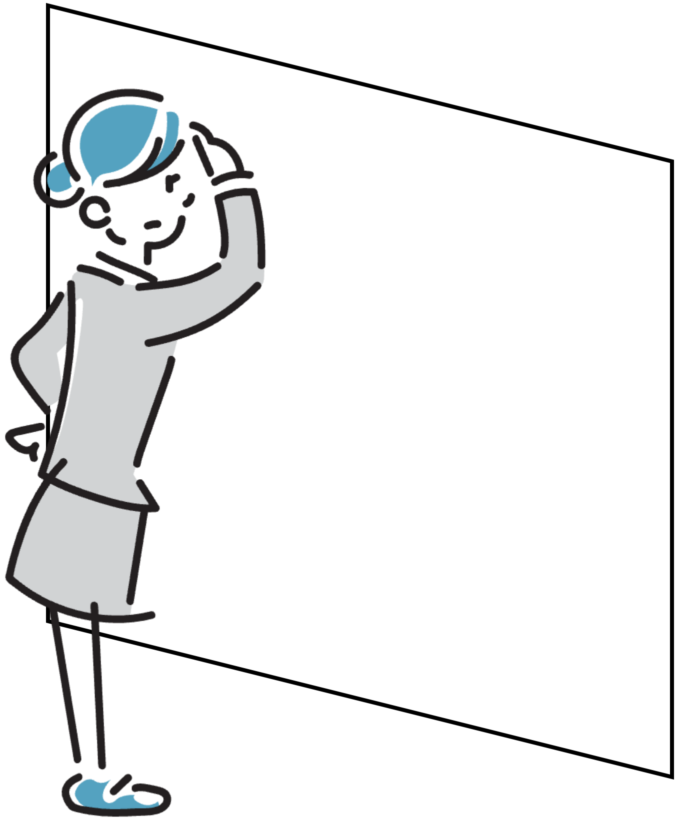
Optics – aberration -

Kyoto University Graduate School of Science Department of Astronomy M2
Chihiro Fukunaga

What is image?

We can see ...

