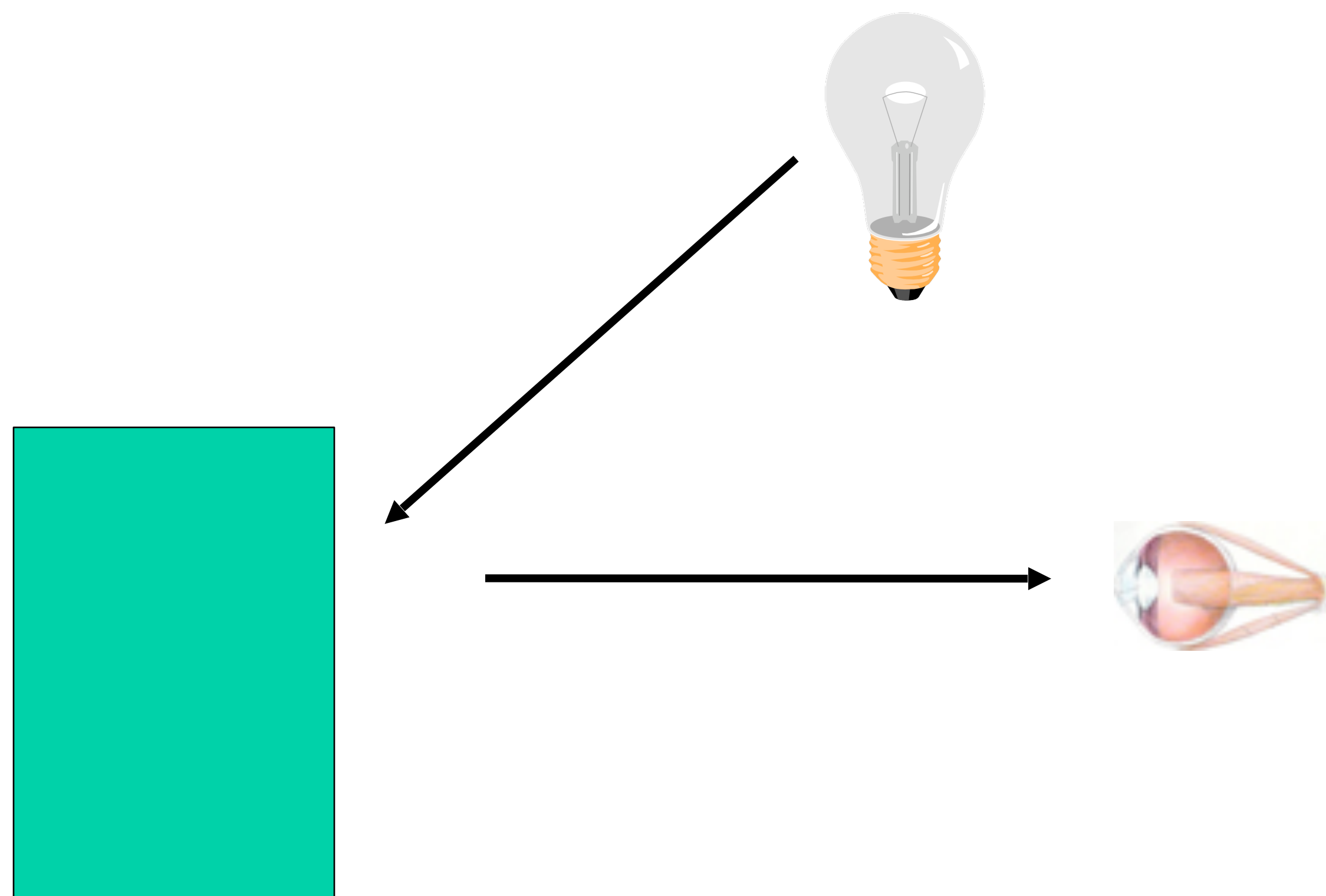


**Del perché la visione dei colori è spaziale e del perché non possiamo misurare colore e spettro con una macchina che usi un obiettivo**

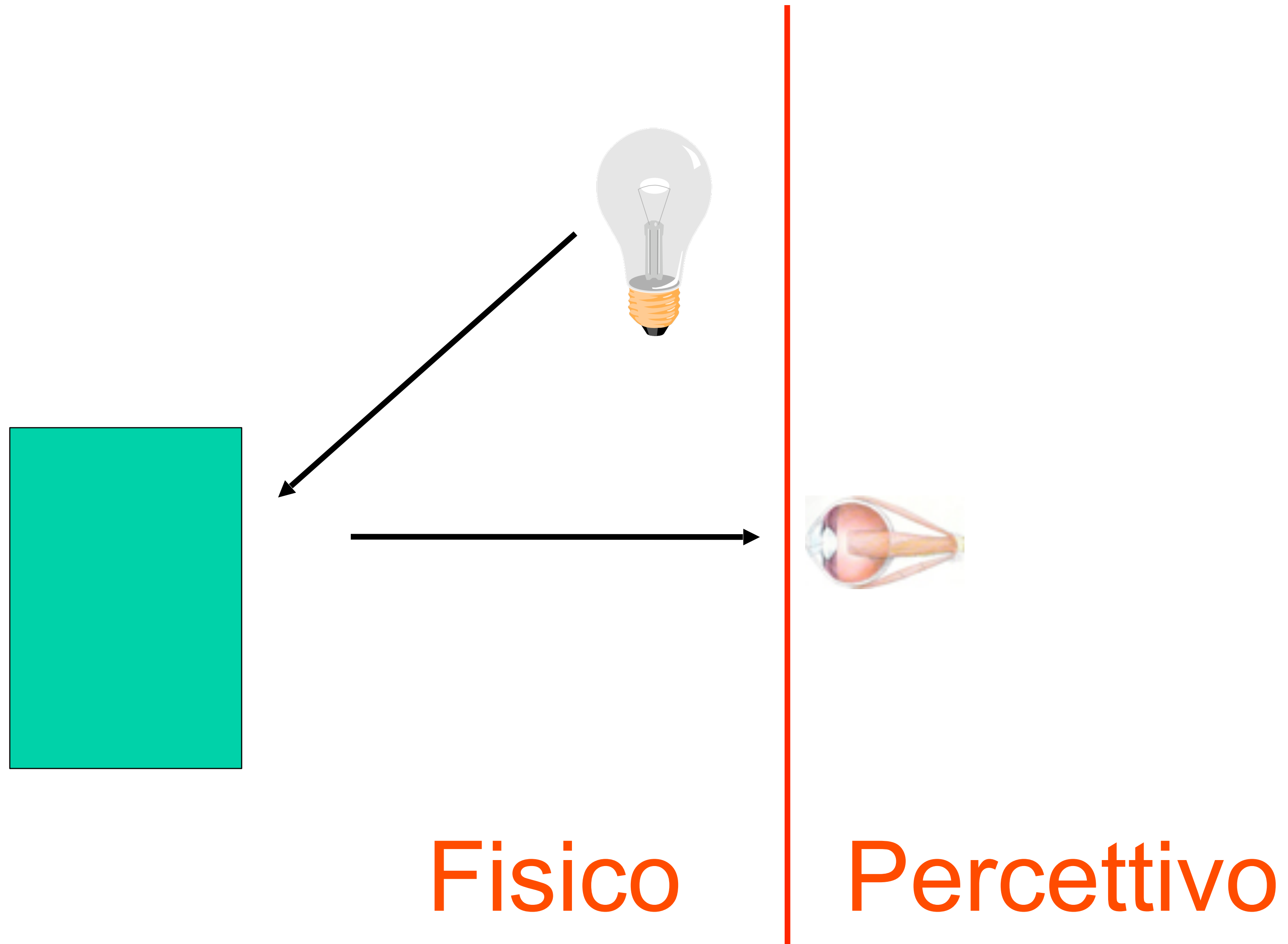
**Alessandro Rizzi**  
**Dipartimento di Informatica**  
**Università degli Studi di Milano**

