# CS4495/6495
# Introduction to Computer Vision

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3A-L1 *Cameras and images*

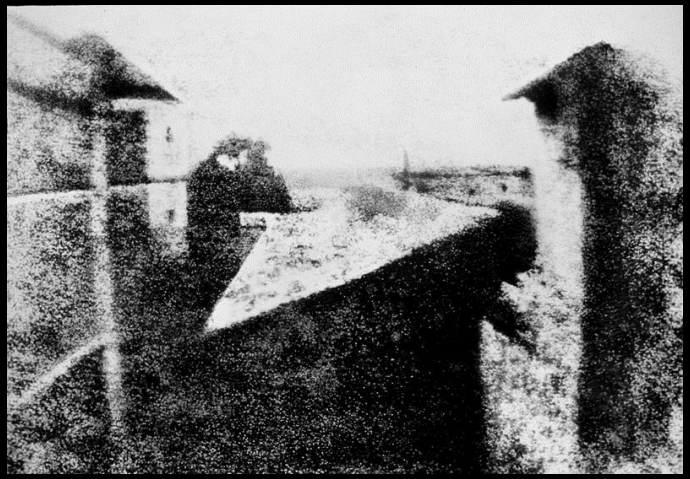
# What is an image?

- Up until now: a function – a 2D pattern of intensity values
- Today: a 2D projection of 3D points