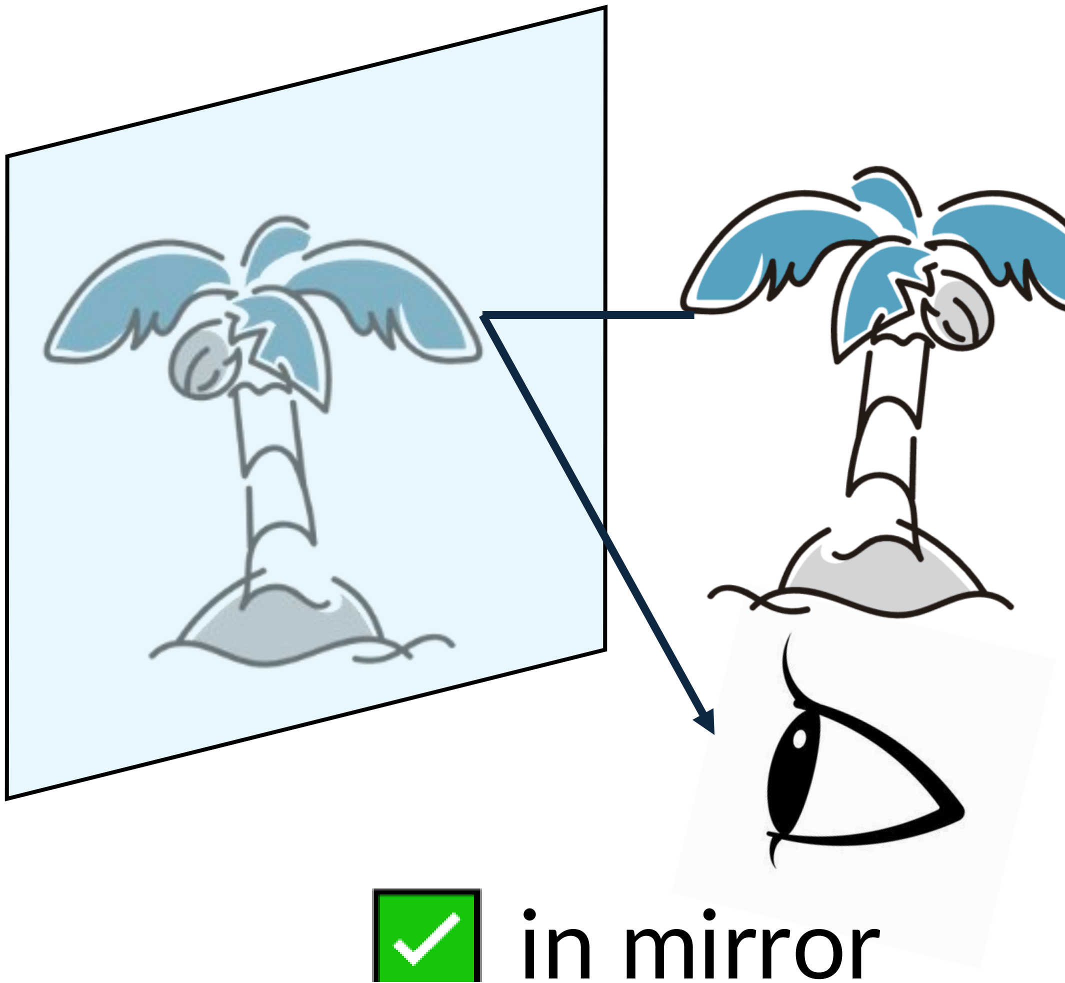
✅ in mirror



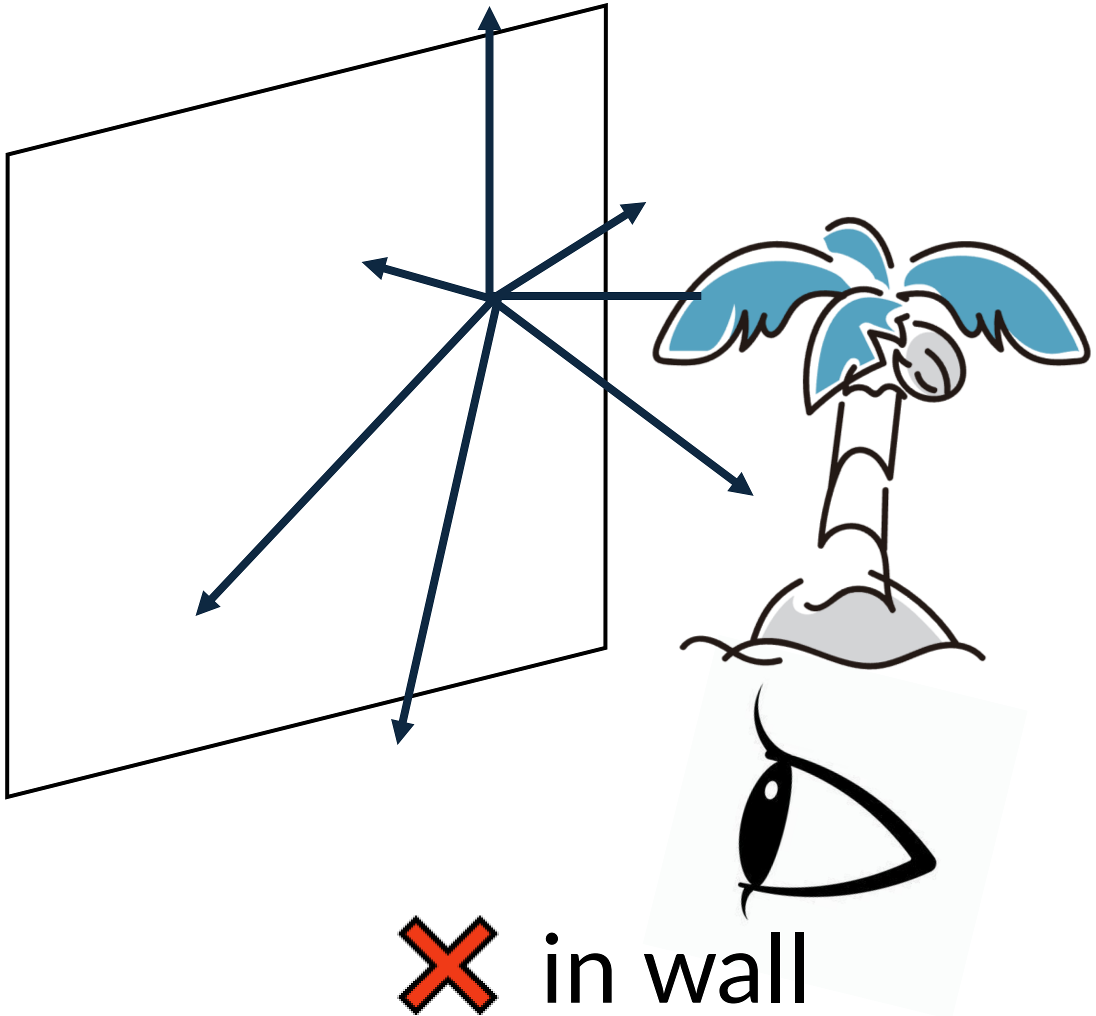
❌ in wall

What is image?

We can see ...



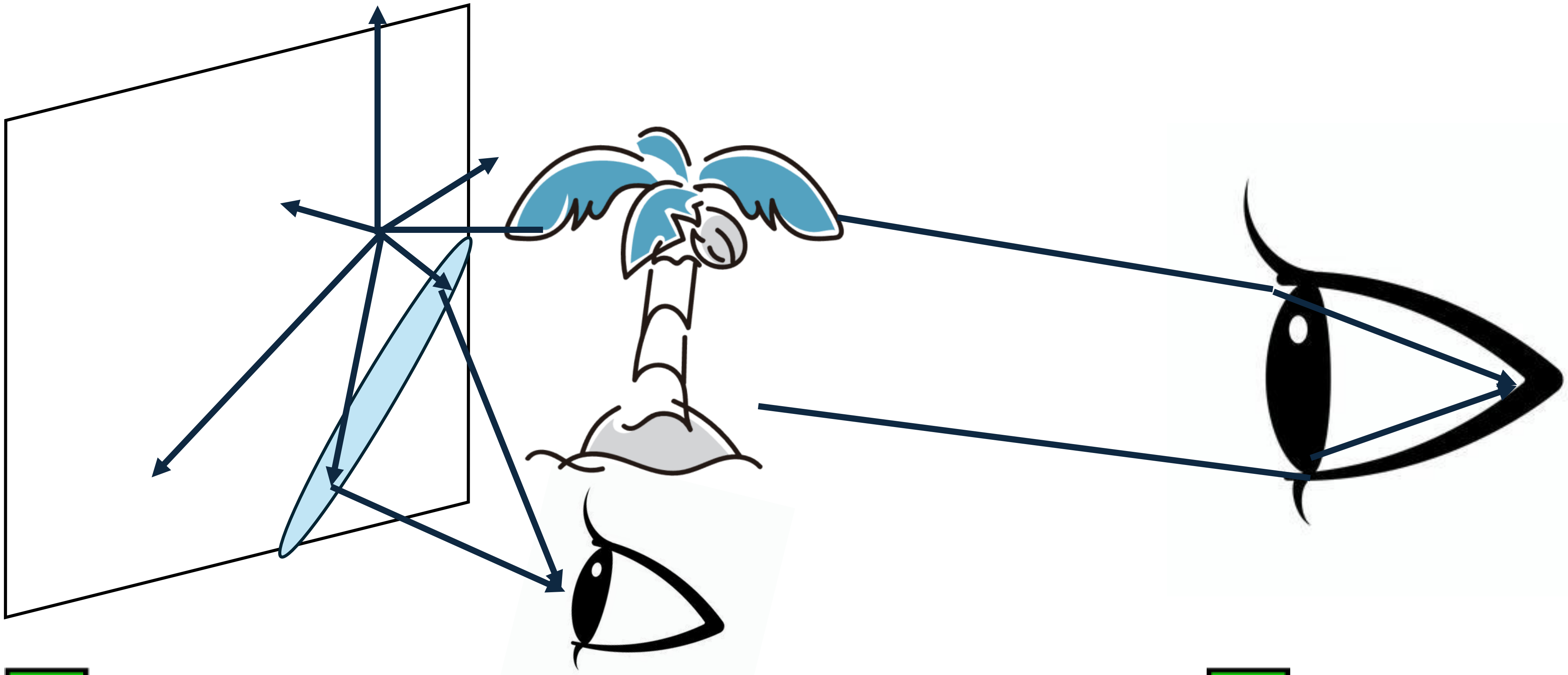
in mirror



in wall

What is image?

