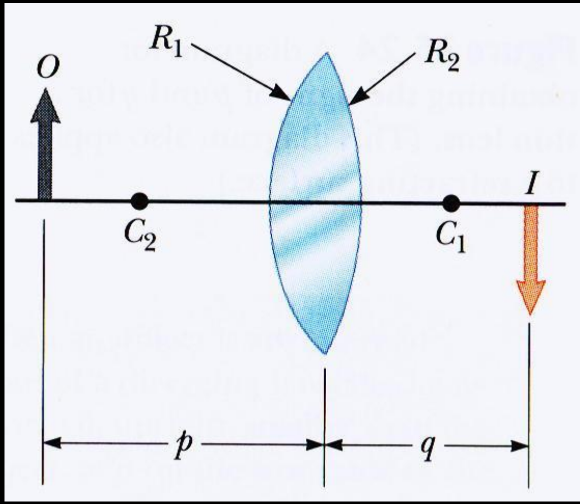
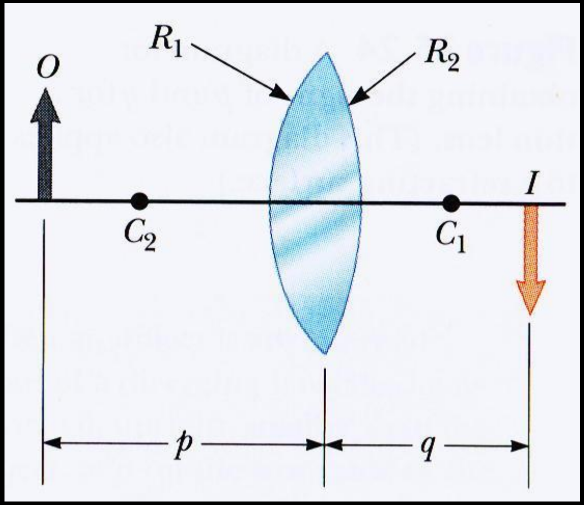
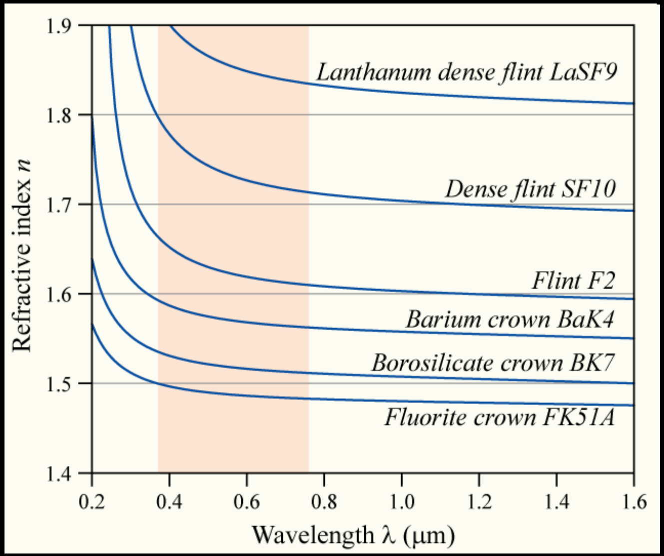
Quiz



- Red light coming from O produces an image at I. Where will blue light coming from O form an image?
  a. same place
  b. closer to the lens
  c. farther from lens

Chromatic Aberration



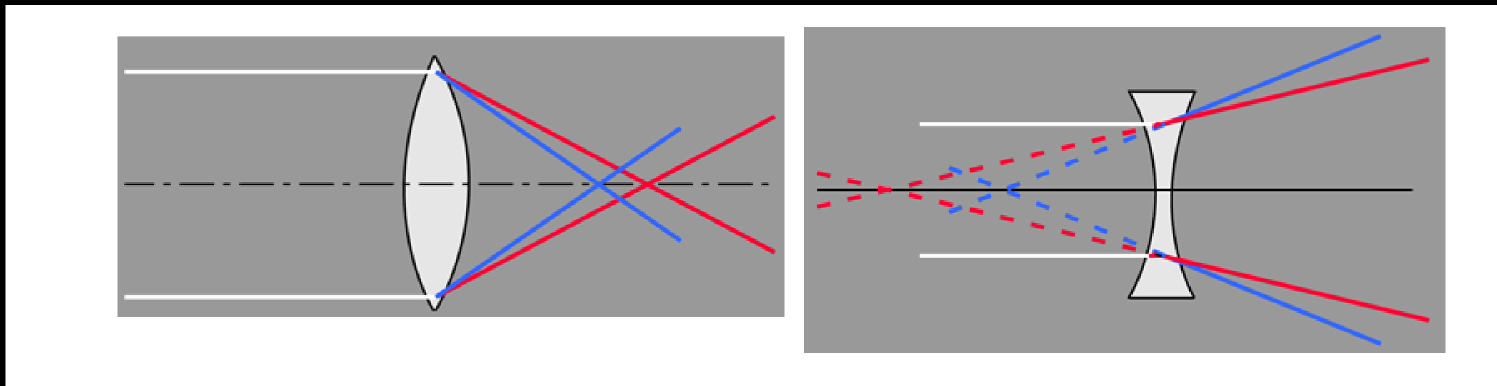


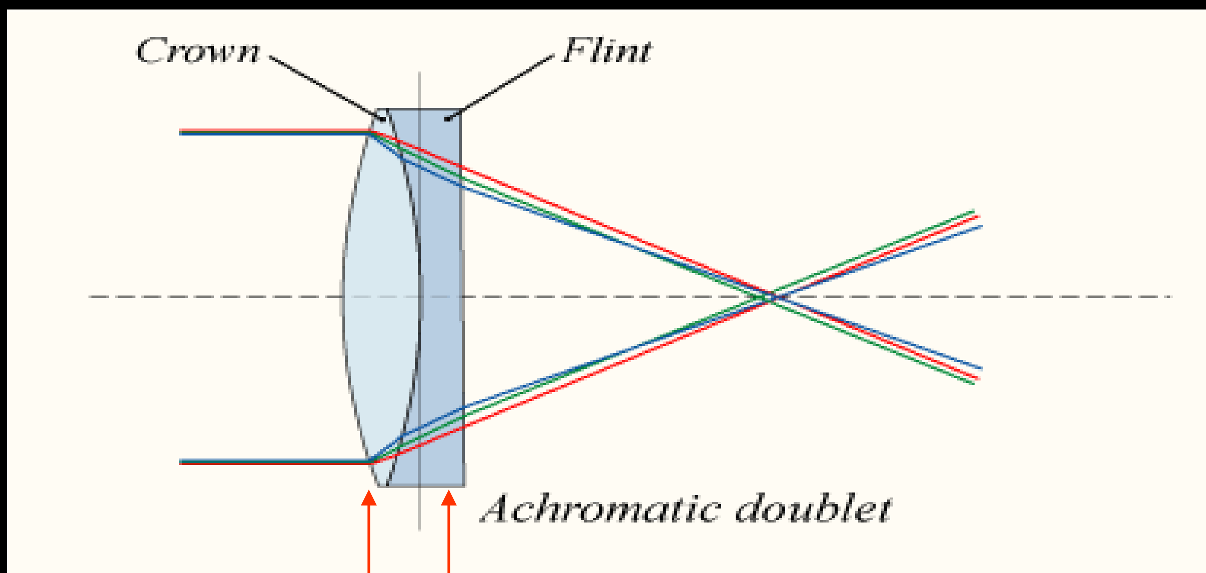
- Red light coming from O produces an image at I. Where will blue light coming from O form an image?
  a. same place
  b. closer to the lens
  c. farther from lens

Lens-makers' eqn:

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

Achromats

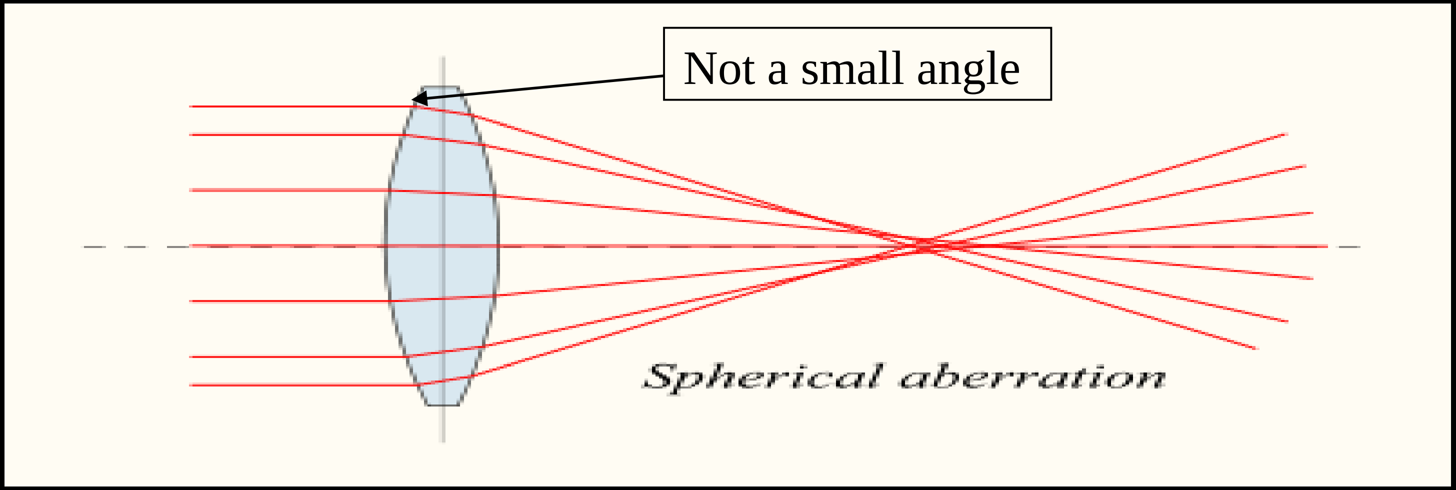




This lens mainly correctsdispersion

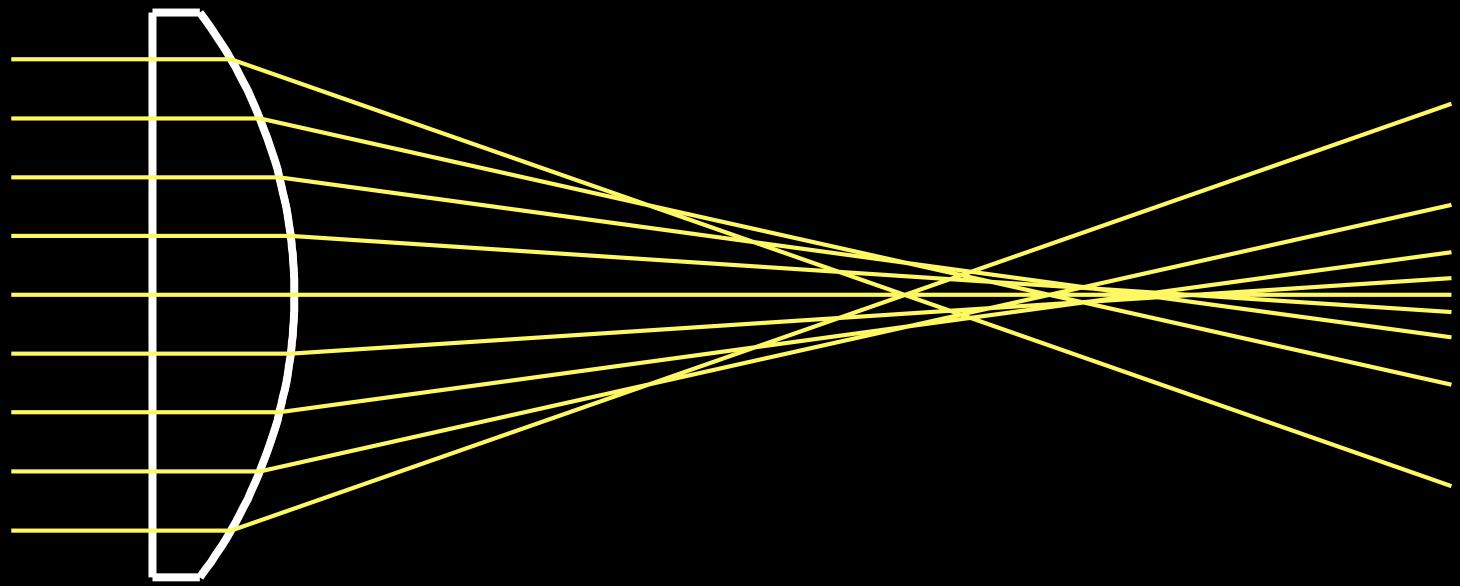
This lens mainly determines f

Spherical Aberration



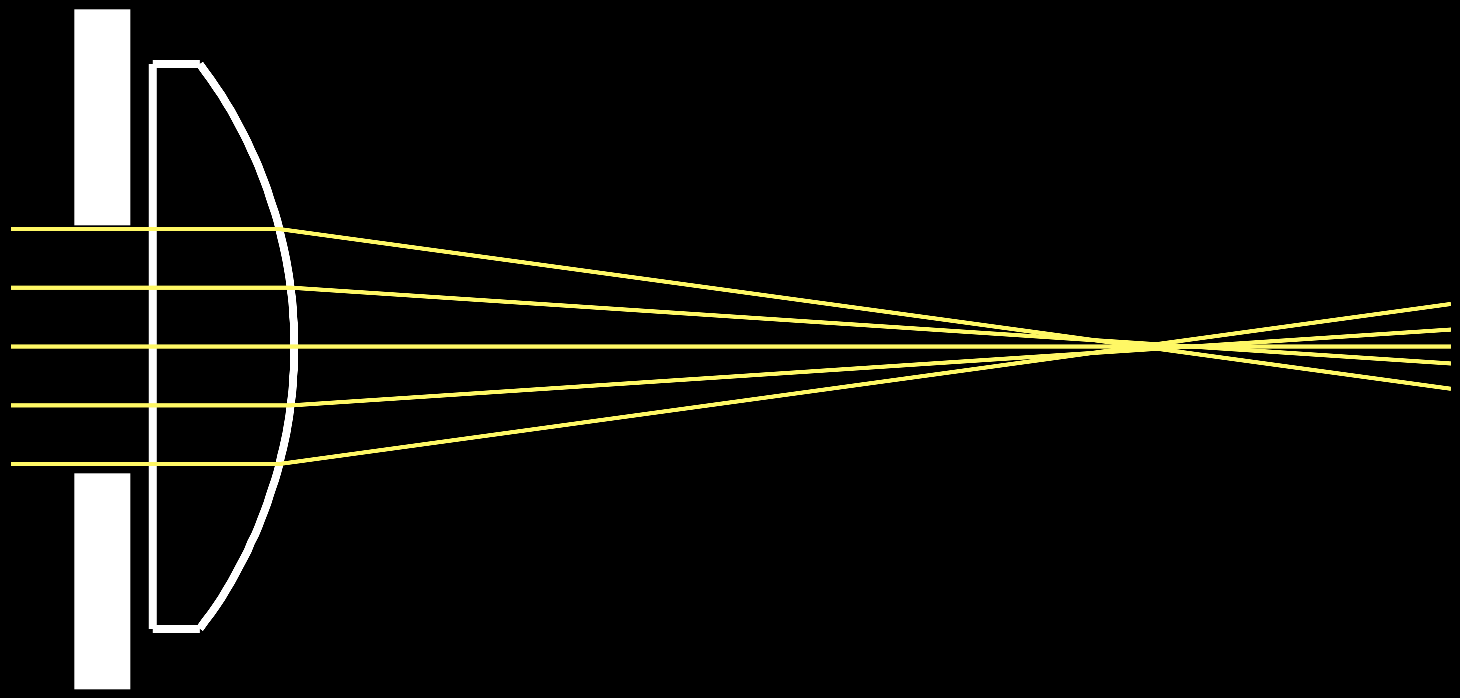
Rays on the outside of the lens focus closer than rays on the inside of the lens

Spherical Aberration

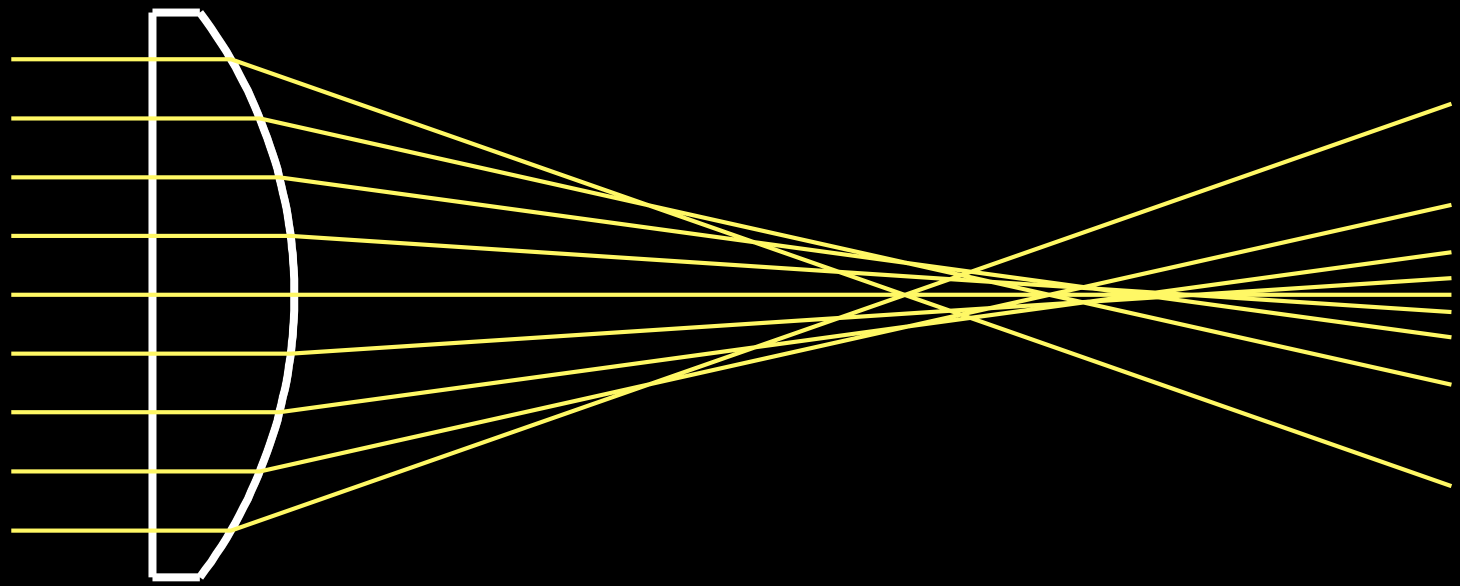


Credit: the next several slides were produced by Dr. Durfee

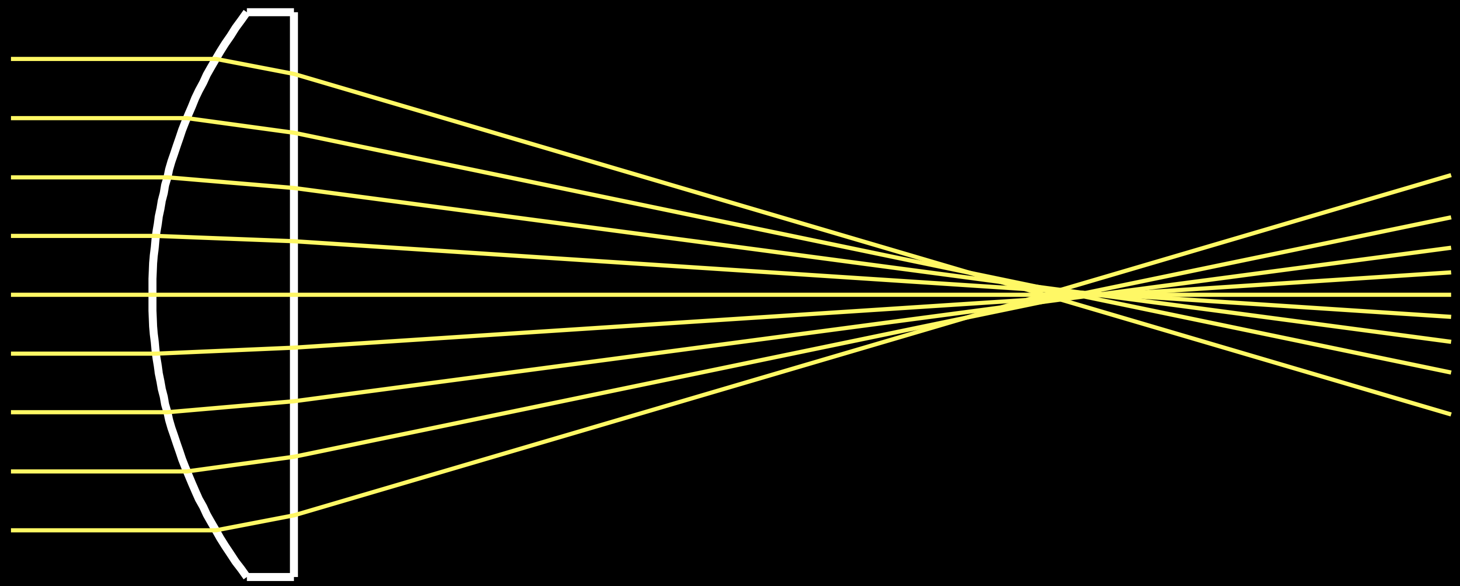
Reducing Spherical Aberration with Aperture



Spherical Aberration



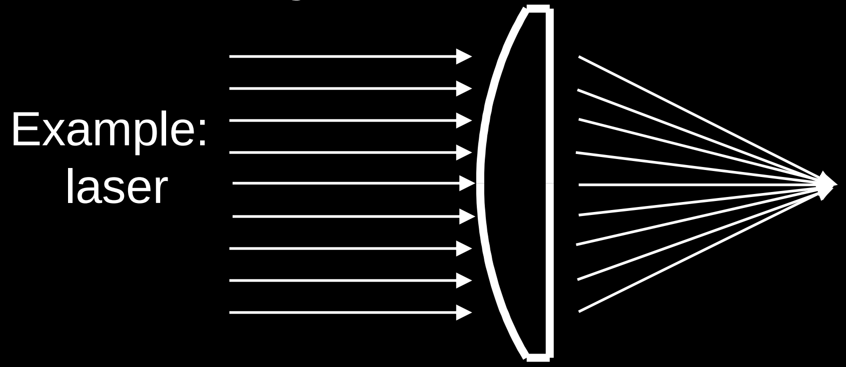
Reducing Spherical Aberration by Reversing Lens