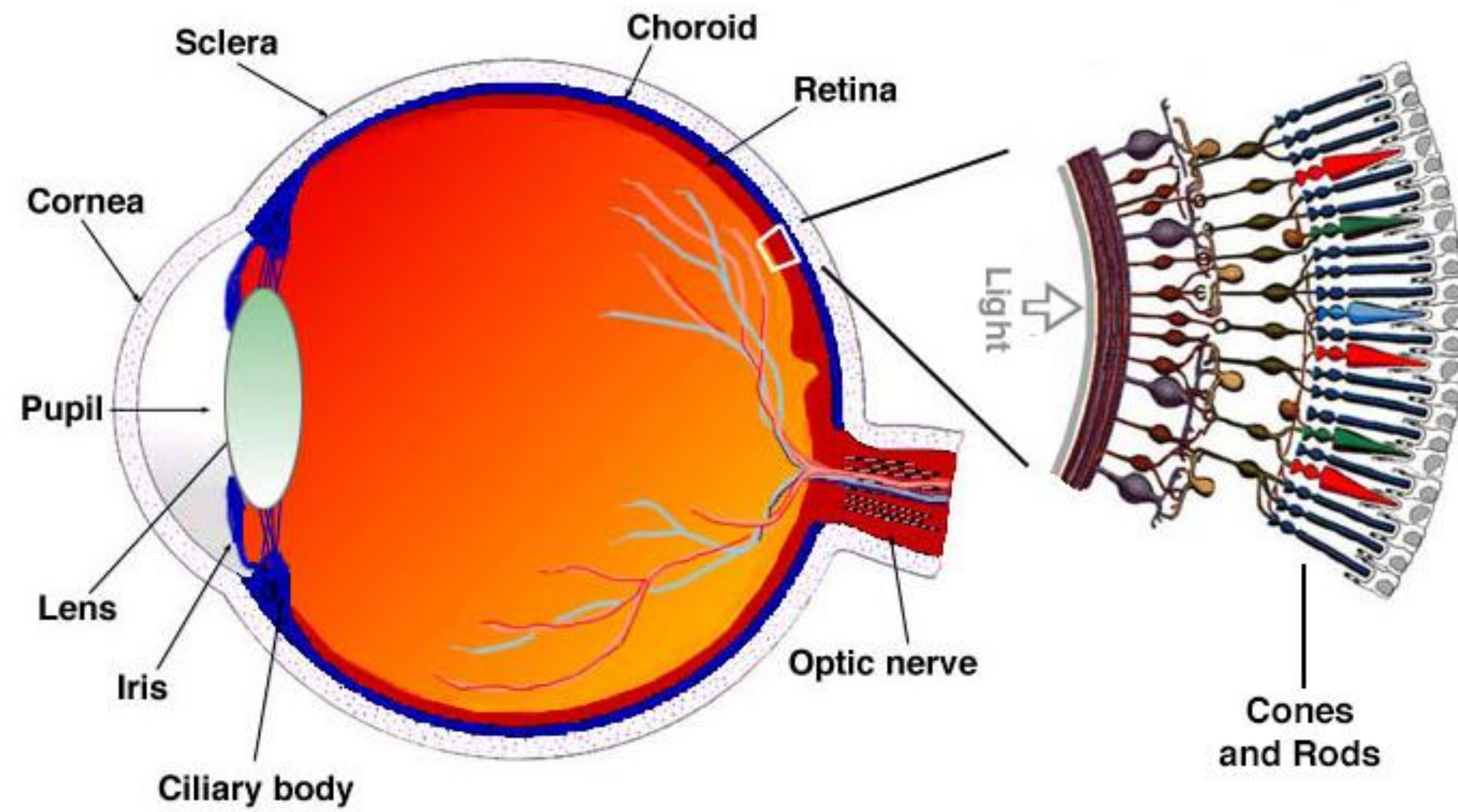
**Venerdì 18 Novembre 2022**

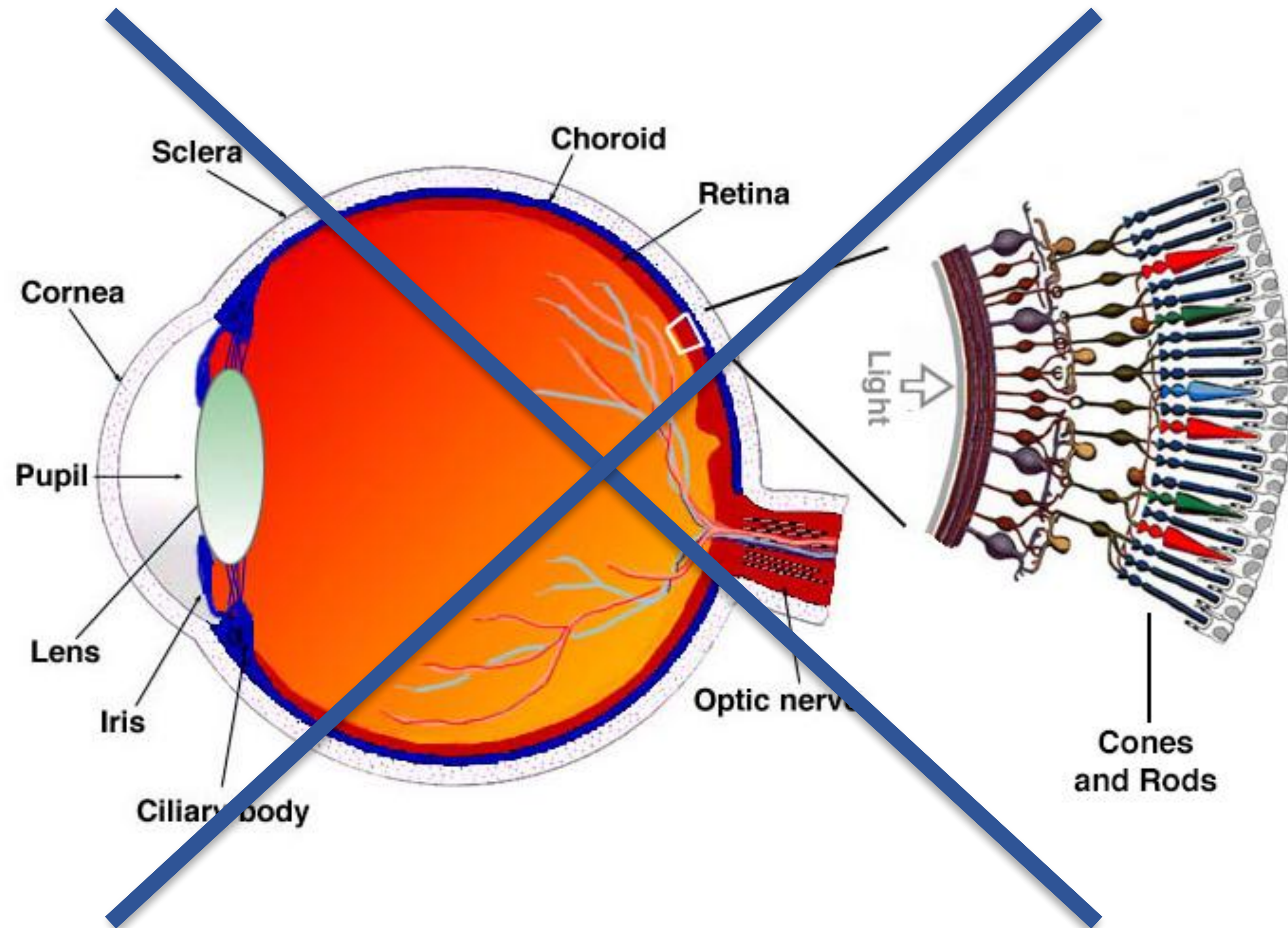
# Il processo visivo

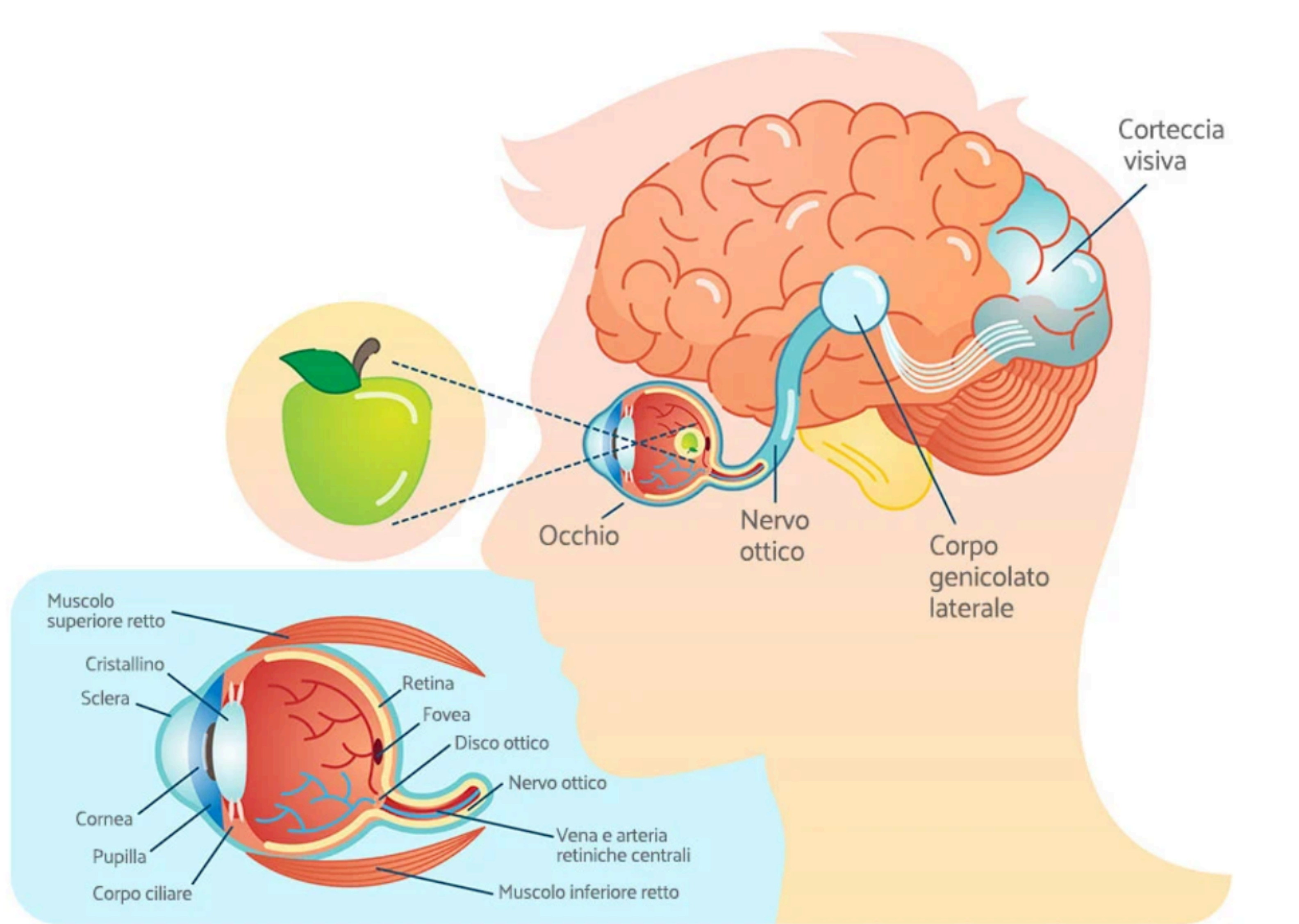


# Il processo visivo

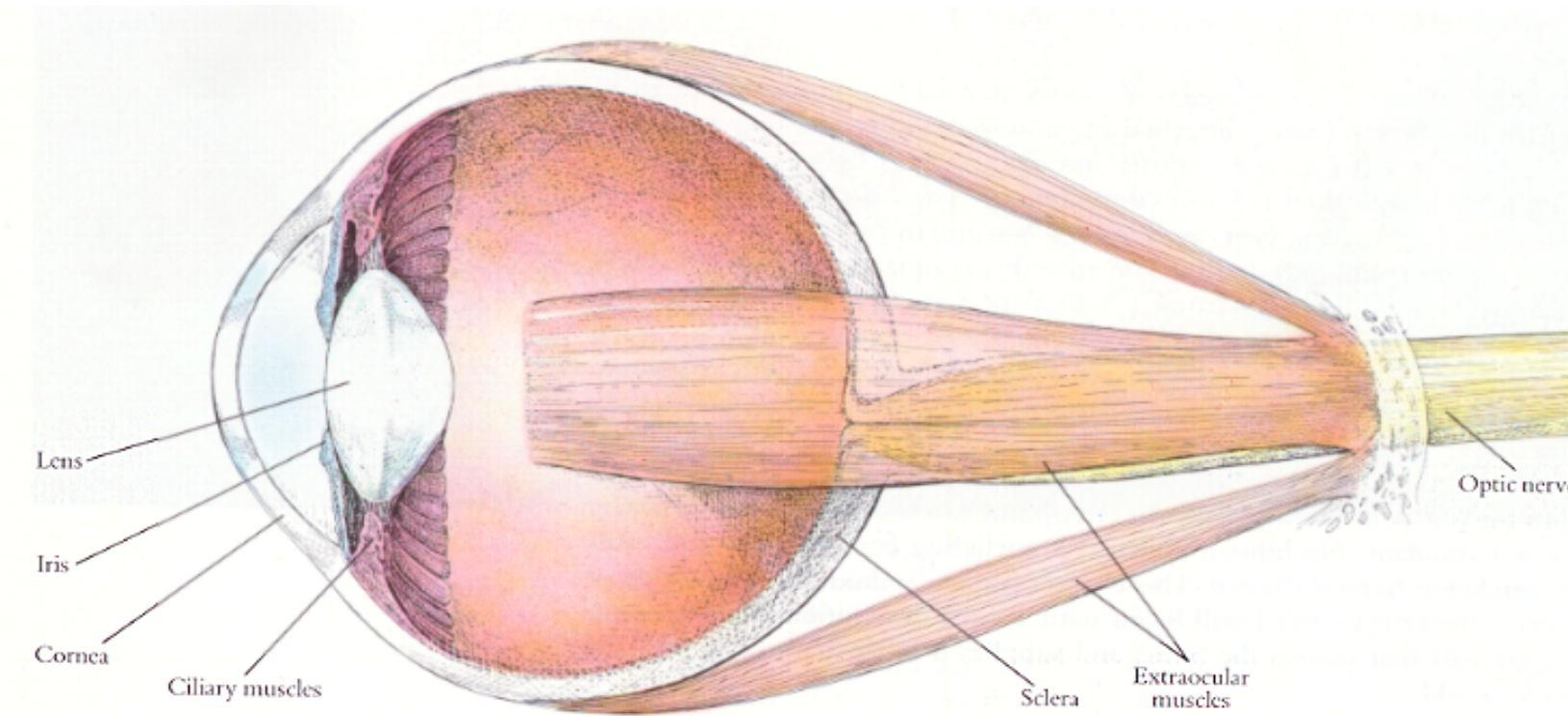




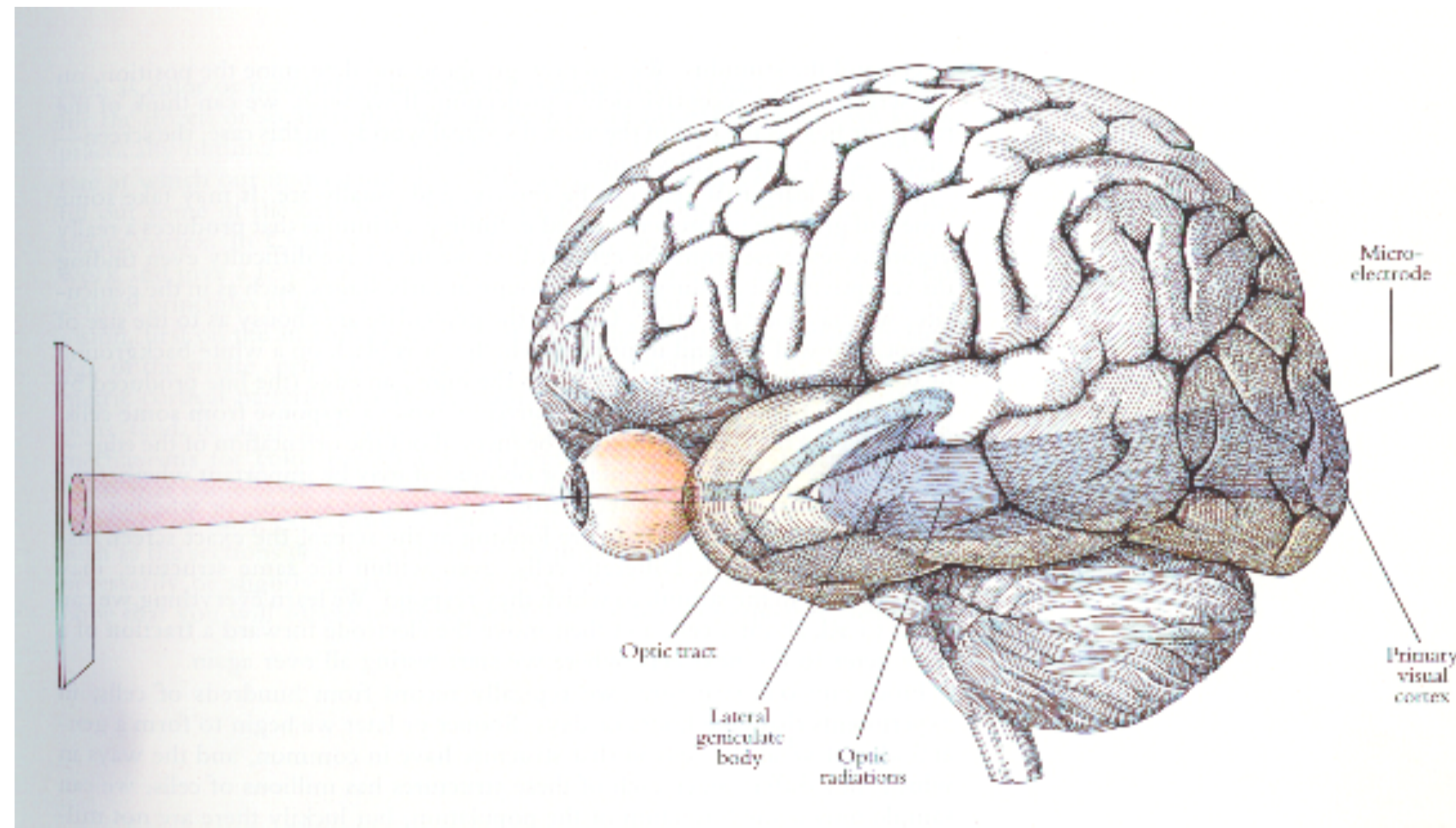




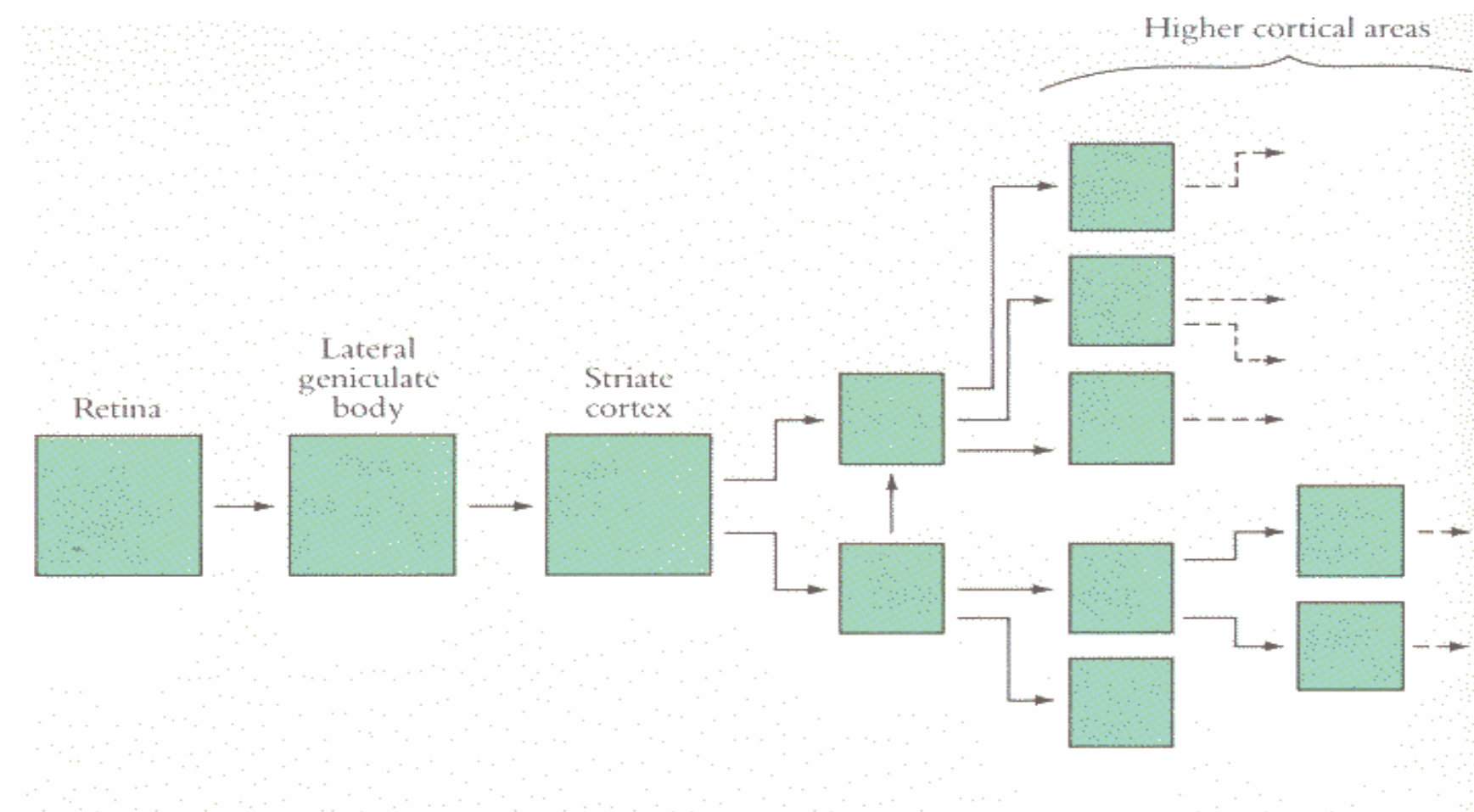
# Dall'occhio



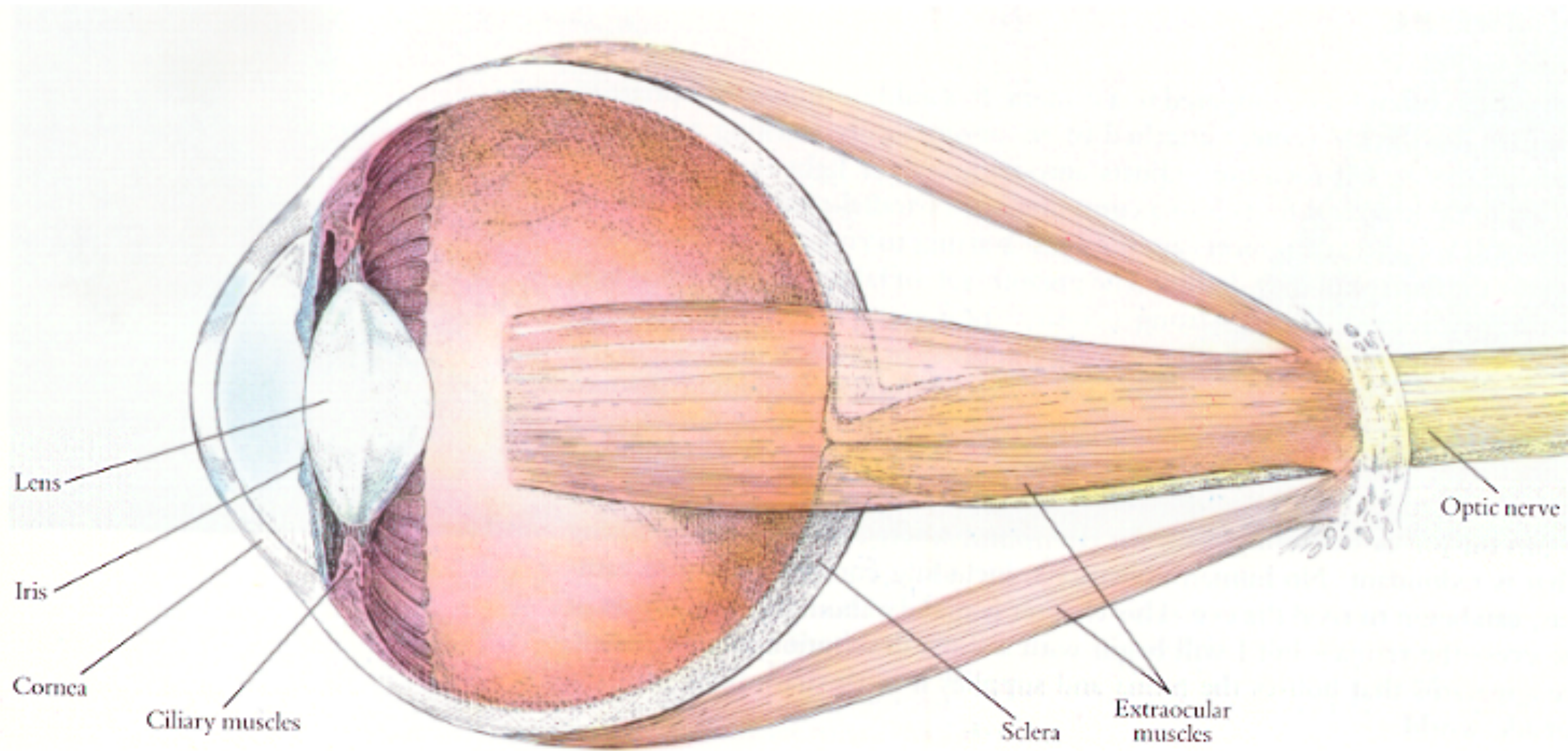
# .. al cervello



# Visual pathway

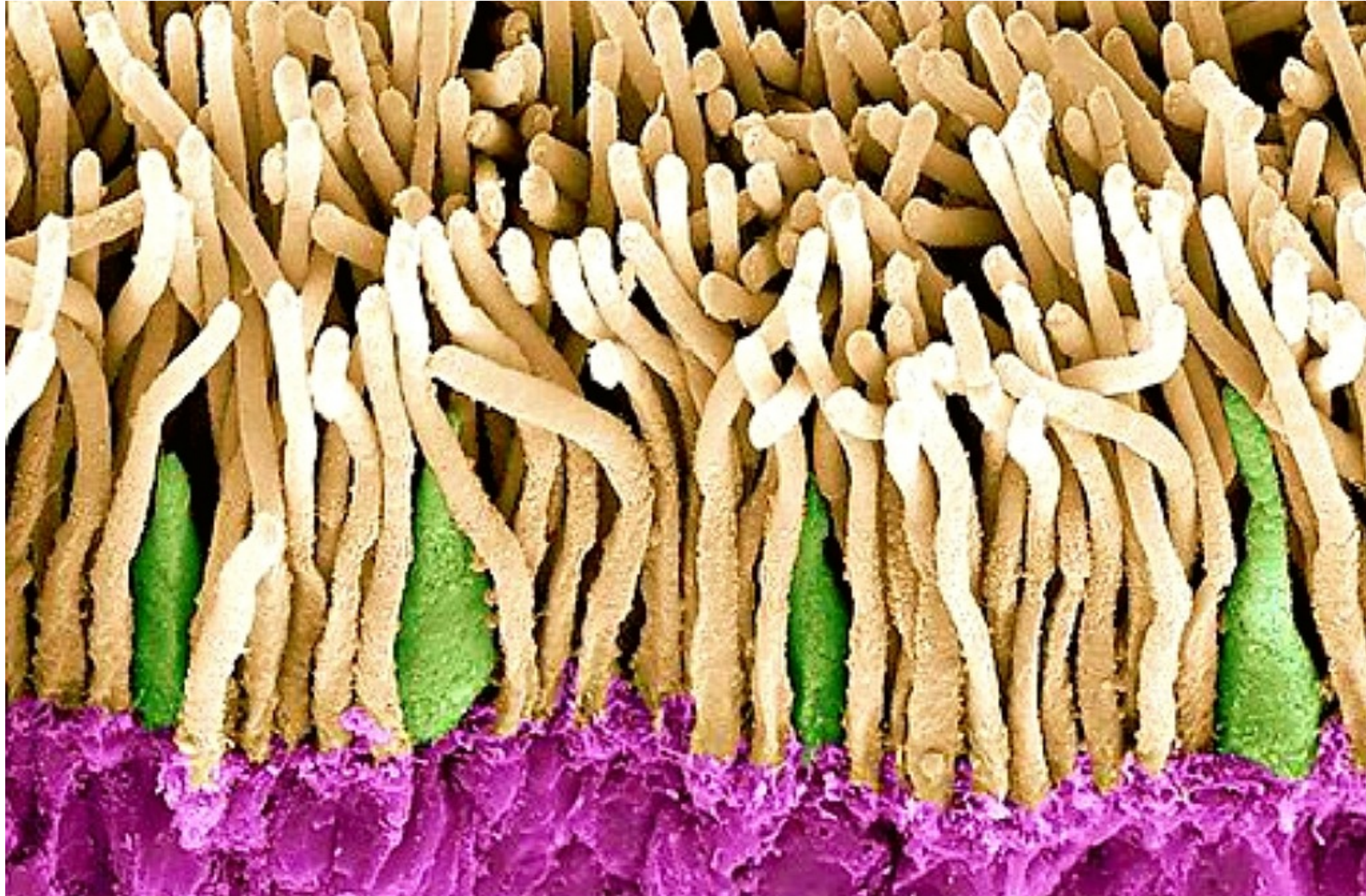


# L'occhio

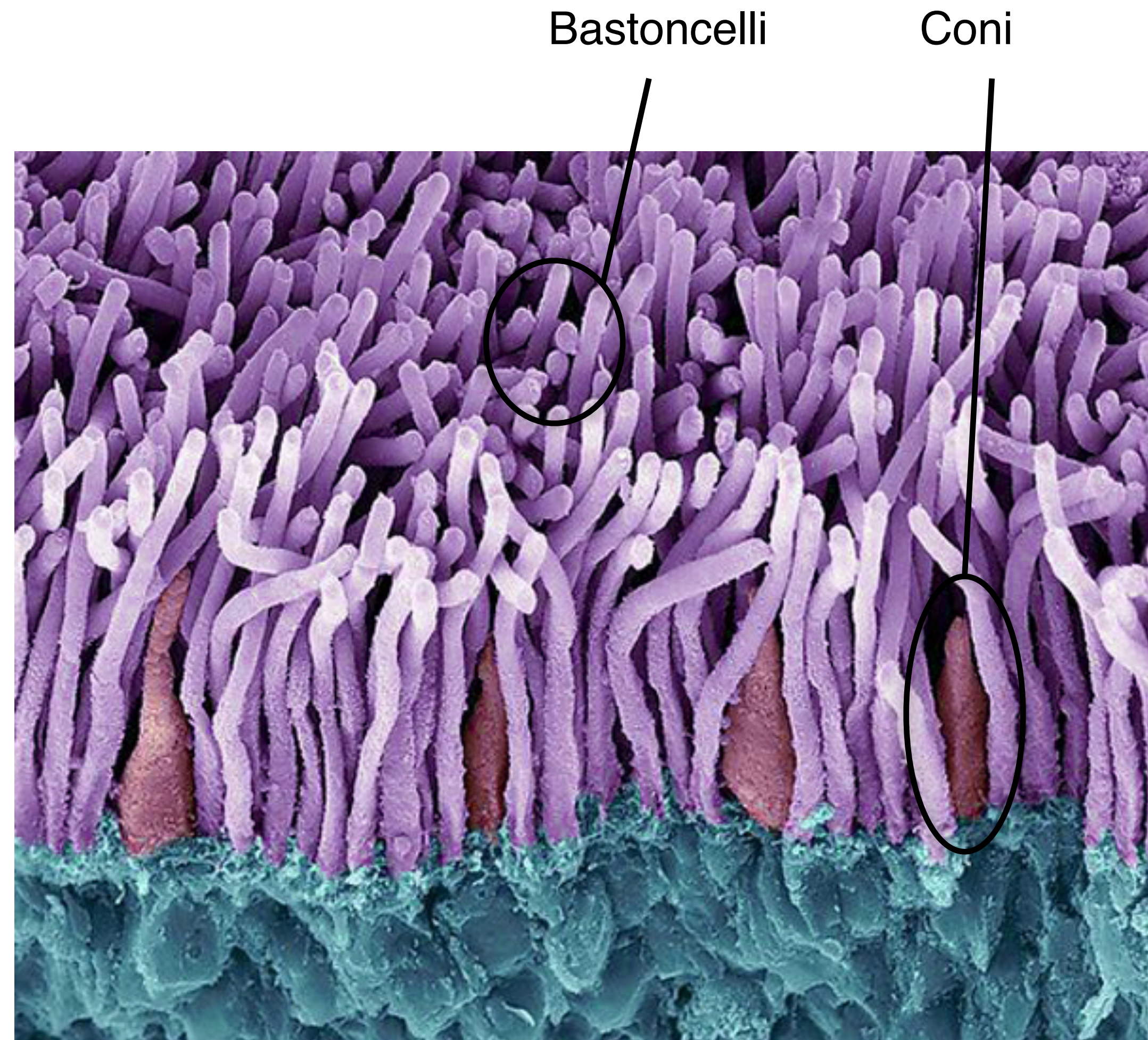
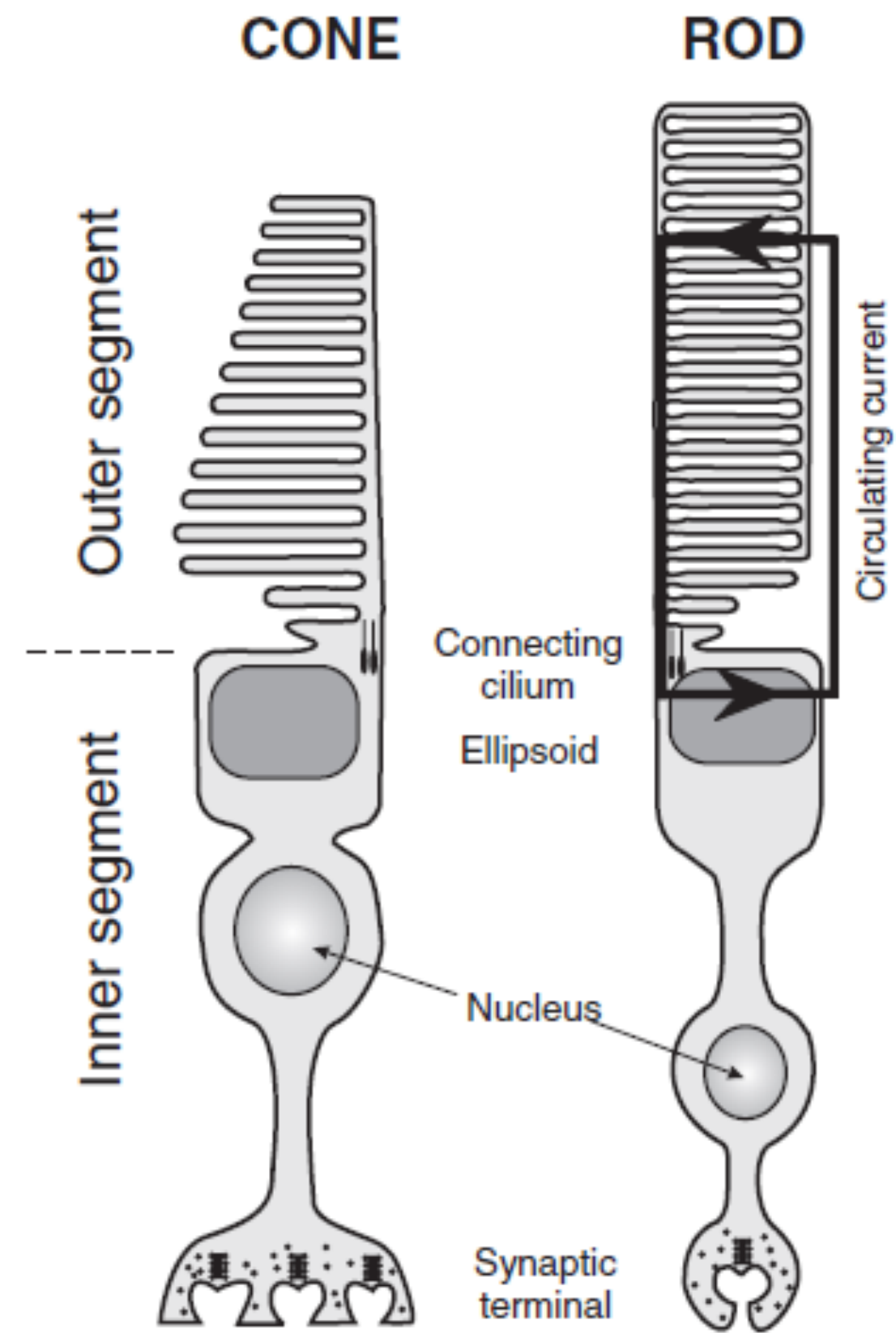