# First Known Photograph – Heliograph

View from the Window at le Gras,
Joseph Nicéphore Niépce 1826

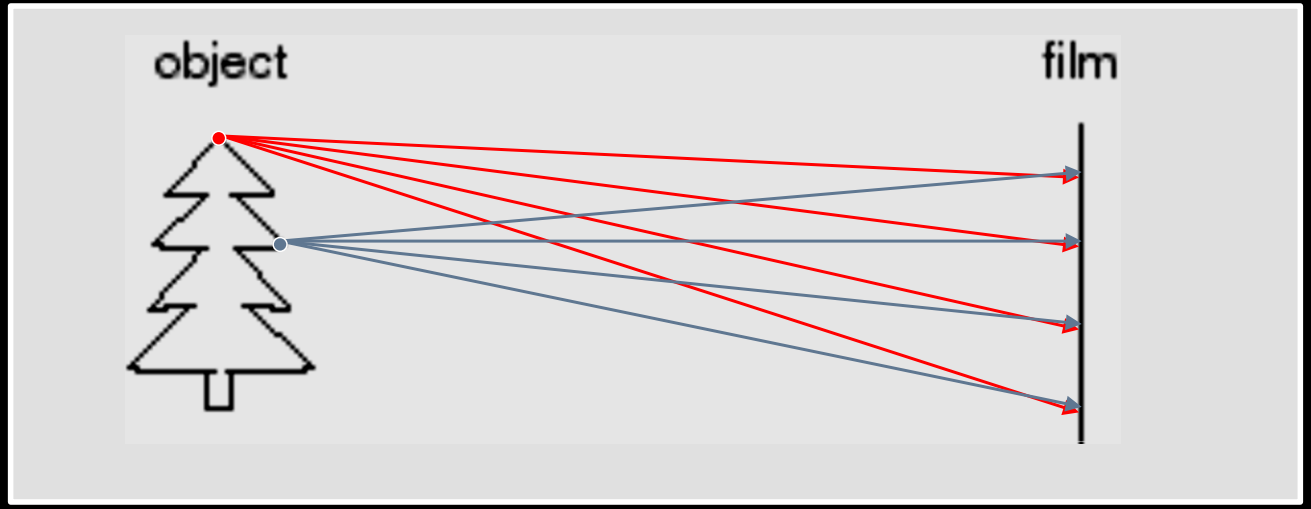
Reproduction, 1952



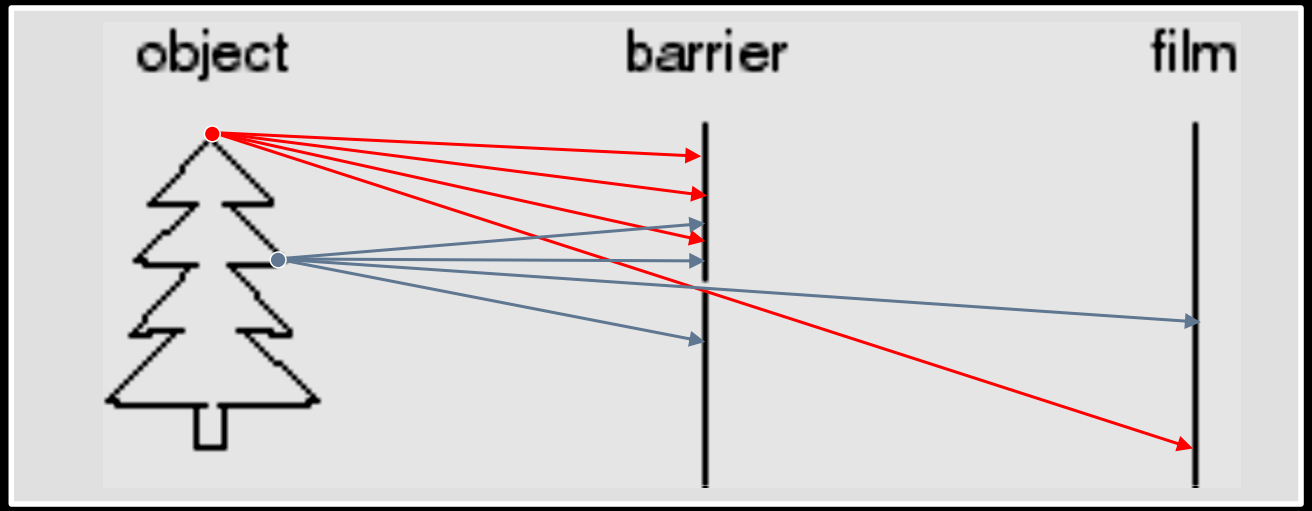
# Projection

# Projection

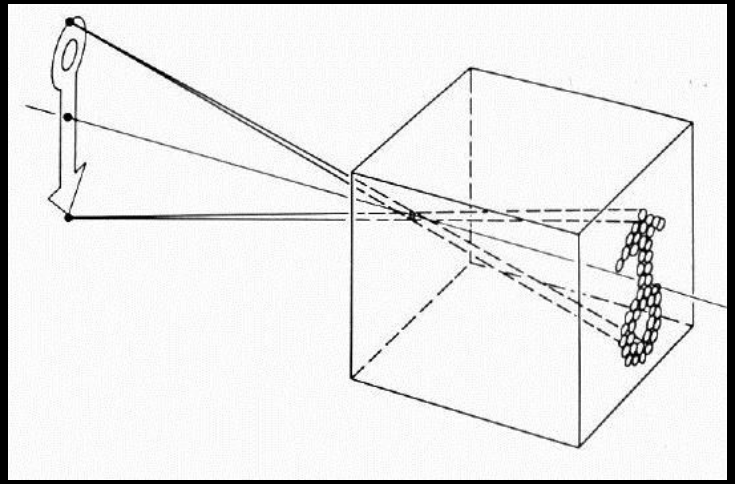
# Image formation – (bad) method

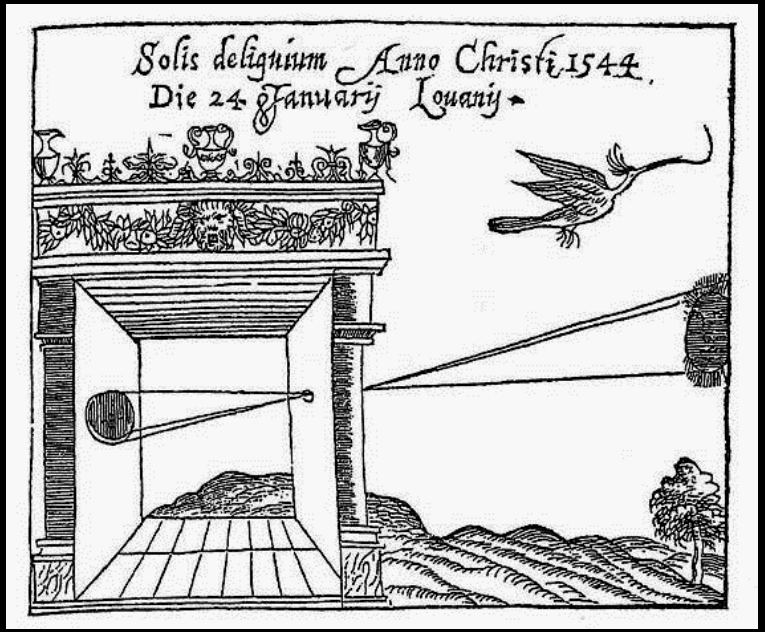


# Pinhole camera



# Camera Obscura (Latin: Darkened Room)



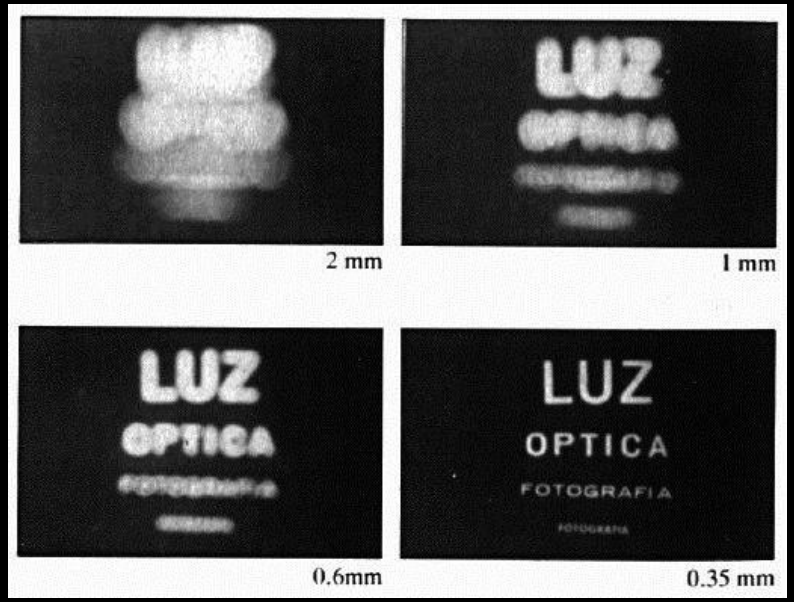


# Home-made pinhole camera

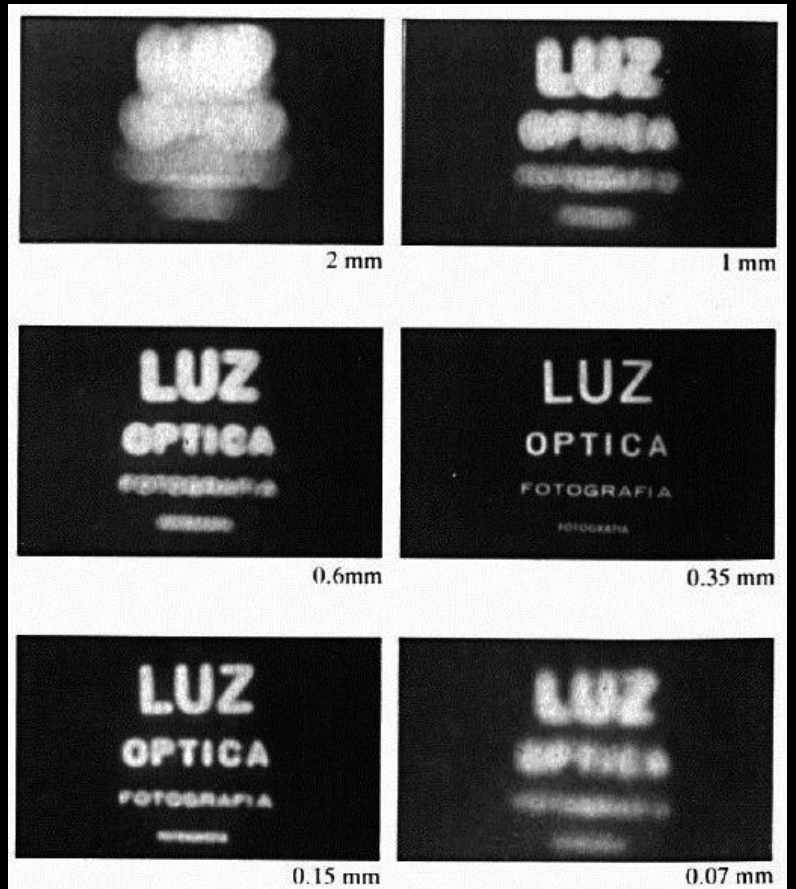

Why so blurry?

