

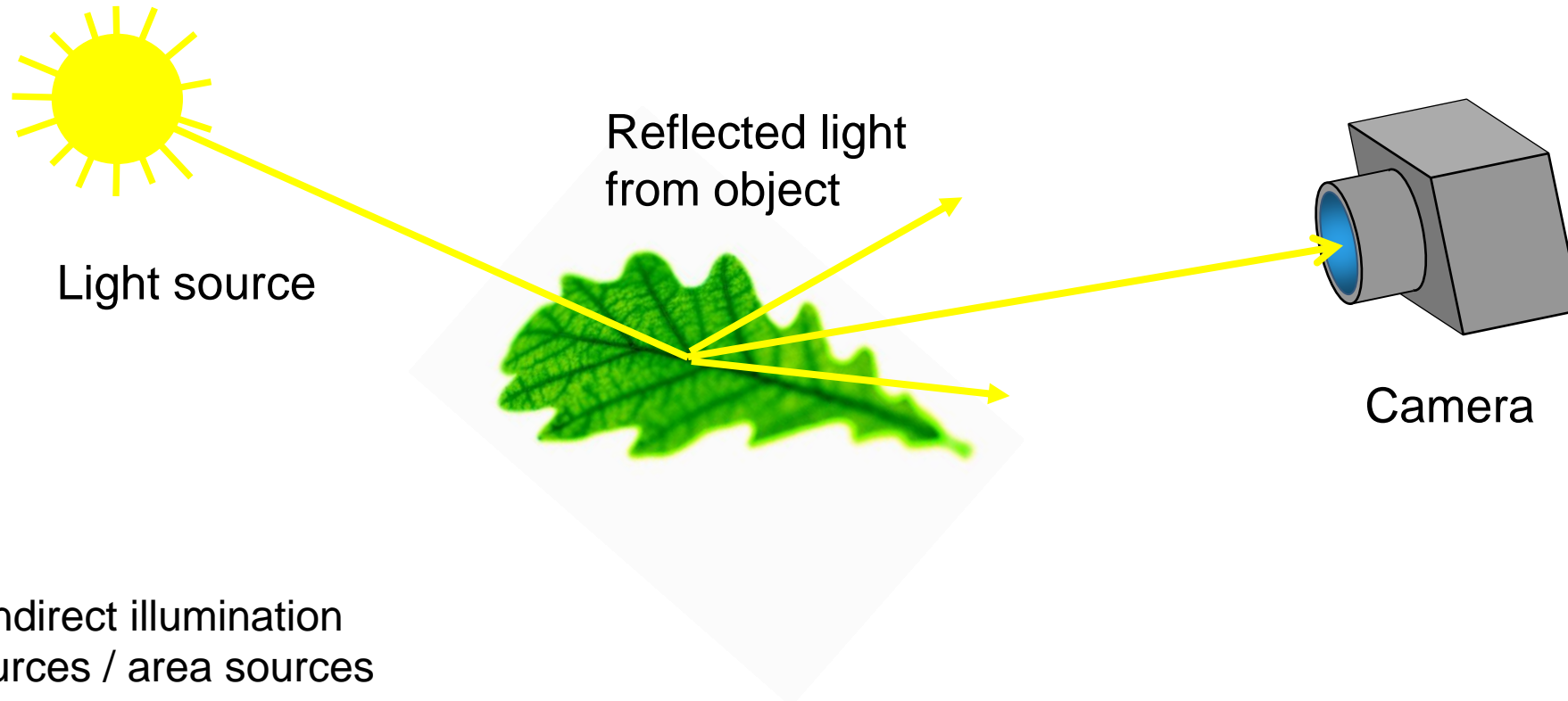
Lecture 1.1

Light, camera, optics and colour

Idar Dyrdal

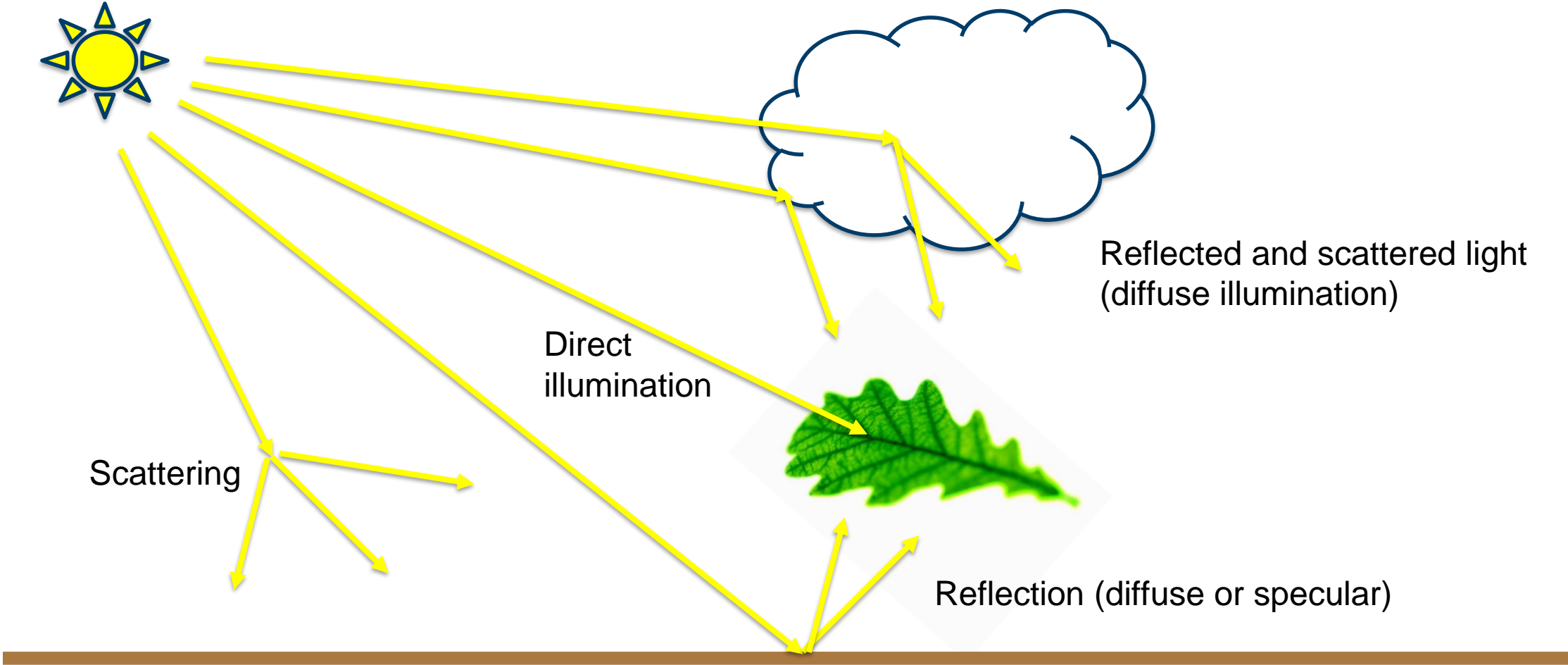


Imaging with visible light

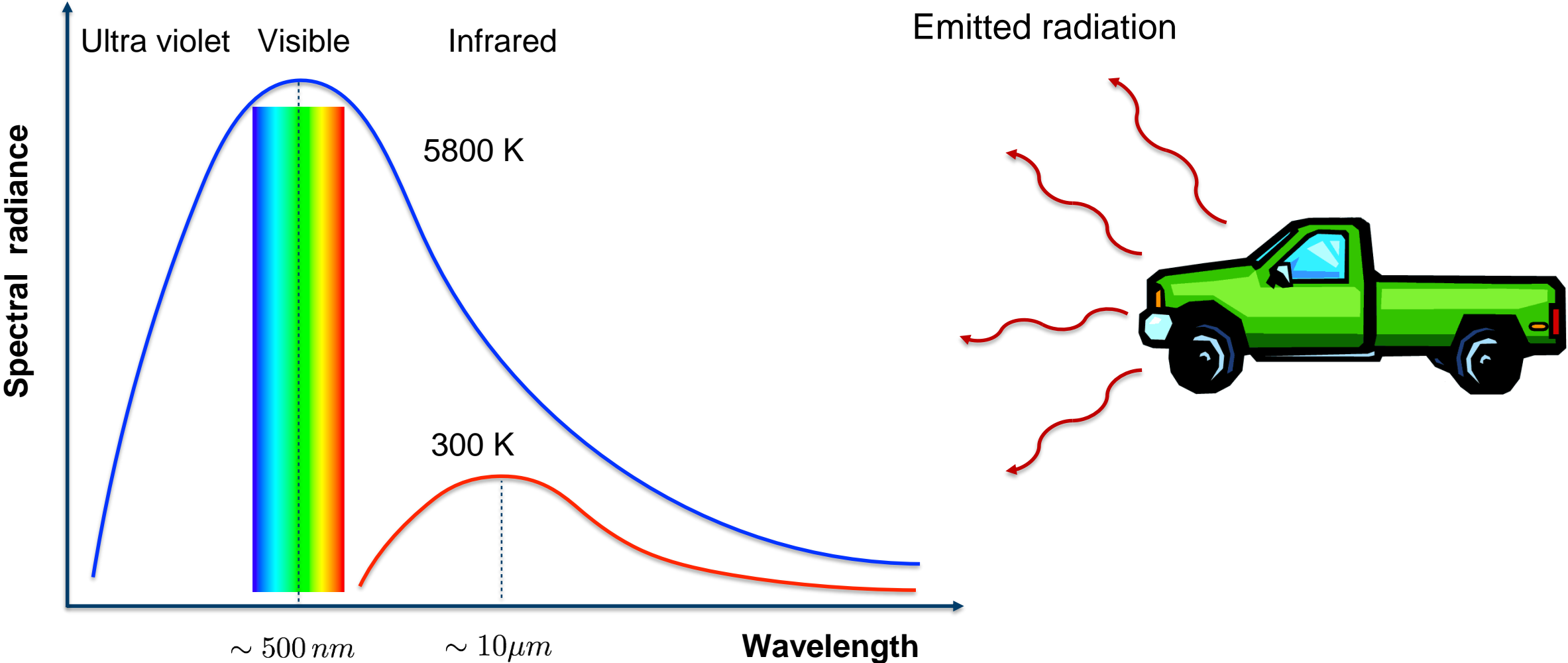


- Direct / indirect illumination
- Point sources / area sources
- Natural / artificial illumination