# Coni e bastoncelli



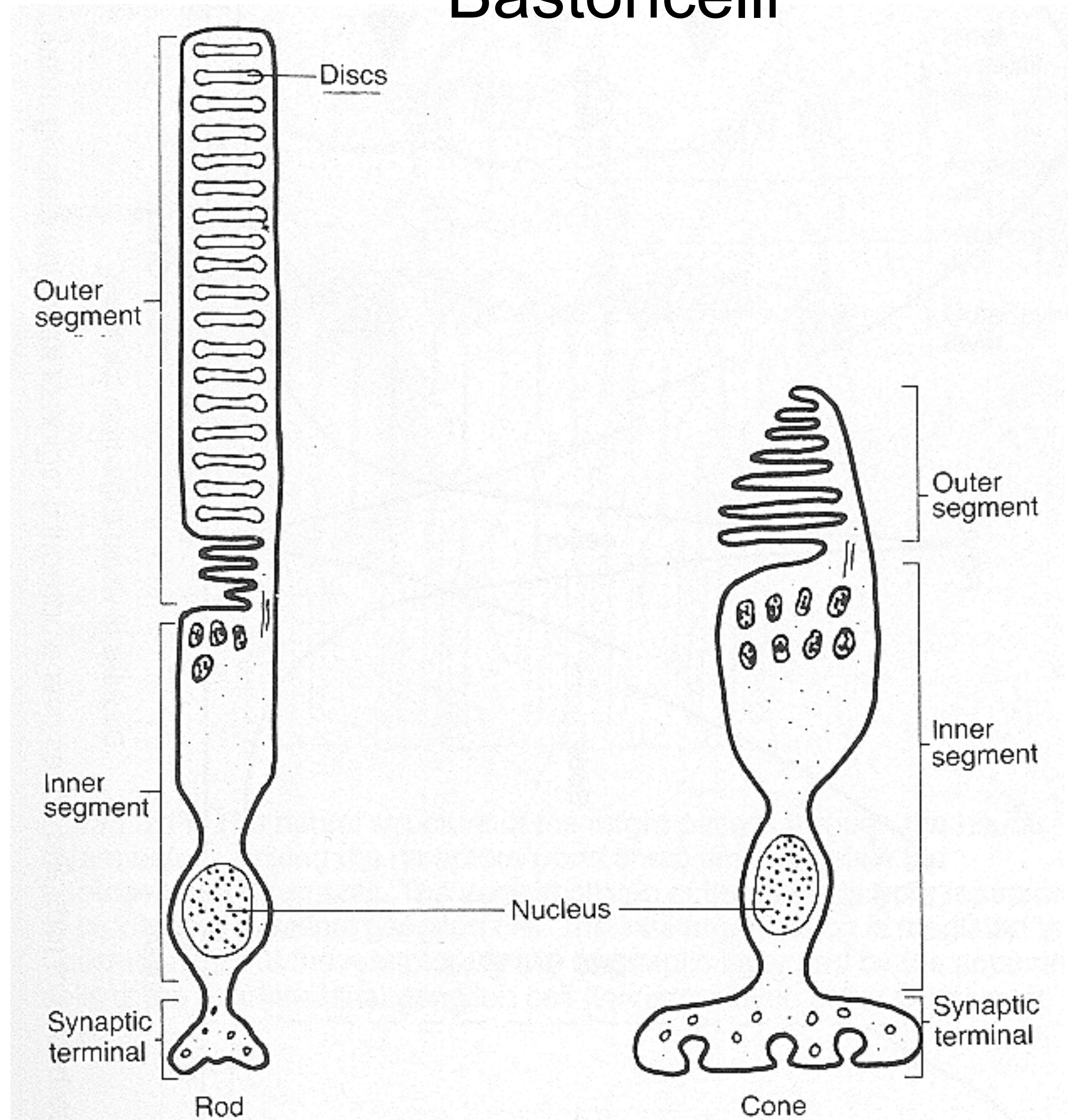
# Coni e bastoncelli



# I fotorecettori

Bastoncelli

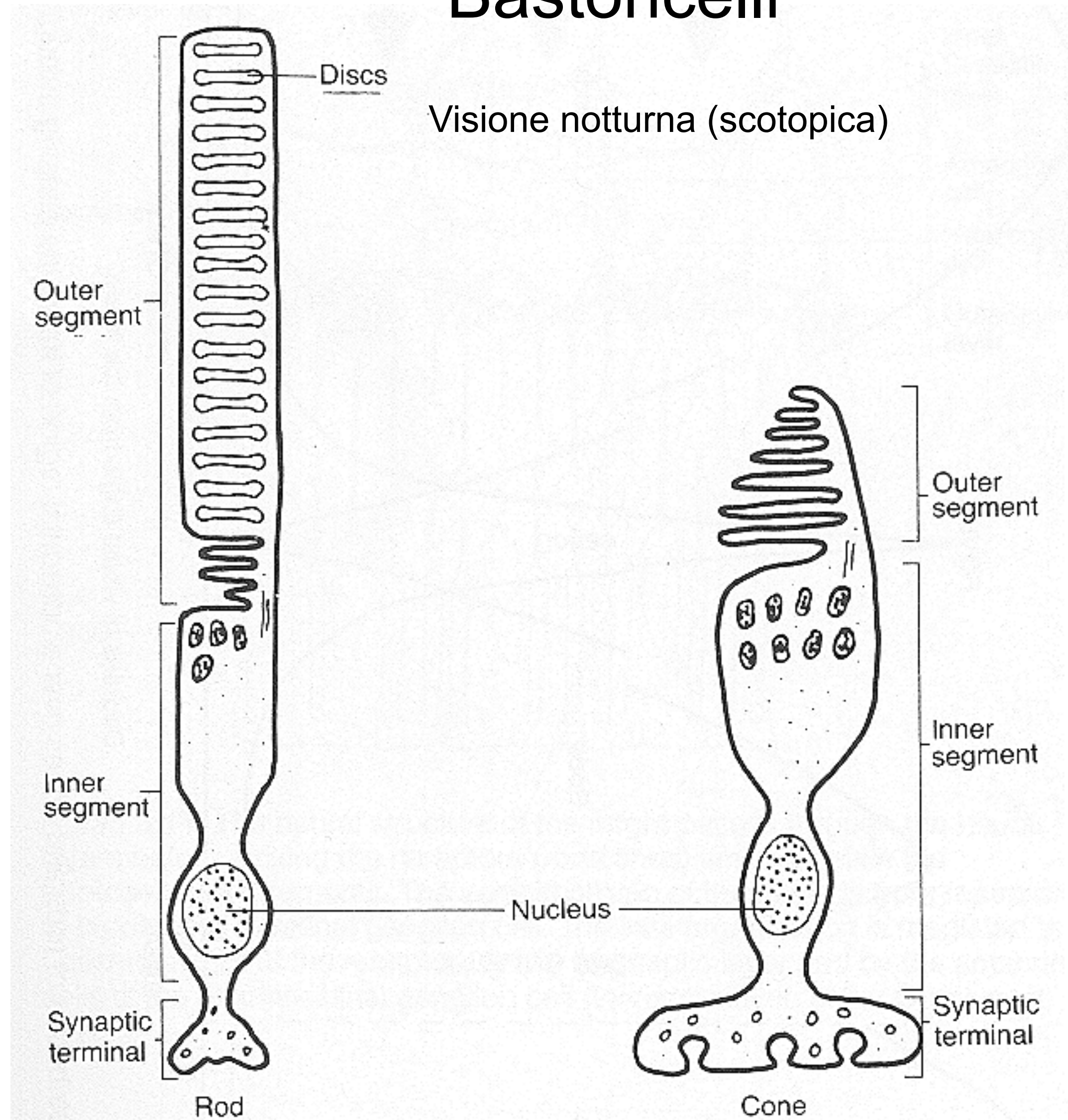
Coni



# I fotorecettori

Bastoncelli

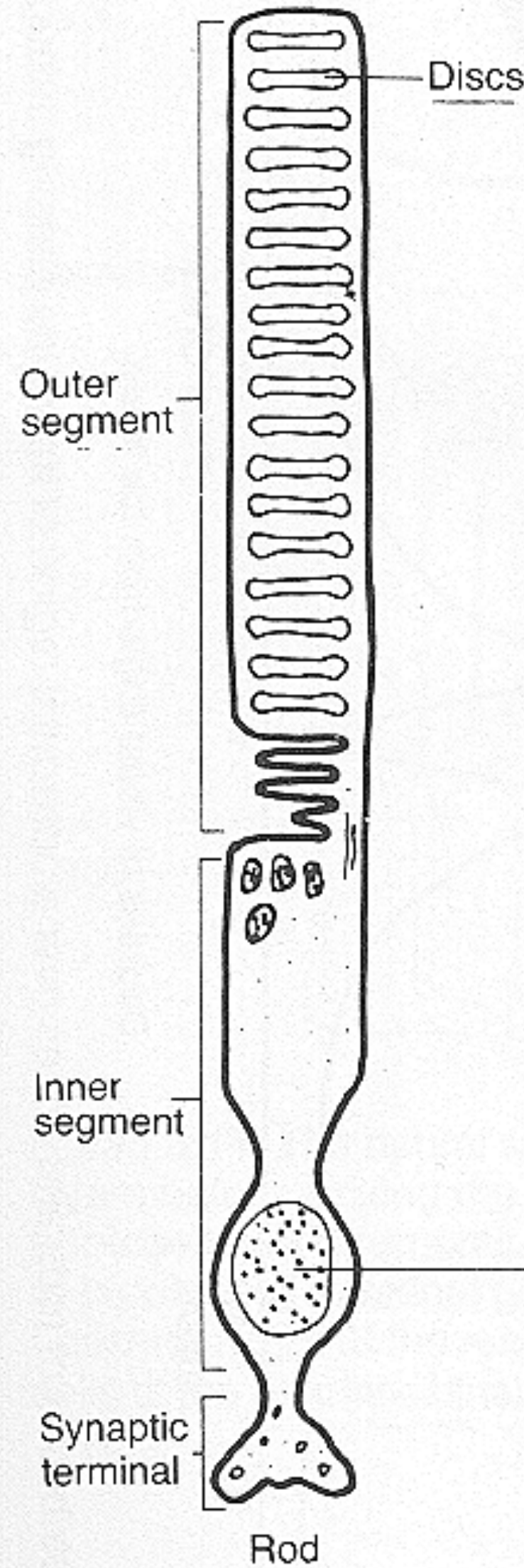
Coni



# I fotorecettori

## Bastoncelli

Visione notturna (scotopica)



## Coni

Visione diurna (fotopica)

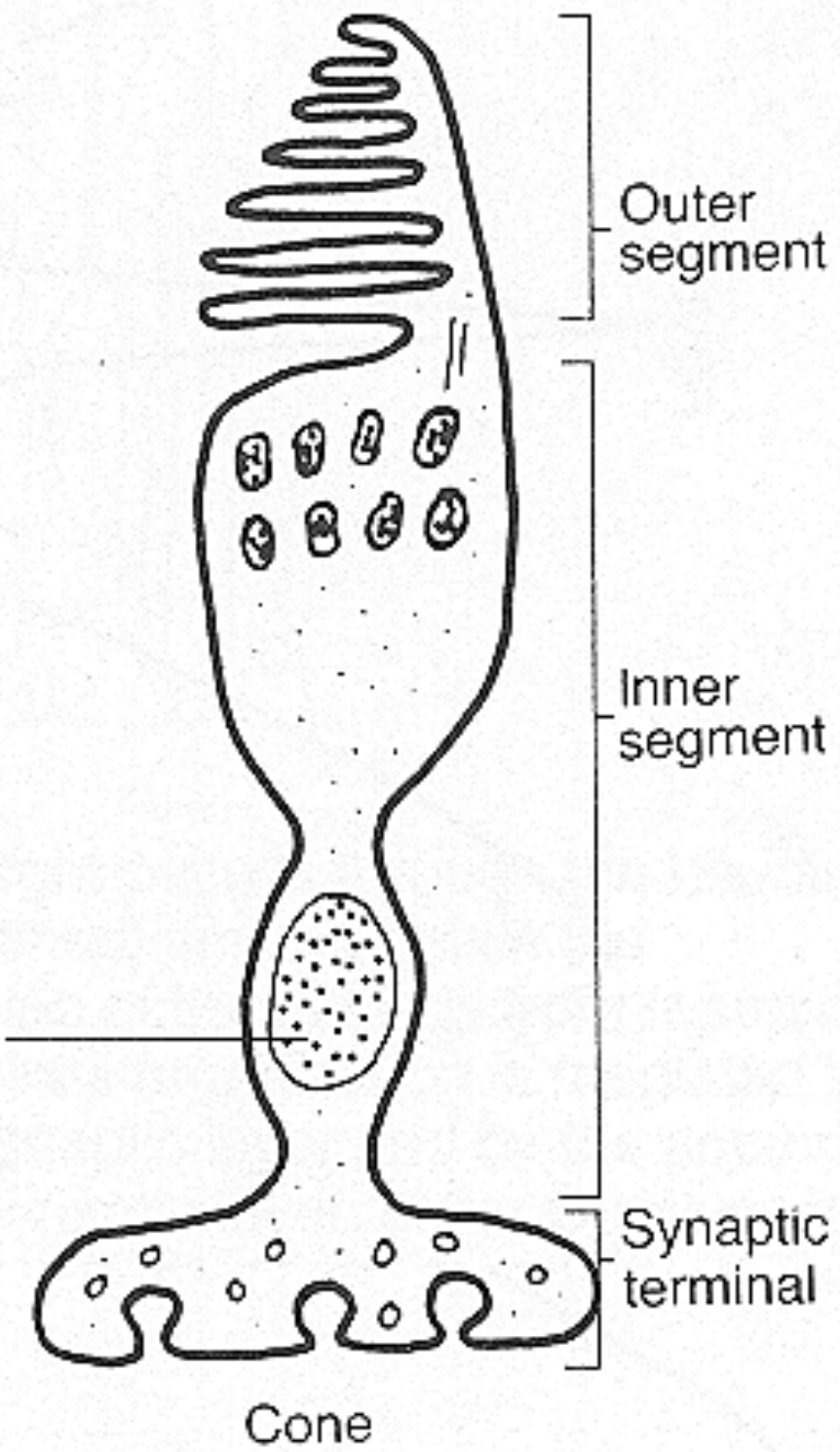
Visione cromatica

Sono di 3 tipi:

Coni L (sensibili alle alte  $\lambda$ )

Coni M (sensibili alle medie  $\lambda$ )

Coni S (sensibili alle basse  $\lambda$ )



# Sensibilità spettrale dei coni

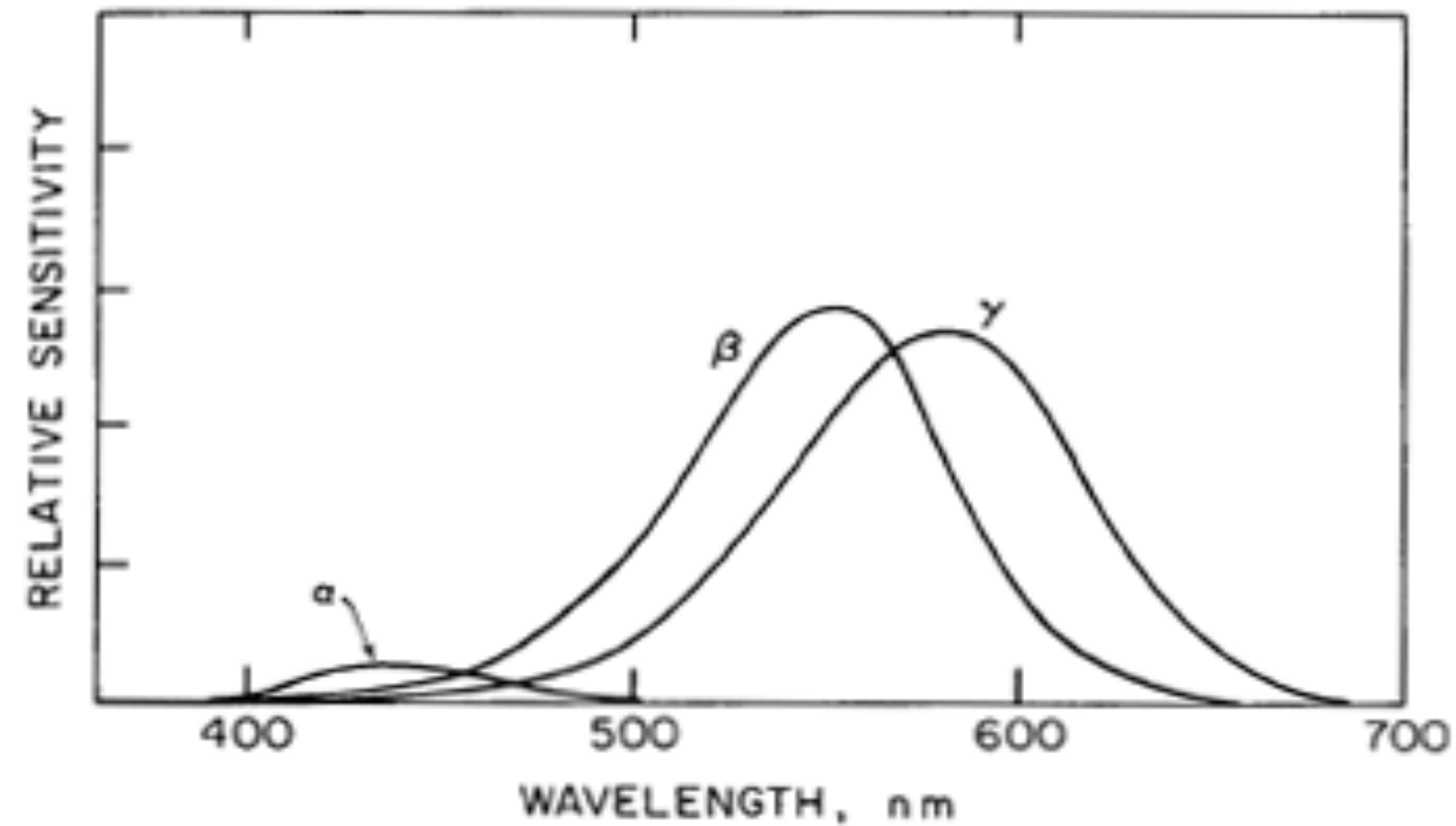
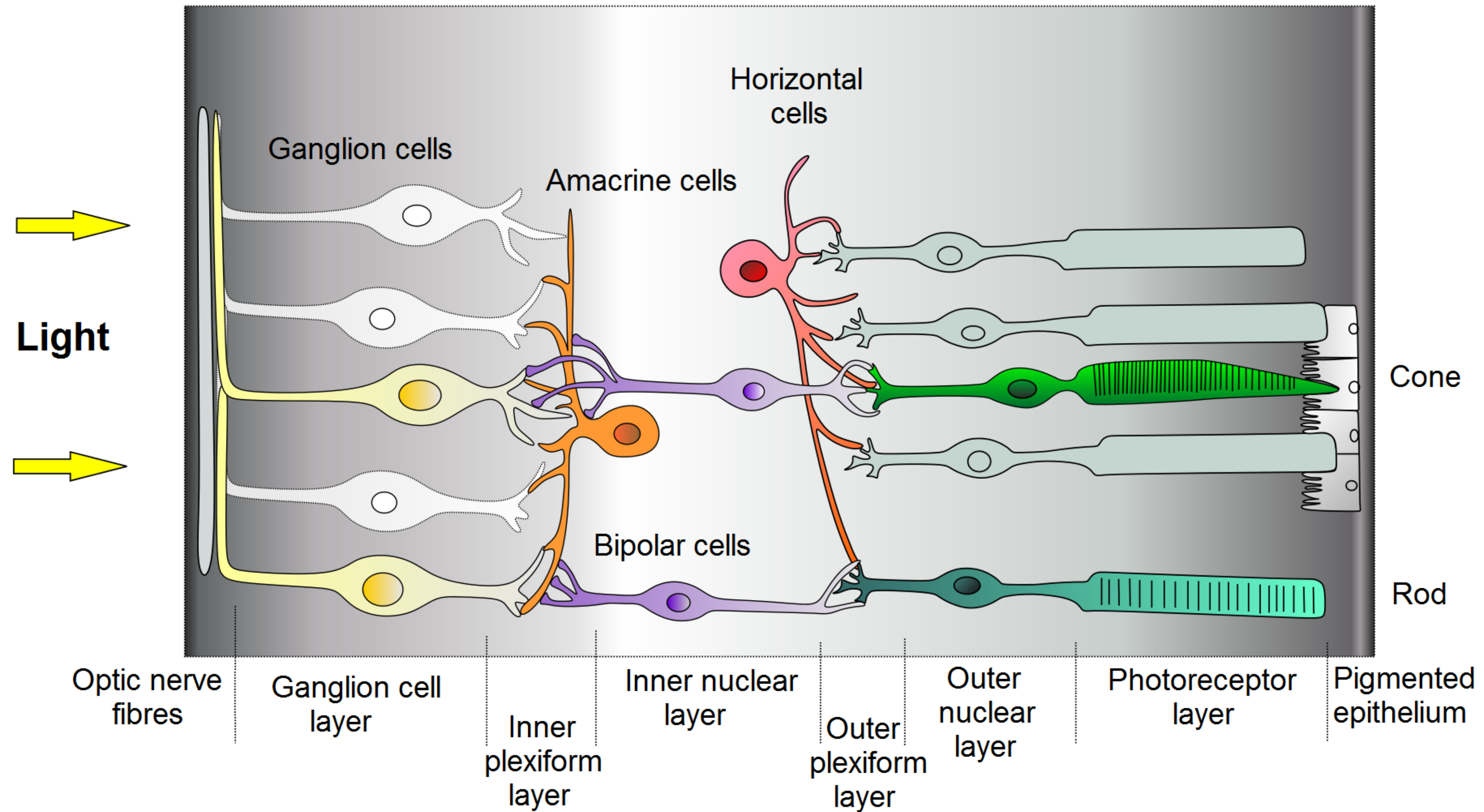


FIGURE 2.2-4. Typical spectral absorption curves of pigments of the retina (10).