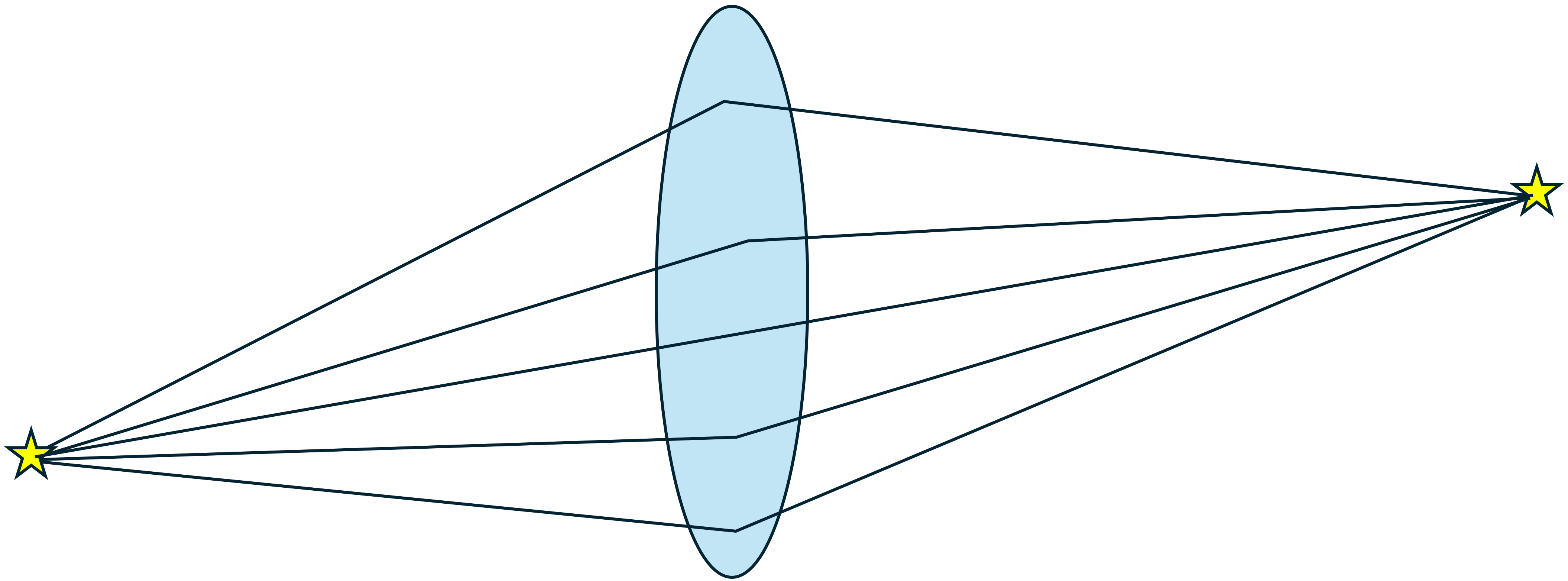
We can see ...



✅ with magnifying glass

✅ eye is also lens

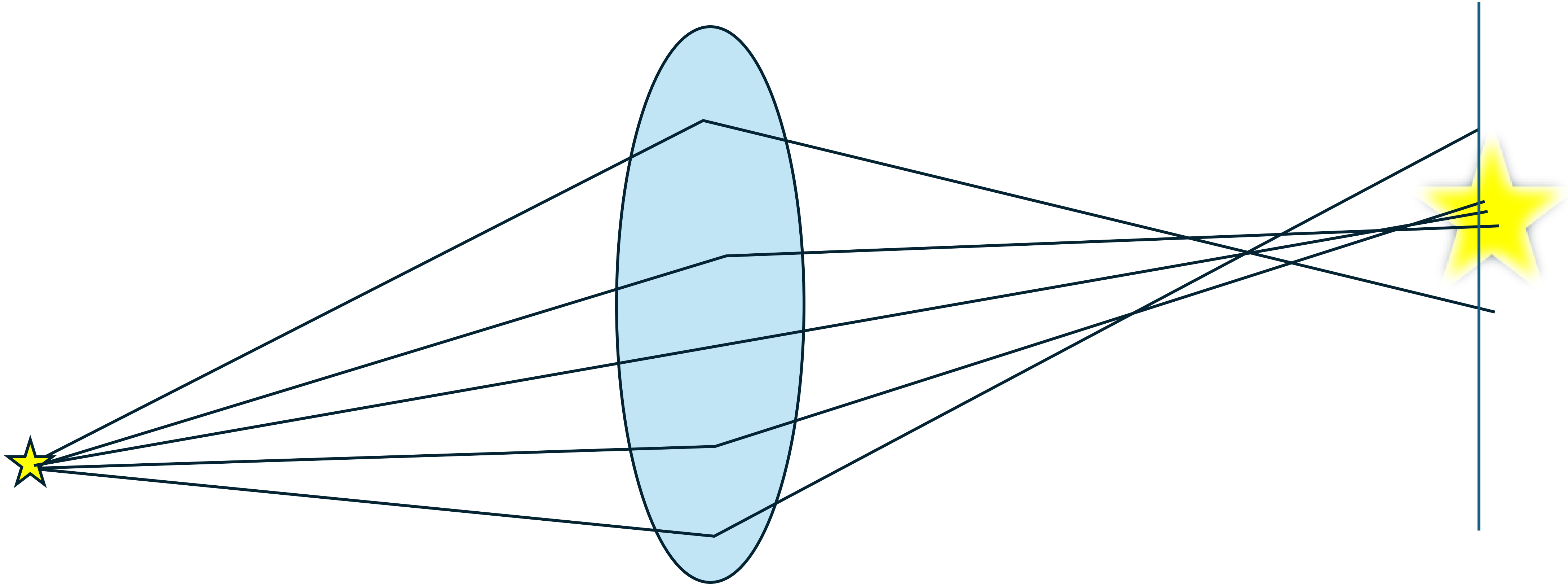
What is "ideal" image?



The light from a single point converges a single point

⇨*ideal image*

What is *not* “ideal” image?