Direct and indirect illumination



Thermal radiation - Planck distribution

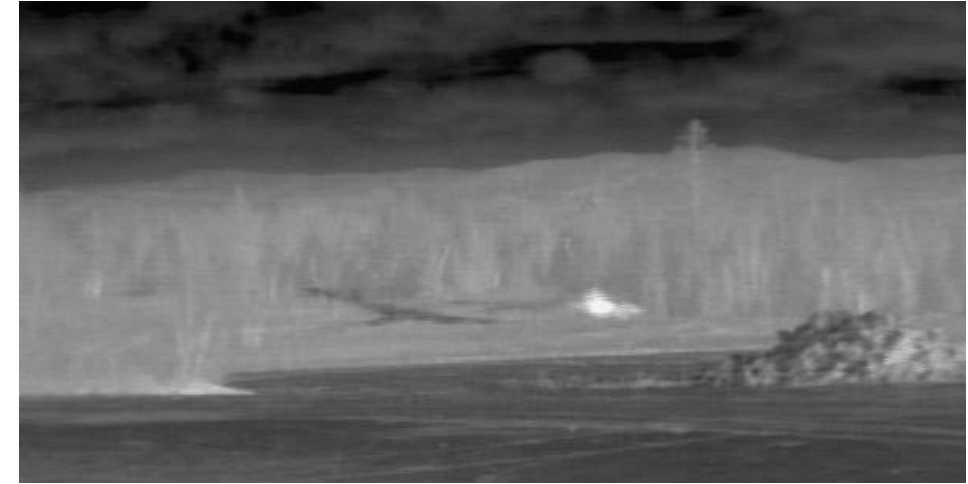


Reflected and emitted radiation



Image in visible light:

- Imaging with **reflected** (and scattered) radiation from the sun or other natural or artificial sources.



Infrared (thermal) image:

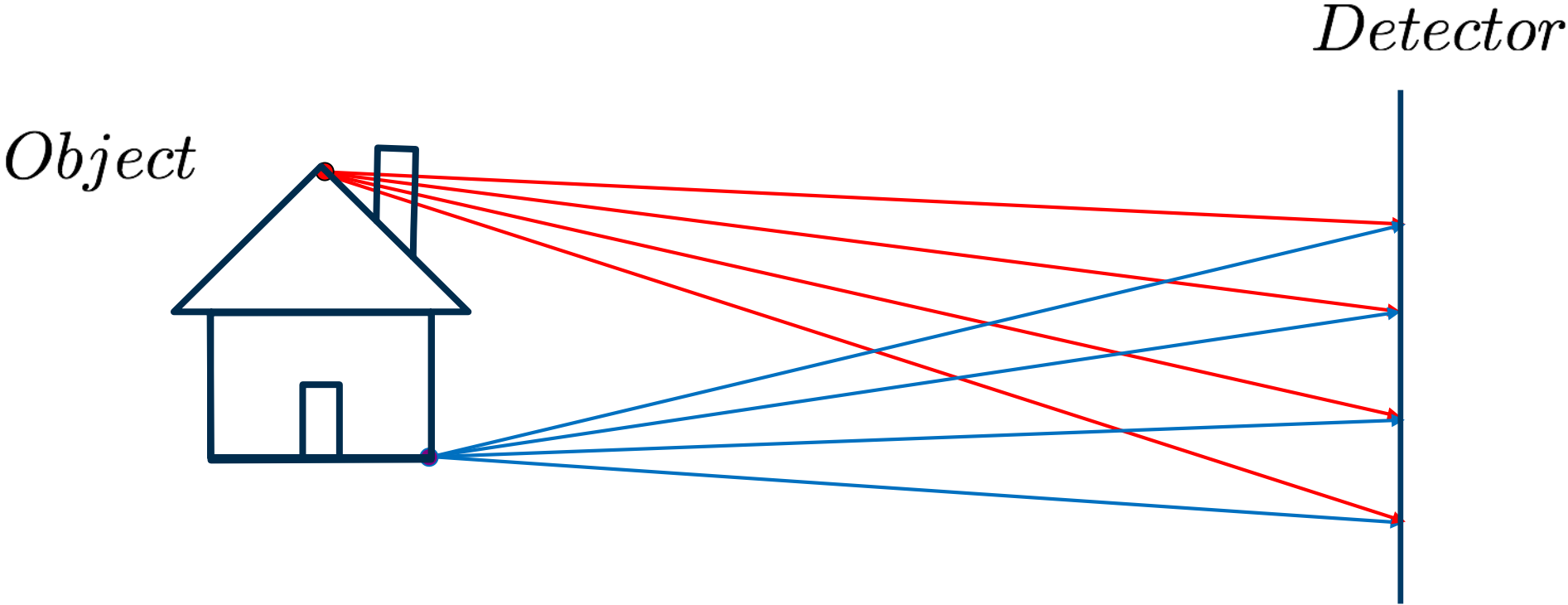
- Imaging with (mainly) the **emitted** thermal radiation from the scene.

Other frequency domains and wave types used for imaging:

- Millimeter waves, x-rays, ... (electromagnetic waves)
- Acoustic (sonar), seismic, ... (mechanical waves)

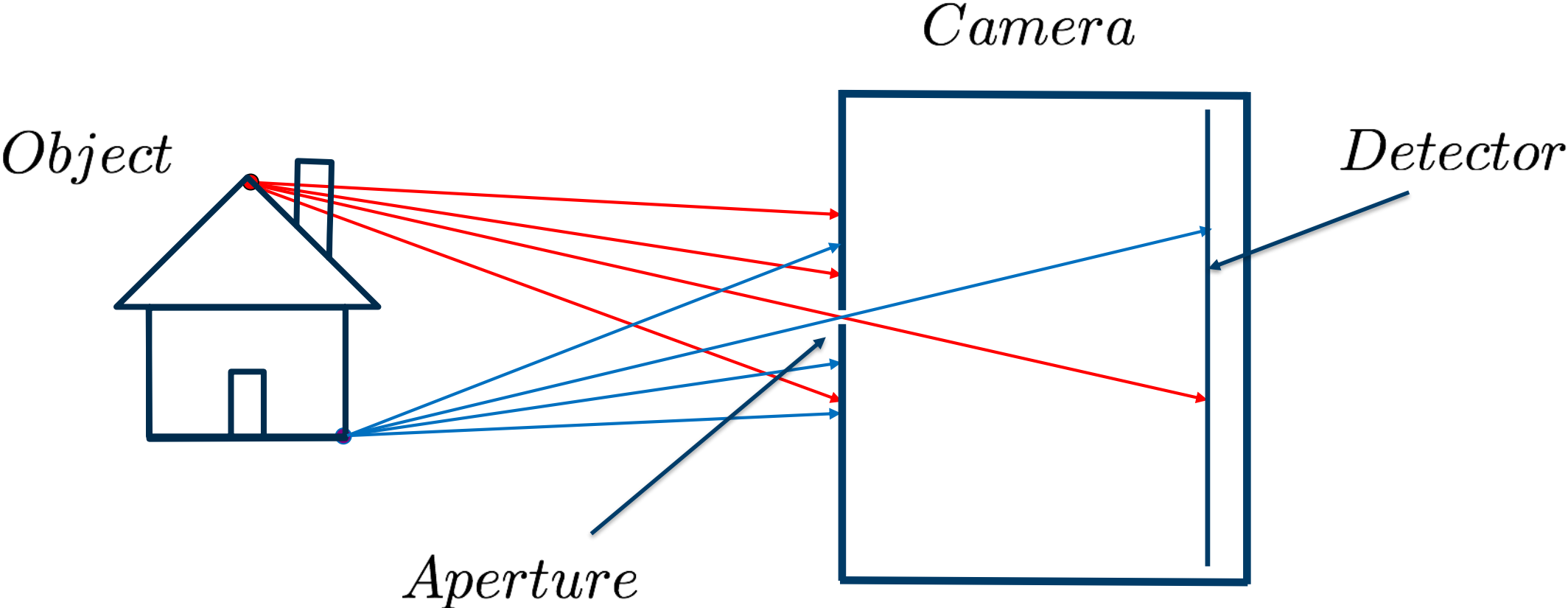


Image formation

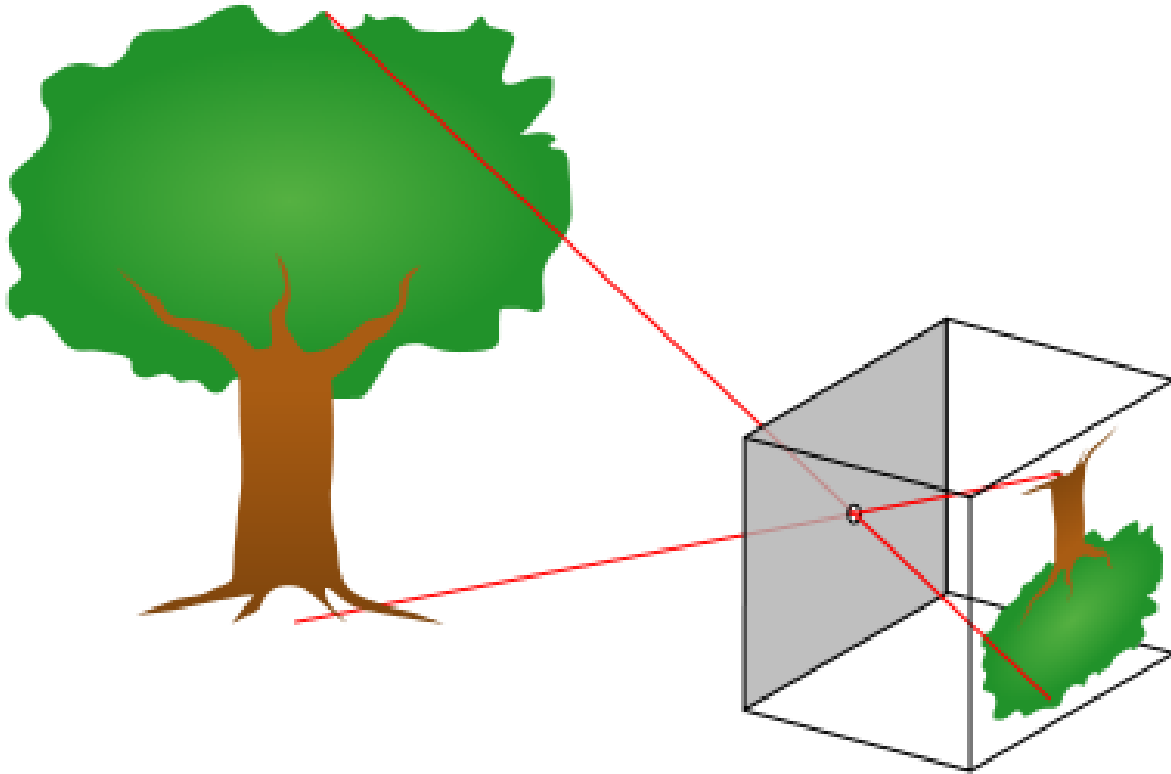


No image is formed!