# **Il segnale retinico**

# La retina

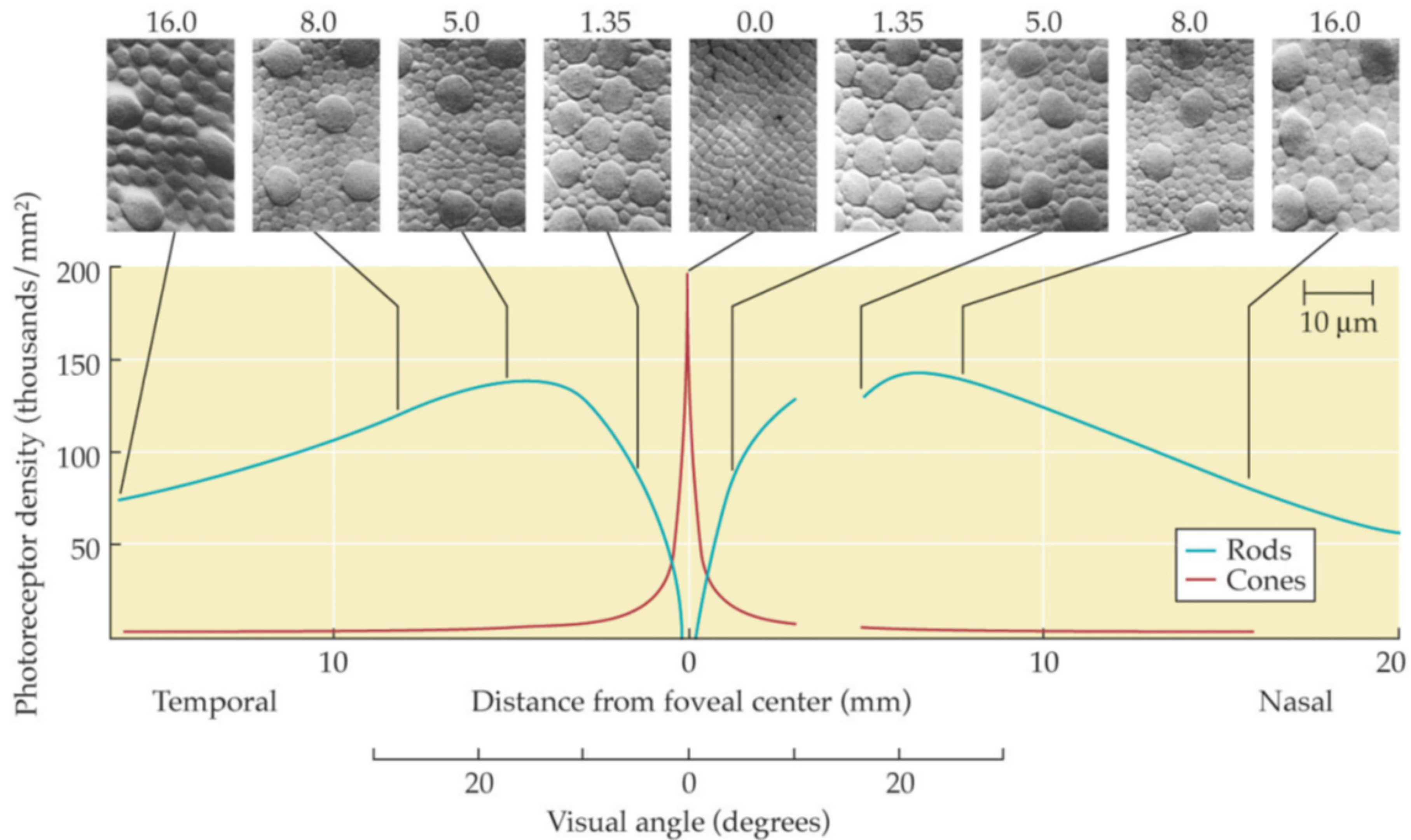




# Cablatura retinale

- 10 strati differenti
- 12 tipi differenti di cellule gangliari
- 27 tipi differenti di cellule amacrine
- Connessione/attivazione ciclo circadiano
- 12 rappresentazioni spazio-temporali differenti
- Inibizione laterale e verticale
- Ipotesi di specializzazione degli strati

# Distribuzione dei fotorecettori



**Le immagini  
esistono ?**

# La visione umana è foveale



[www.cartome.org](http://www.cartome.org)

Un'immagine completa non è mai presente sulla retina

L C C M O  
C X A T A  
A I I Y E S A I G R  
C F F T U C O N T  
I I I

S. Anstis, 1974

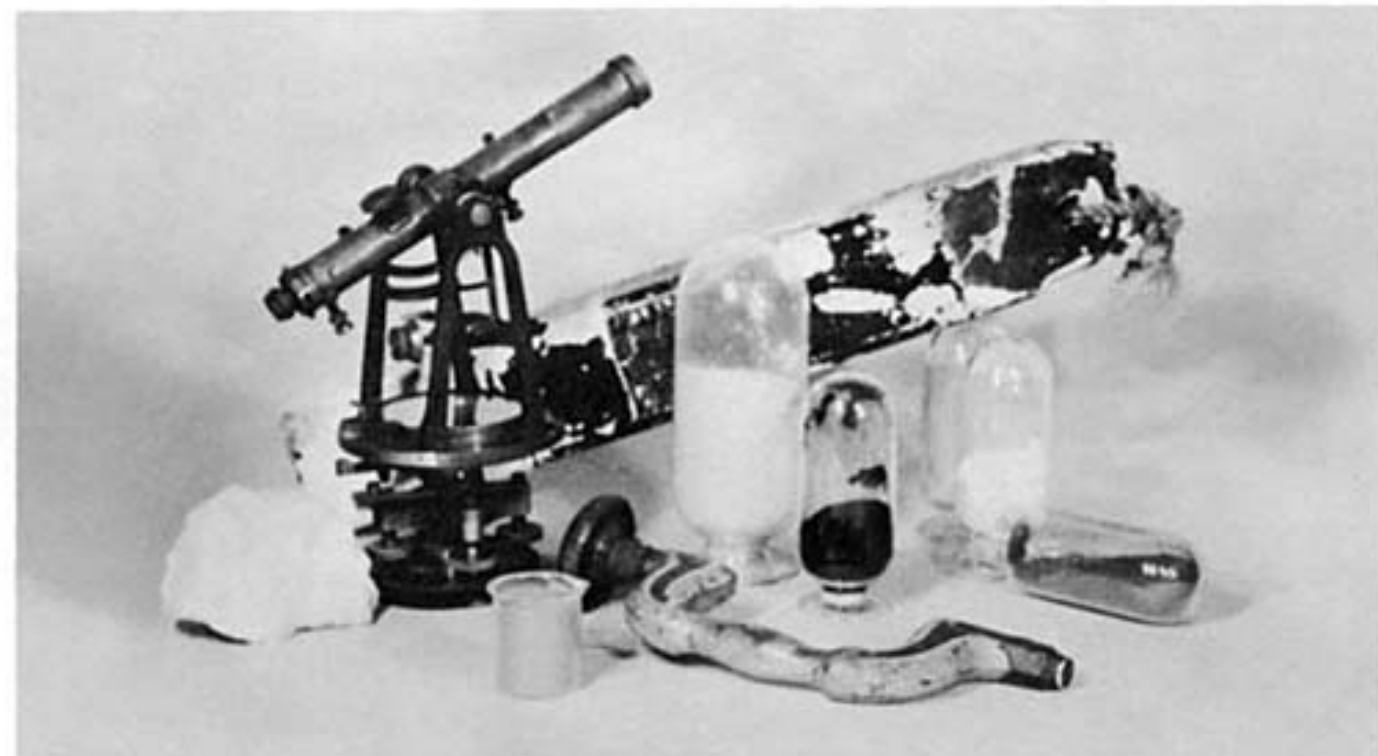
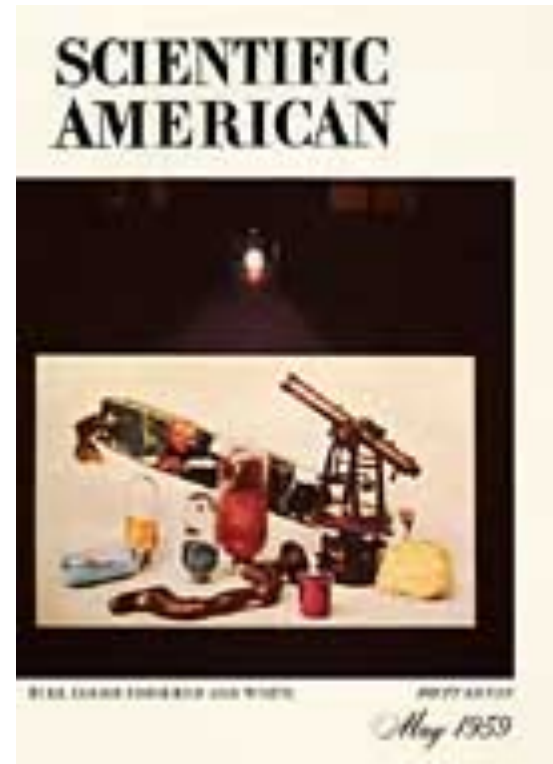


Edwin Land

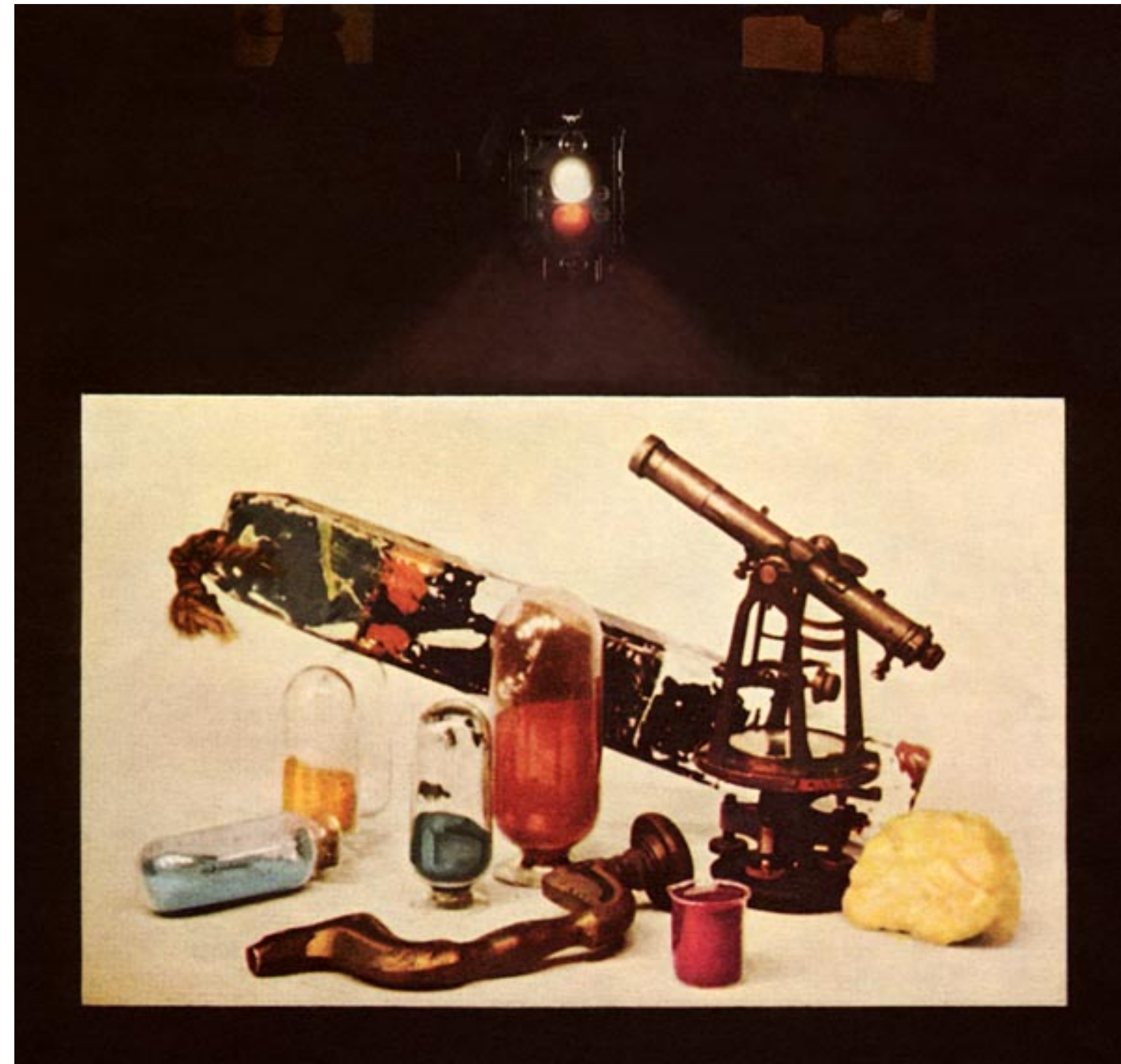


John McCann

# SCIENTIFIC AMERICAN 1959



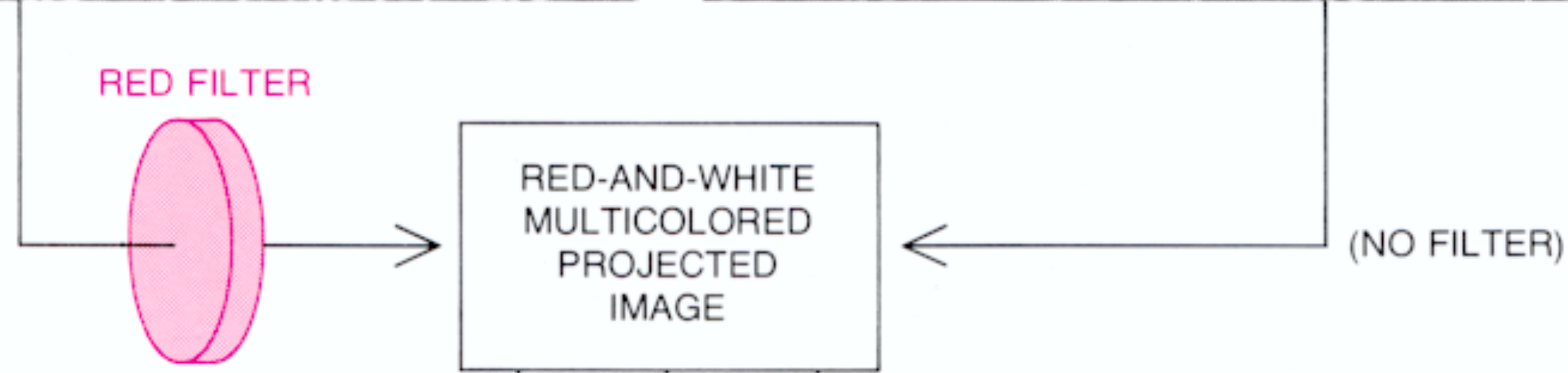
LONG AND SHORT RECORDS are provided by transparencies of these black-and-white photographs made through a red filter (*top*) and a green filter (*bottom*). In projection the long record (*top*) is illuminated by the longer of two wavelengths or bands of wavelengths, and the short record is illuminated by the shorter wavelength or band of wavelengths.



LONG-WAVE ("RED") SEPARATION RECORD



MIDDLE-WAVE ("GREEN") SEPARATION RECORD



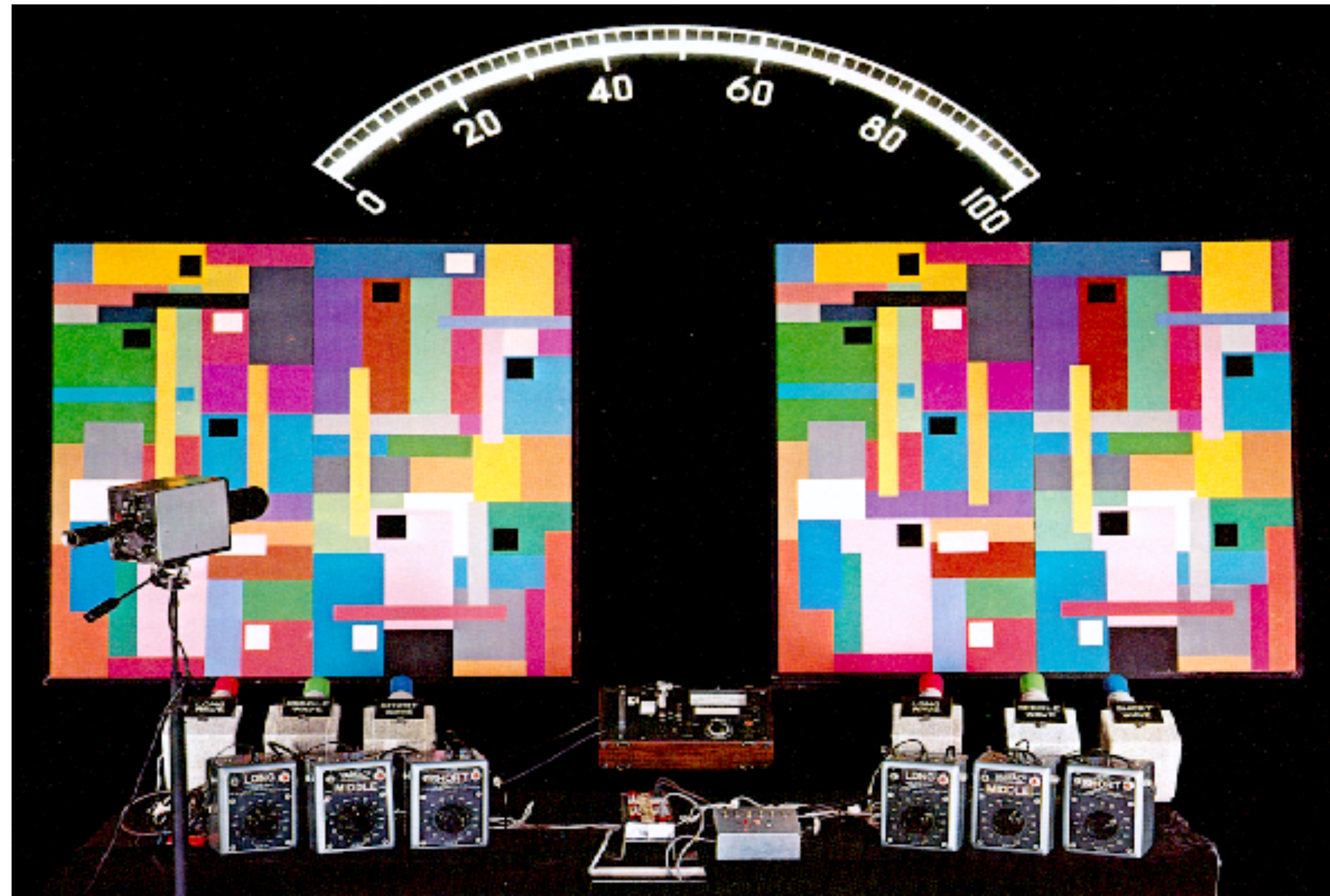
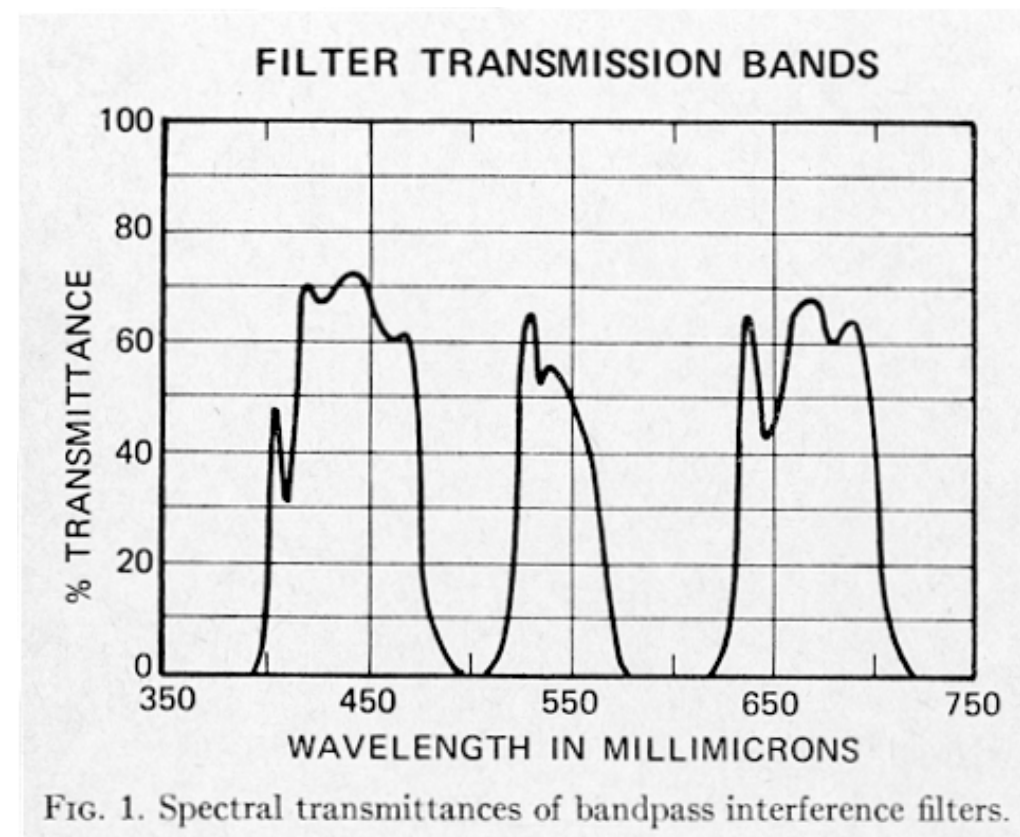