http://www.debevec.org/Pinhole/

# Shrinking the aperture

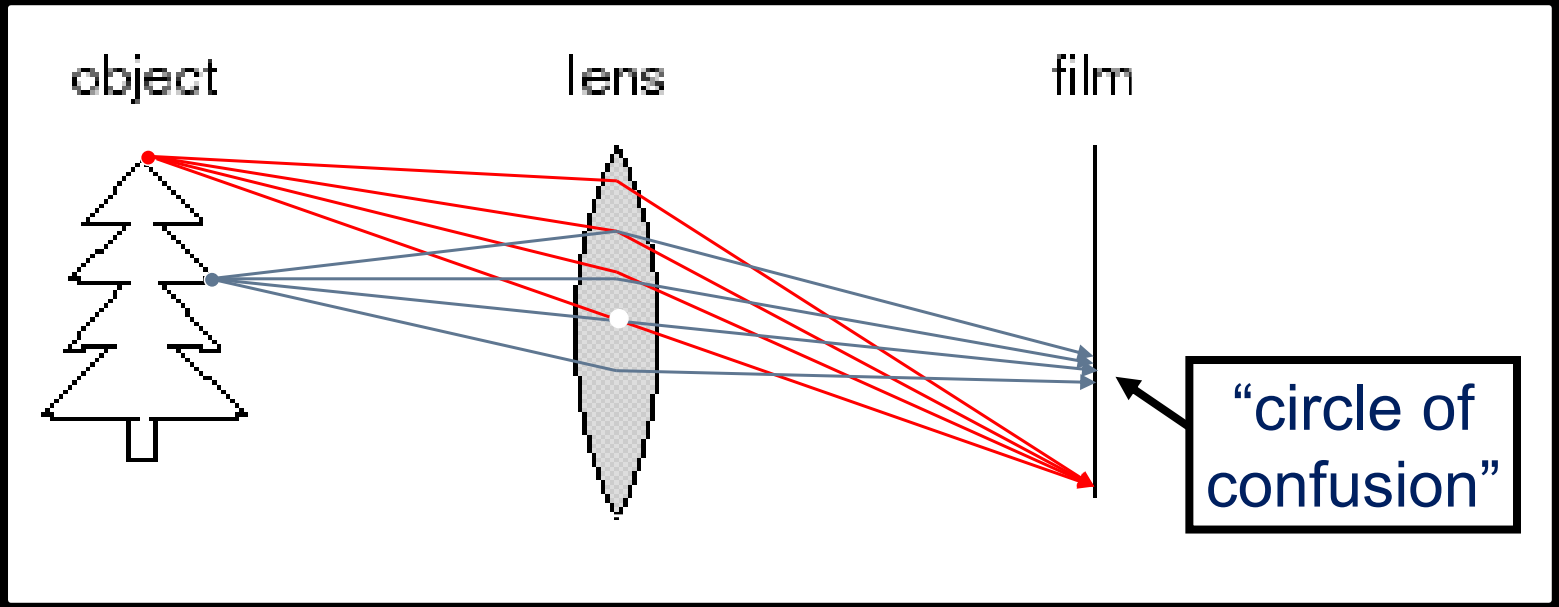


# Shrinking the aperture

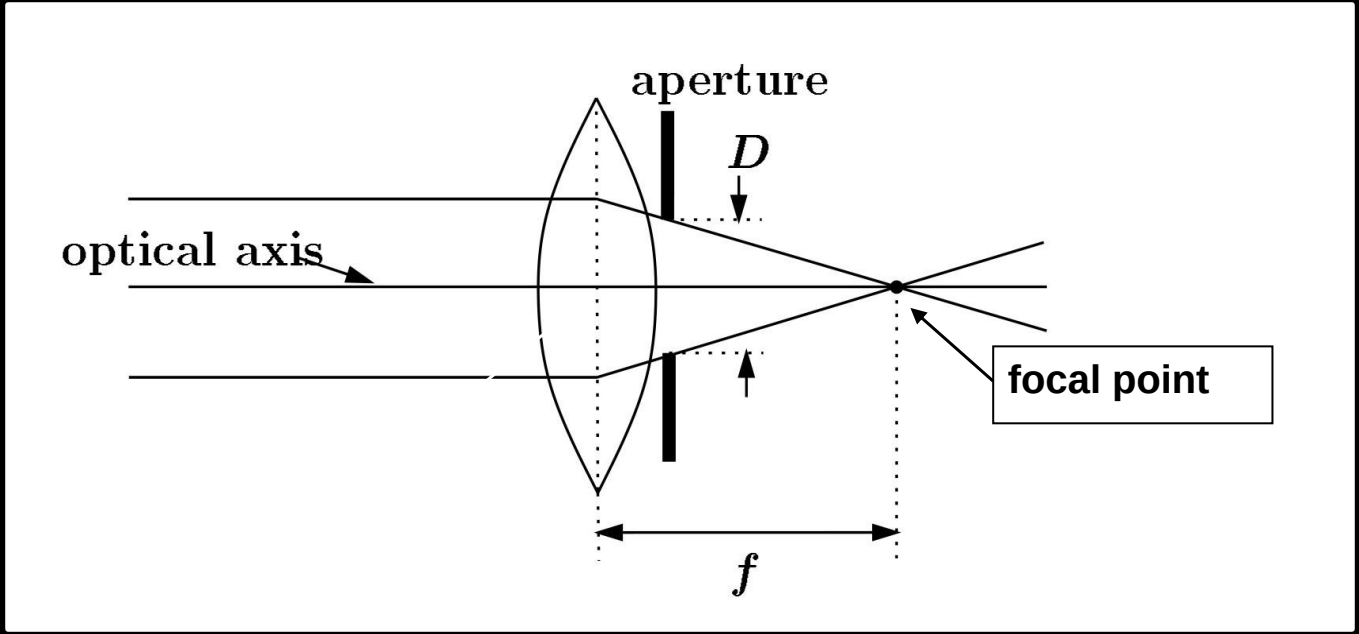


# A little bit of computational photography

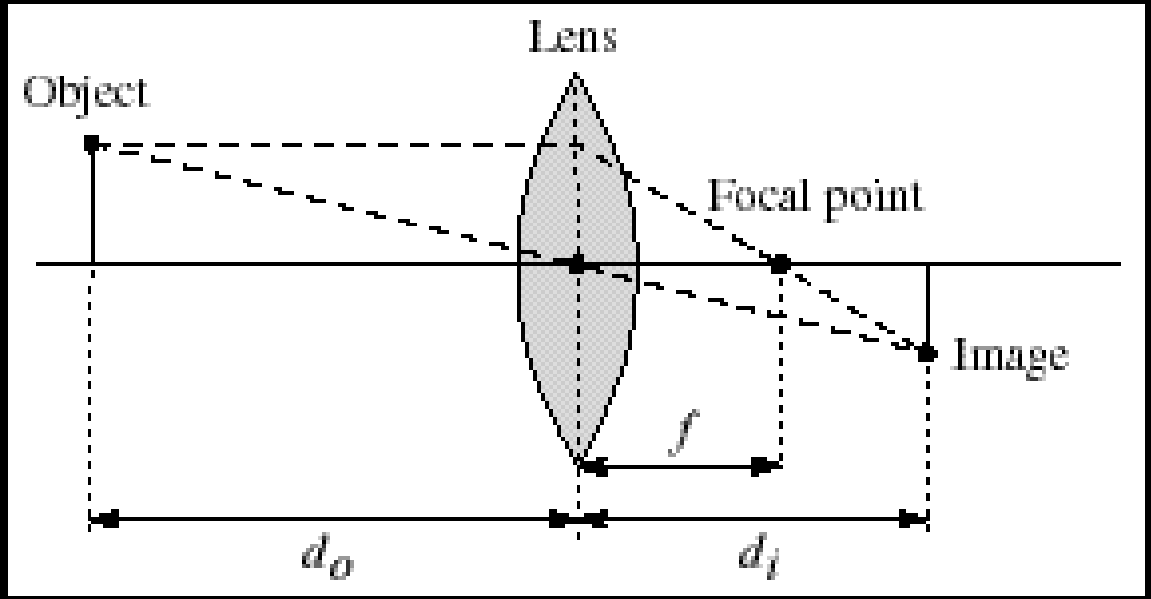
# Adding a lens – and concept of focus



# Lenses

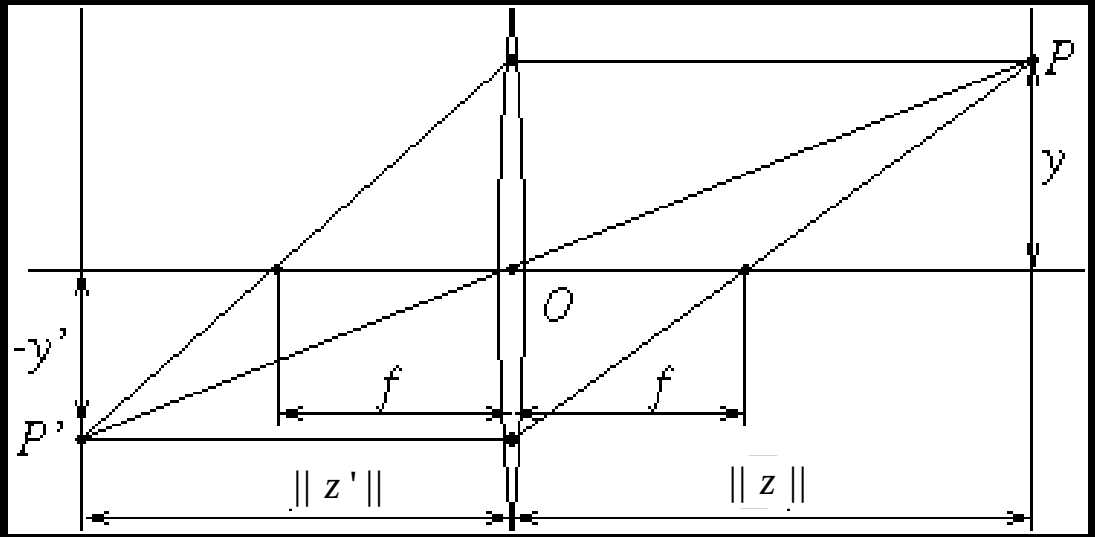


# Thin lenses



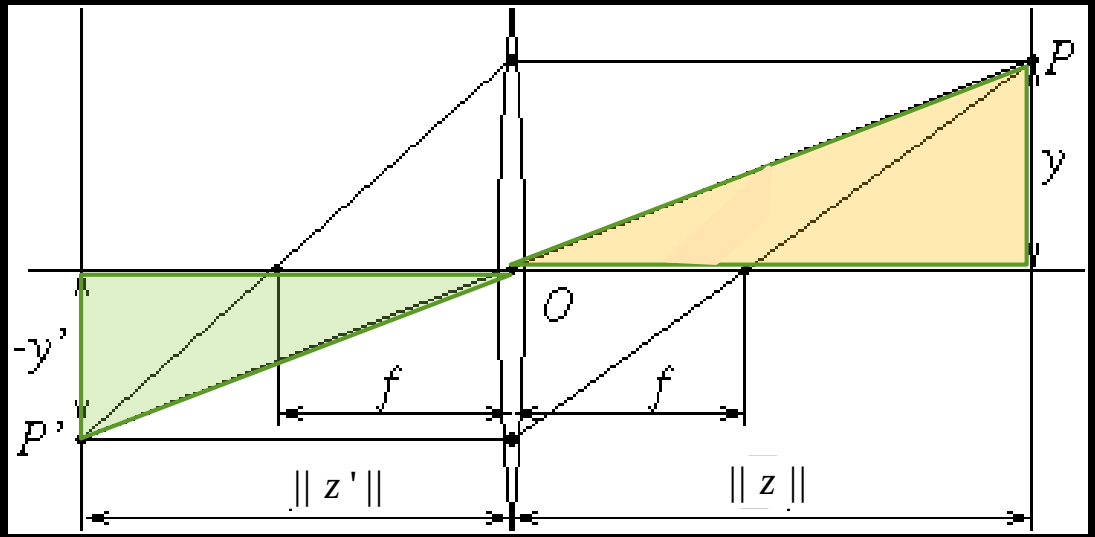

Slide by Steve Seitz