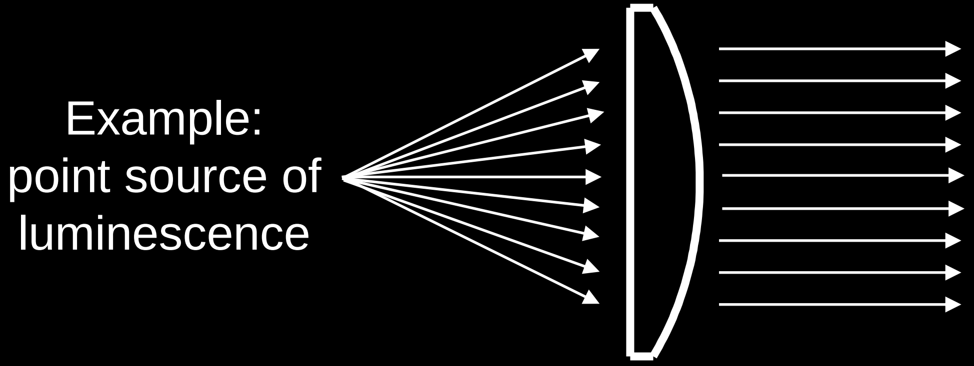
Curved side facing parallel rays

Spherical Aberration Rules:
“Flat to curved, curved to flat”

Parallel rays: curved side first



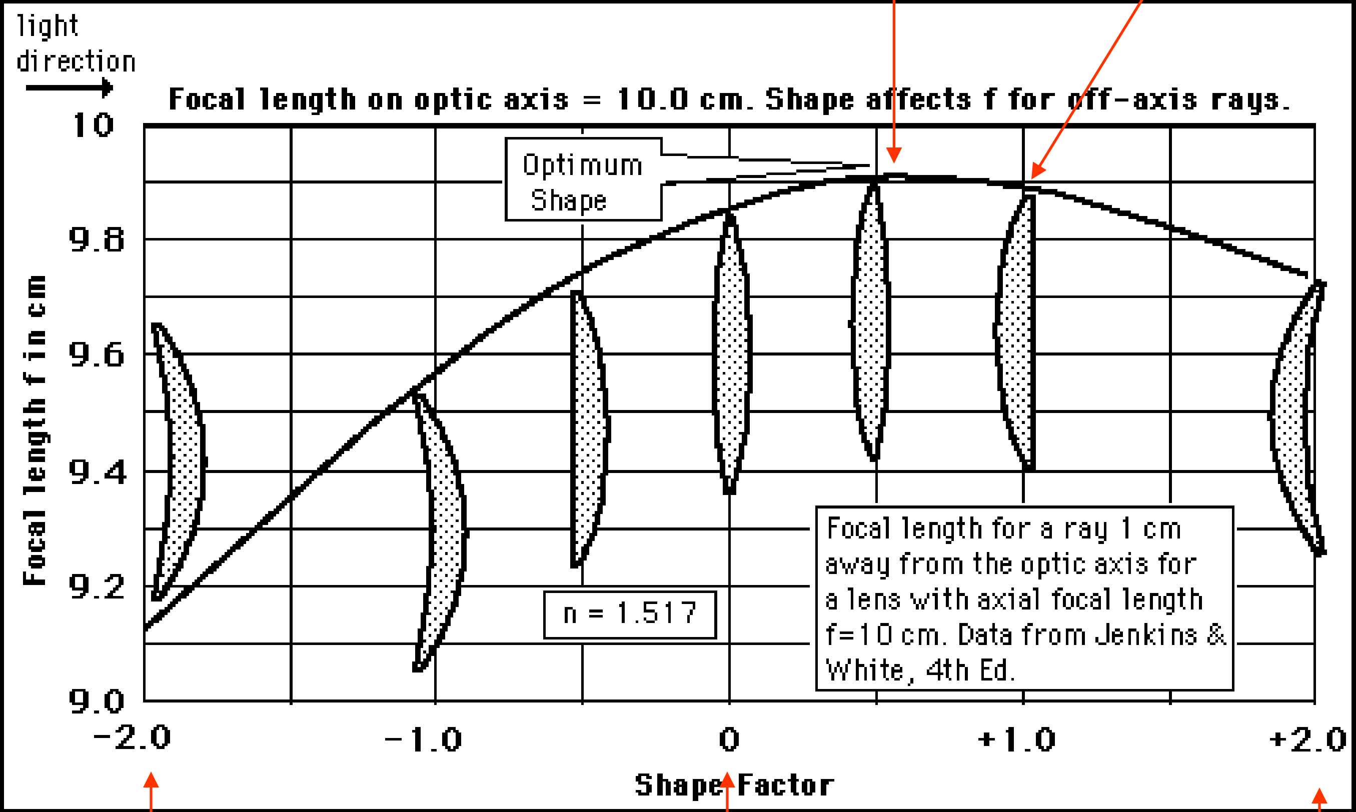
Diverging rays: flat side first



Shape of lens

plano-convex: close to optimum when this direction

optimum



$R_2 = 1/3\ R_1$

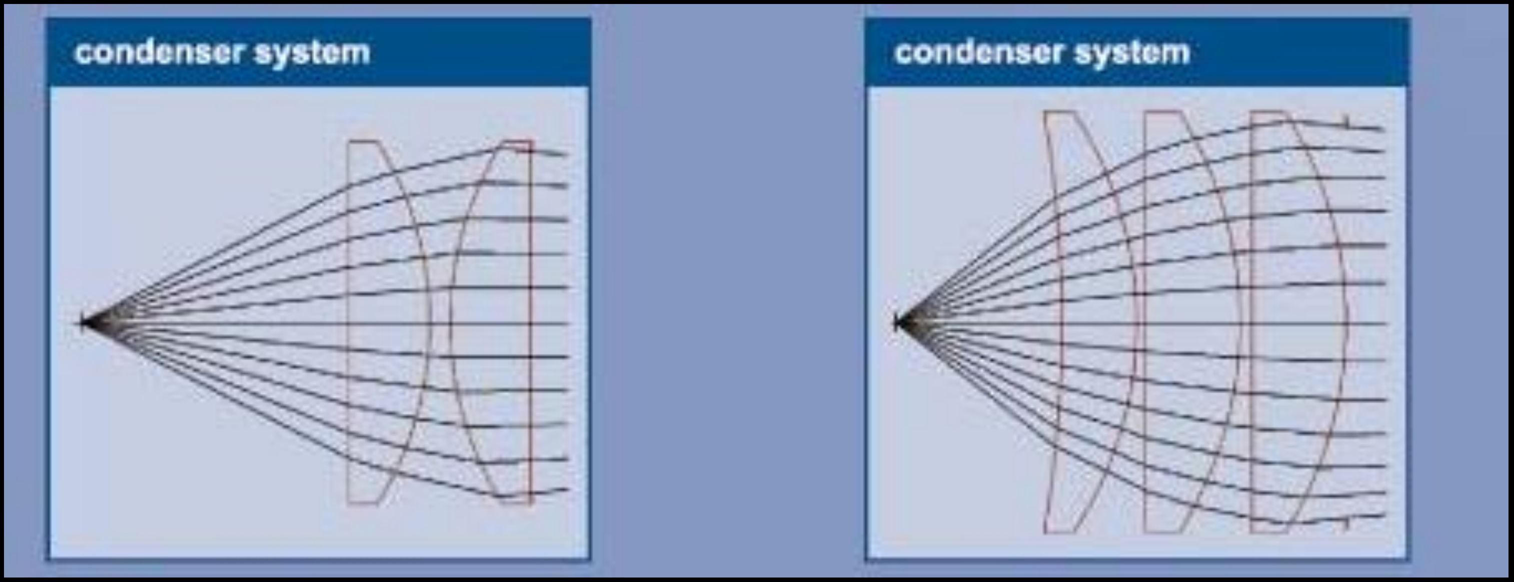
$R_2 = -R_1$

$R_2 = 3\ R_1$

shape factor = $(R_2+R_1)/(R_2-R_1)$

Acknowledgement: I got this from Dr. Hess, but I don't know where he got it from.

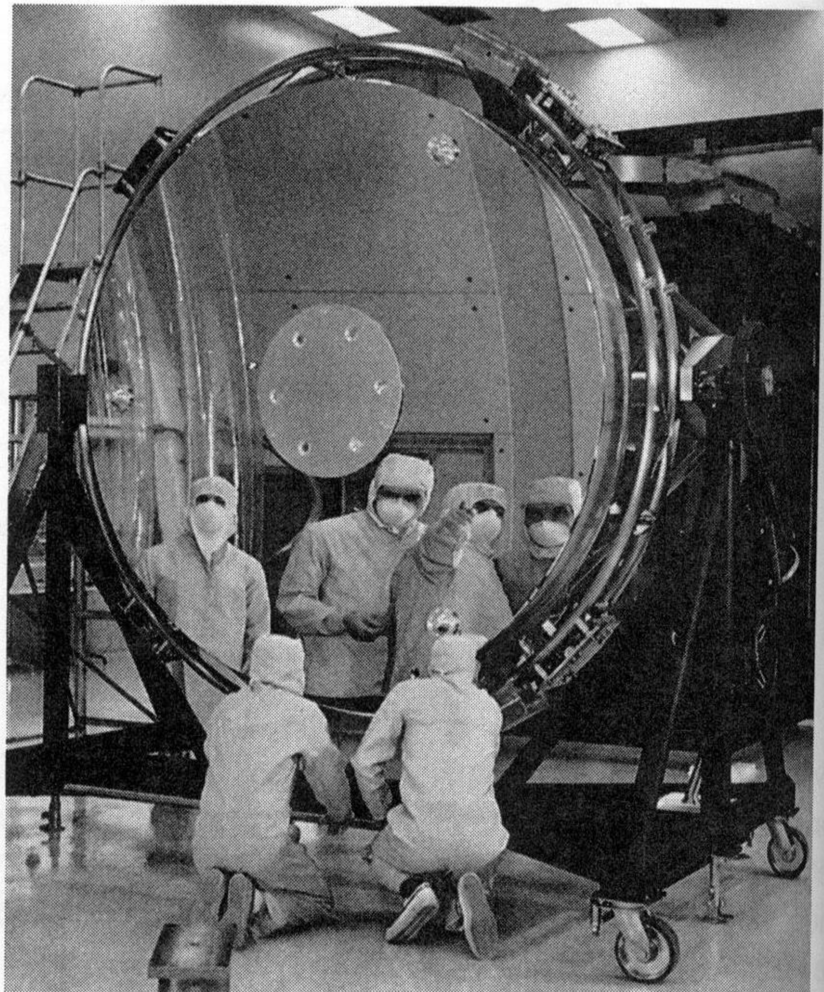
Ray Tracing To Correct For Aberration



Acknowledgement: I got this from Dr. Hess, but I don't know where he got it from.

The 1993 Hubble Telescope Repair

Pictures and
story from Hecht



The 2.4-m-diameter hyperboloidal primary mirror of the Hubble Space Telescope. (Photo courtesy of NASA.)