# Retinex at 40

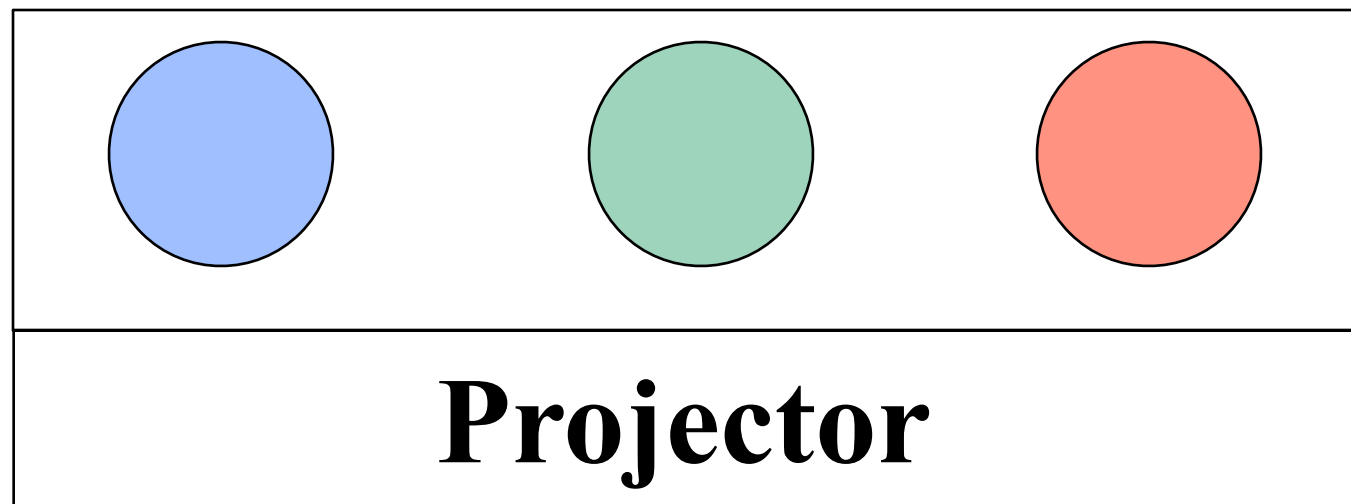
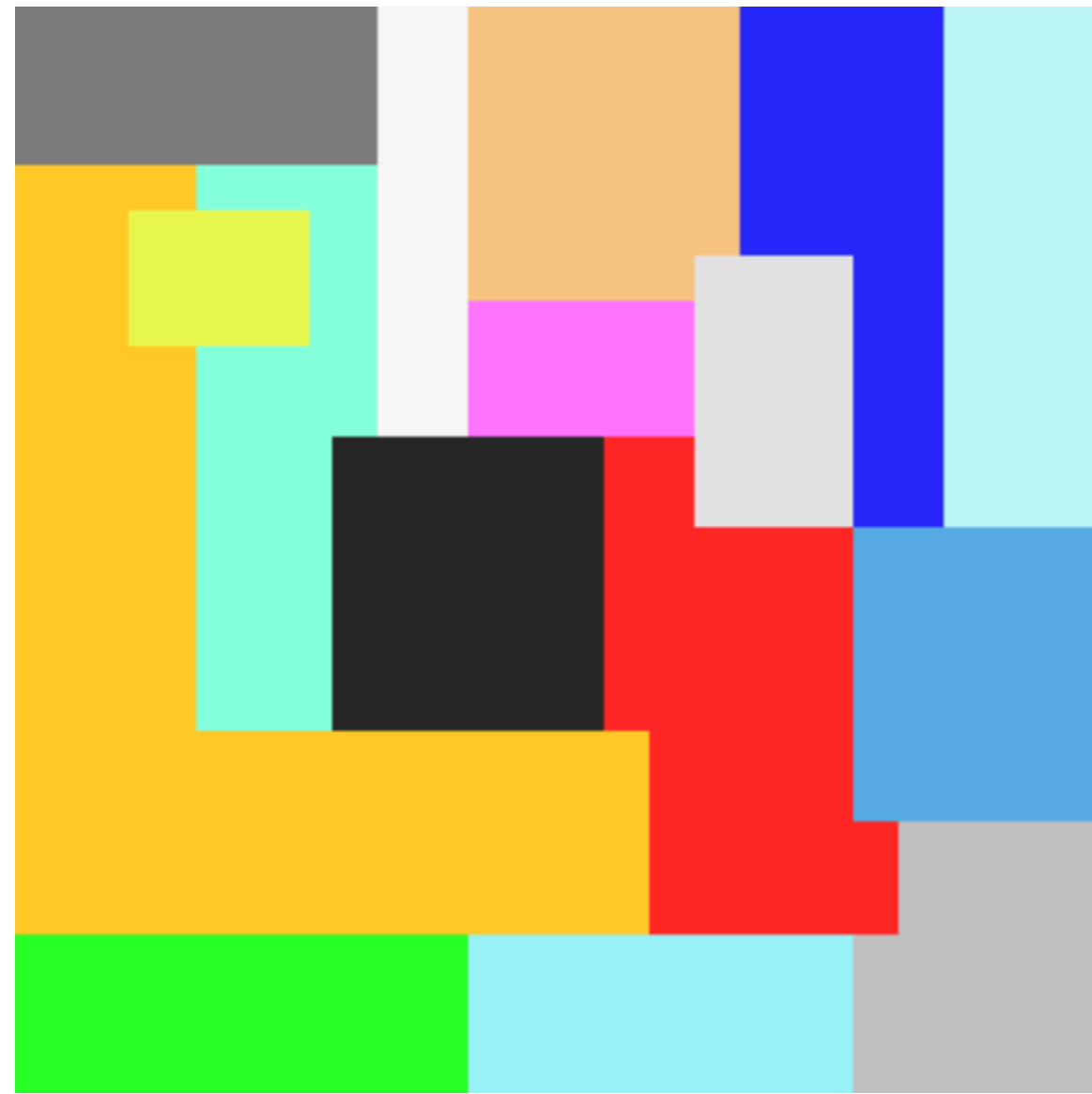
S. Jose (CA) 2002



# Altro esperimento di Land







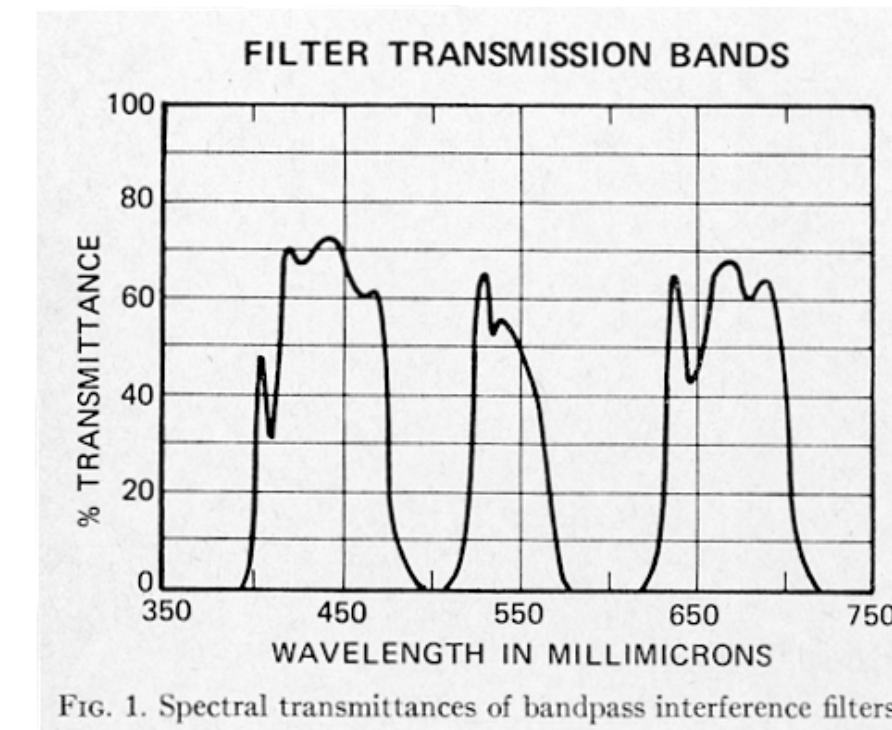
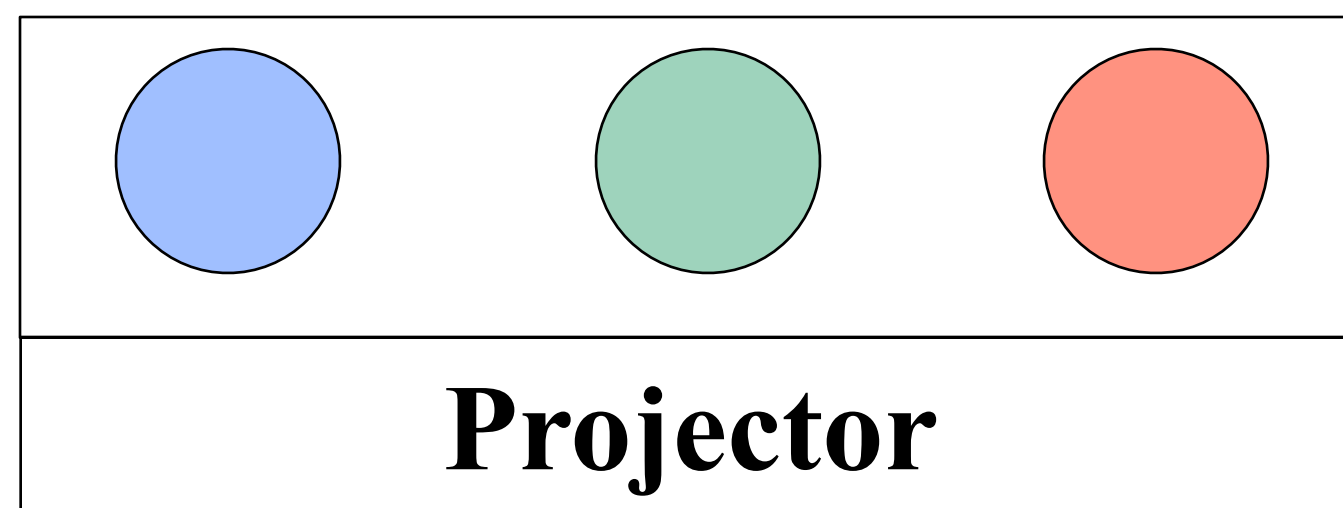
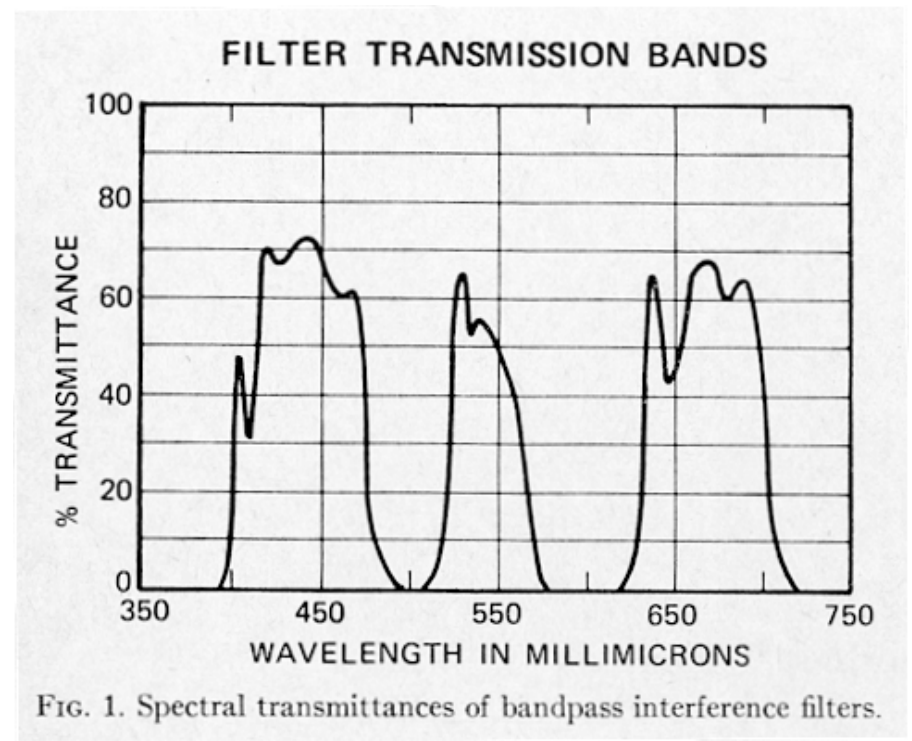
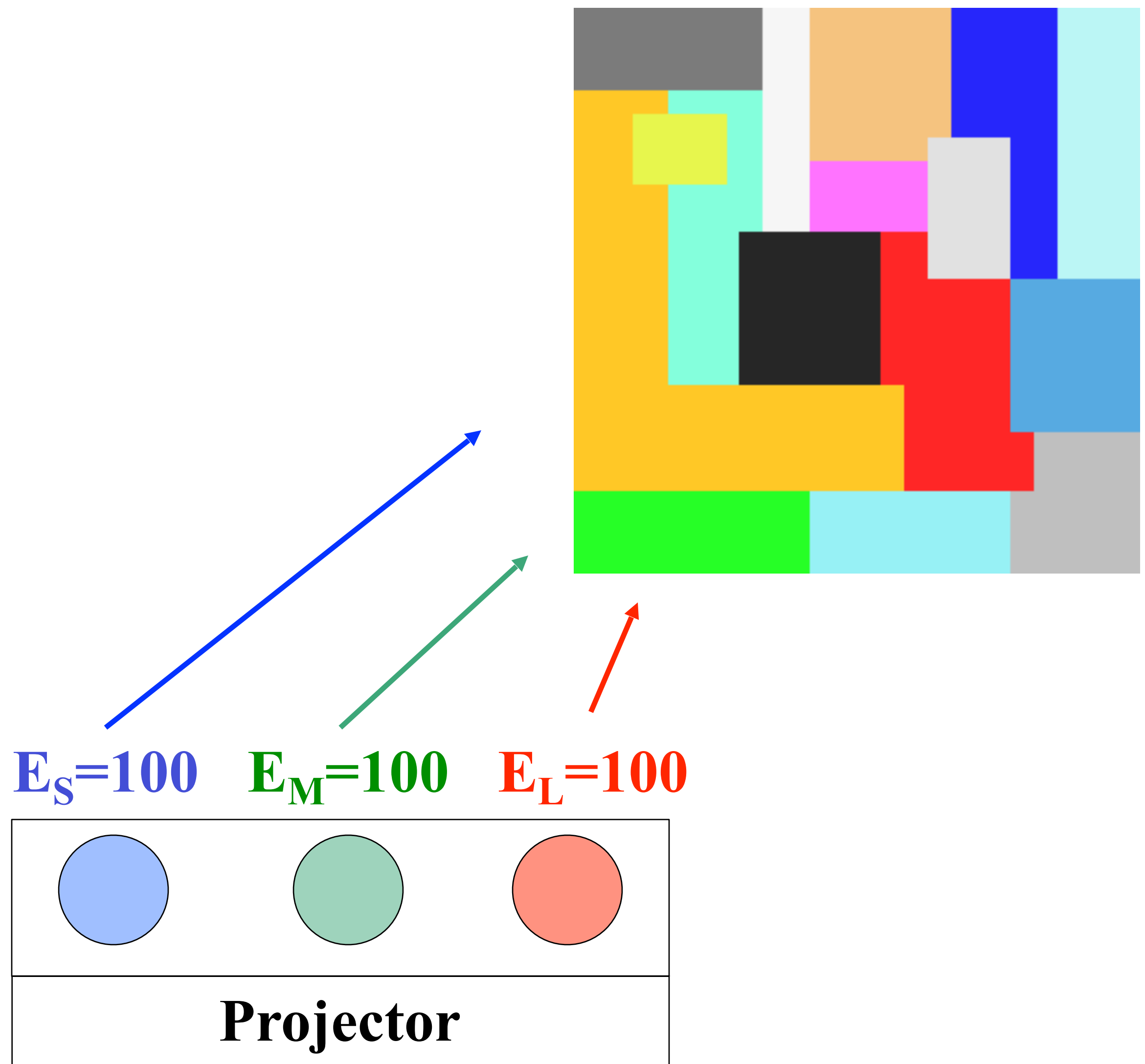
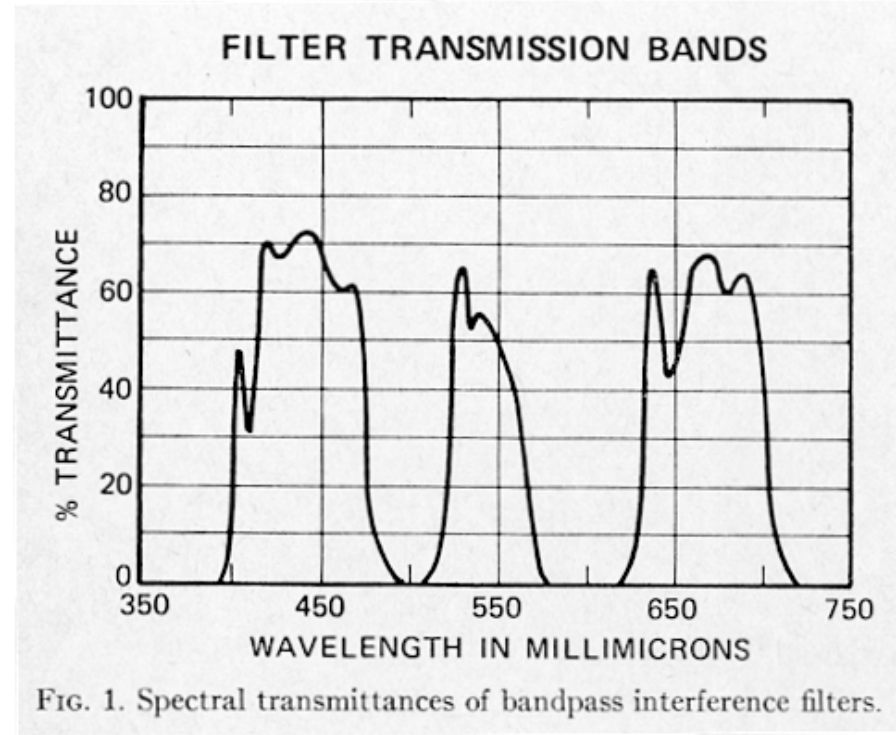
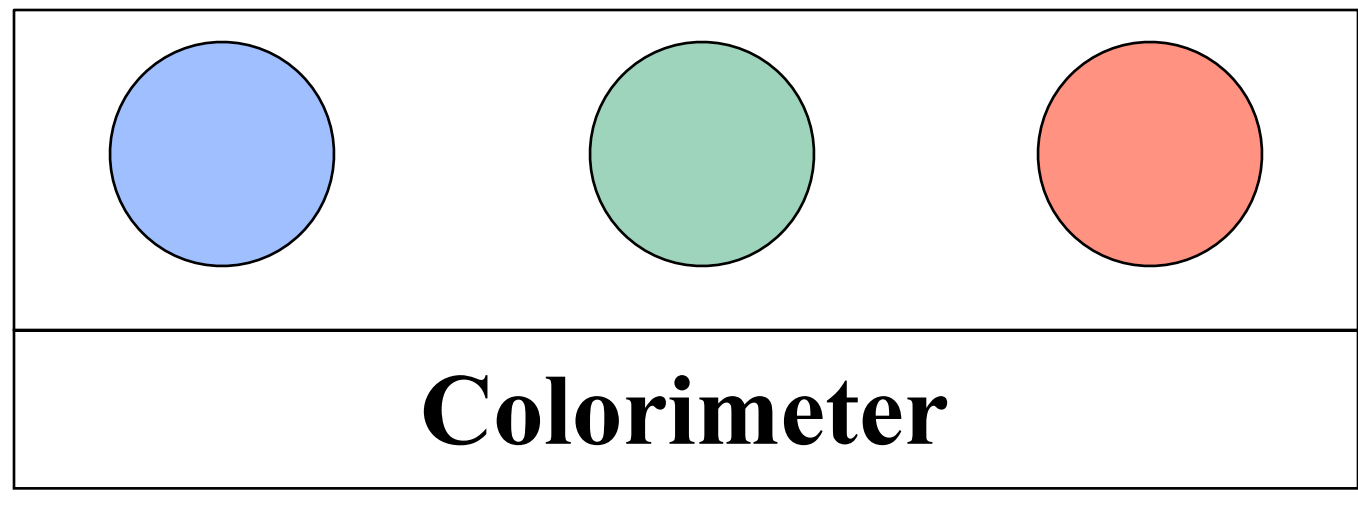
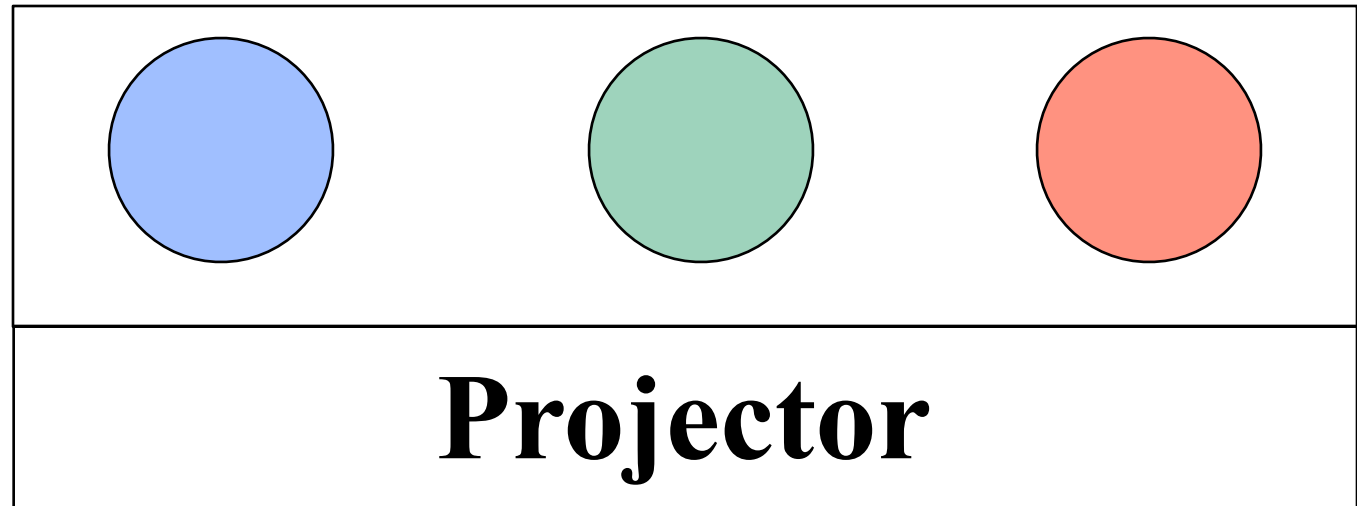
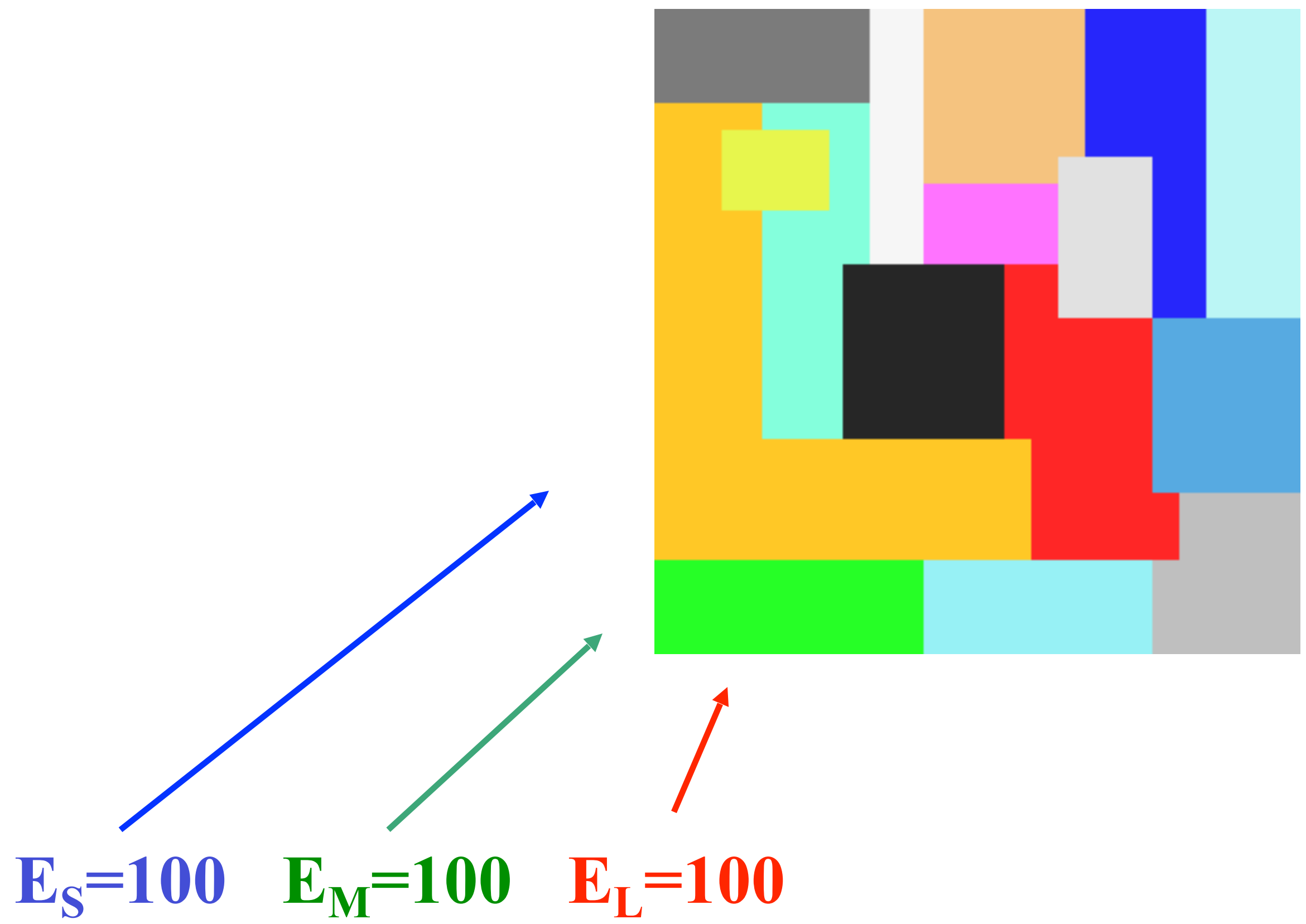