Simple camera - Pinhole camera



Pinhole camera



Small aperture



Dark image

Large aperture

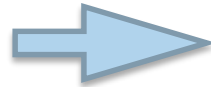
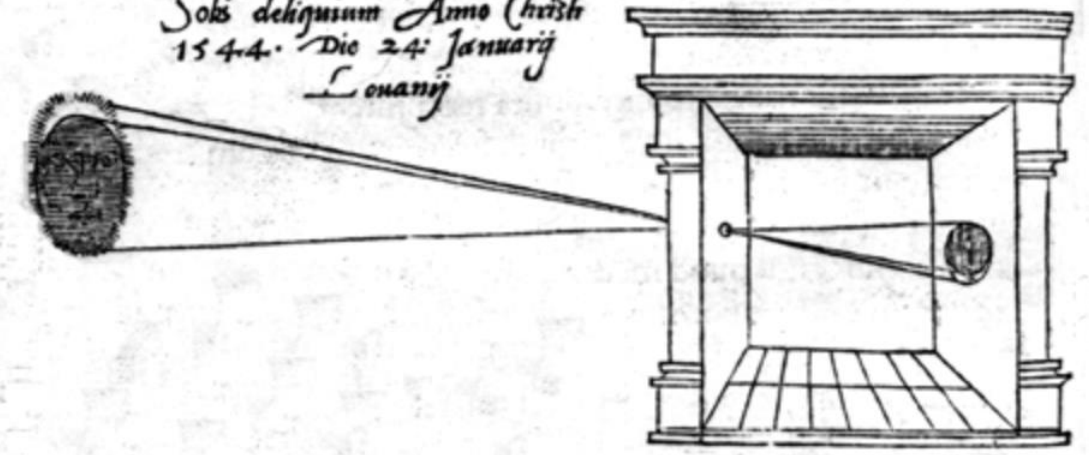


Image out of focus

Camera obscura

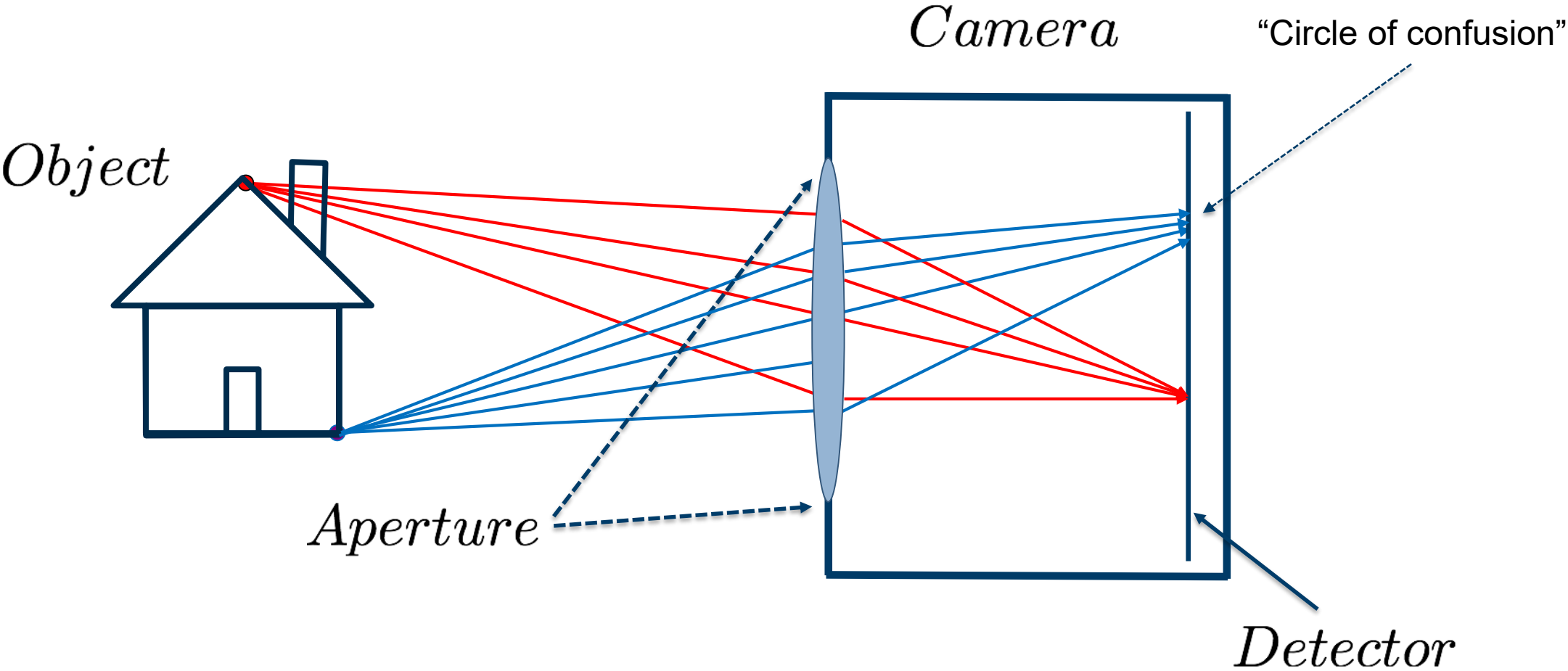
illum in tabula per radios Solis, quam in caelo contingit: hoc est, si in caelo superior pars deliquiū patiatur, in radiis apparebit inferior deficere, vt ratio exigit optica.

*Solis deliquium Anno Christi
1544. Die 24. Ianuarij
Louanij*

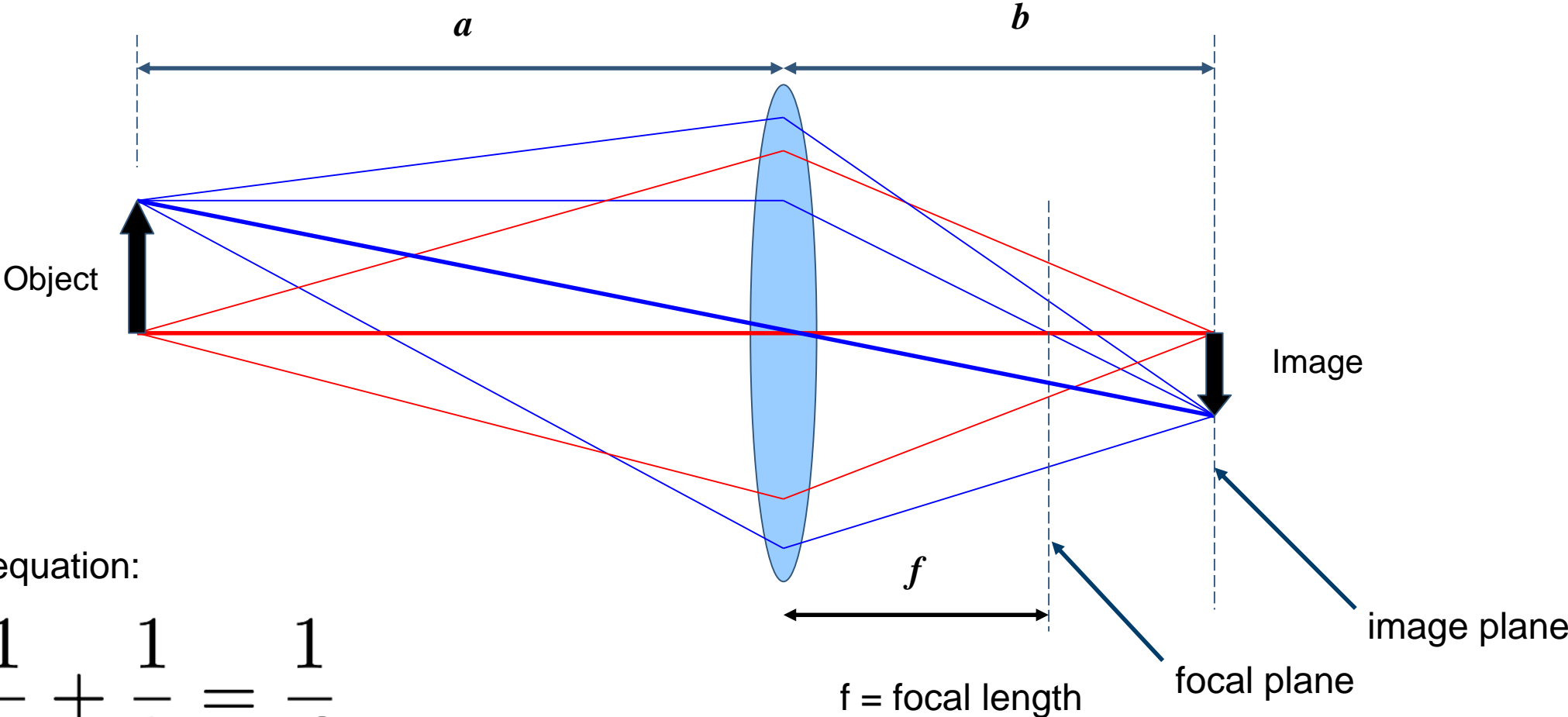


Sic nos exactè Anno .1544. Louanii eclipsim Solis obseruauimus, inuenimusq; deficere paulò plus q̄ dex-