# The thin lens



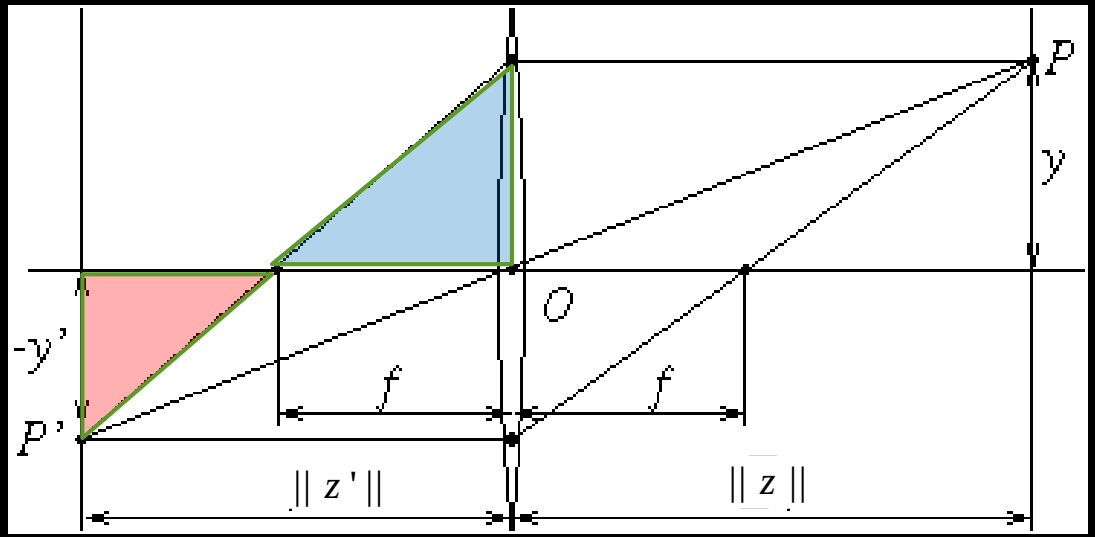

Computer Vision - A Modern Approach
Slides by D.A. Forsyth

# The thin lens




$$\frac{-y'}{y} = \frac{\| z' \|}{\| z \|}$$

# The thin lens

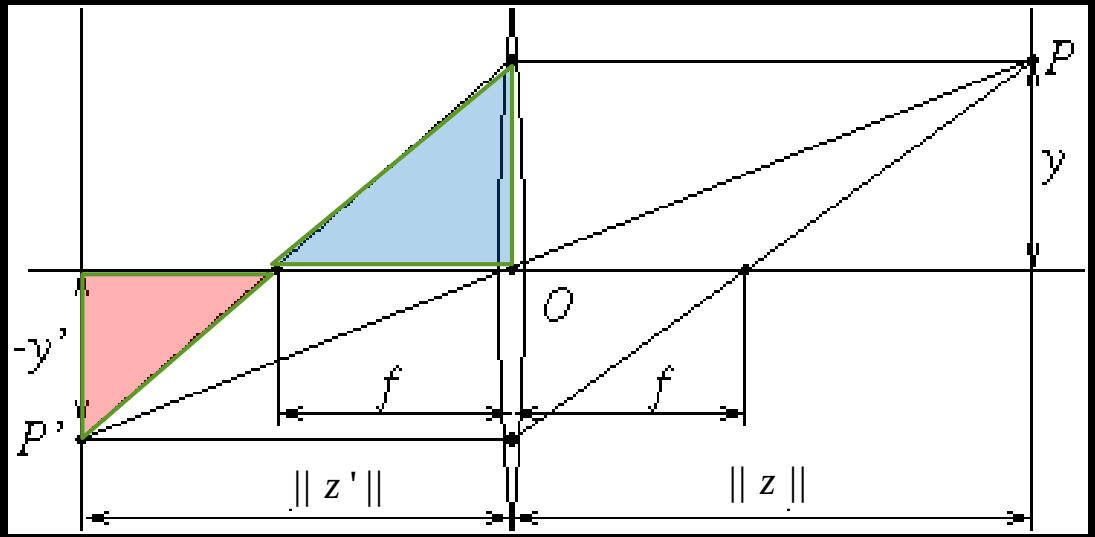



$$\frac{-y'}{y} = \frac{\| z' \|}{\| z \|}$$

$$\frac{-y'}{y} = \frac{\| z' \| - f}{f}$$

$$\rightarrow \frac{\| z' \|}{\| z \|} = \frac{\| z' \| - f}{f}$$

# The thin lens equation

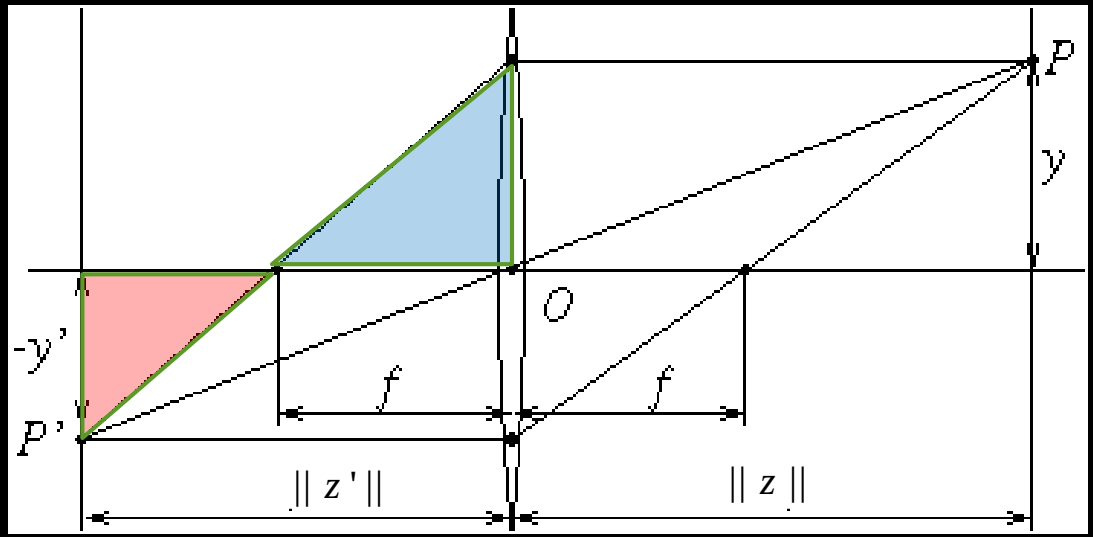