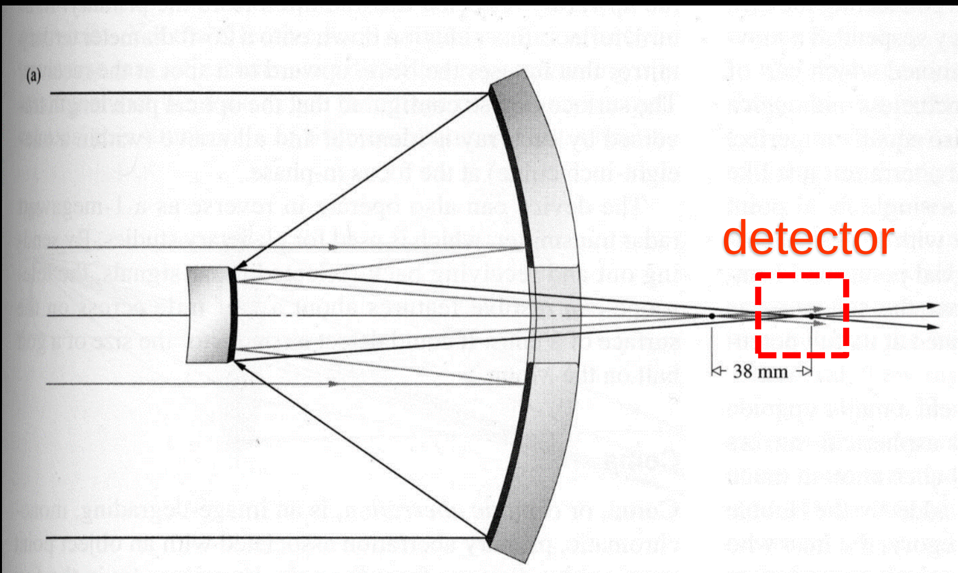
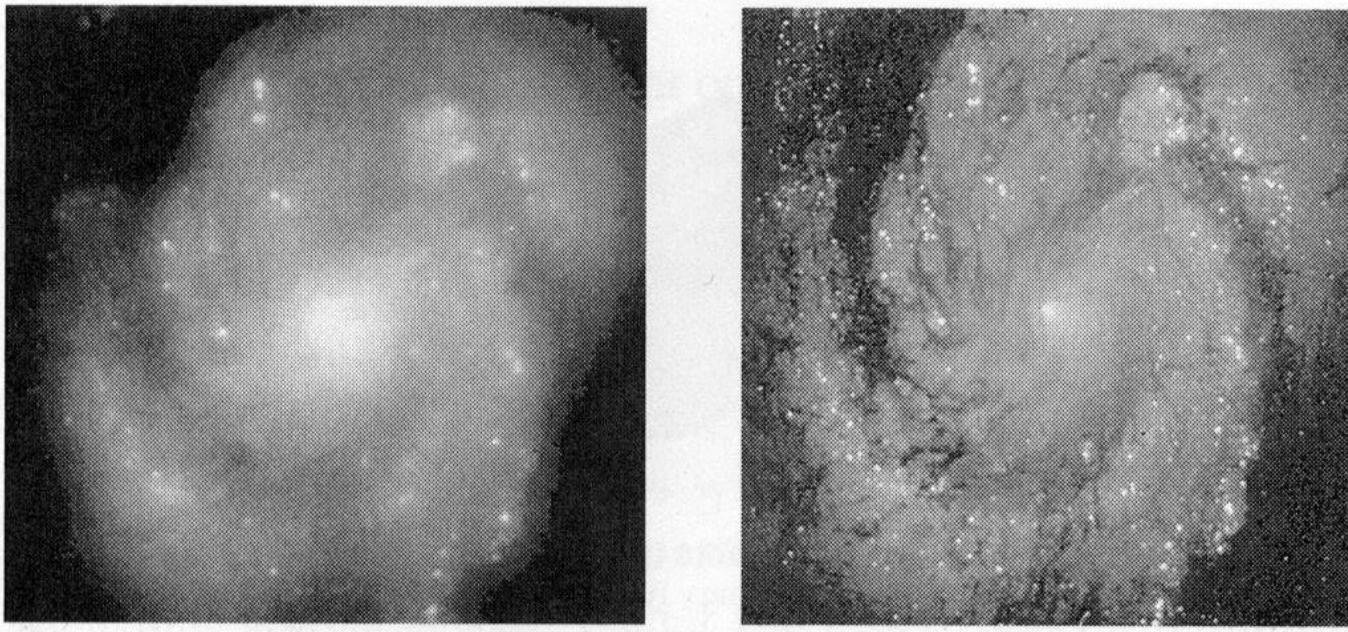
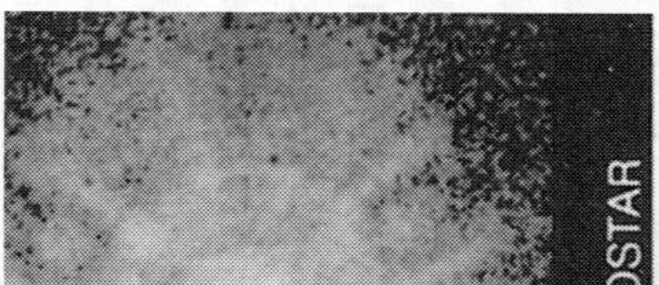
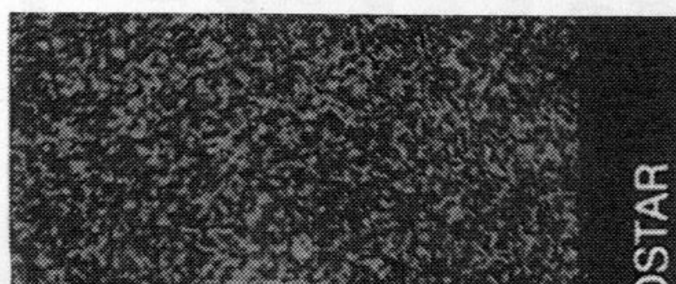


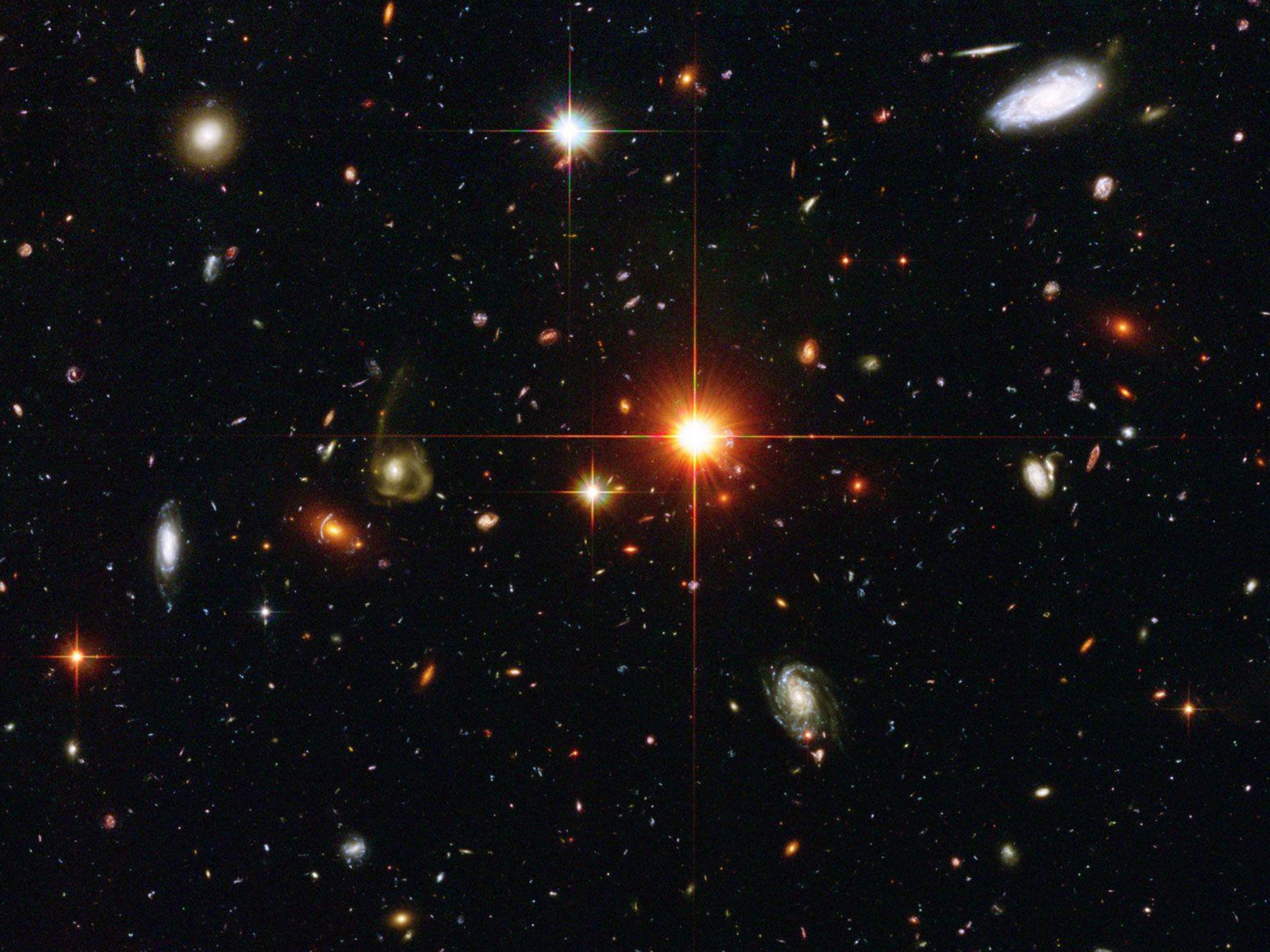
Figure 6.19 (*a*) Because the primary mirror is too flat, rays from the outer edges met at a point 38 mm beyond the point where inner rays converge.

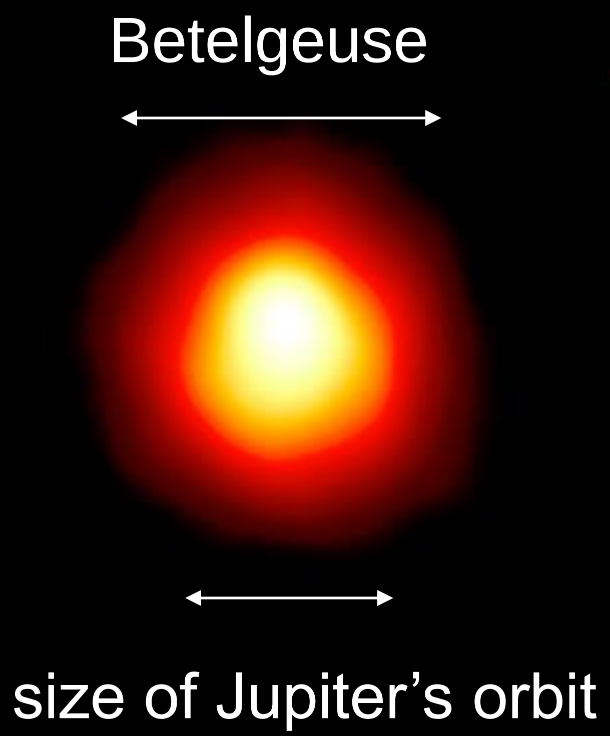


HST images of the M-100 galaxy with (before repair) and without (after repair) spherical aberration. (Photos courtesy of NASA.)