Camera with a lens



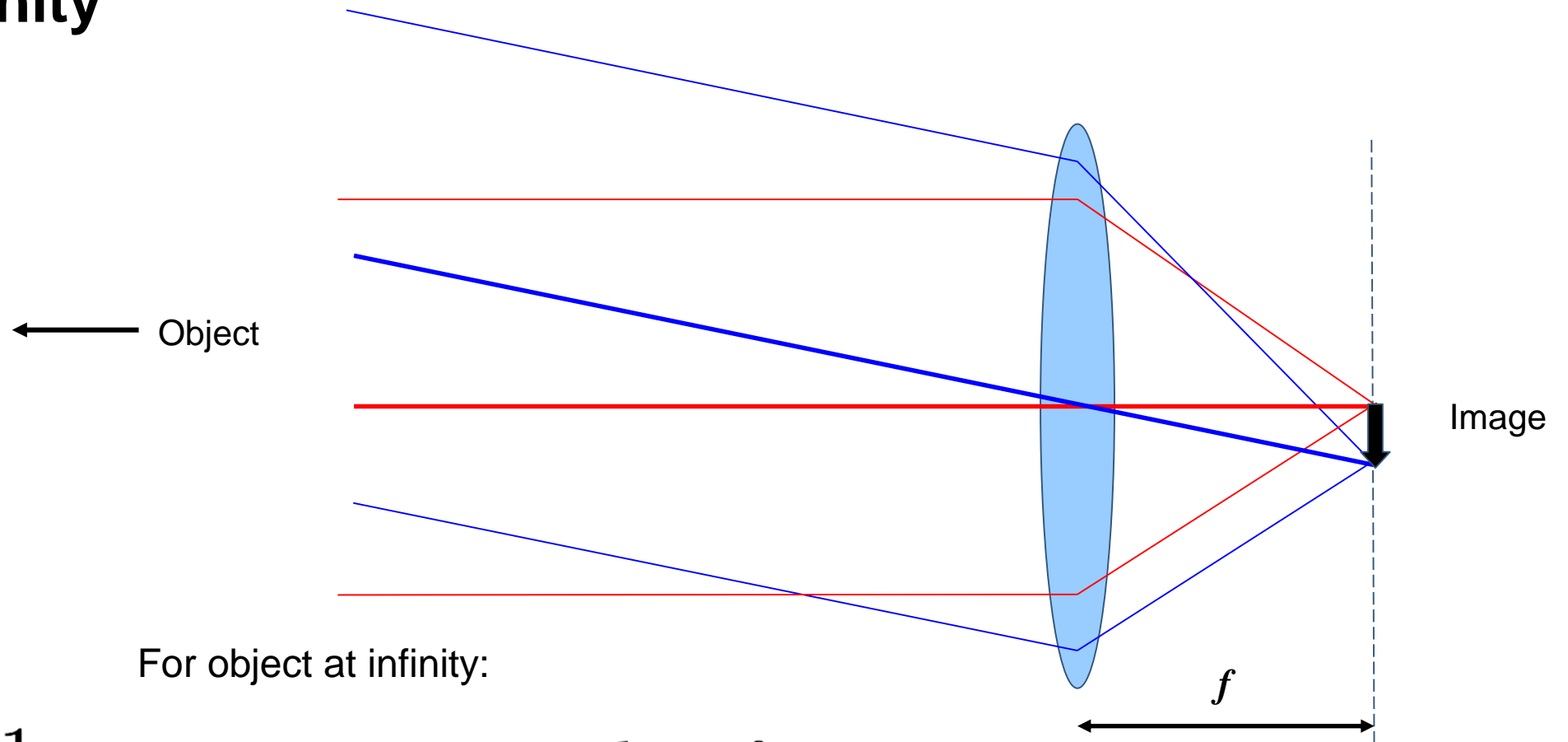
Imaging with a lens



Lens equation:

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

Object at infinity



Lens equation:

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

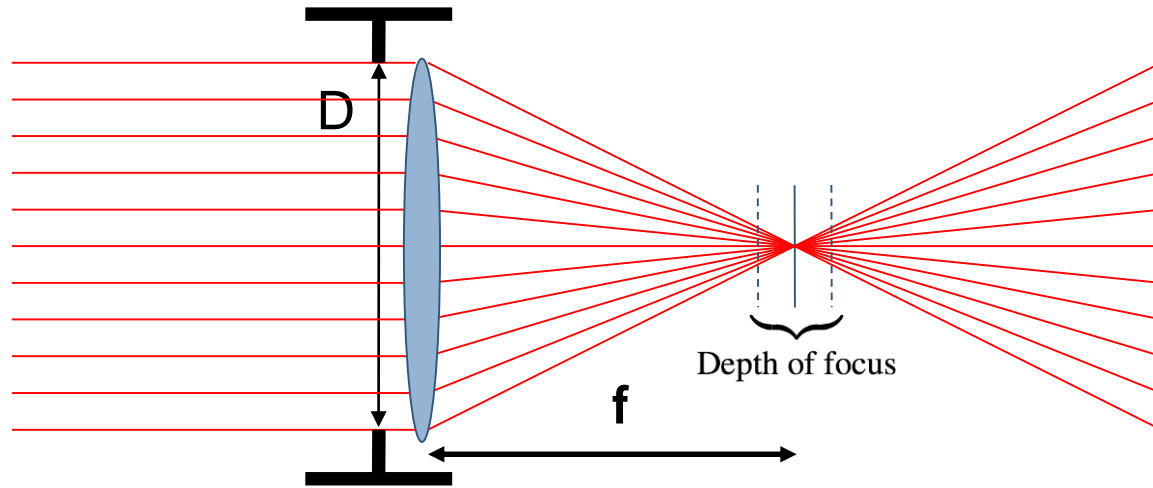
For object at infinity:

$$a = \infty \Rightarrow b = f$$

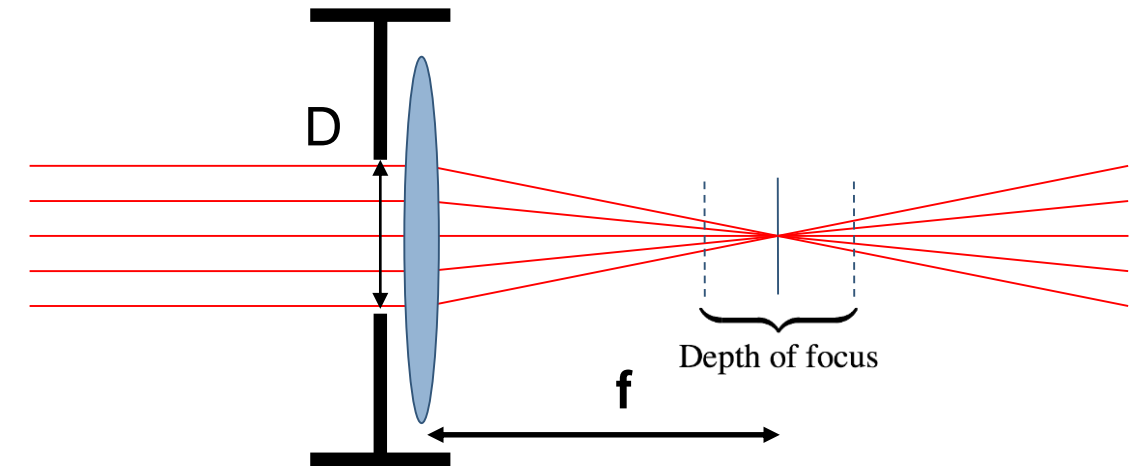
i.e. image is formed in focal plane.

Depth of focus

Large aperture

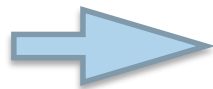


Small aperture



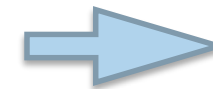
F-number: f/D (examples: $f/2.8$, $f/4$, $f/5.6$, $f/8$, $f/11$, $f/22$)