$$\frac{|| z' ||}{|| z ||} = \frac{|| z' || - f}{f}$$

$$\rightarrow \frac{1}{|| z ||} = \frac{1}{f} - \frac{1}{|| z' ||}$$

$$\rightarrow \frac{1}{|| z' ||} + \frac{1}{|| z ||} = \frac{1}{f}$$

# The thin lens equation




**Any object point satisfying this equation is in focus.**

$$\rightarrow \frac{1}{\| z' \|} + \frac{1}{\| z \|} = \frac{1}{f}$$

# Thin lenses

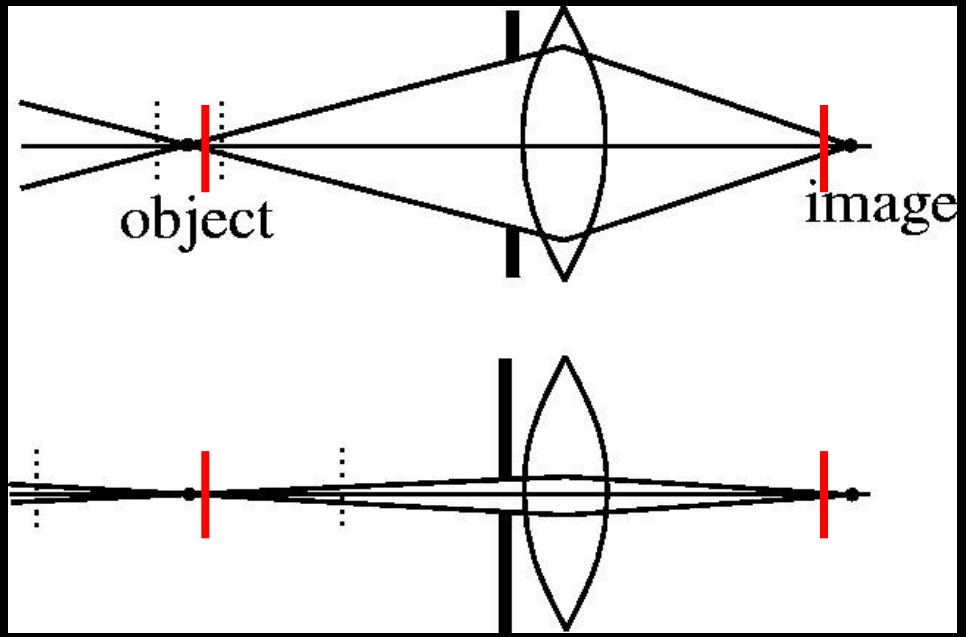
http://www.phy.ntnu.edu.tw/java/Lens/lens_e.html

(by Fu-Kwun Hwang )