FIG. 1. Spectral transmittances of bandpass interference filters.

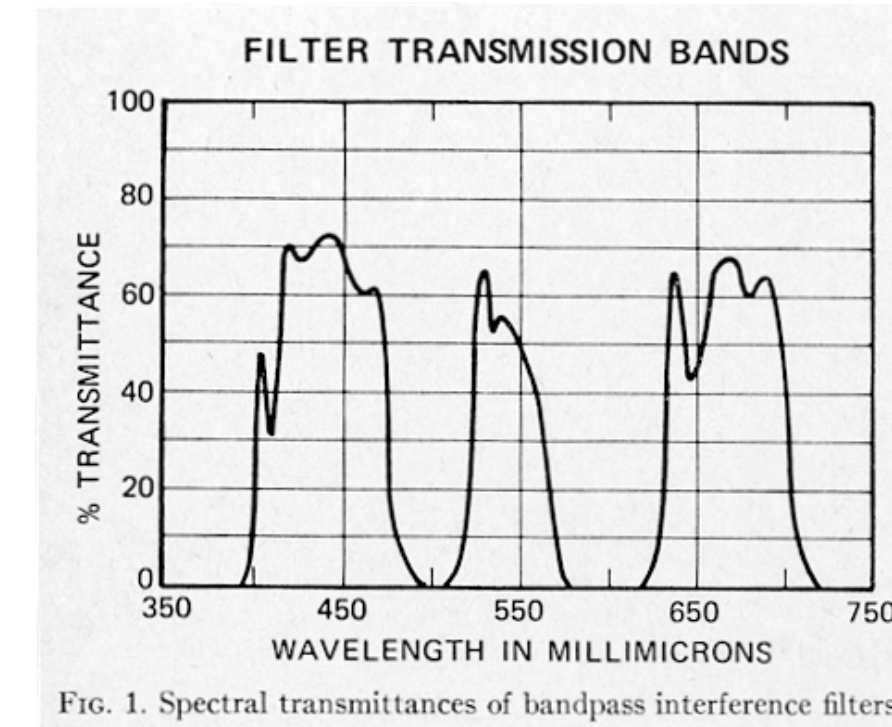
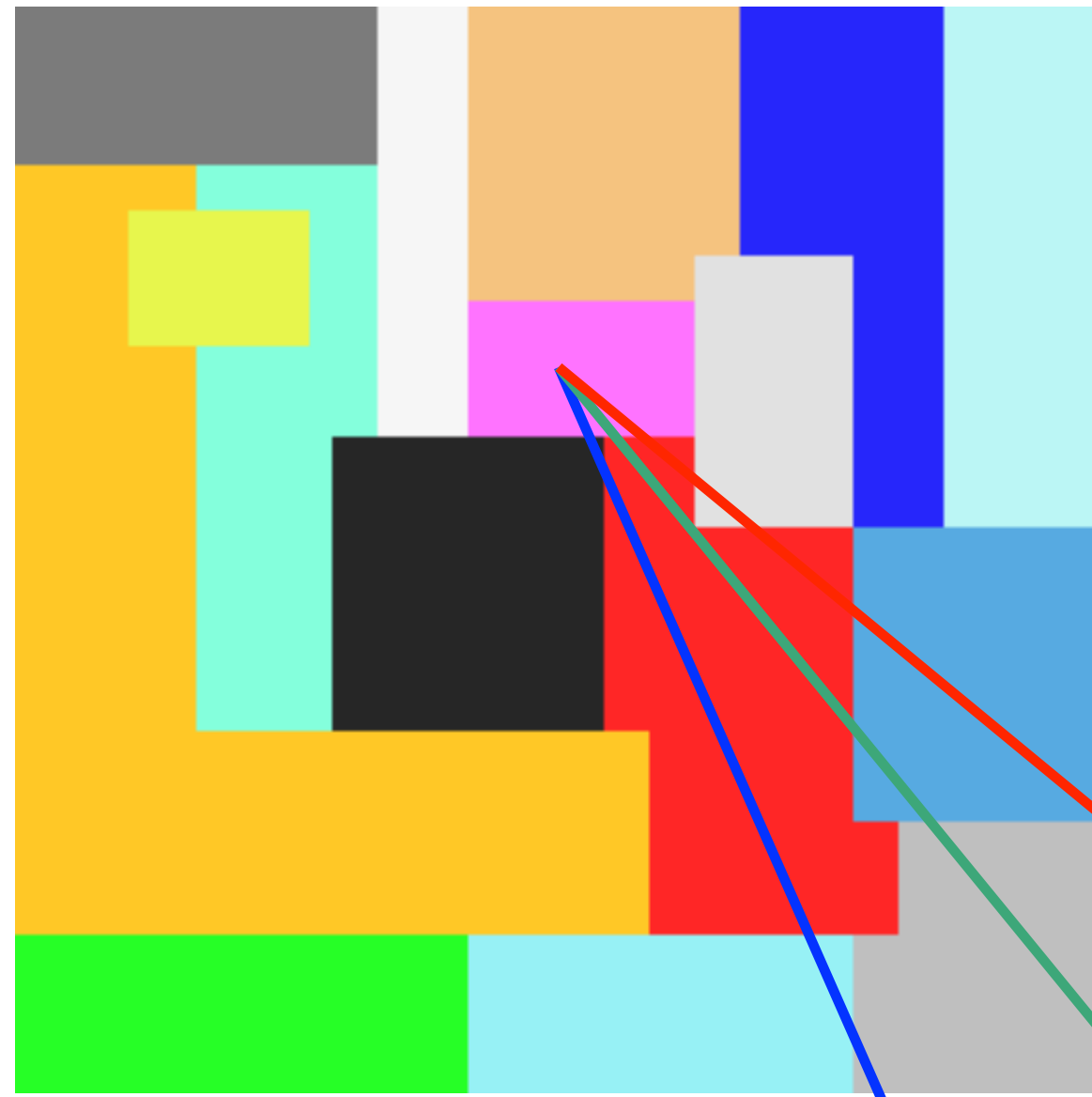
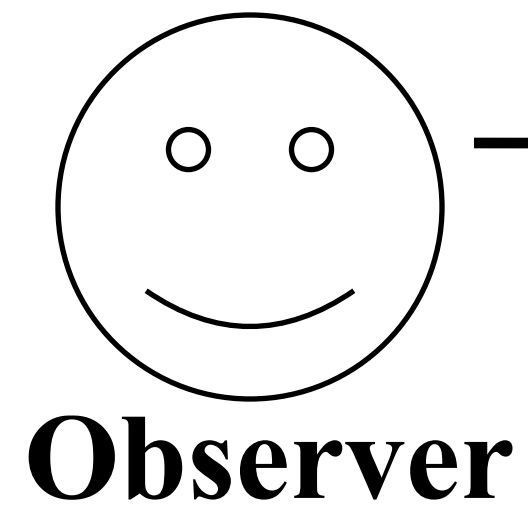