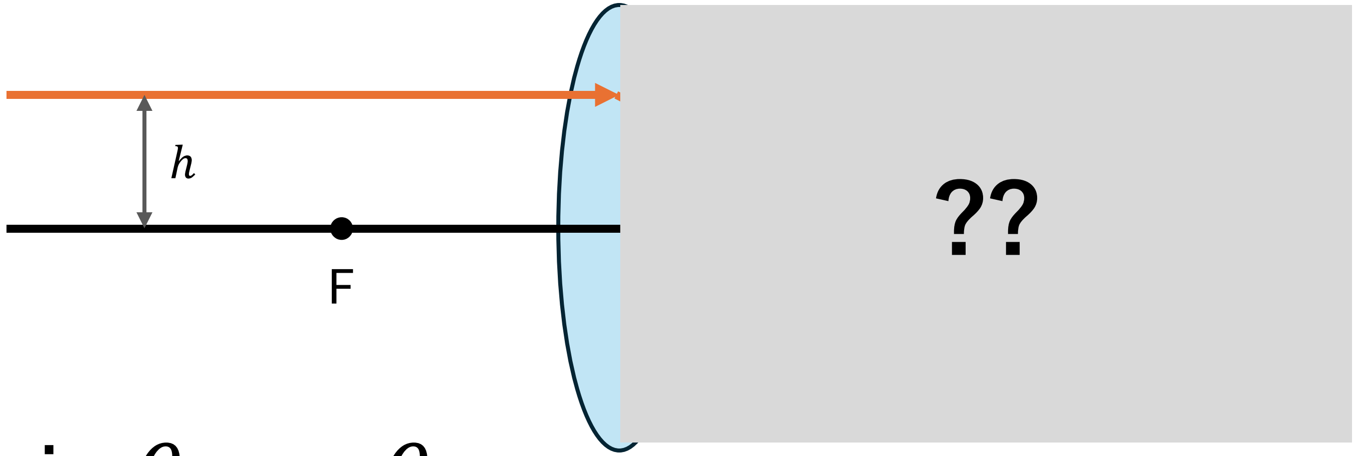


The light from a single point doesn’t converges a single point

⇨***aberration***

What is “ideal” image?

What we learned in school :



Valid only near axis: $h = r\sin\theta \approx r\theta$

※ r : coverture of lens

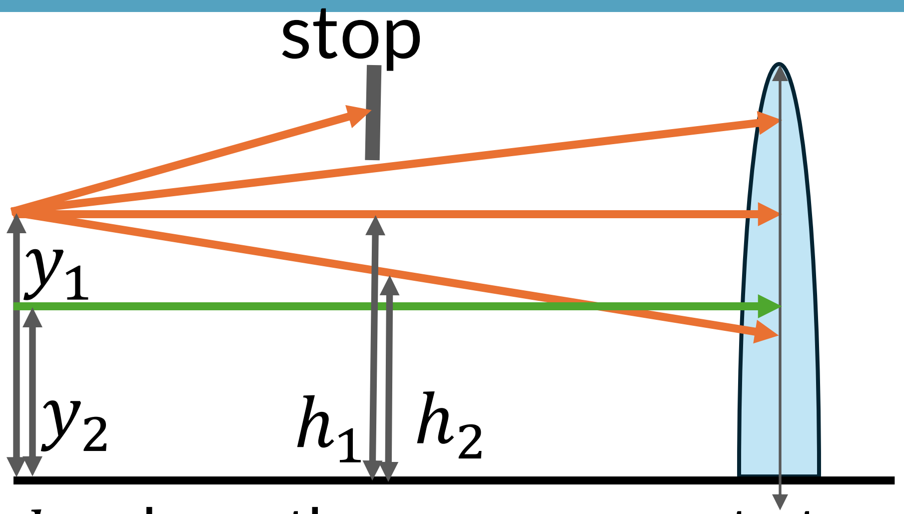
Seidel region

$$h = r\sin\theta = r\left(\theta - \frac{\theta^3}{3} + \frac{\theta^5}{120} - \cdots\right) \approx r\left(\theta - \frac{\theta^3}{3}\right)$$

✅ more realistic

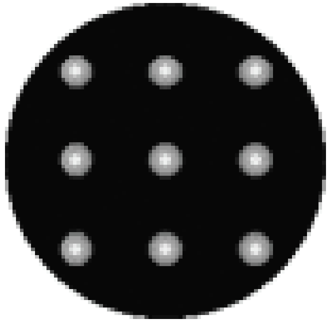
🤔 have to consider ***aberration***

Seidel aberration



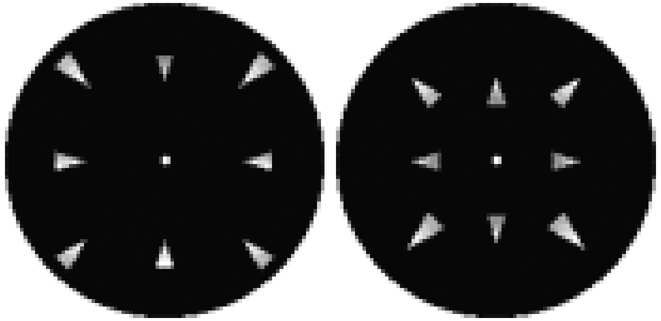
h: where the ray passes at stop
y:the object height