Small f-number



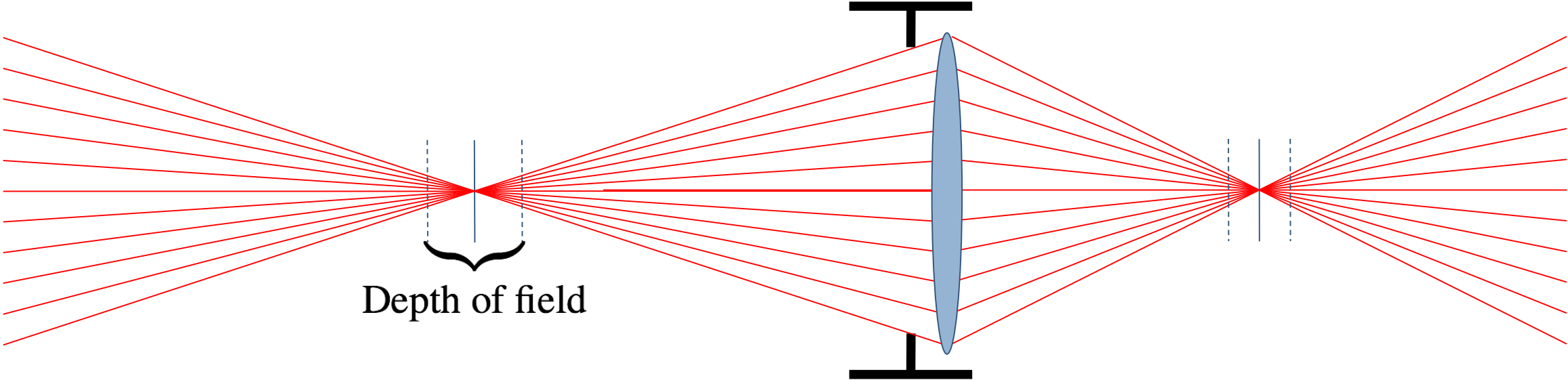
Narrow depth of focus

Large f-number



Large depth of focus

Depth of field – large aperture



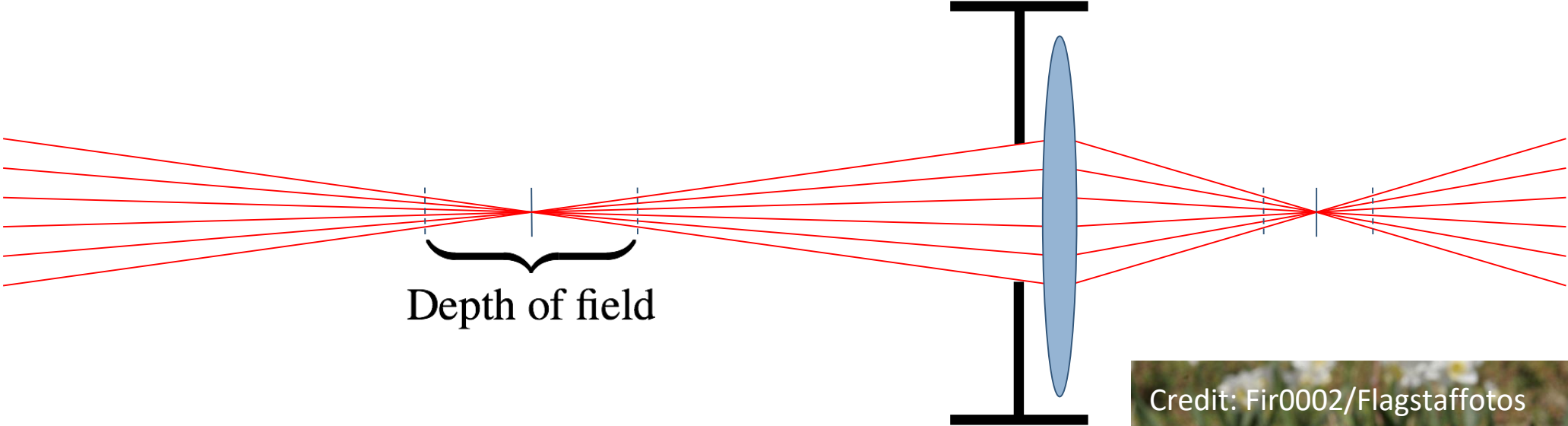
Large aperture



Narrow depth of field



Depth of field – small aperture



Small aperture



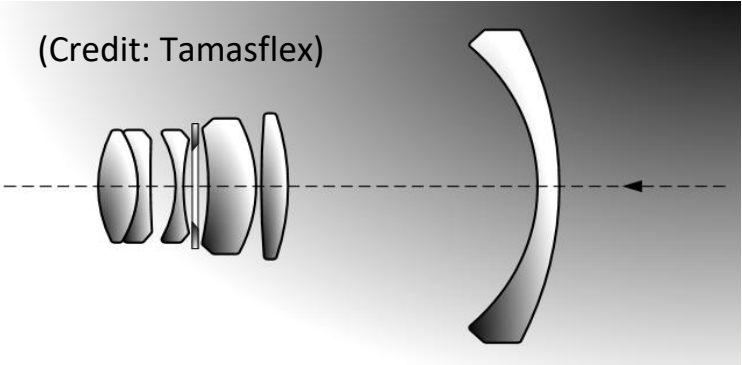
Large depth of field



Too small aperture will lead to *diffraction* and loss of sharpness

Practical lenses

(Credit: Tamasflex)

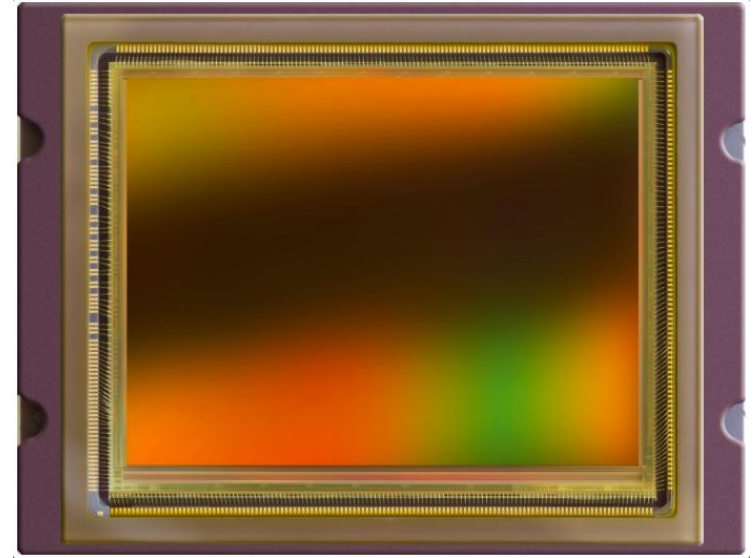
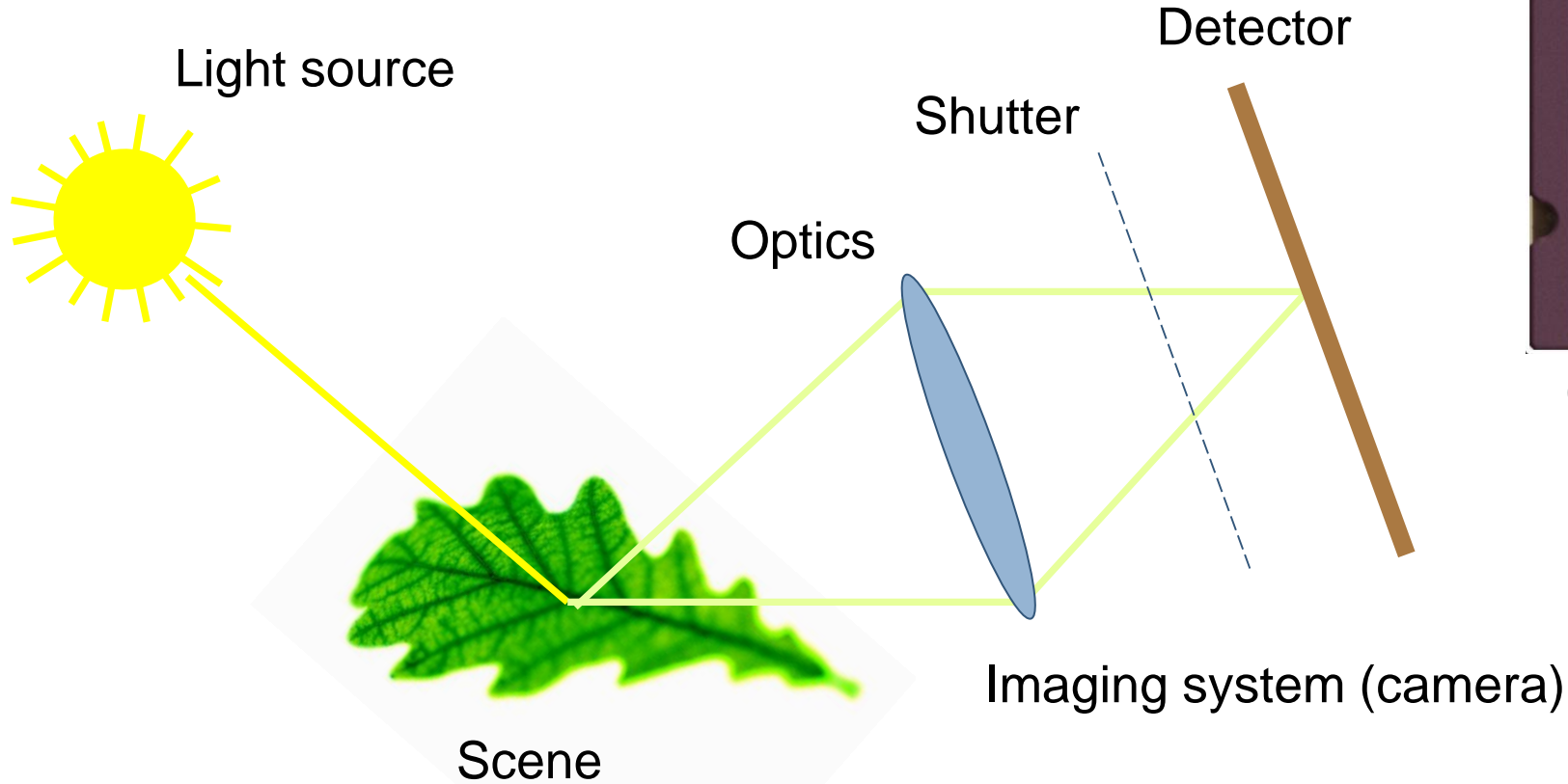


Fixed focal length lens



Zoom lens (variable focal length)

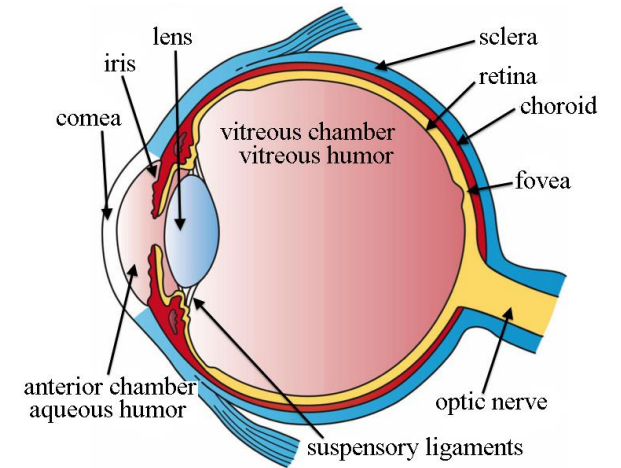
Image capture



CMOS image sensor (CMOSIS 48Mp)

Shutter:

- Mechanical / electronic
- Global / rolling



(Artwork by Holly Fischer)

Digital image



$j \rightarrow$

$i \downarrow$

255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255
255	255	255	0	0	255	255	255	255	255
255	255	255	0	0	85	255	255	255	255
255	255	0	85	85	0	255	255	255	255
255	255	0	85	85	170	170	255	255	255
255	85	85	0	170	170	85	85	255	255
255	255	170	170	85	85	85	255	255	255
255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255