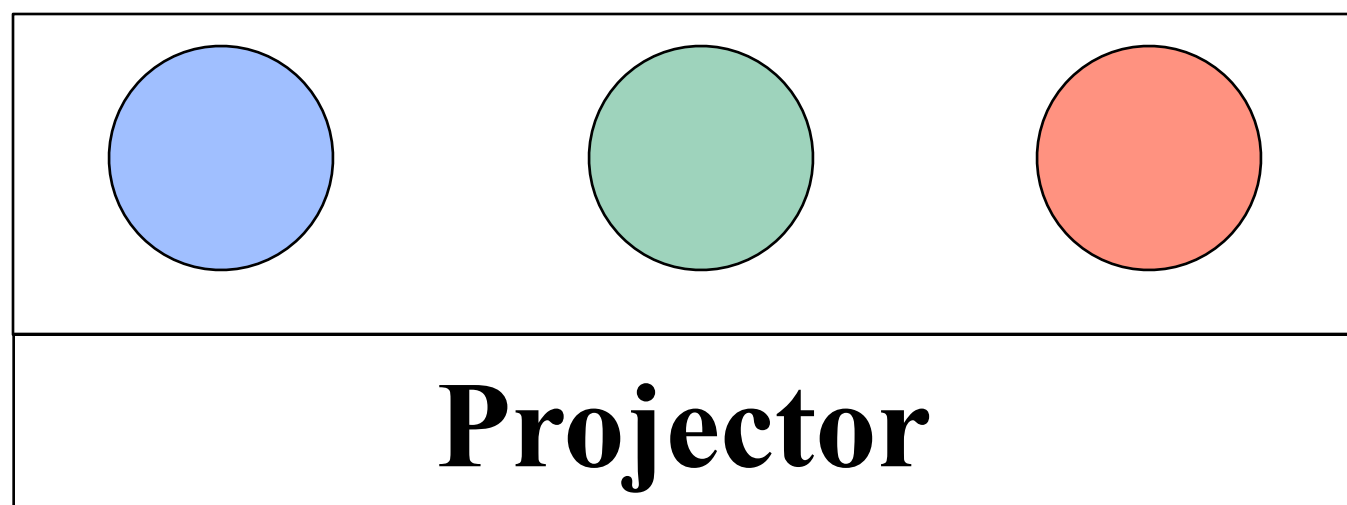




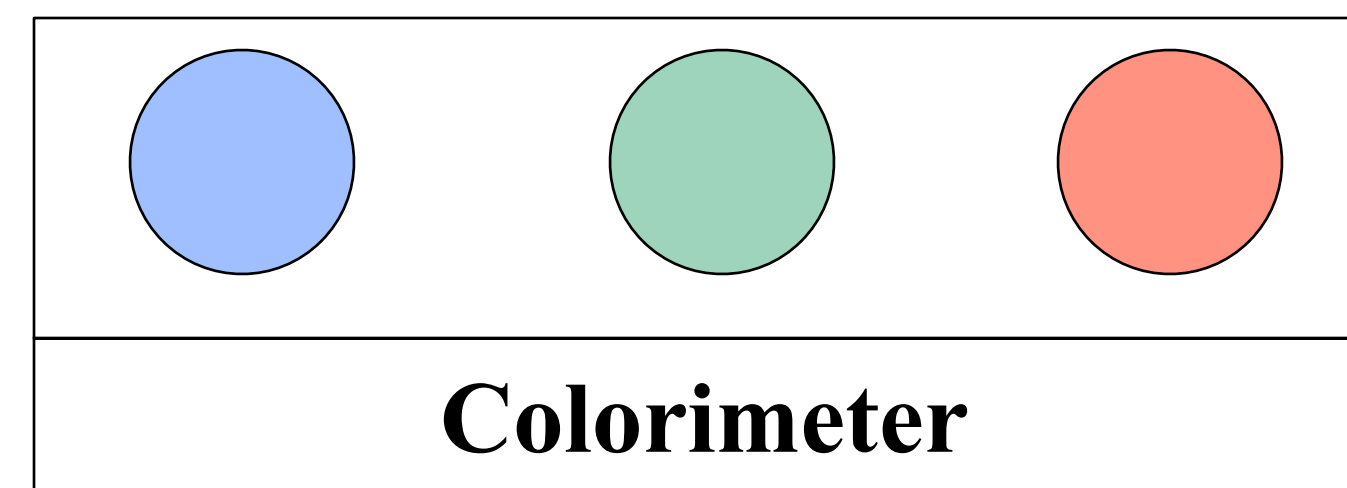


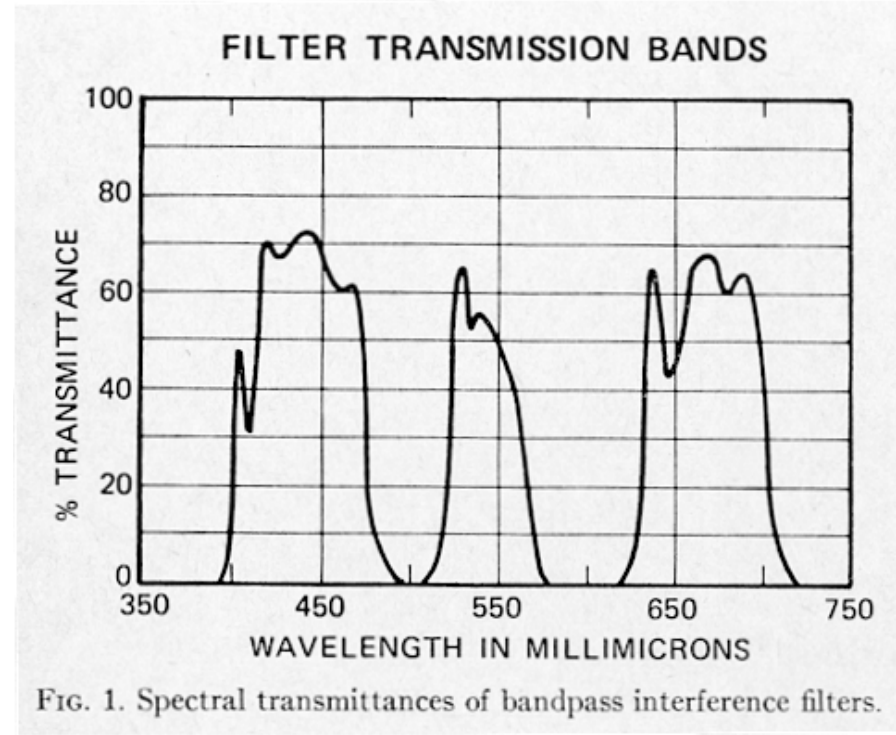
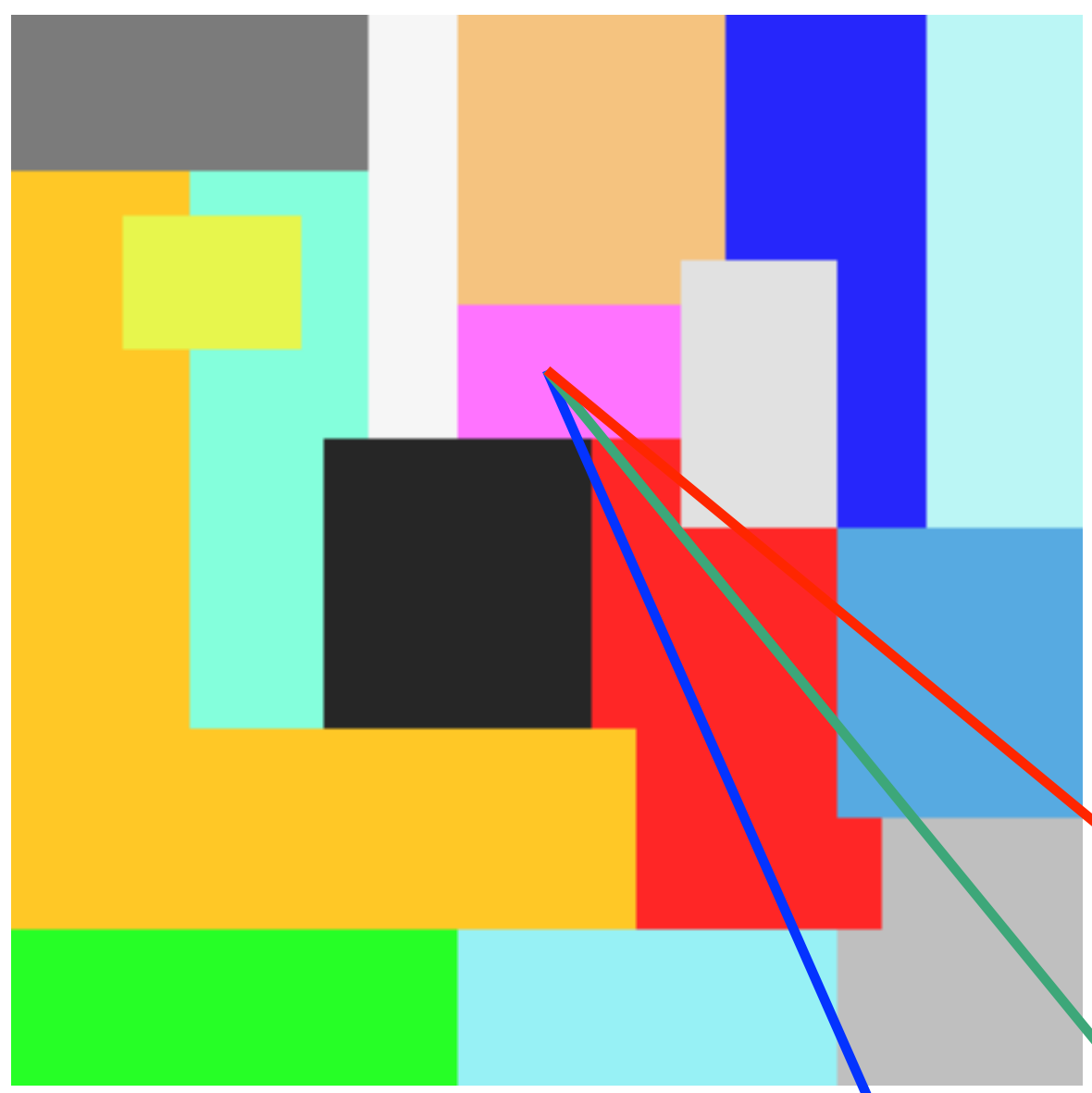
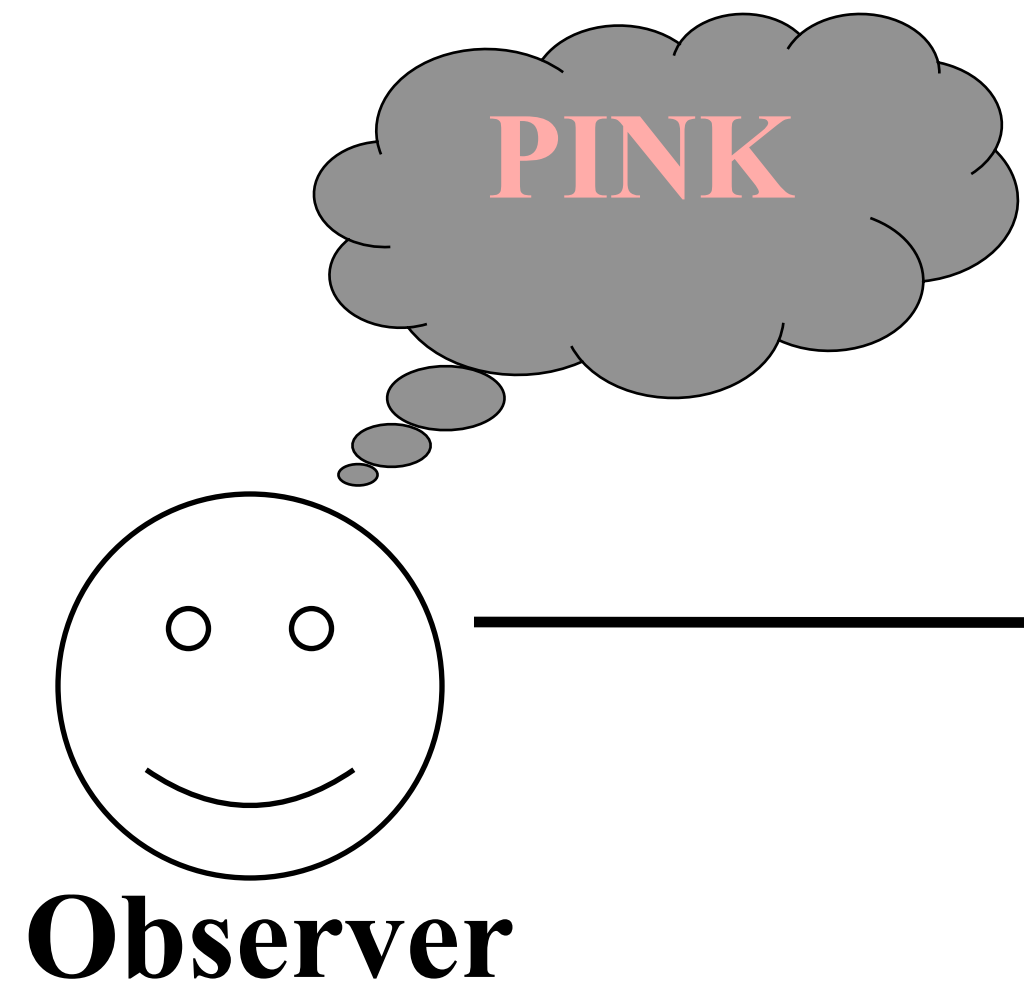


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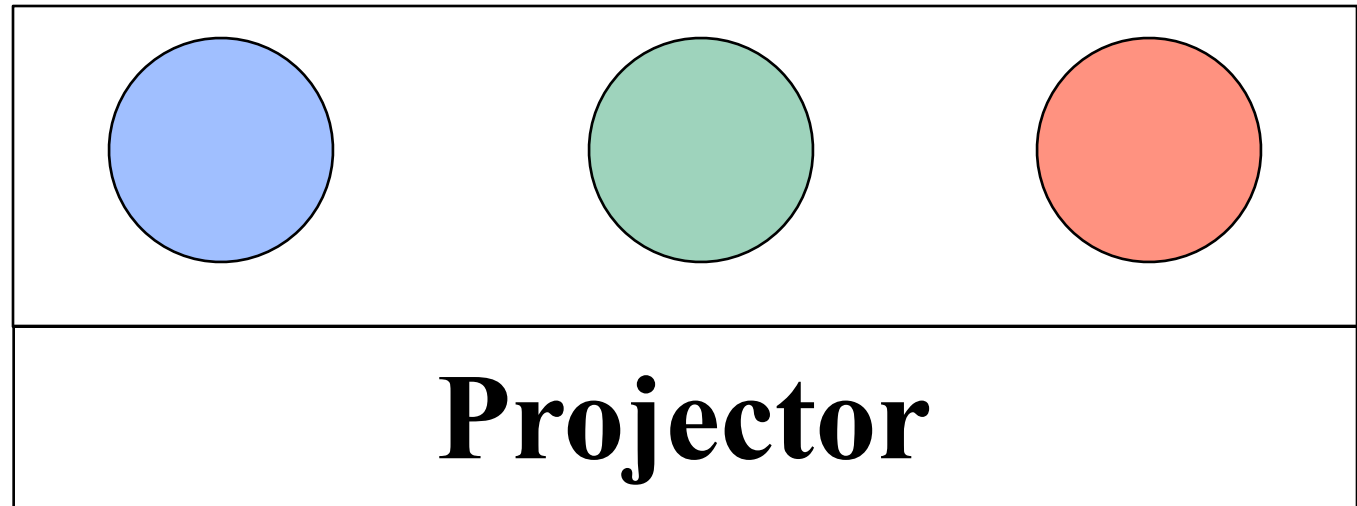


$L_S=255$   $L_M=115$   $L_L=255$

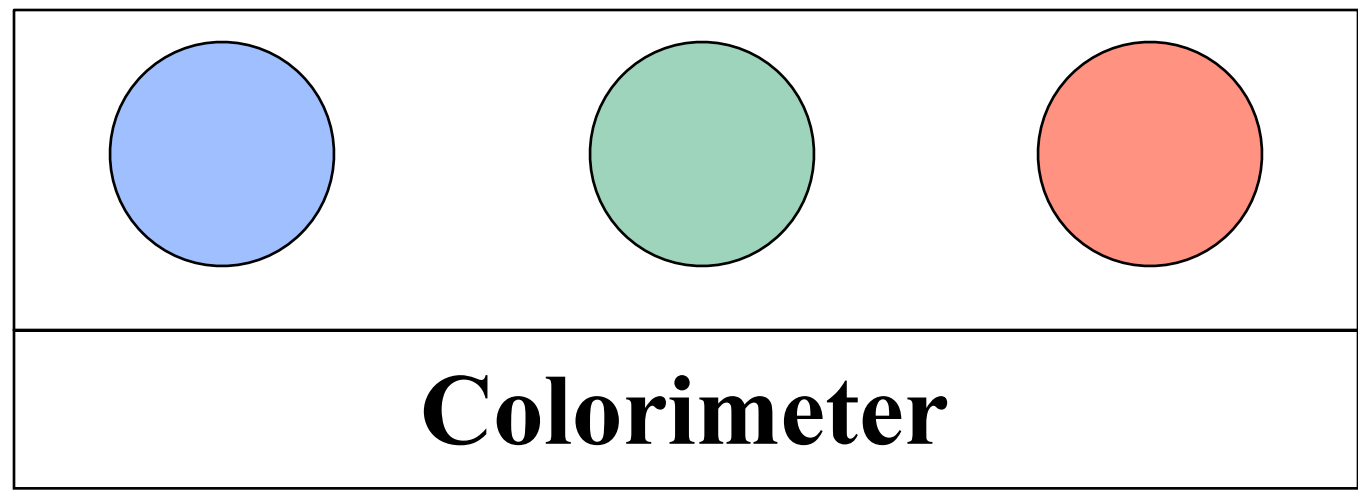


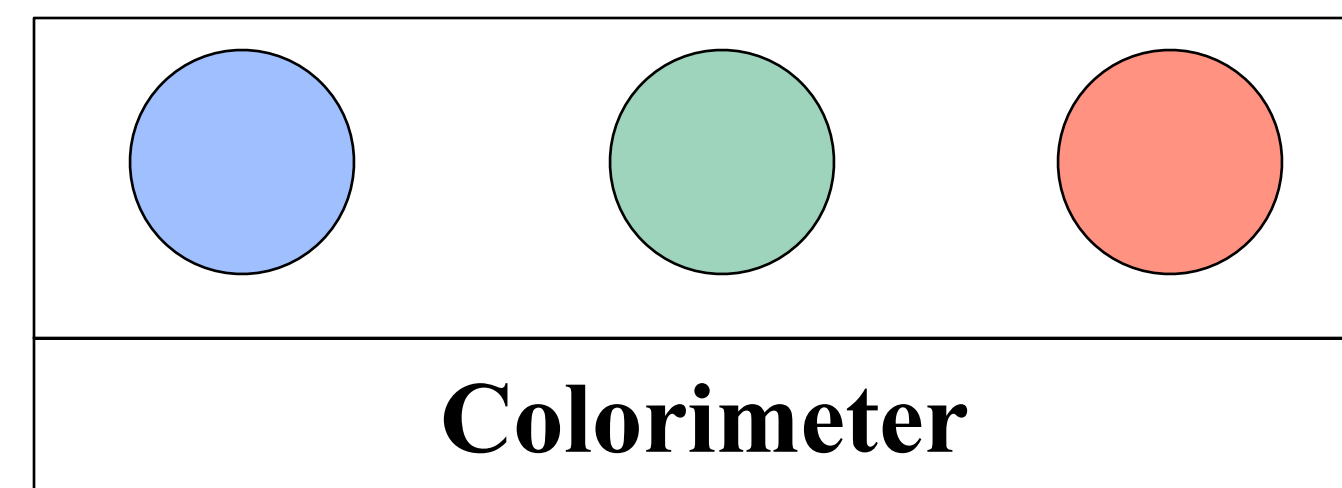
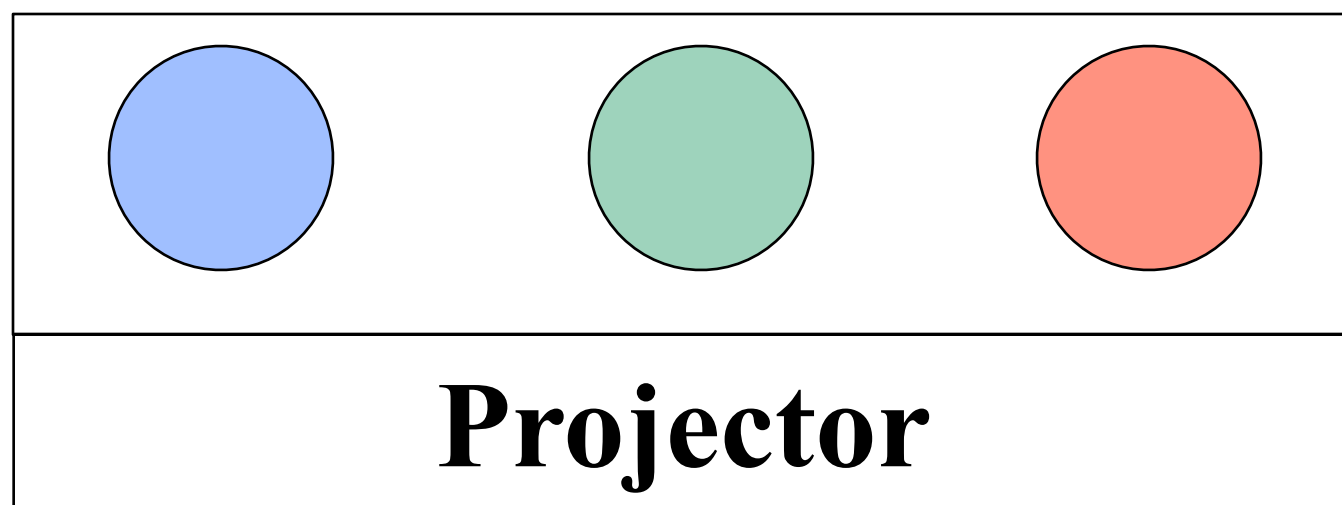
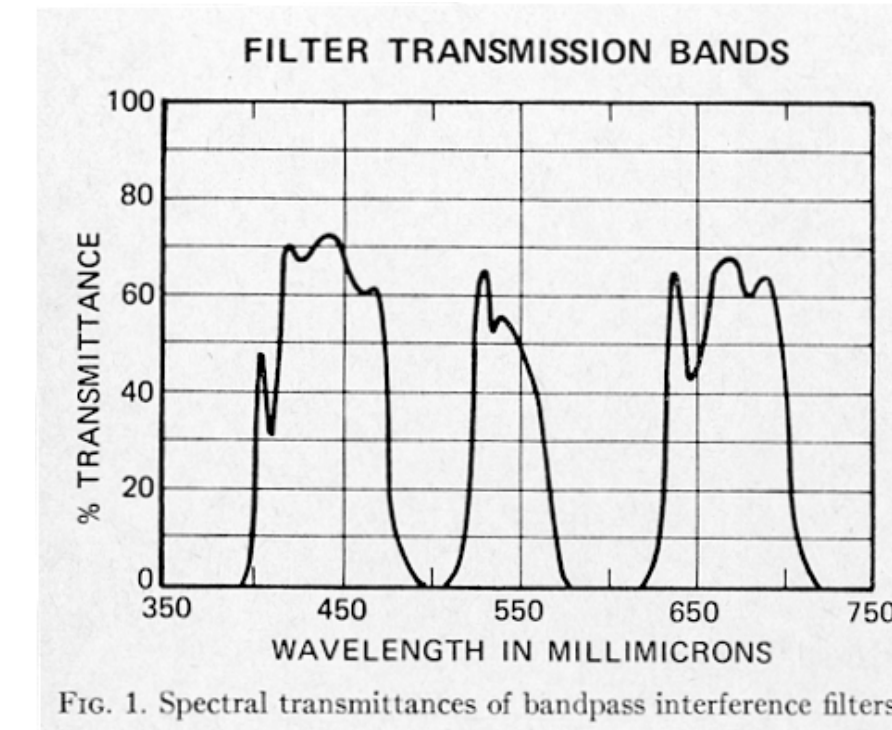
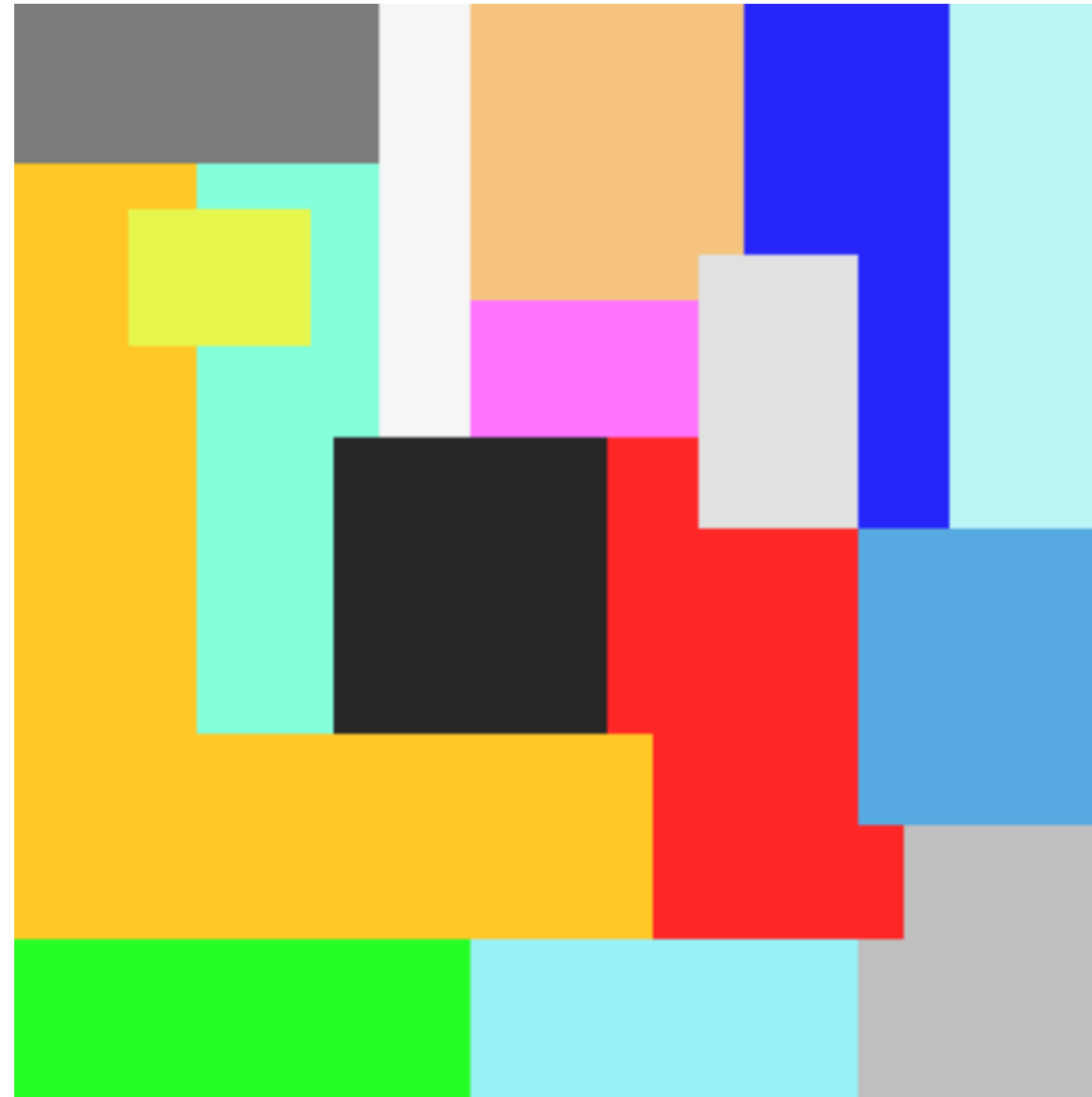
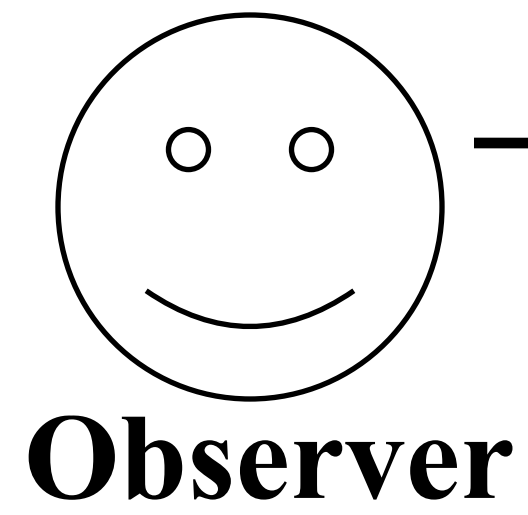