Spherical aberration



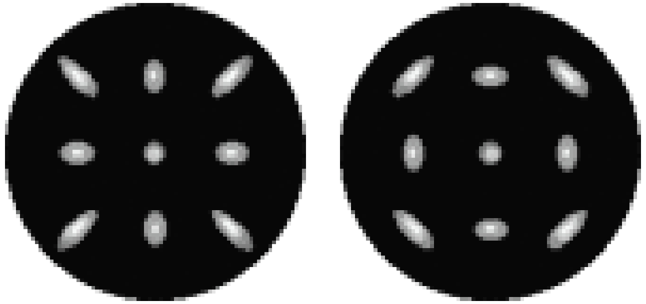
$\boldsymbol{h^3}$

comma



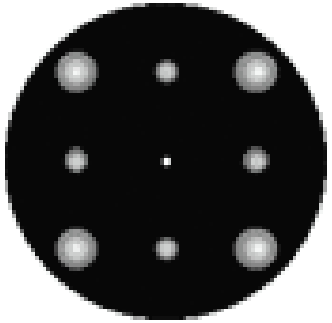
$\boldsymbol{h^2 y}$

astigmatism



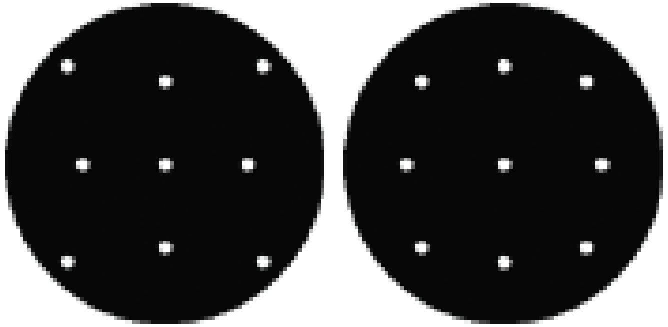
$\boldsymbol{hy^2}$

field curvature



$\boldsymbol{hy^2}$