# Varying Focus

Ren Ng

# Depth of field



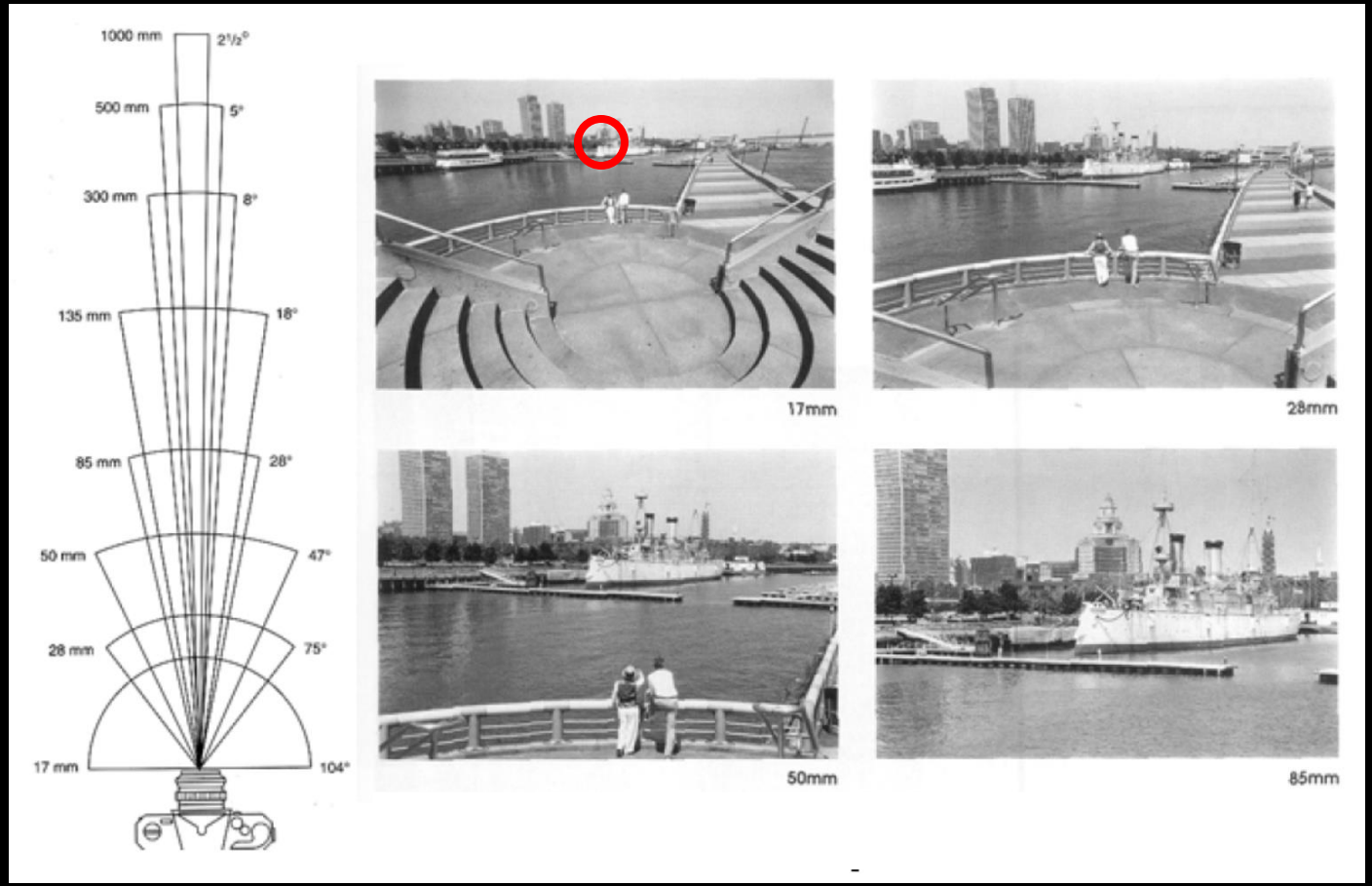

*f* / 5.6 = large aperture

*f* / 32 = small aperture

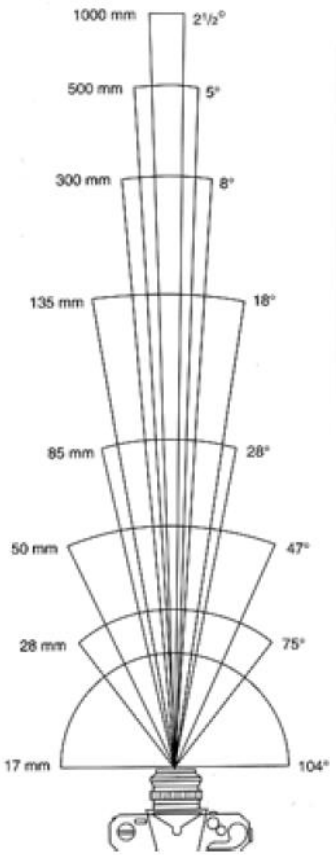
Flower images from Wikipedia http://en.wikipedia.org/wiki/Depth_of_field

# Nice Depth of Field effect

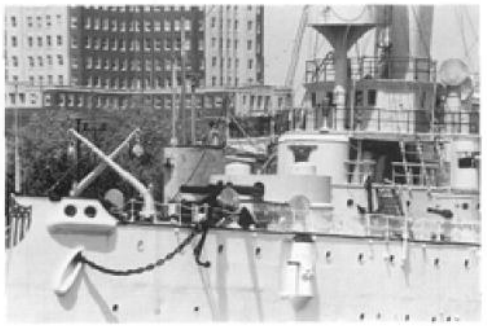
# Field of View (Zoom)