$image(i, j)$

Colour images

Red



Green

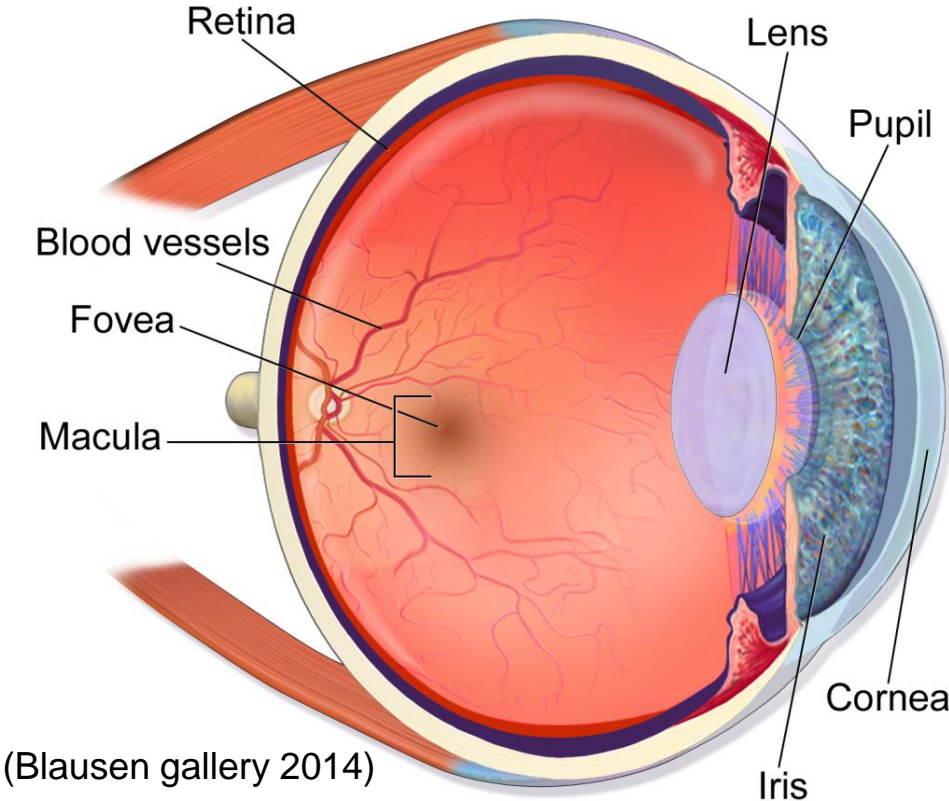


Blue



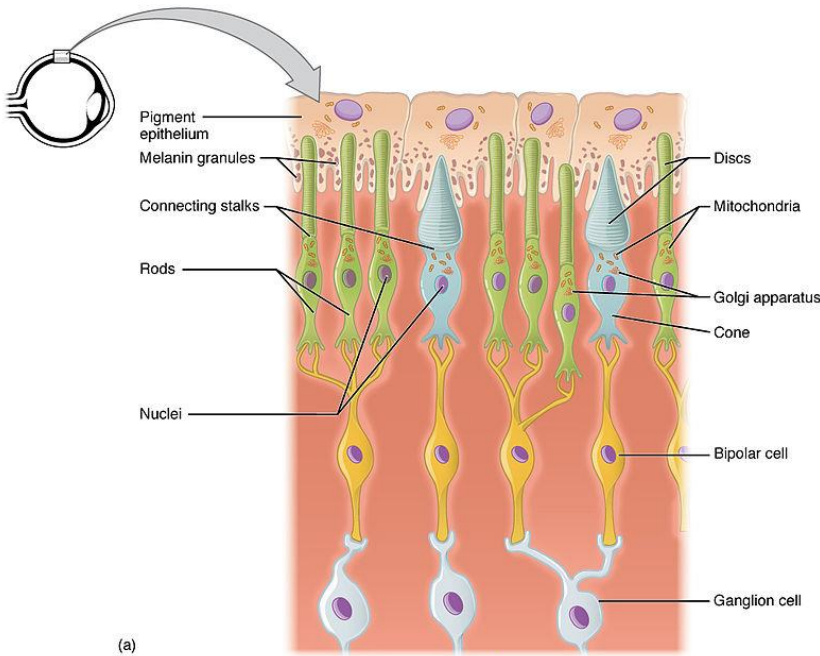
RGB colour image

Human Vision



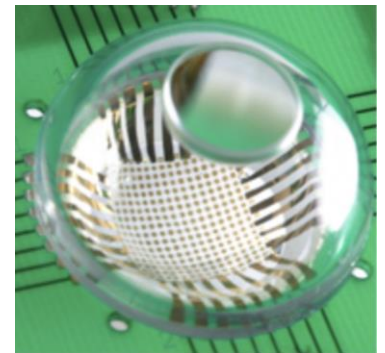
(Blausen gallery 2014)

Eye Anatomy

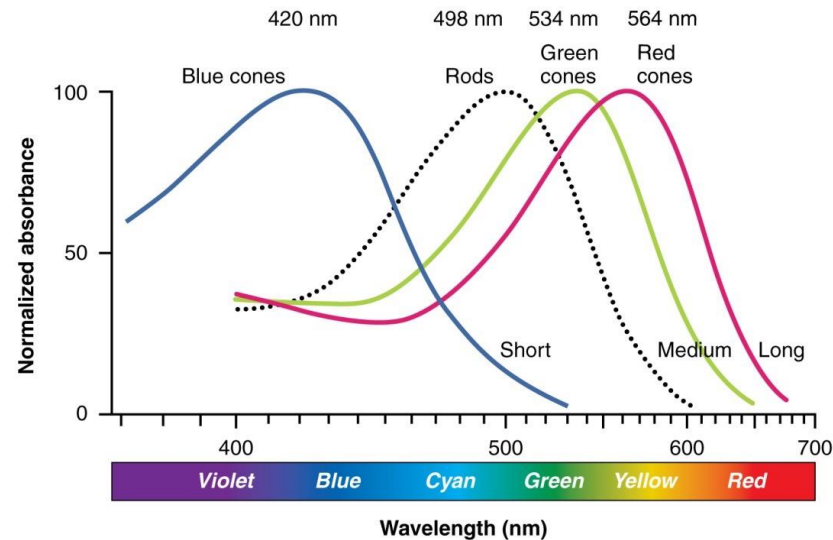


(a)

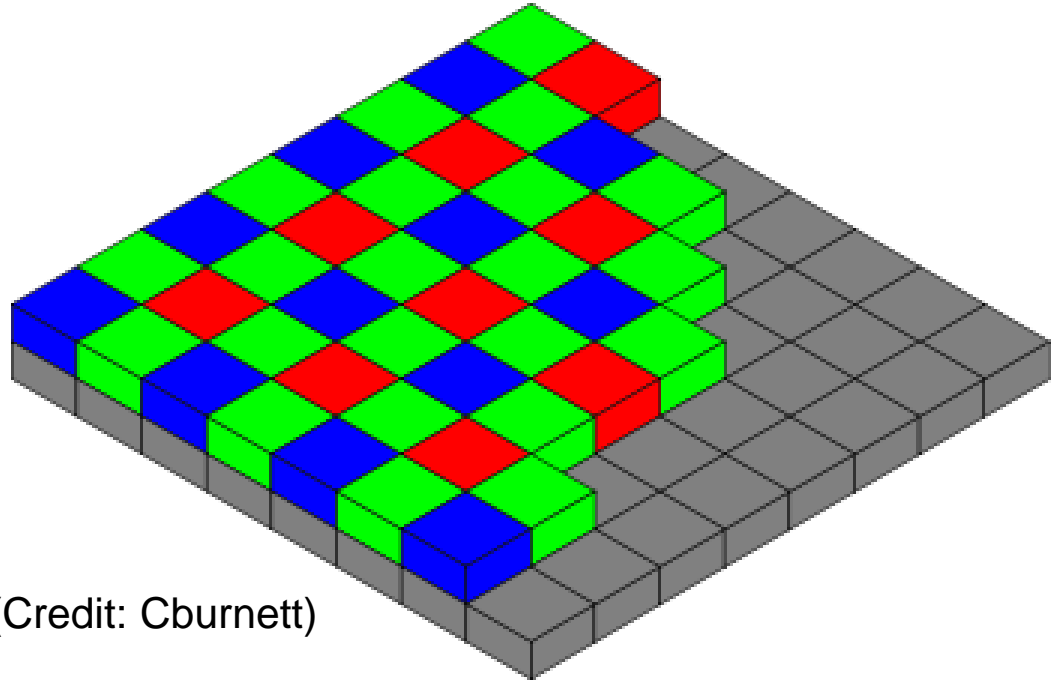
(OpenStax College - Anatomy & Physiology)



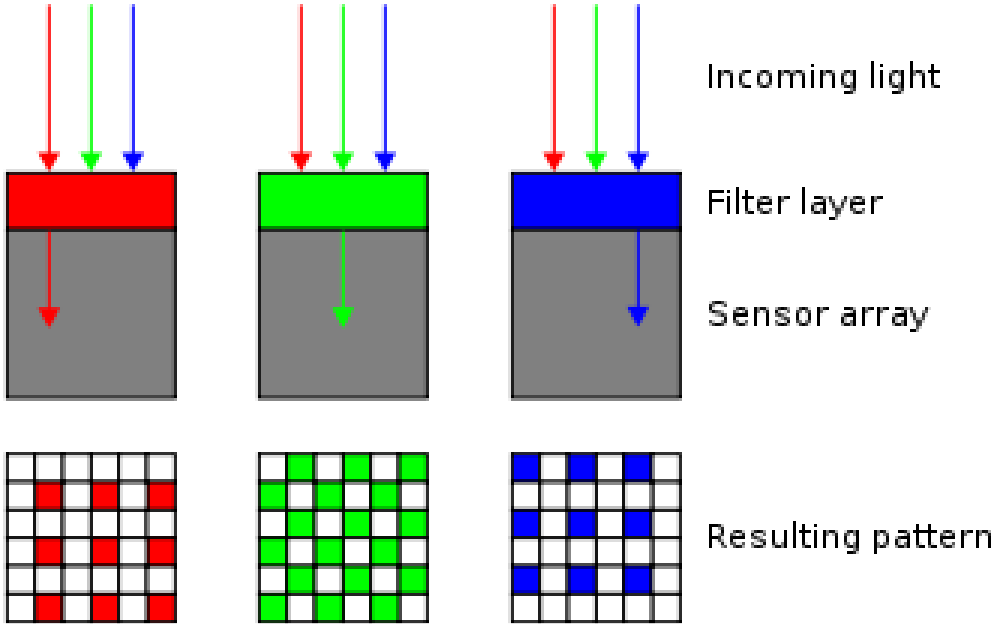
(MIT Technology Review 2008)