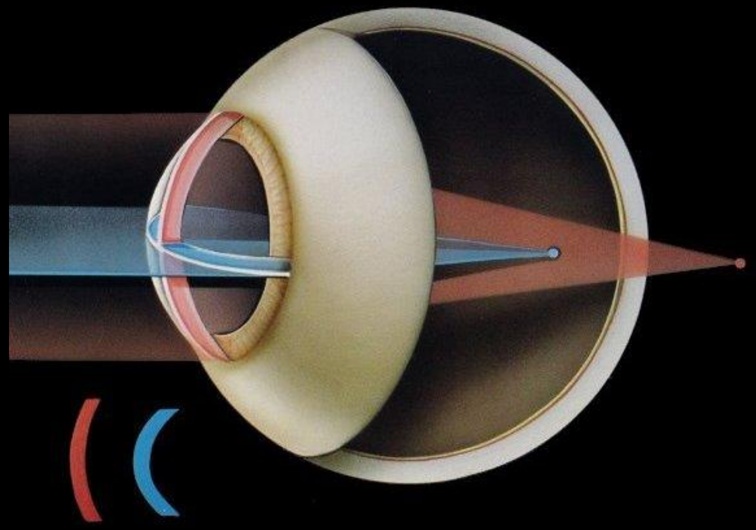


angular size: similar to resolving a car's headlights from 6,000 miles away

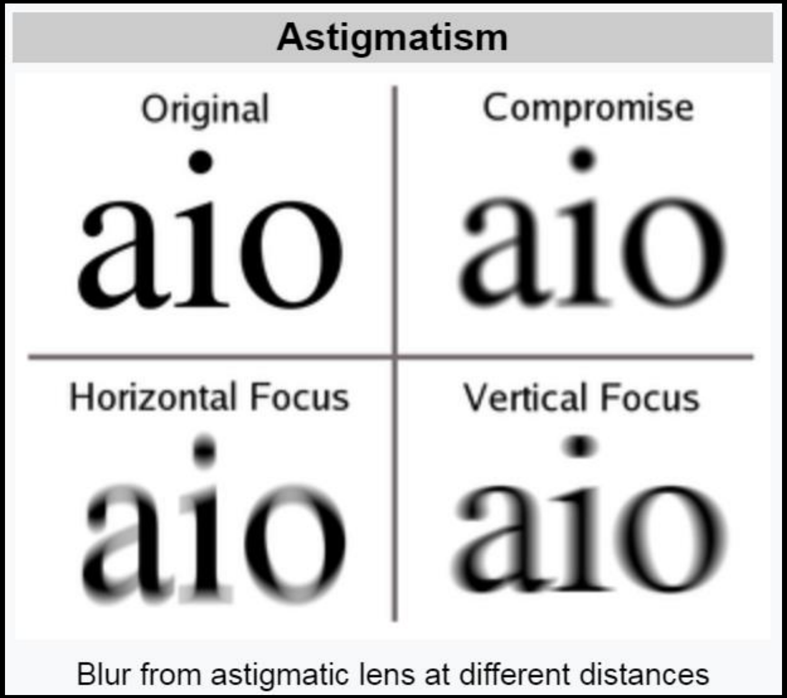
http://www.spaceimages.com/atofbet.html

Astigmatism

- Lens shape = spherical + cylindrical: rays in different planes have different focal lengths



Viestenz et al. Zeitschrift der Deutschen Ophthalmologischen Gesellschaft, 104, 620-7 (2007).

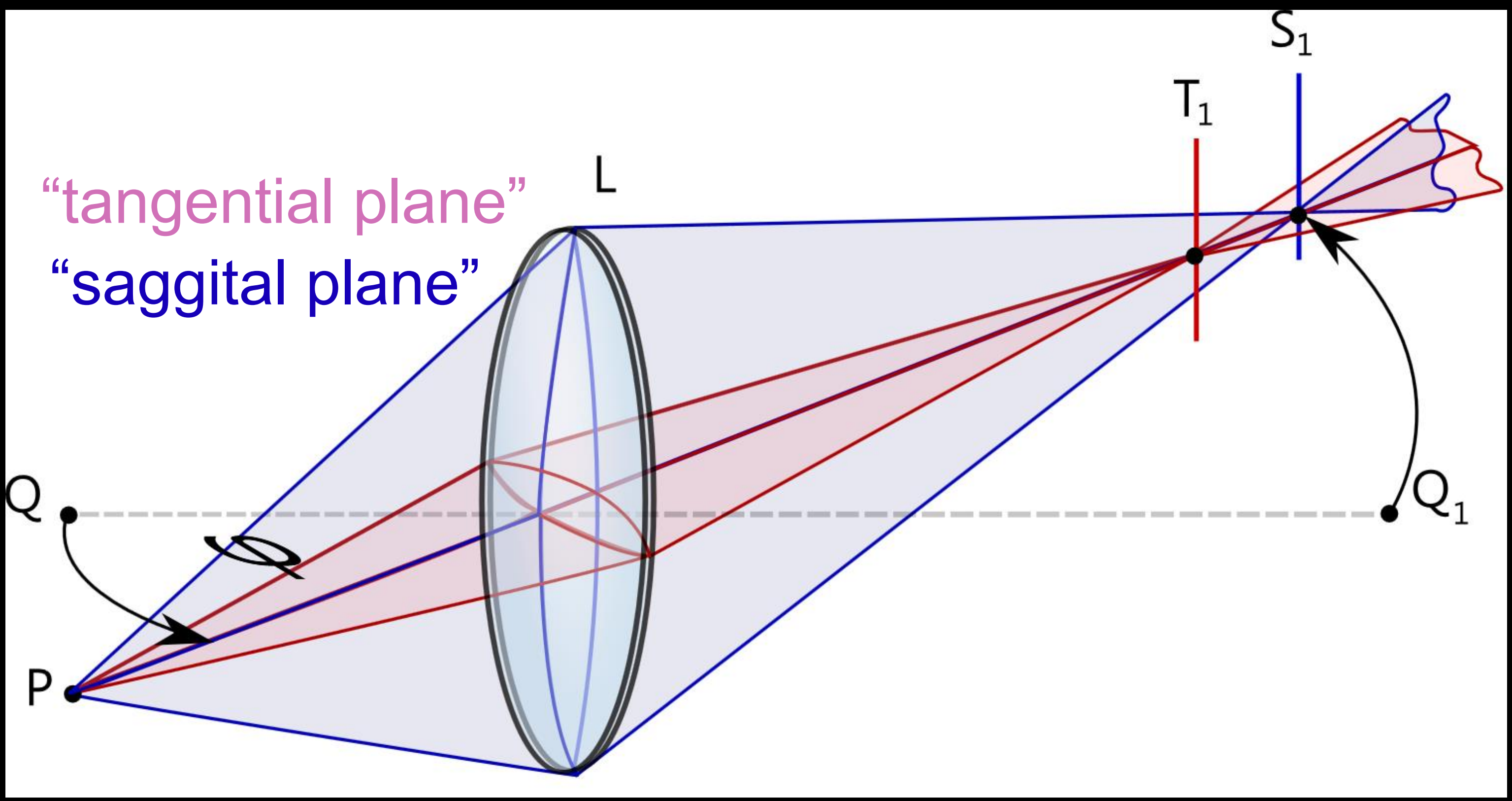


Wikipedia: “Astigmatism”

Correction: add an opposite cylindrical component in corrective lens

Astigmatism, part 2

- Rays in different planes have different focal lengths



Wikipedia: "Astigmatism (optical systems)"

Coma

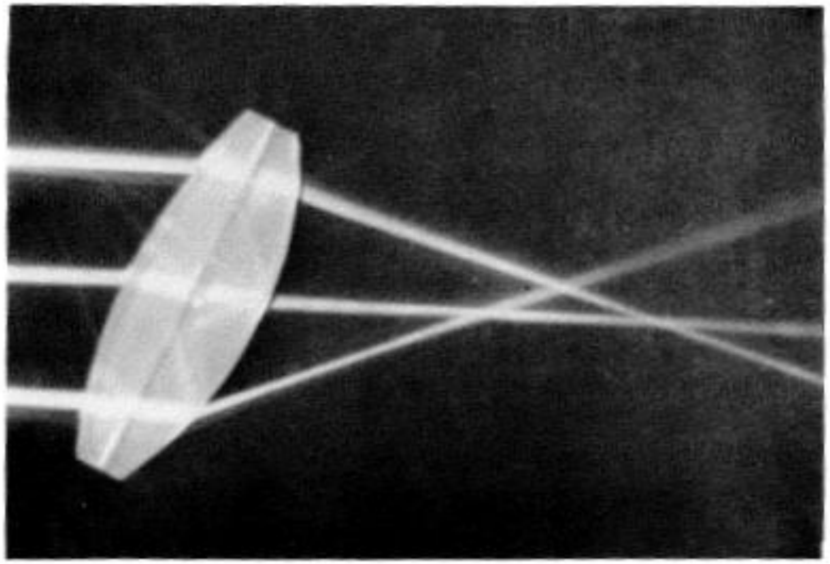
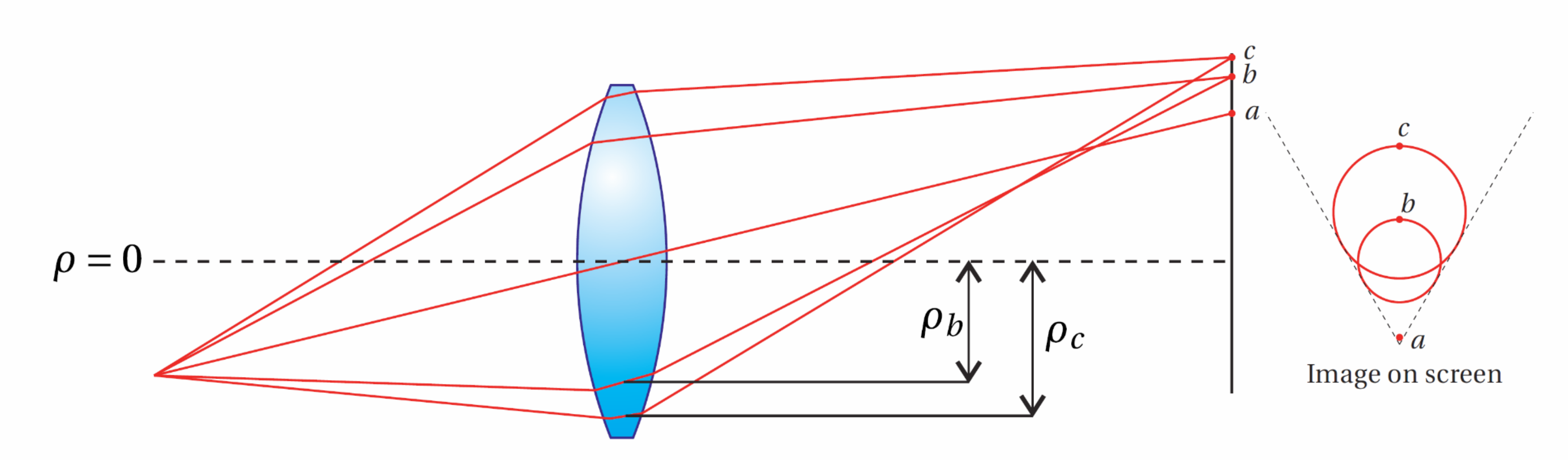


Fig. 6.18 Positive coma. [Photo by E.H.]