# Field of View (Zoom)




135mm

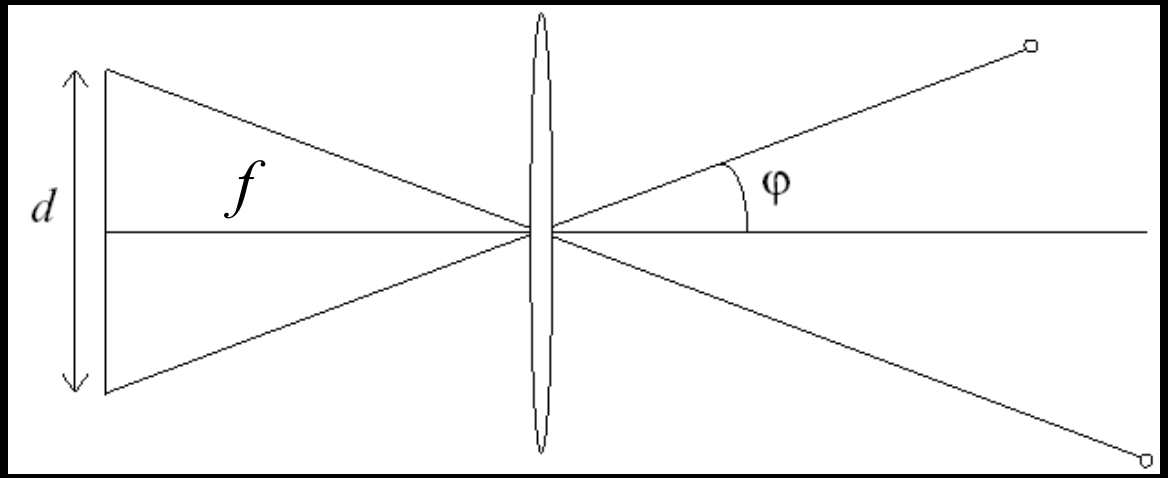


300mm

# FOV depends on Focal Length

*d* is the “retina” or sensor size

$$\phi = 2\tan^{-1}\left(\frac{d\ /\ 2}{f}\right)$$




Larger Focal Length => Smaller FOV

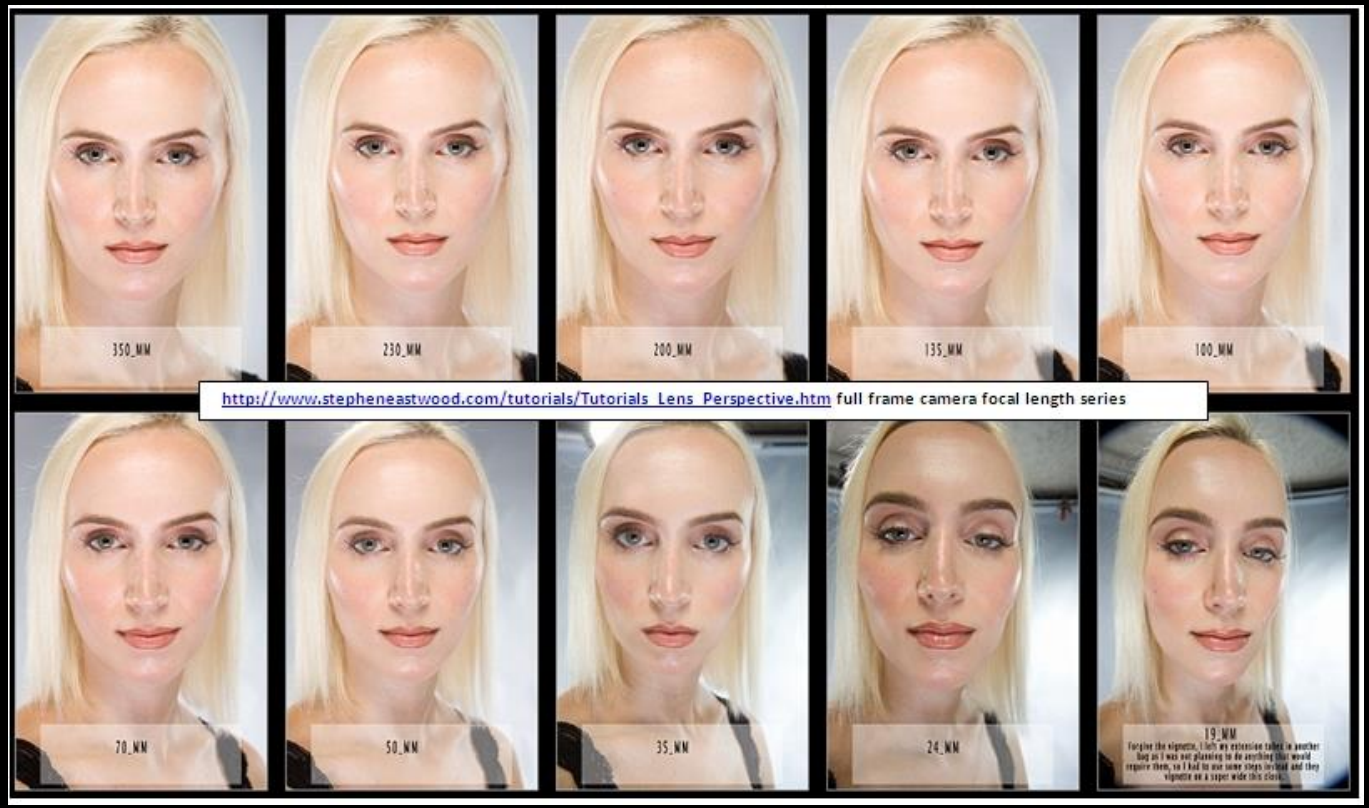
# Zooming and Moving are not the same…

# Field of View / Focal Length

Large FOV, small *f*
Camera close to car

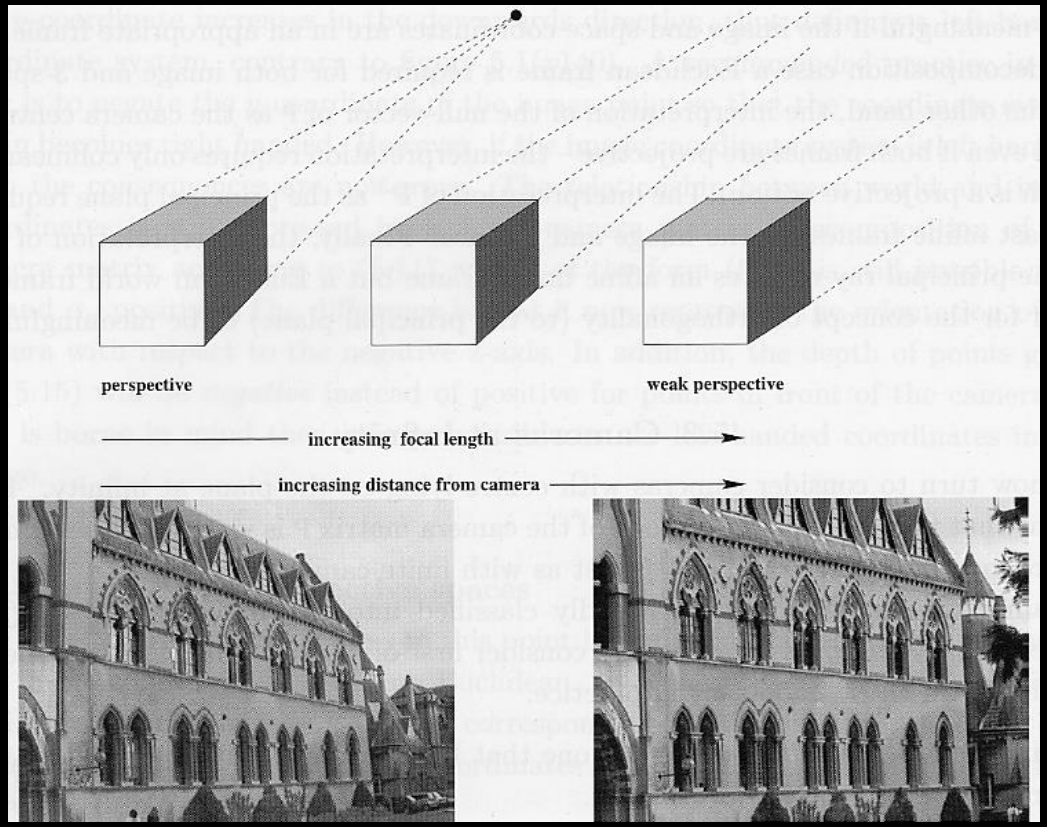
Small FOV, large *f*
Camera far from the car