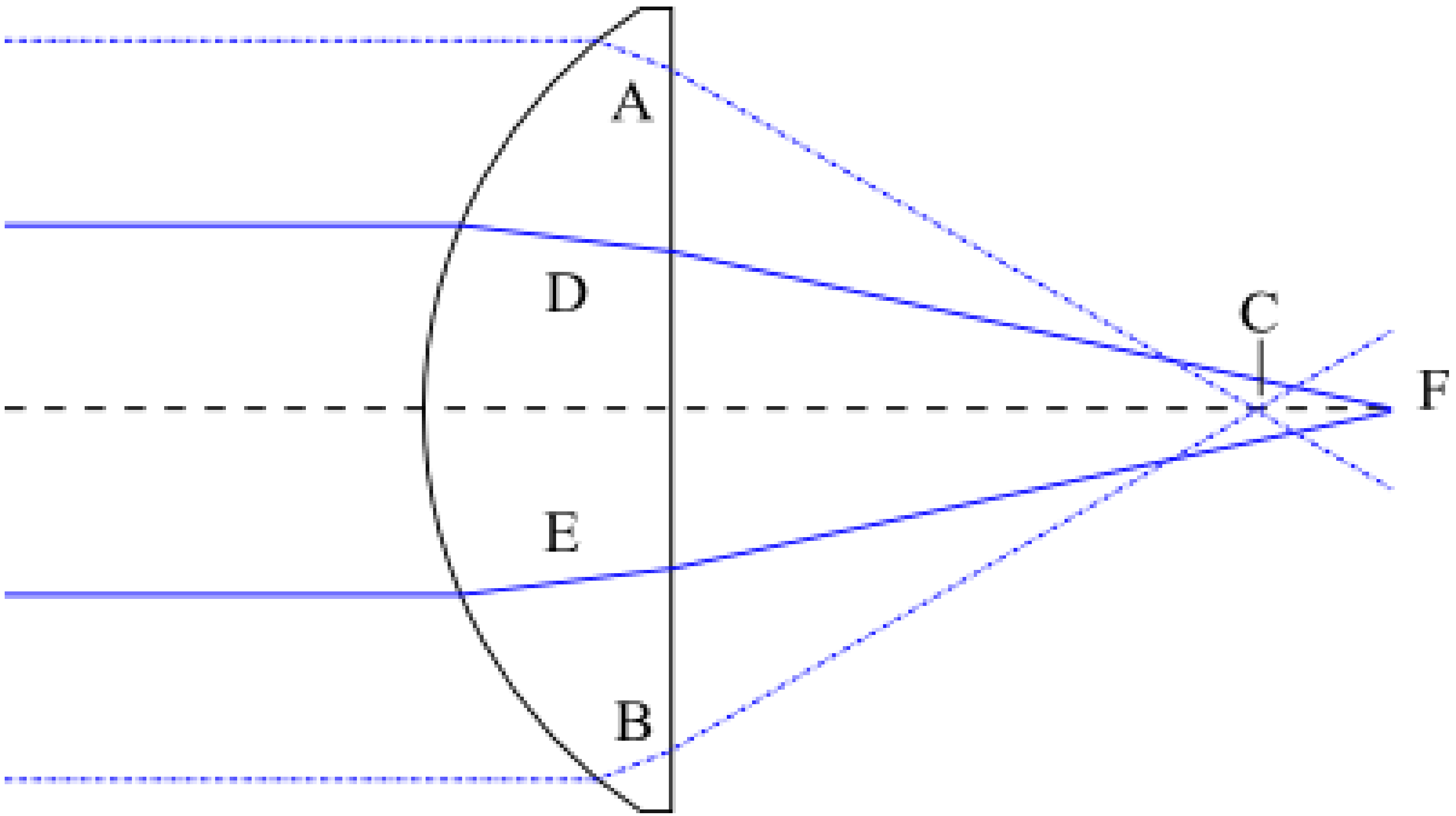
distortion

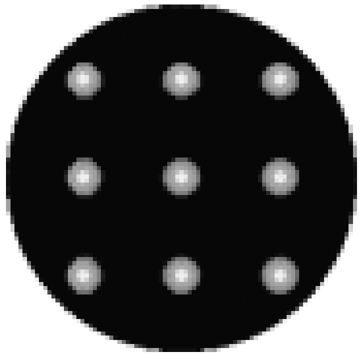


$\boldsymbol{y^3}$

Spherical aberration

proportional to h^3

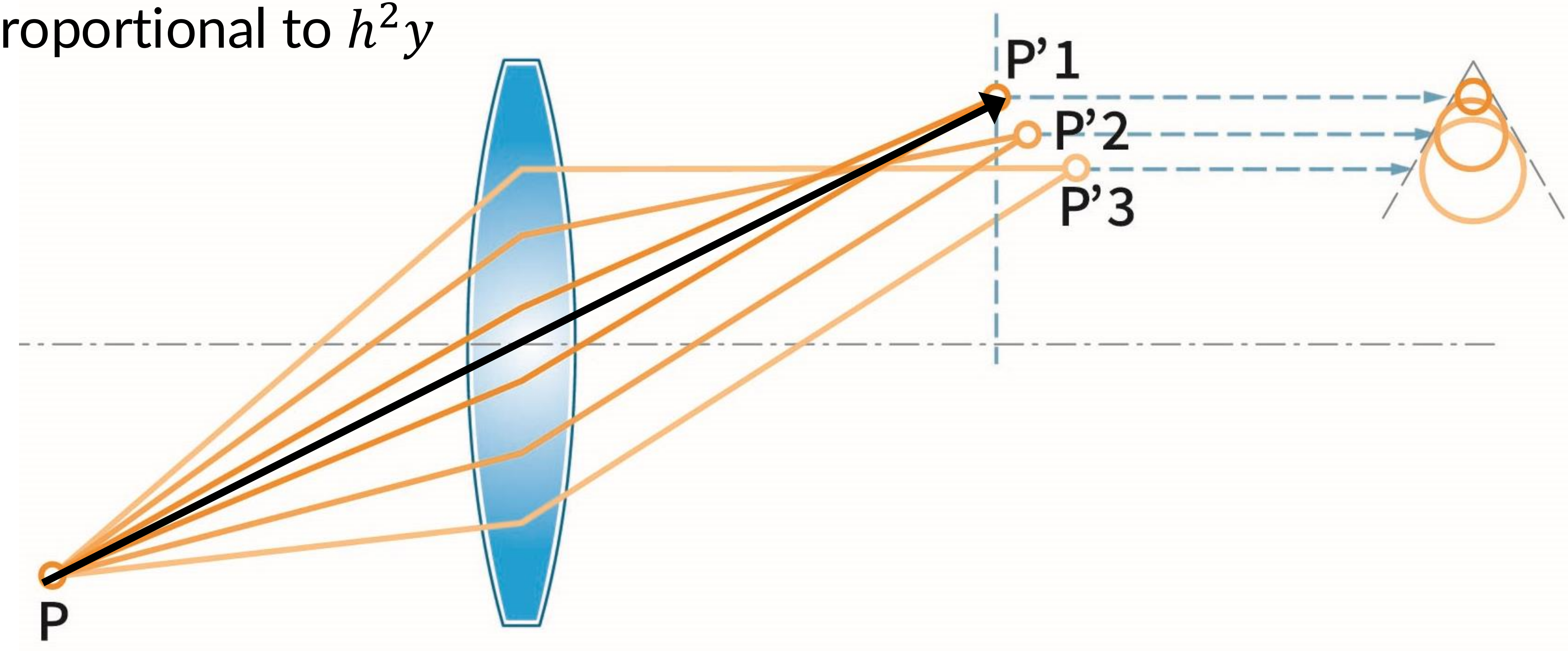




from [Optipedia]

coma

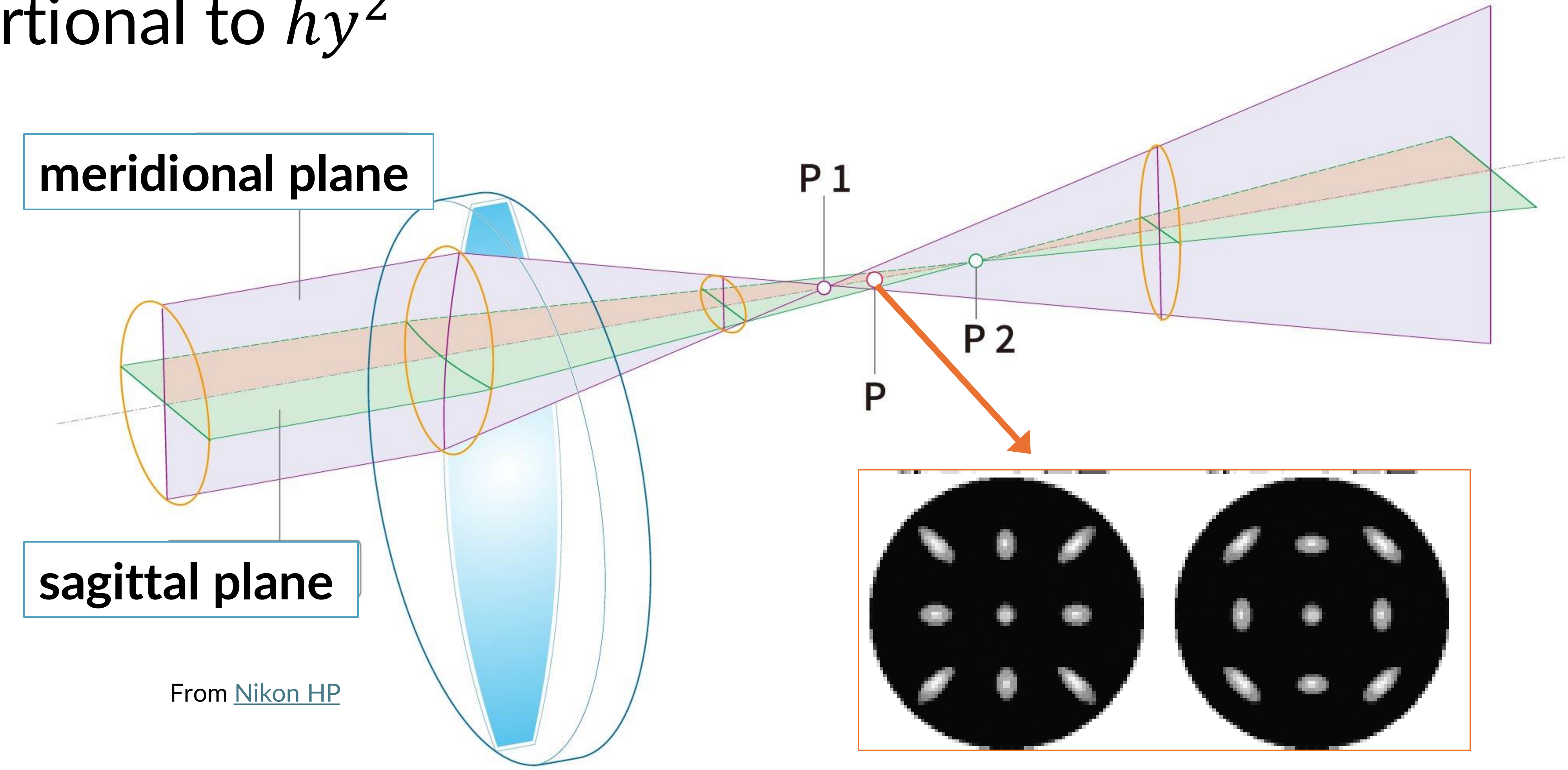
proportional to $h^2 y$



From [Nikon HP]