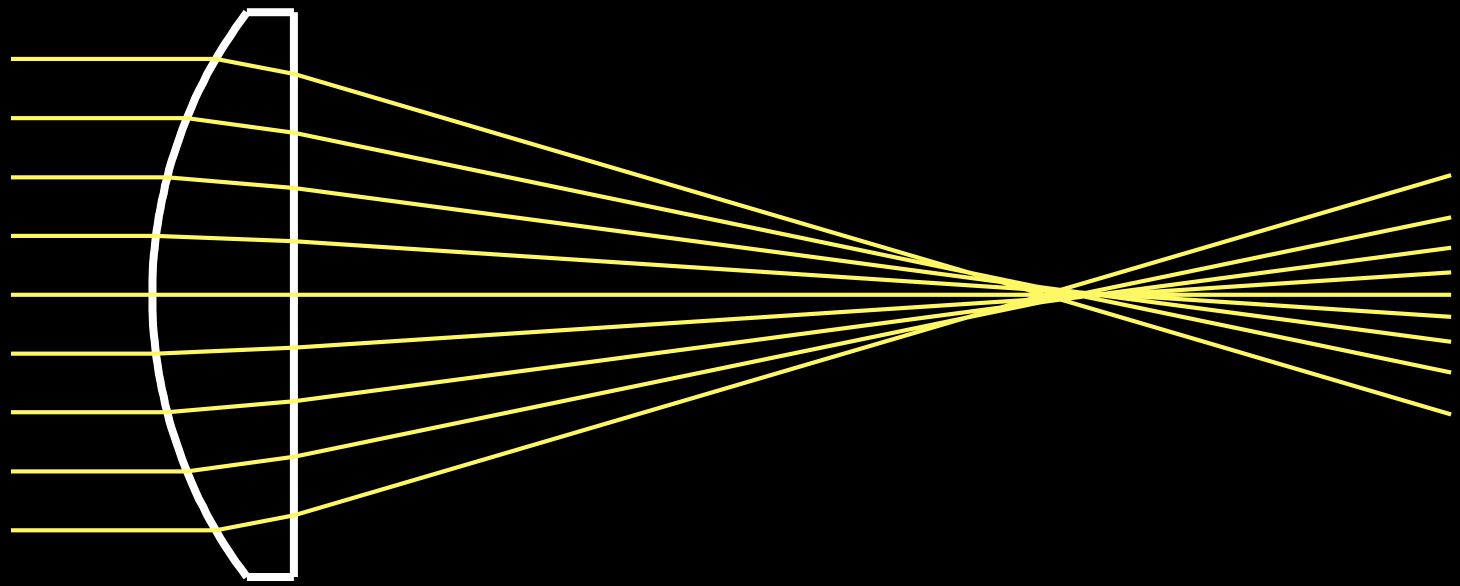
from Hecht

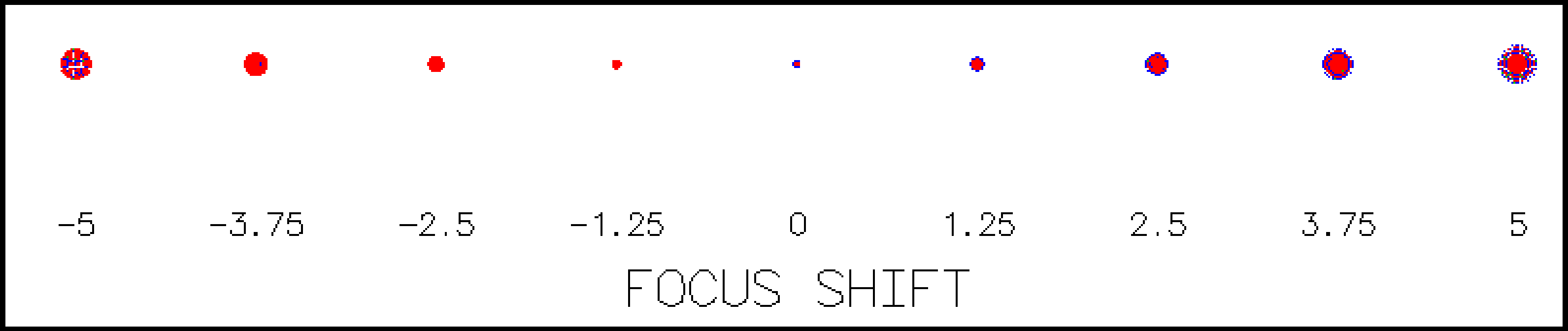
from P&W



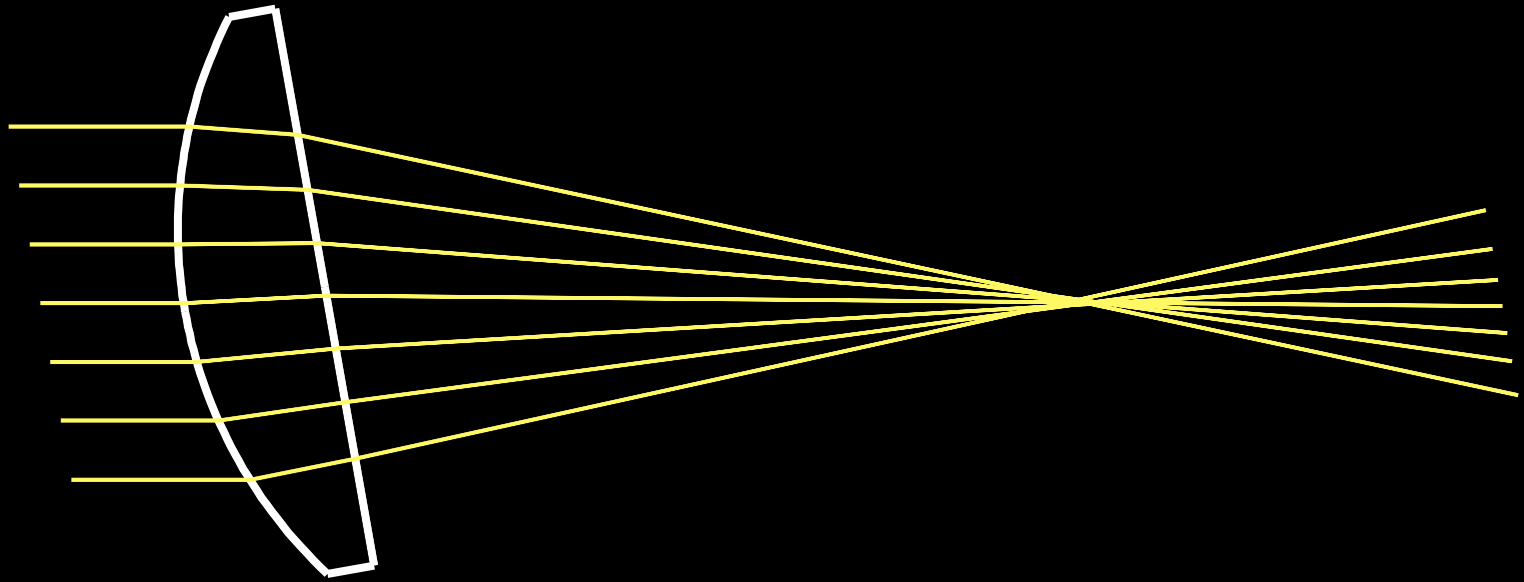
0 Degree Tilt

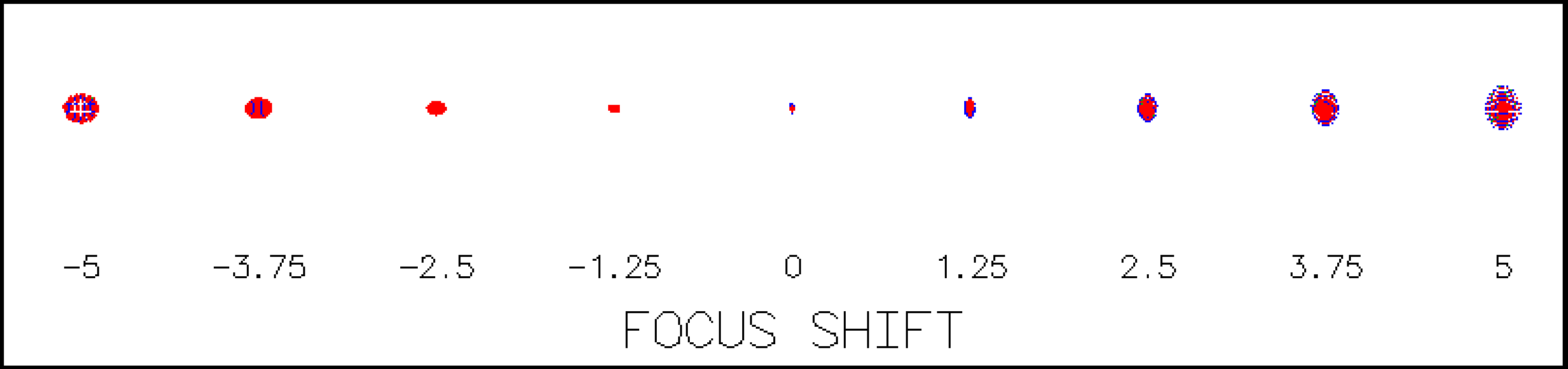
(next few slides from Dr. Durfee)