Colour Sensing in digital cameras - Bayer filter



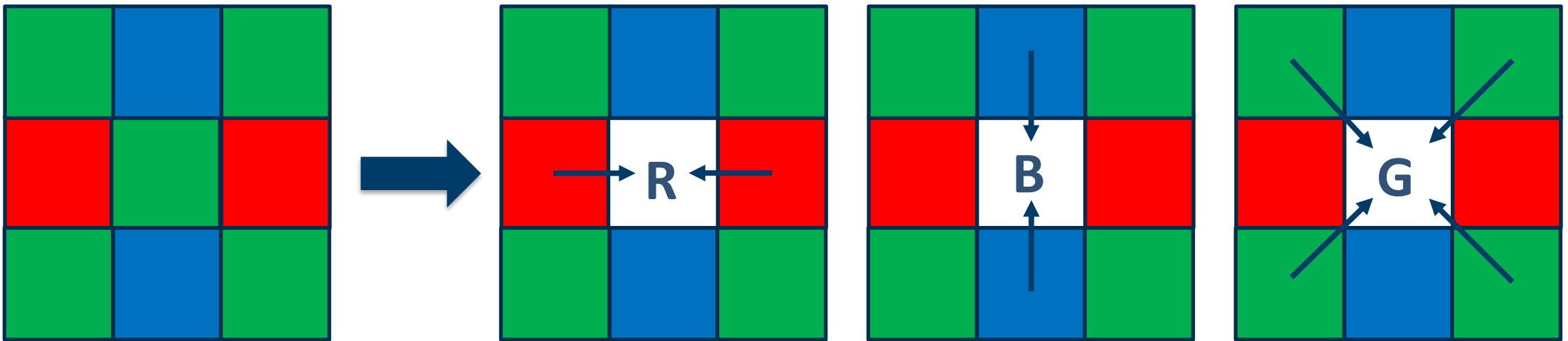
(Credit: Cburnett)



Undersampled (incomplete) colour information

Demosaicing (debayering)

Reconstruction of full colour image from incomplete colour information from the image sensor.



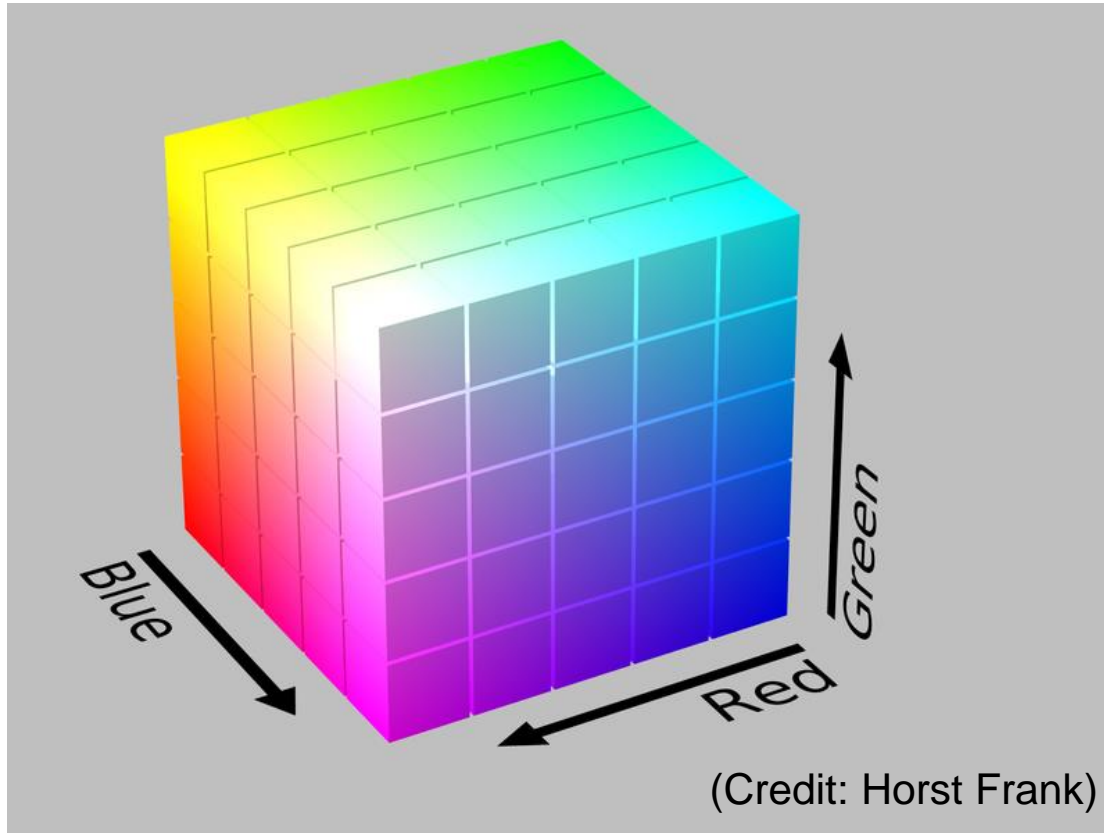
Algorithms:

- Nearest-neighbor interpolation
- Bilinear interpolation
- Bicubic interpolation

Other methods:

- Splines
- Lanczos resampling
- Methods utilizing pixel values

RGB colour space



Normalized RGB values:

$$r = \frac{R}{R + G + B}$$

$$g = \frac{G}{R + G + B}$$

$$b = \frac{B}{R + G + B}$$

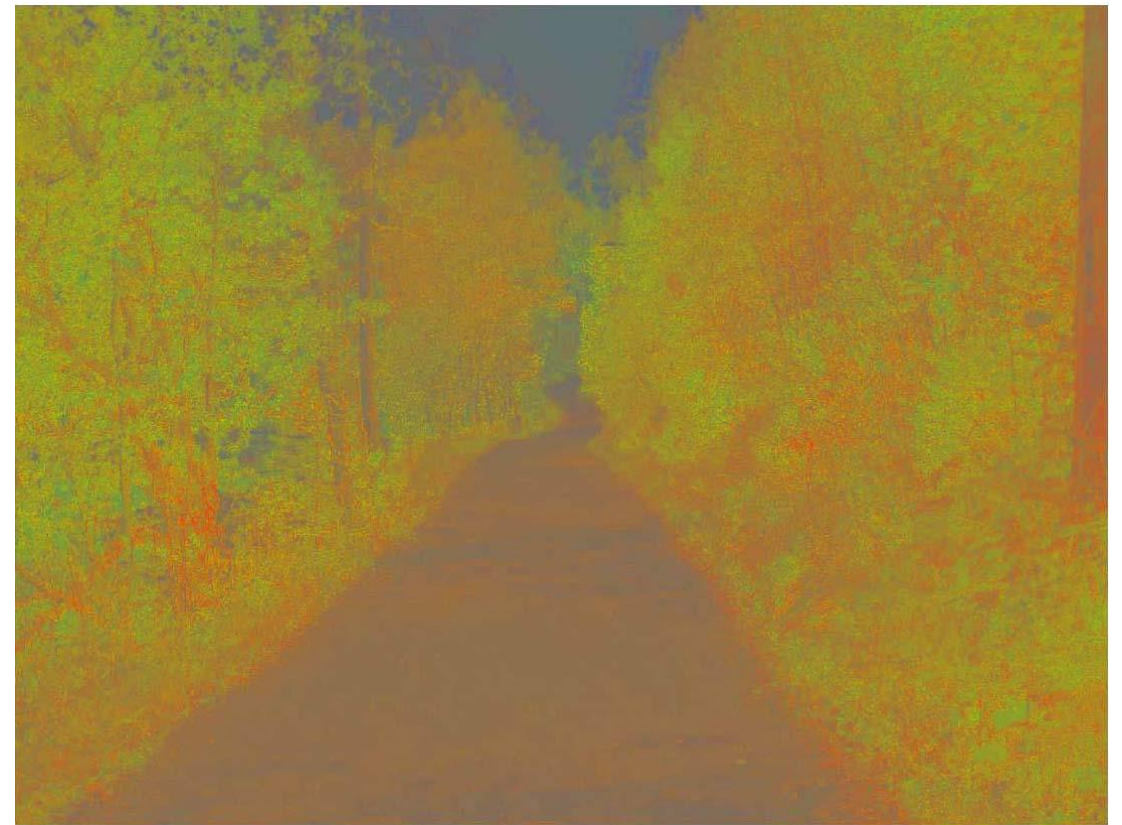
(Illumination invariance)

Colour coordinate systems: $RGB \Rightarrow XYZ \Rightarrow LAB$

RGB normalization (example)