# Perspective and Portraits



# Perspective and Portraits


# Effect of focal length on perspective effect




From Zisserman & Hartley

# Dolly Zoom

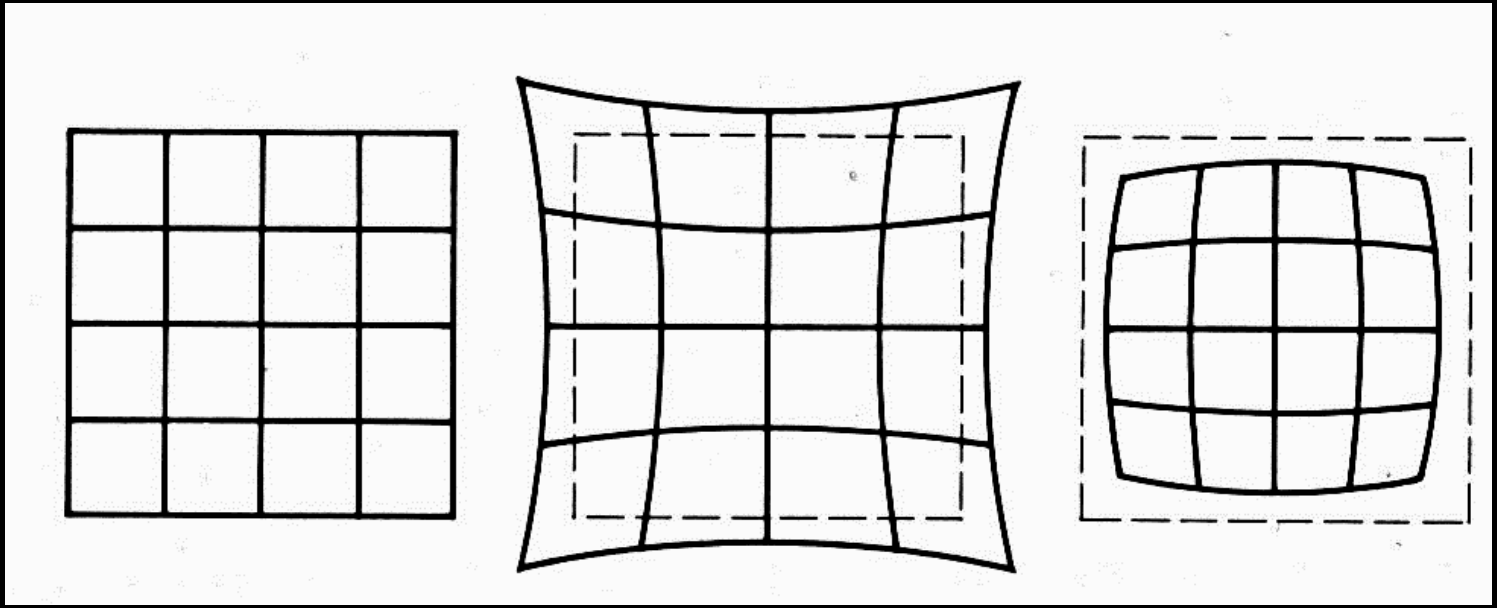
Pioneered by Hitchcock in *Vertigo* (1958)

Original(YouTube link) (2:07)  Widely used (YouTube link)

Jim Rehg

# But reality can be a problem…

# Geometric Distortion



No distortion

Pin cushion

Barrel

# Correcting radial distortion

from Helmut Dersch

# Chromatic Aberration

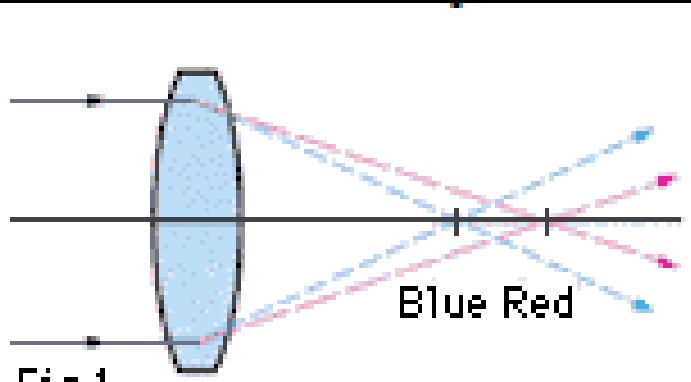



Fig.1
Axial chromatic aberration

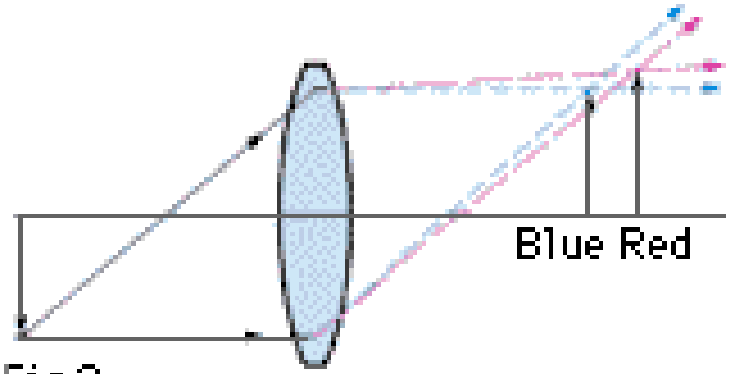
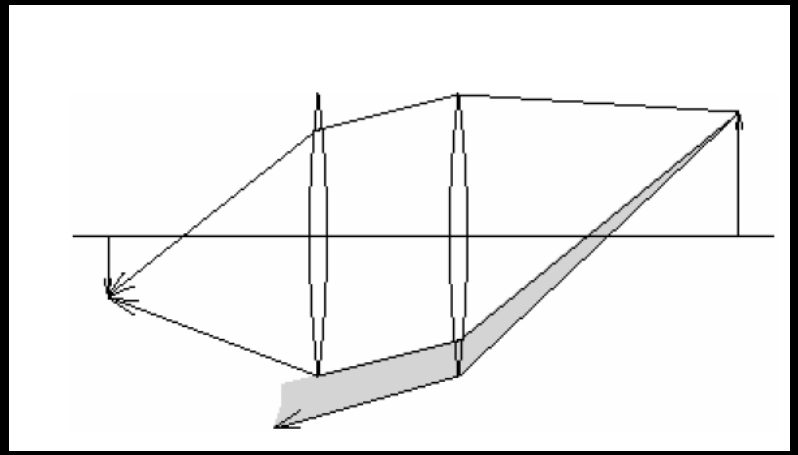



Fig.2
Magnification chromatic aberration

Rays of different wavelength
focus in different planes

# Chromatic Aberration

# Vignetting



# Lens systems

*Nikon 24-70mm zoom*