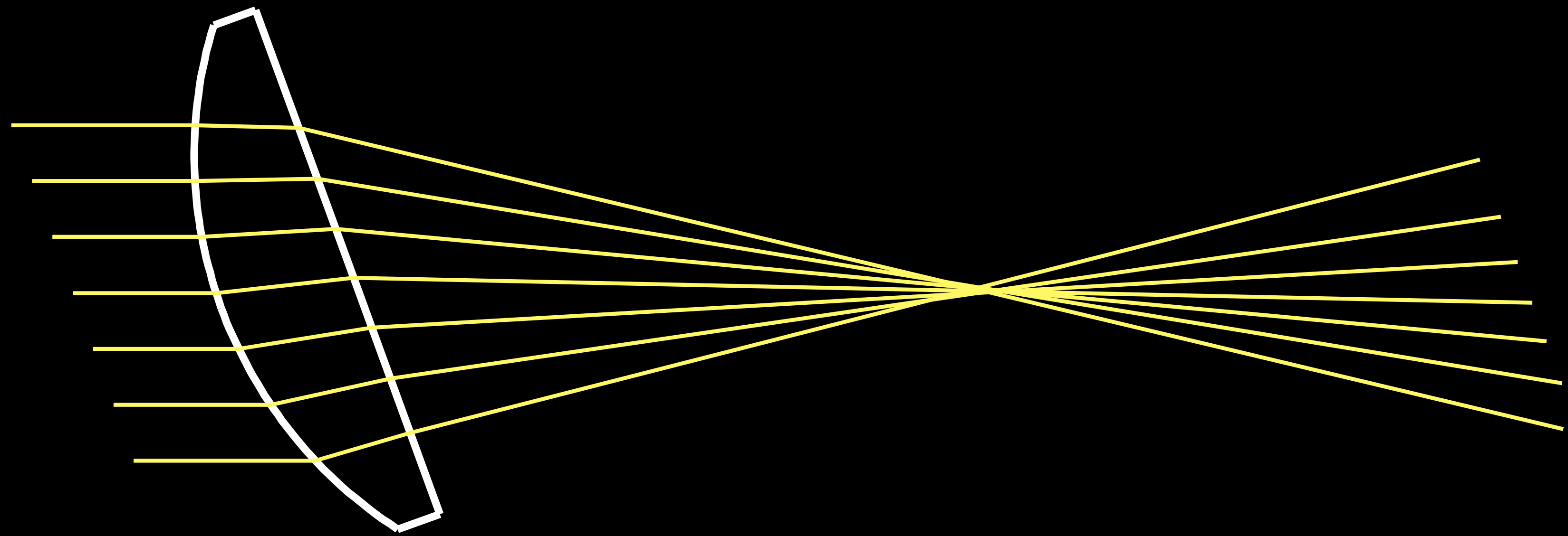


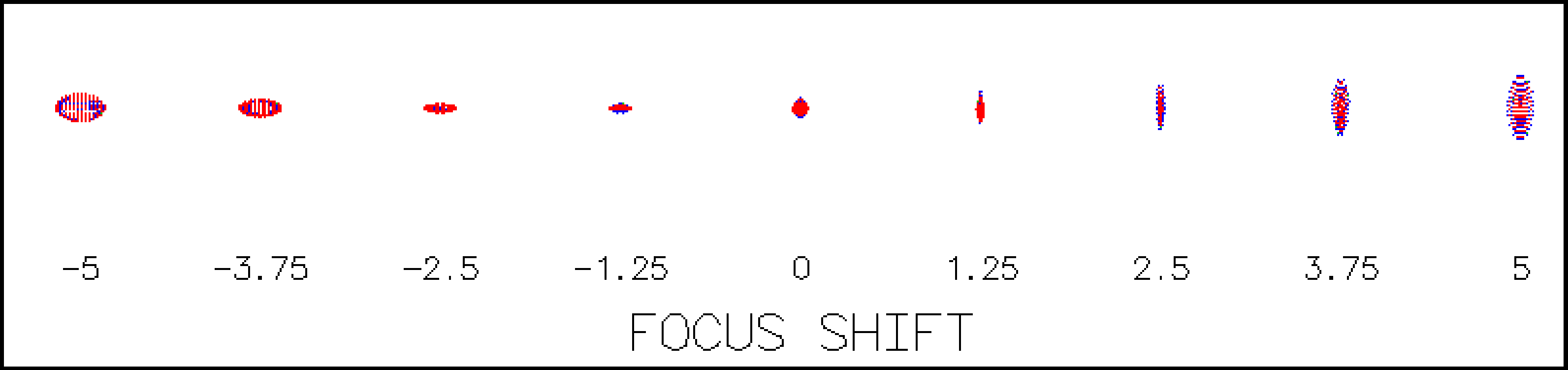
10 Degree Tilt



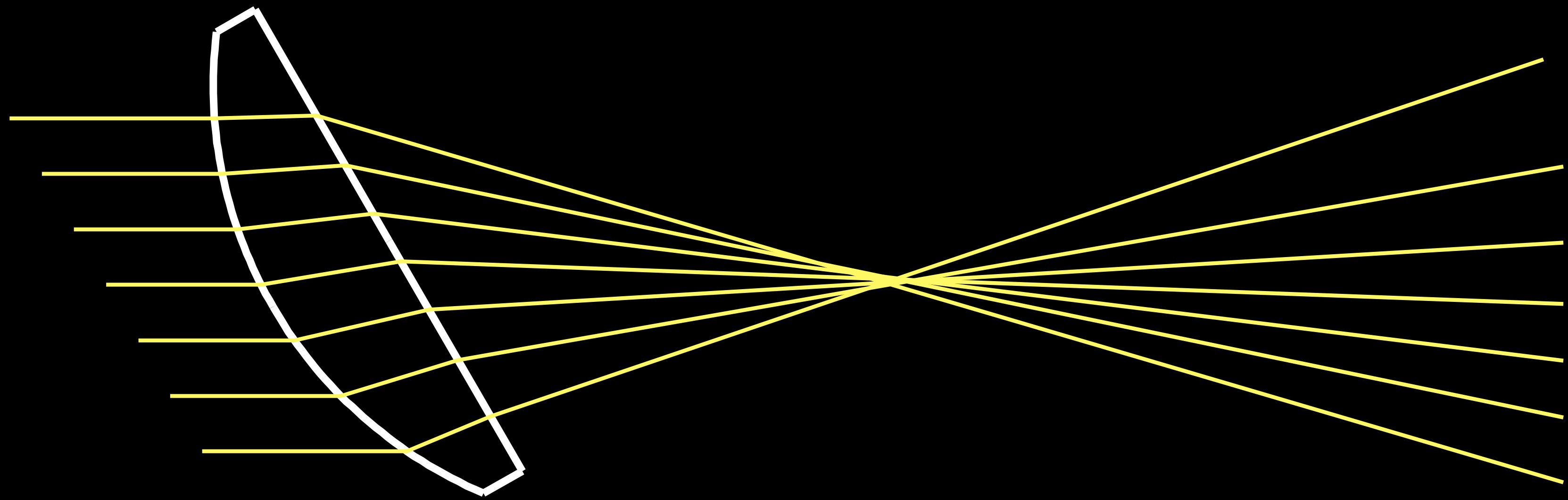


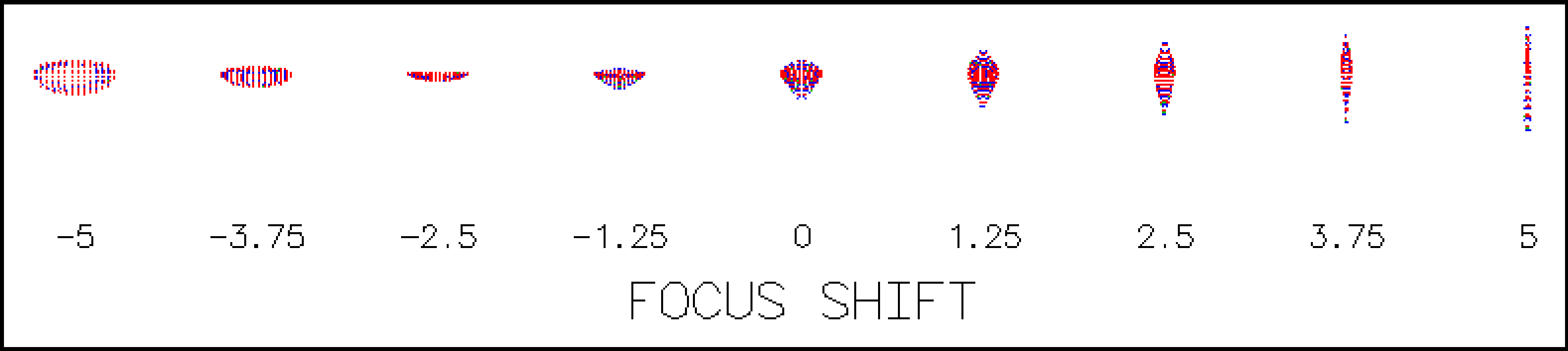
20 Degree Tilt



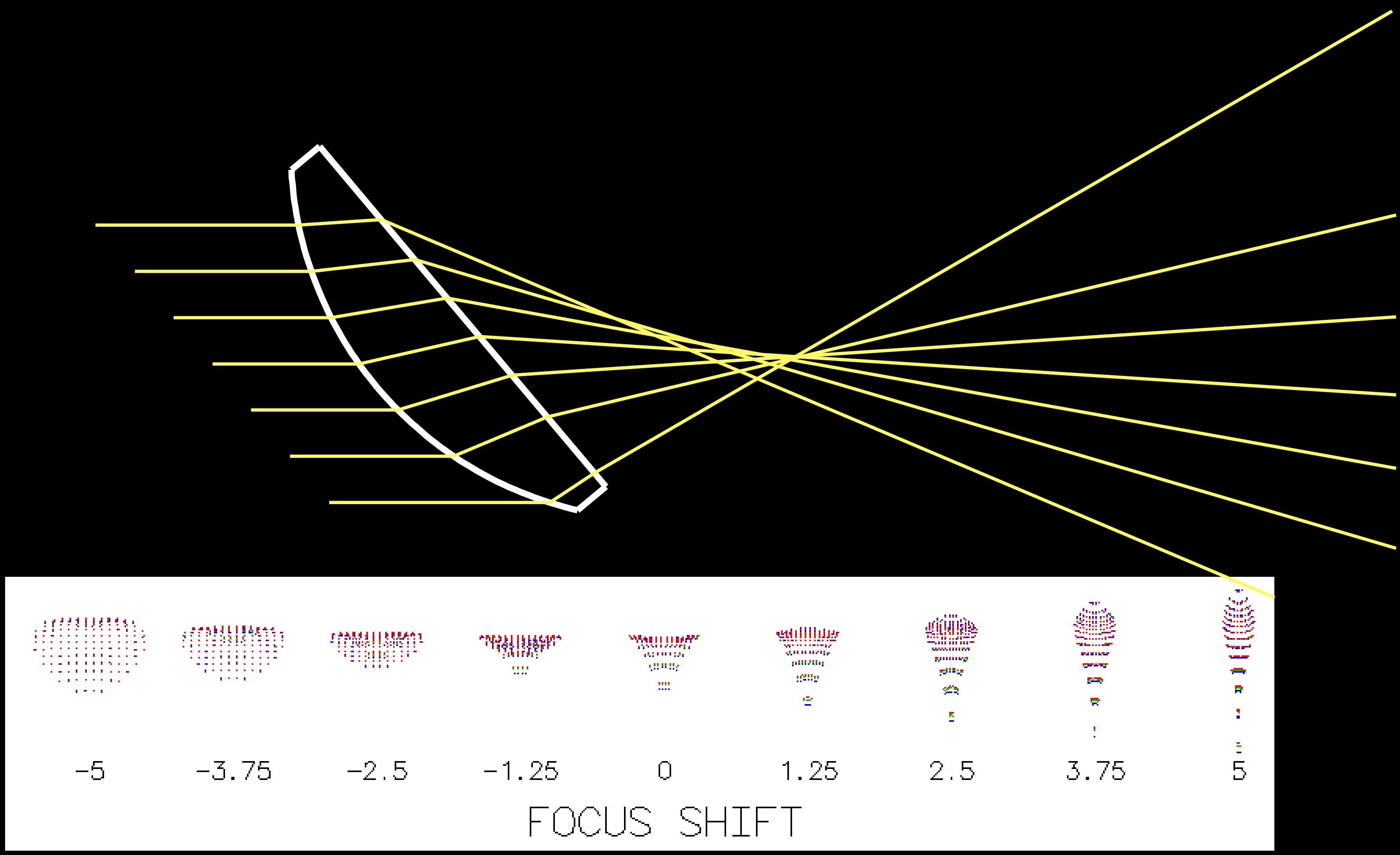


30 Degree Tilt

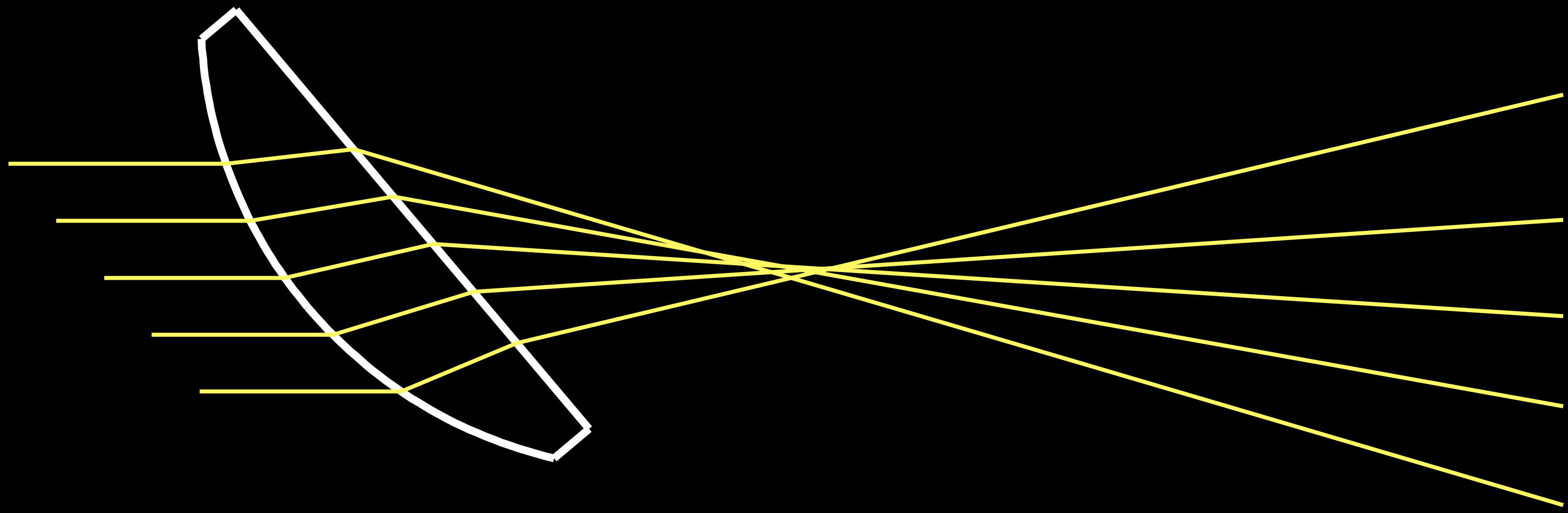


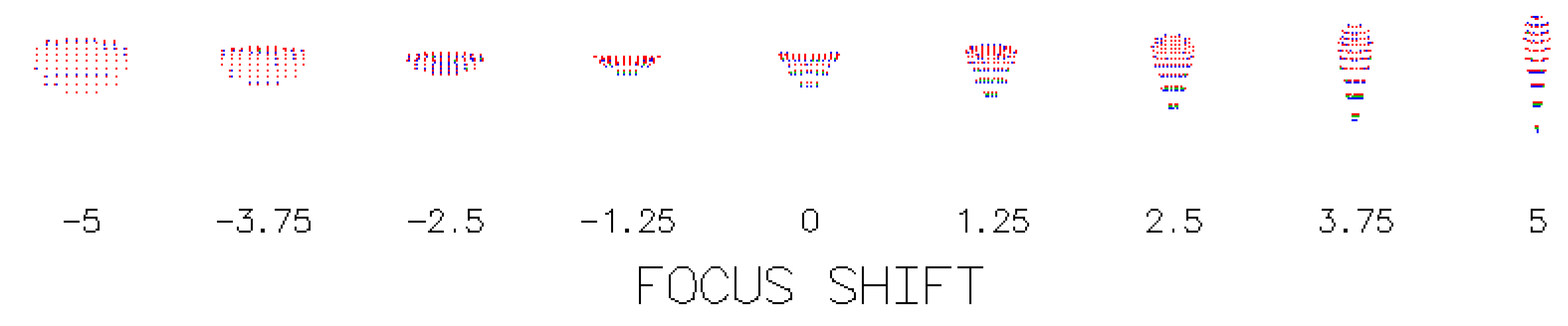


40 Degree Tilt

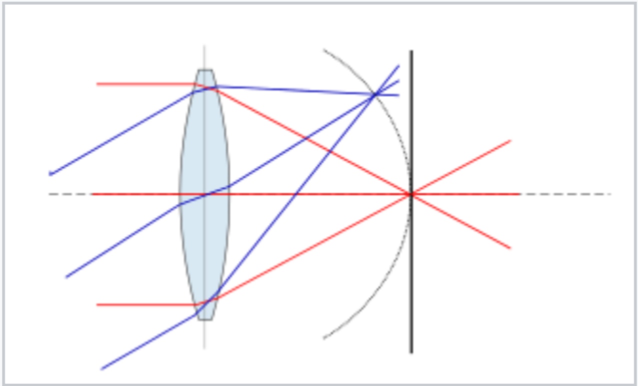


40 Degree Tilt + Aperture





Petzval field curvature



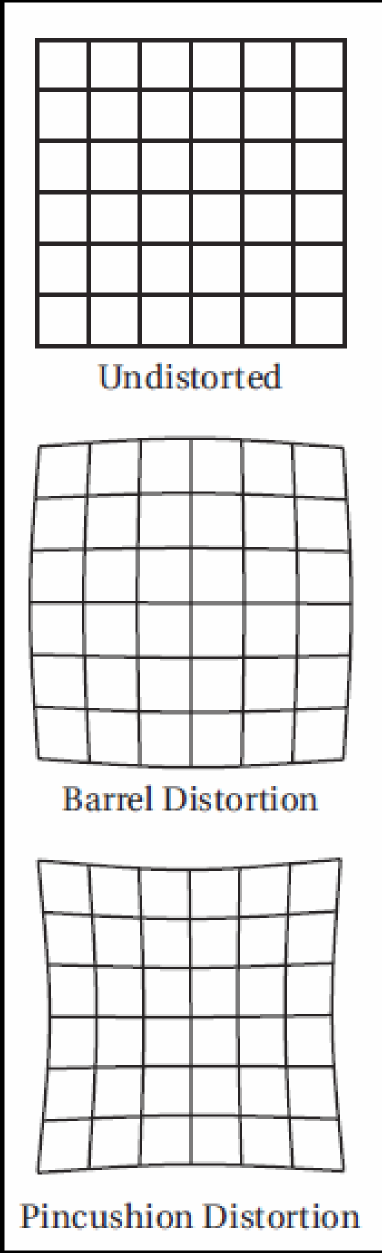
Field curvature: the image "plane" (the arc) deviates from a flat surface (the vertical line).