astigmatism

proportional to hy^2

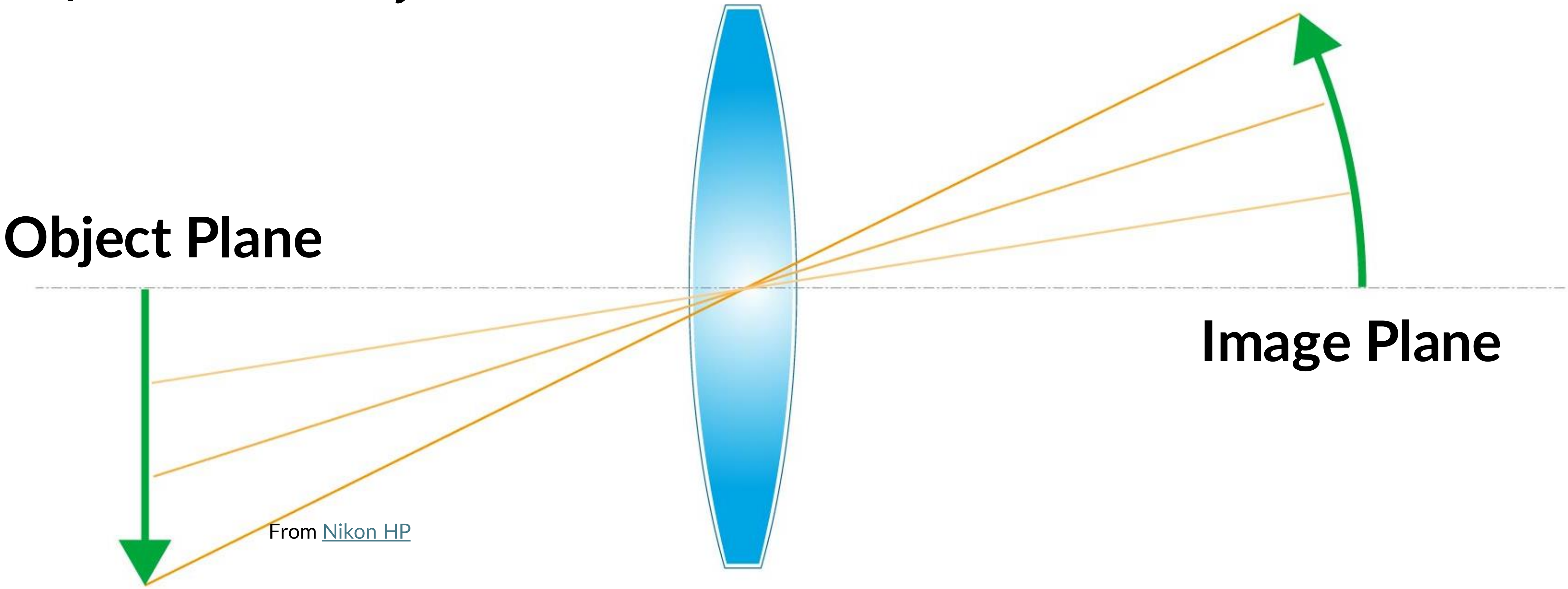


From Nikon HP

From Introduction to Reflecting Telescope Optics for Amateur Astronomers byYoshida (2005)

field curvature

proportional to hy^2

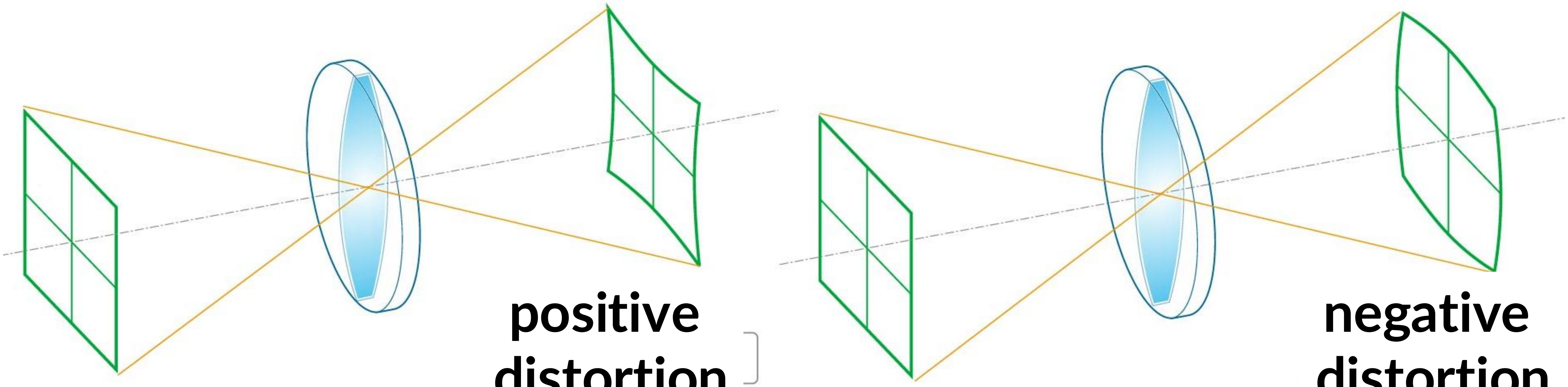


From Nikon HP

From Introduction to Reflecting Telescope Optics for Amateur Astronomers byYoshida (2005)

distortion

proportional to y^3



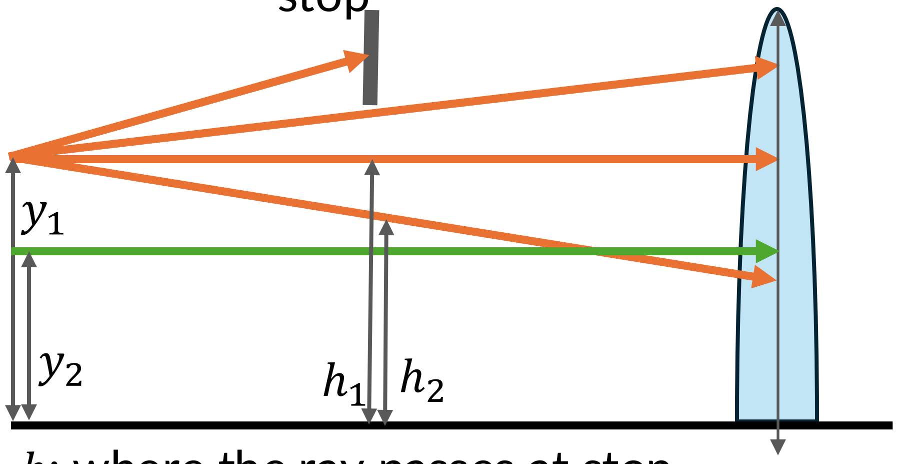
positive distortion

negative distortion

From Nikon HP

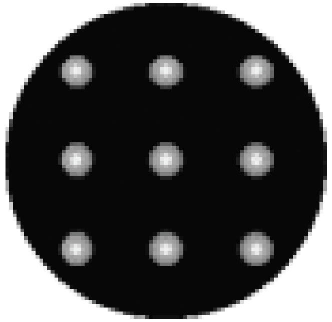
From Introduction to Reflecting Telescope Optics for Amateur Astronomers byYoshida (2005)