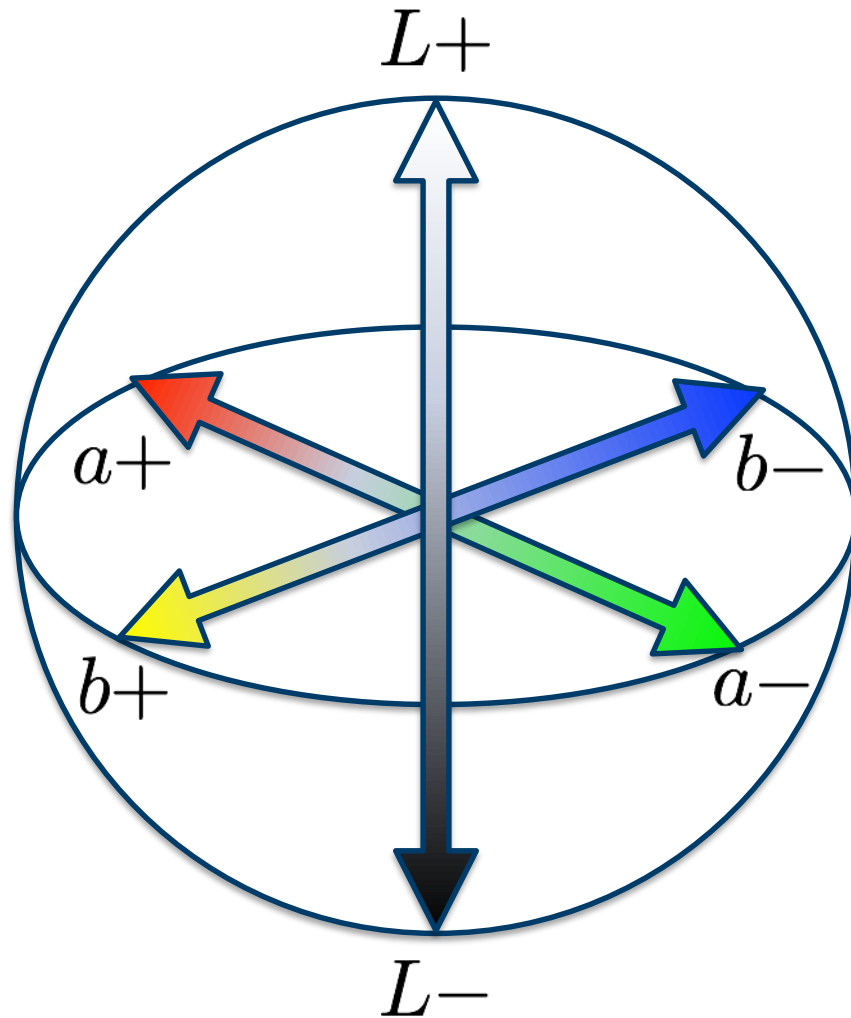


RGB original



Normalized RGB

Lab colour space (CIE 1976 L^* a^* b^*)



“Perceptually uniform” colour space:

- Approximation to human vision
- L^* = Lightness
- a^* , b^* = Colour opponent dimensions

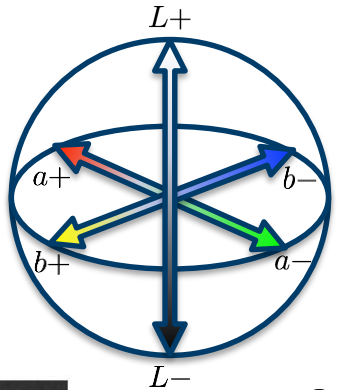
- L^* = darkest black to brightest white (0 - 100)
- a^* = green to red (-100 to +100)
- b^* = blue to yellow (-100 to +100)

Lab - example

L



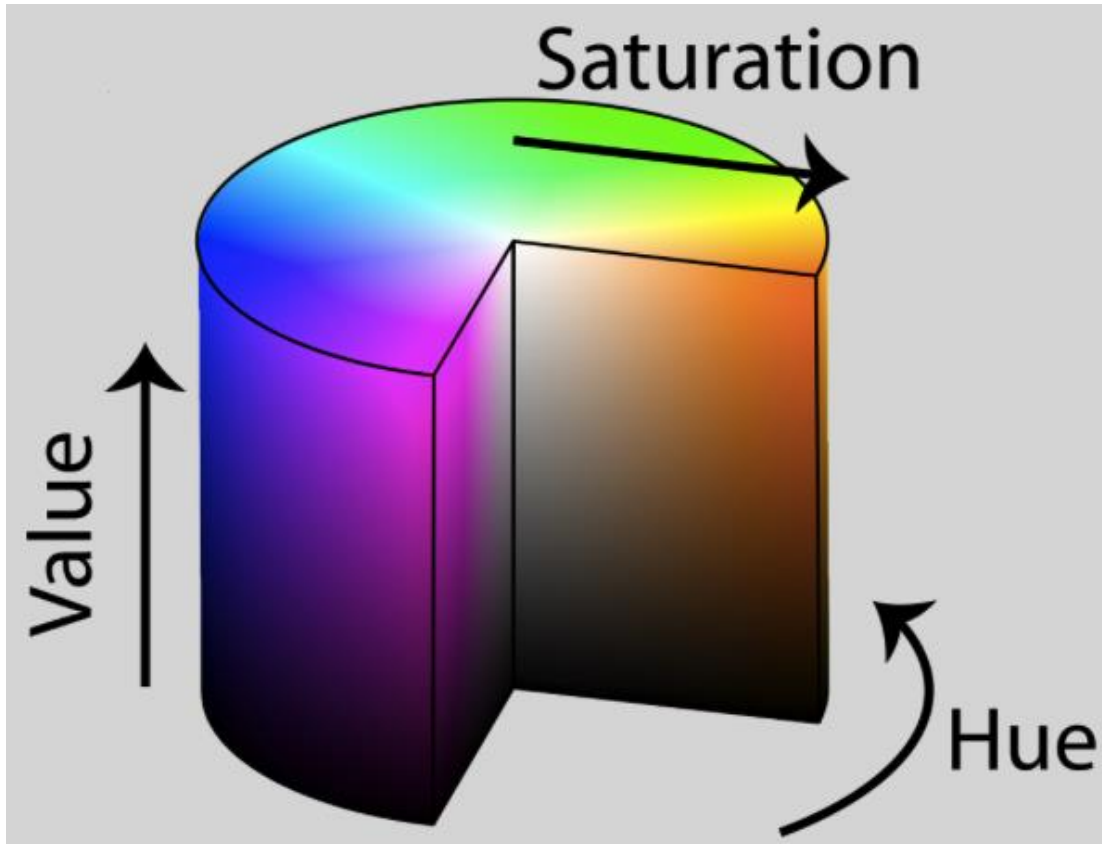
a



b



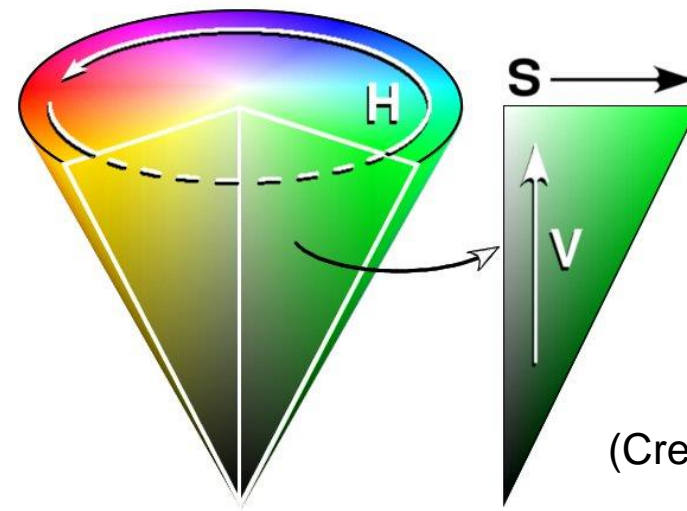
HSV colour space (Hue, Saturation, Value)



(Credit: Jacob Rus, 2010)

Intuitive colour space:

- Cylindrical representation of RGB values
- Hue = angle from 0° to 360°
- Saturation = 0 - 100% (gray to primary colour)
- Value = 0 - 100% (totally black to bright colours)

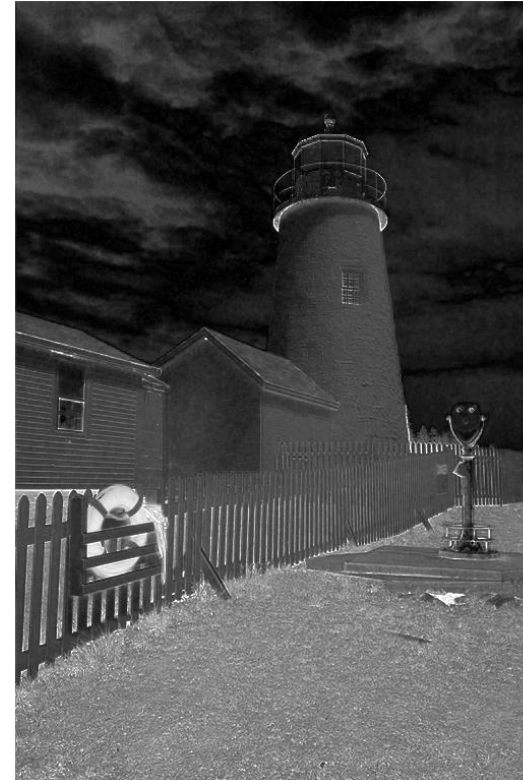


(Credit: Wapcaplet)

HSV - example



Hue



Saturation

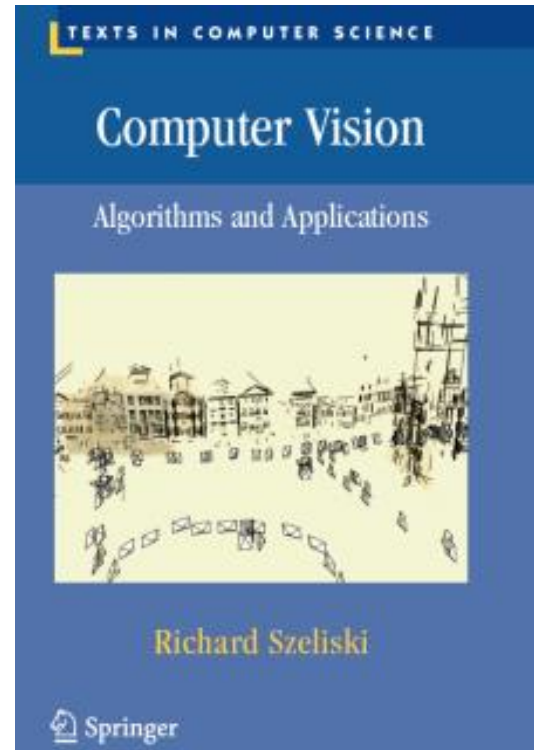


Value

Summary

Image formation:

- Illumination
- Cameras
- Optics
- Image Capture
- Colour Sensing.



More information: Szeliski 2.2 and 2.3

Free download:

http://szeliski.org/Book/drafts/SzeliskiBook_20100903_draft.pdf