Usual solution: use multiple lenses to form one overall “lens” whose focal length increases with ray angle

Solution 2: Curve your detector. This is detector on Keppler space telescope (searching for extra-solar planets)

Wikipedia: Petzval field curvature

Distortion



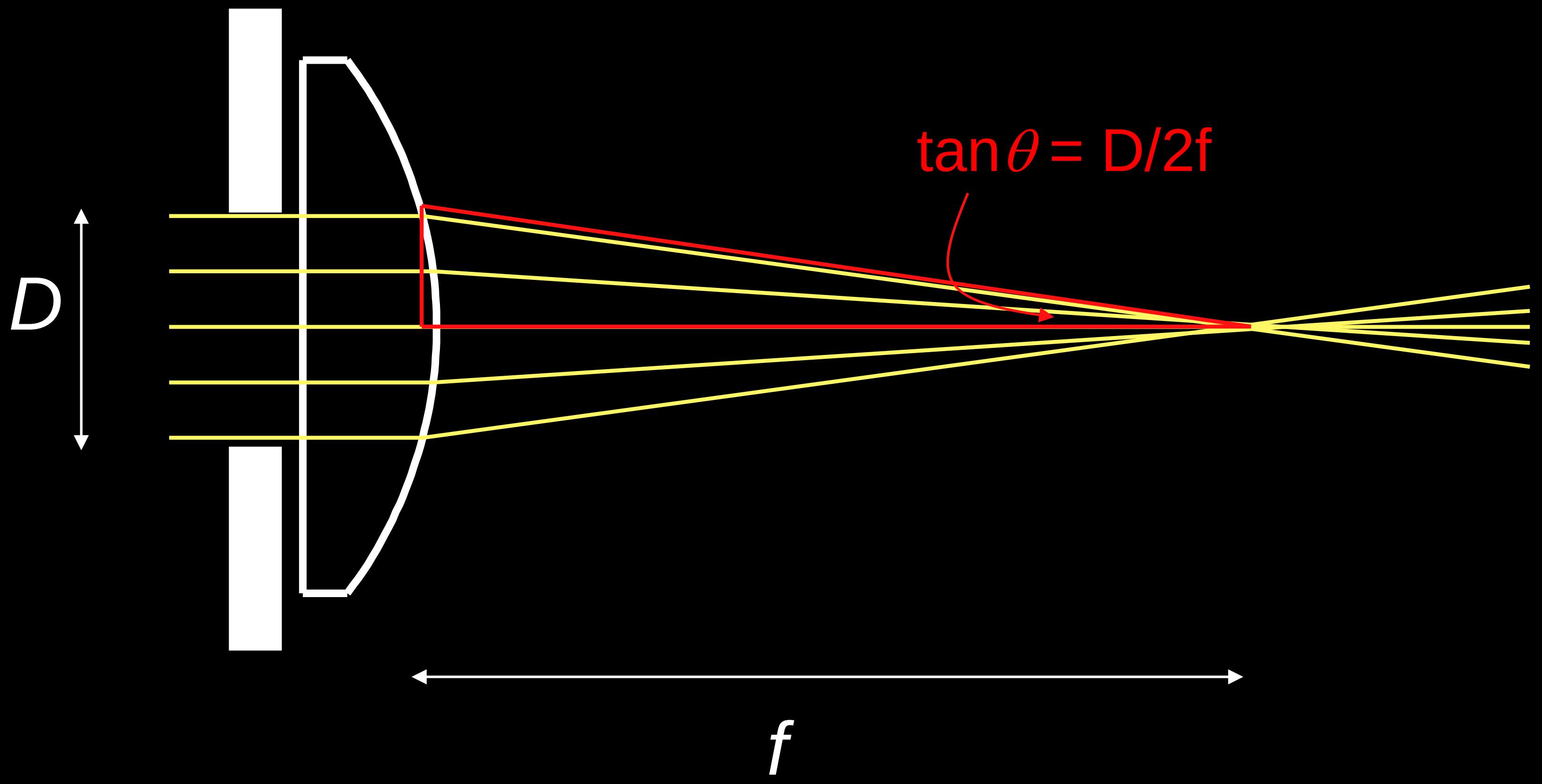
Far from center: magnification = less

Far from center: magnification = more

Wikipedia: Distortion (optics)

Apertures

- f-number = "f/#" = f/D



"Numerical aperture": NA = sin θ

= D/2f for small angles

(= 1/(2f-number))