Seidel aberration



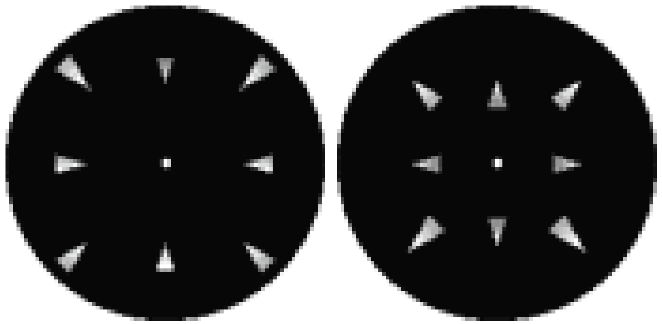
h: where the ray passes at stop
y:the object height

Spherical aberration



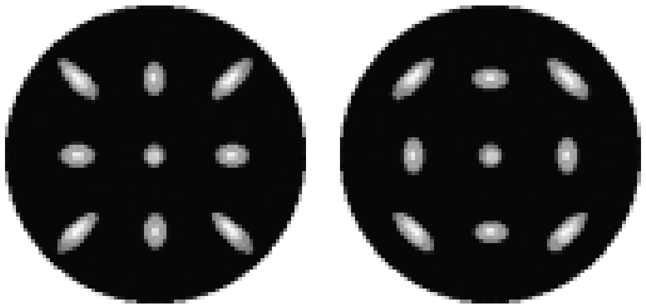
$\boldsymbol{h^3}$

comma



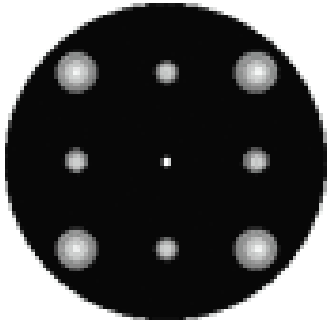
$\boldsymbol{h^2 y}$

astigmatism



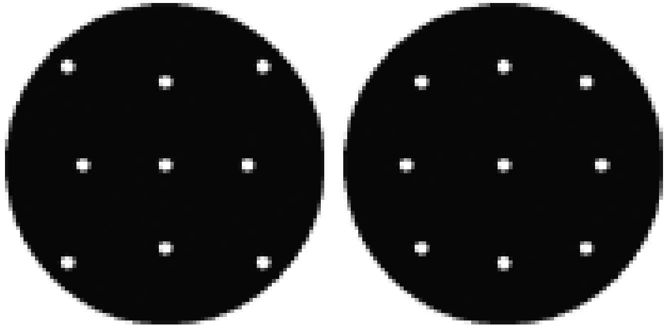
$\boldsymbol{hy^2}$

field curvature



$\boldsymbol{hy^2}$

distortion

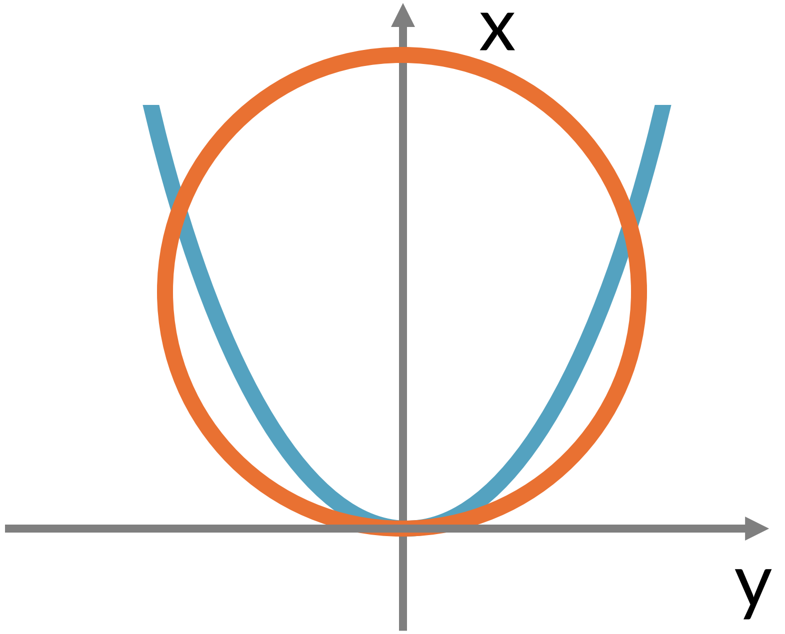


$\boldsymbol{y^3}$

Deriving Spherical aberration

The equation for a conic section:

$$x = \frac{y^2}{R + \sqrt{R^2 - (K+1)y^2}}$$



How big is the difference between

Sphere (K = 0) and Parabola (K = -1)??

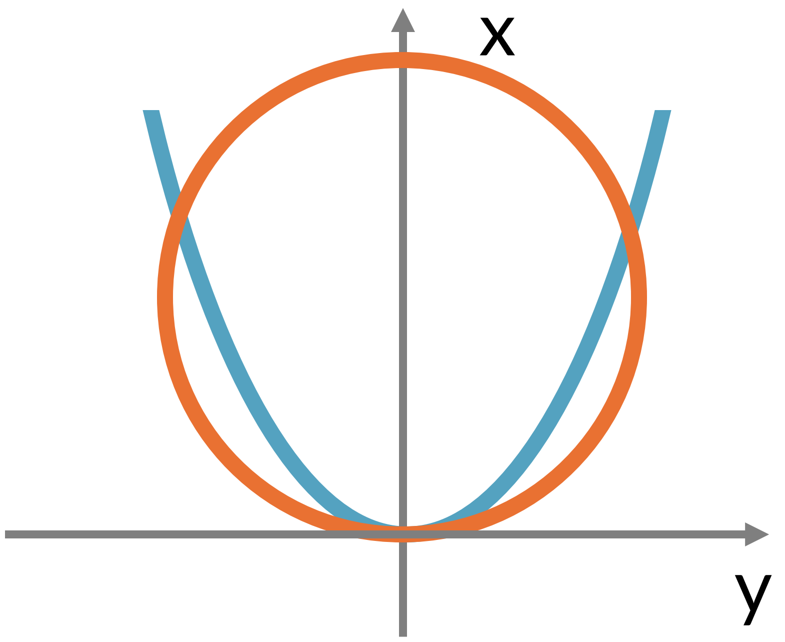
Let's substitute and derive!

note ; $\frac{y}{R} \ll 1$

Deriving Spherical aberration

Answer

$$x(K=0)-x(K=-1)\sim\frac{h^4}{8R^3}$$



Note :
This is "Wavefront Spherical Aberration",
and you can derive h^3 by differentiate this