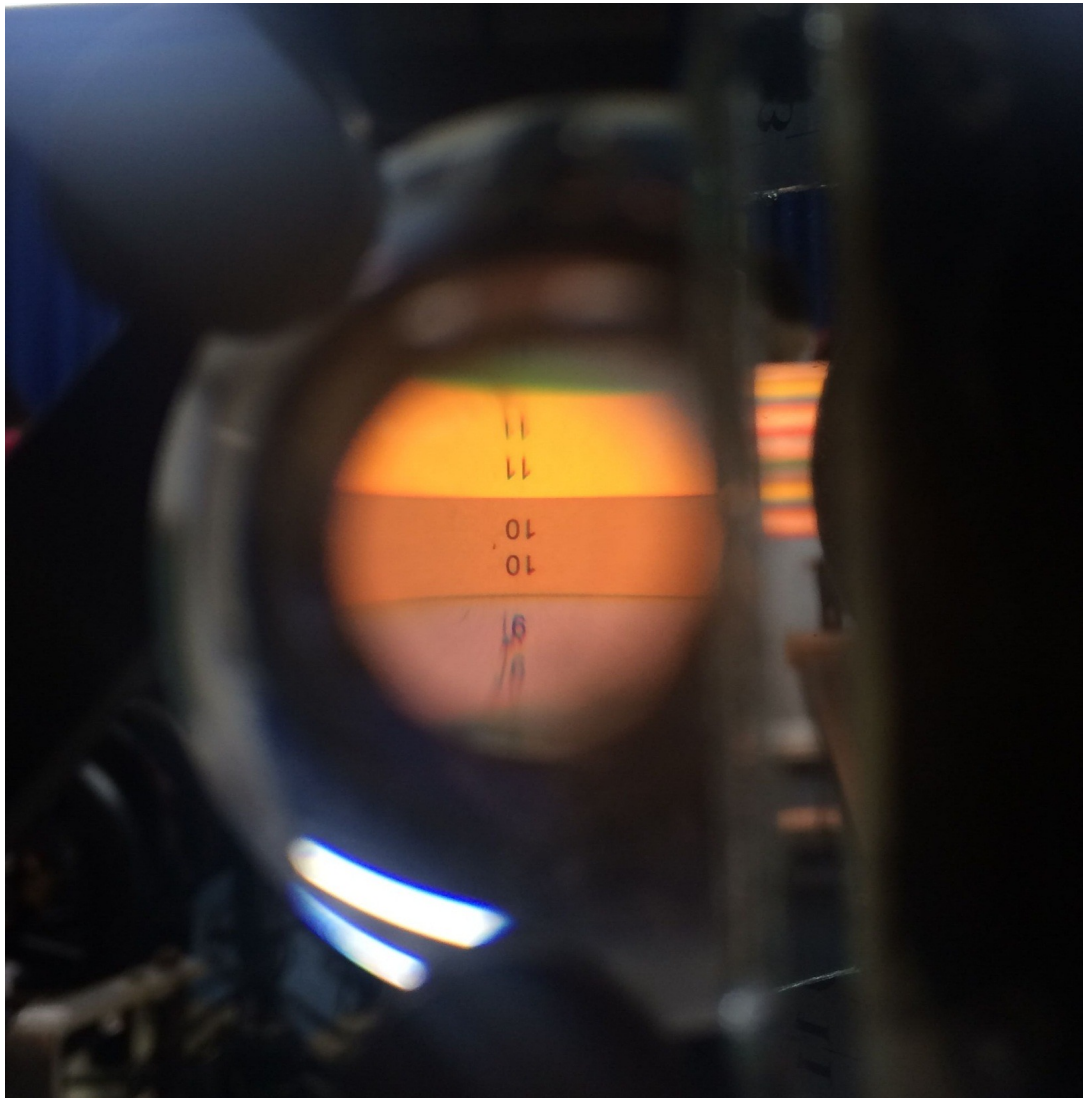
Microscopes

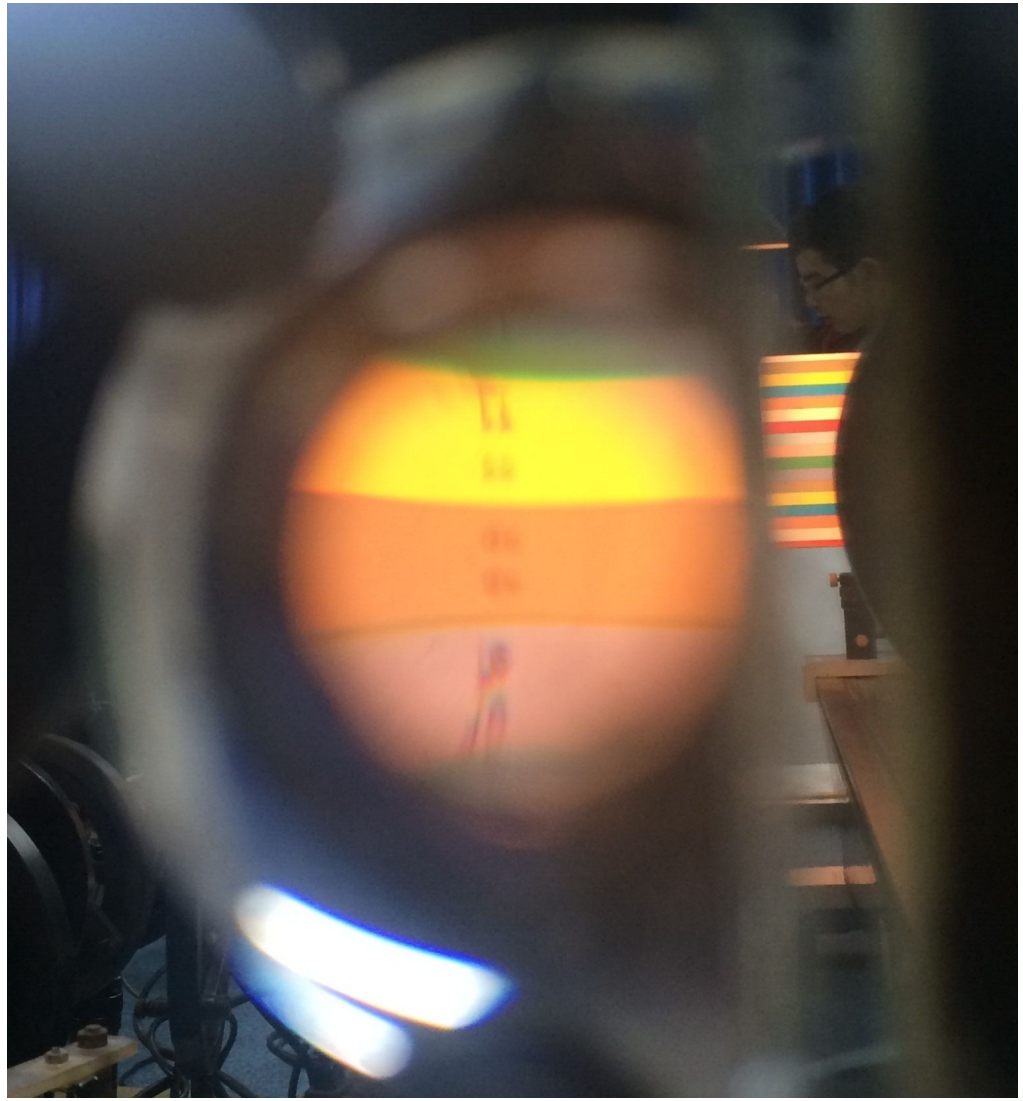


$$M_m = \frac{y''}{y}$$

y=0.2 mm

Telescopes





何明全

mingquan.he@cqu.edu.cn 理科楼519

THANK YOU！