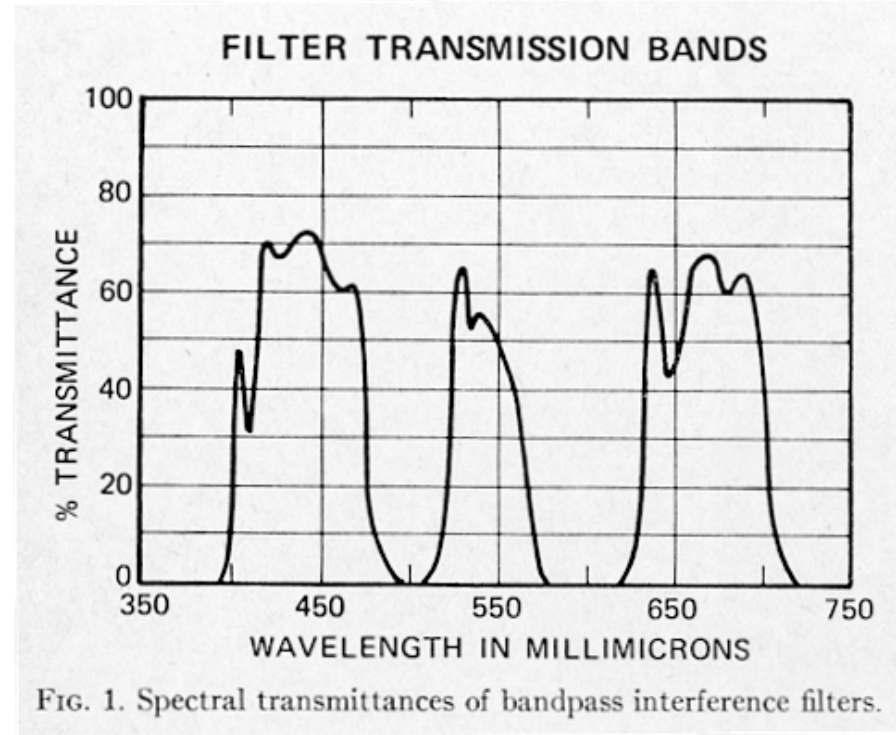
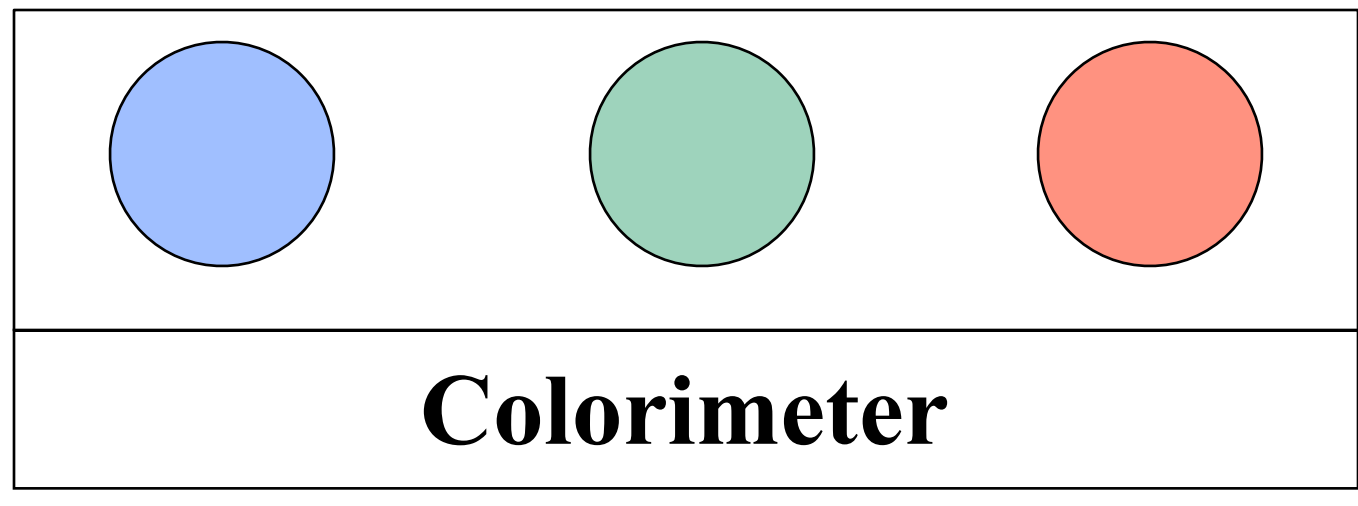
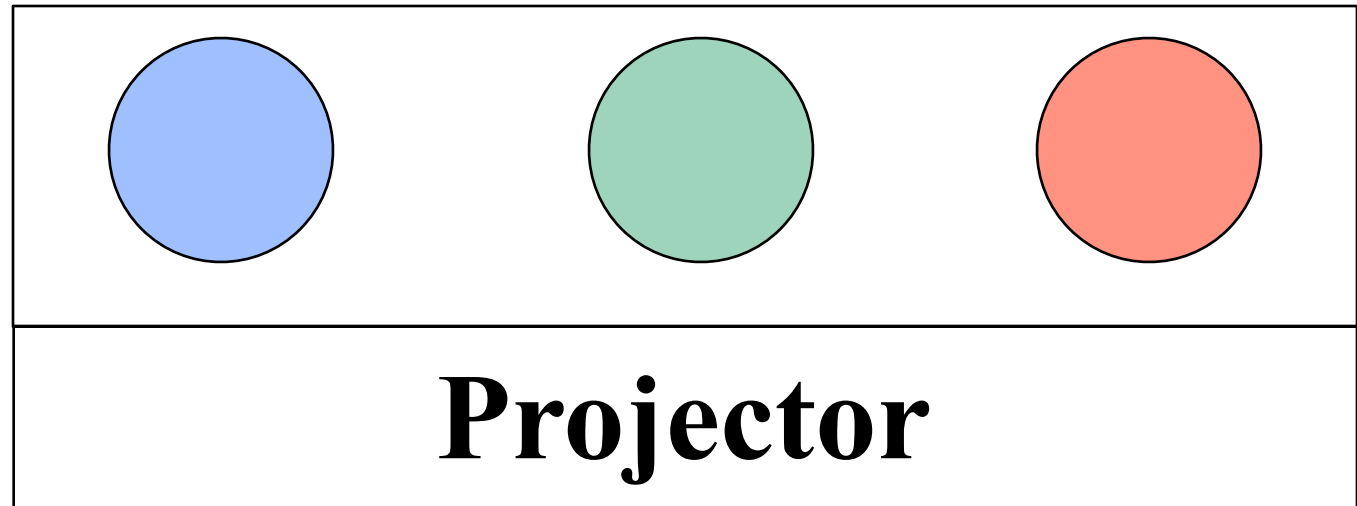
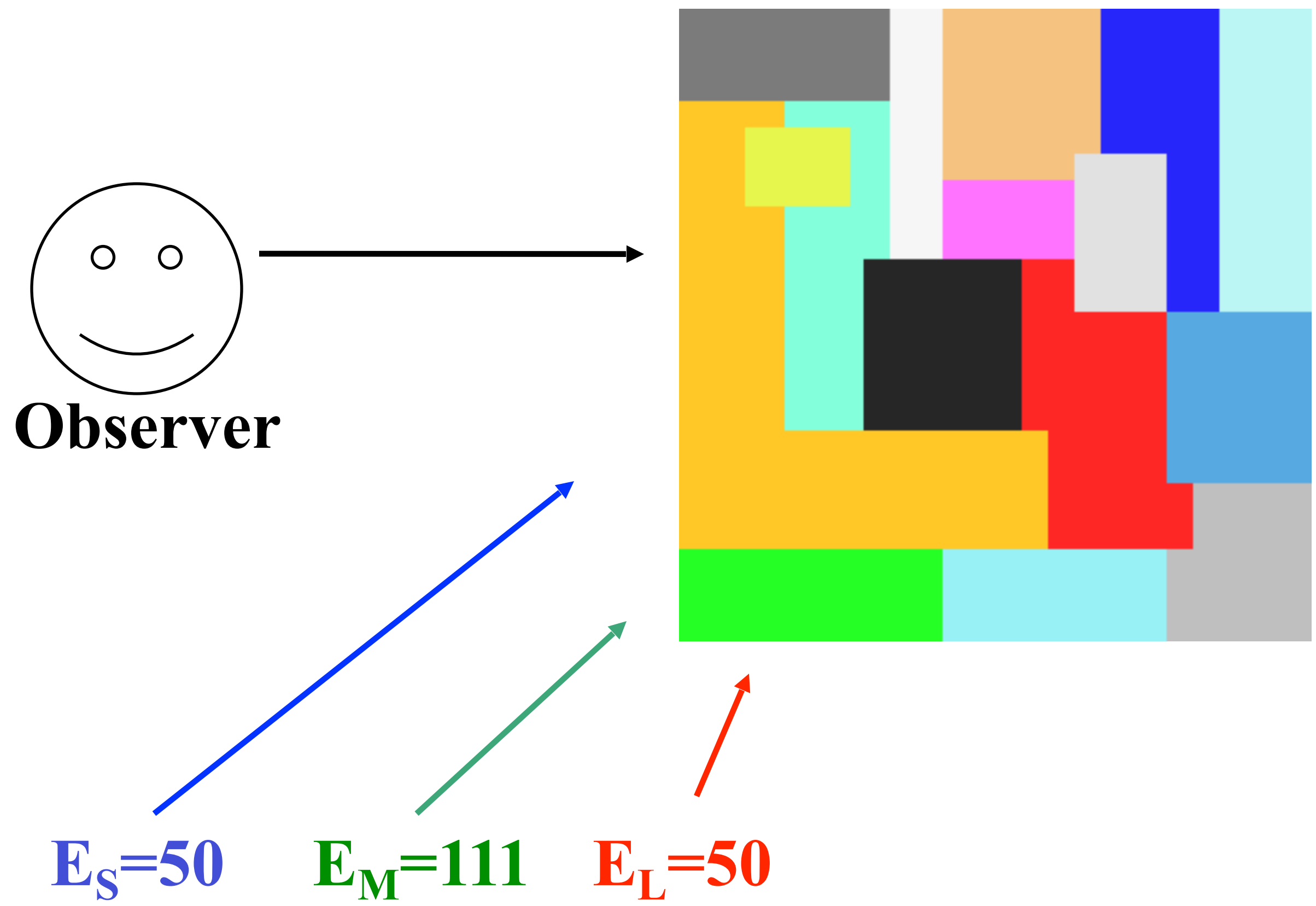
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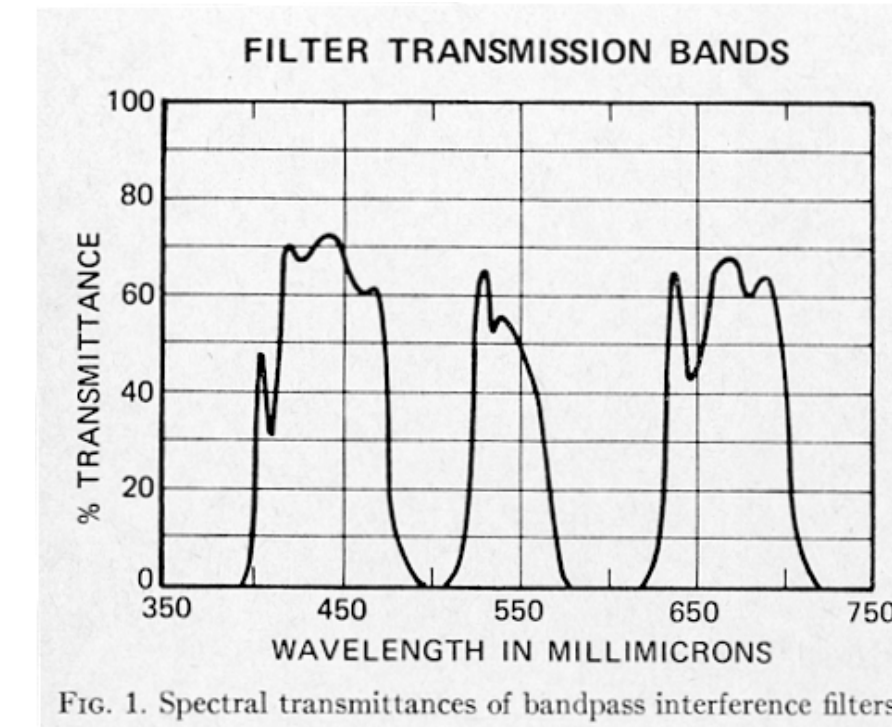
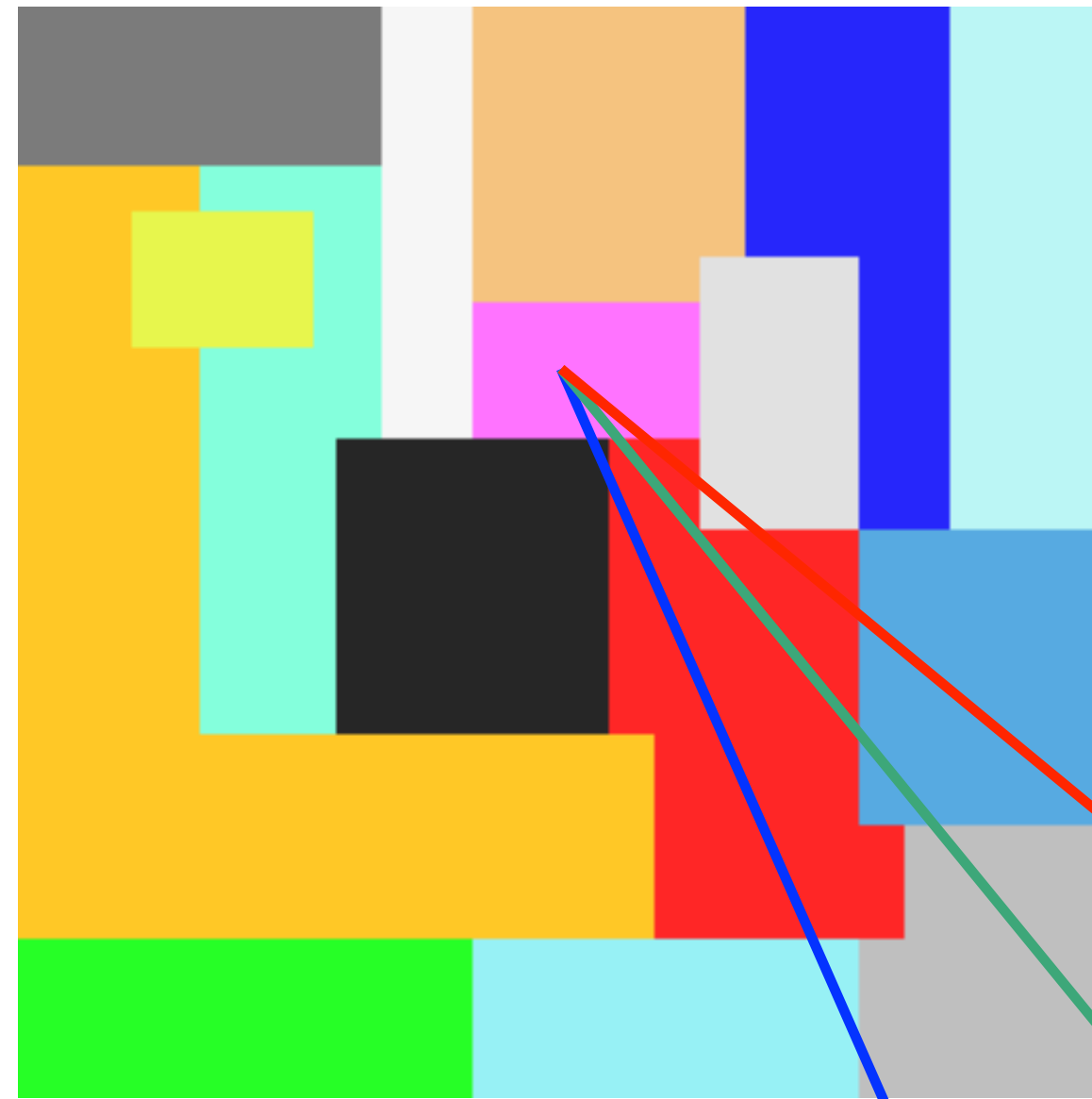
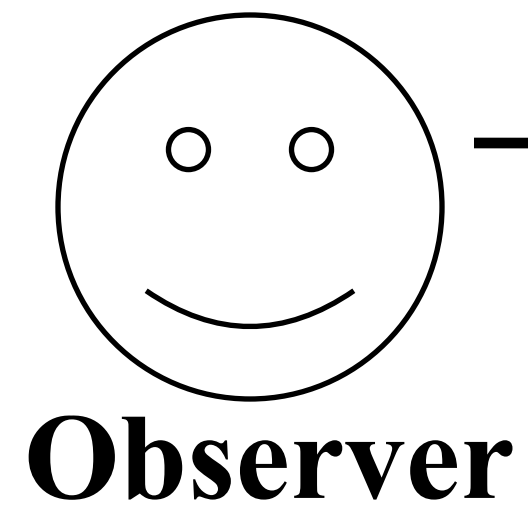


$L_S=255$     $L_M=115$     $L_L=255$

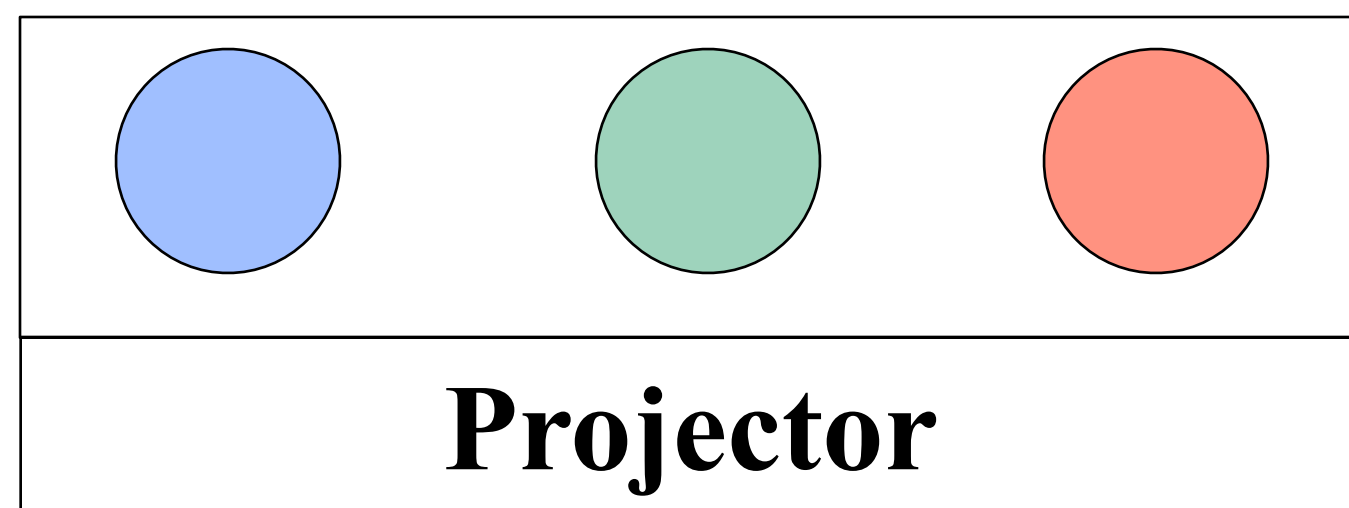




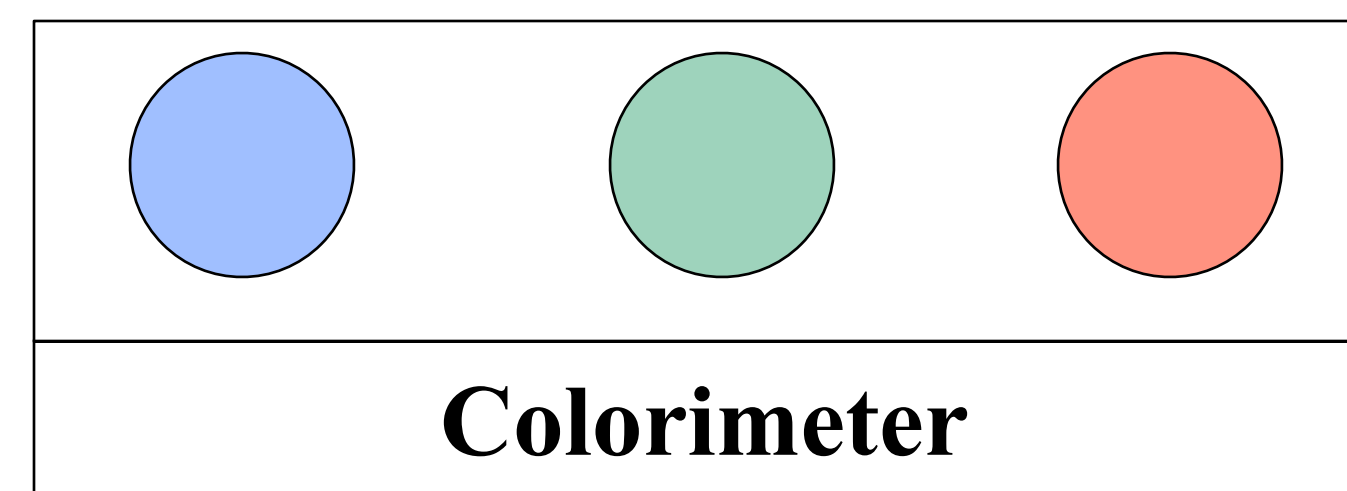


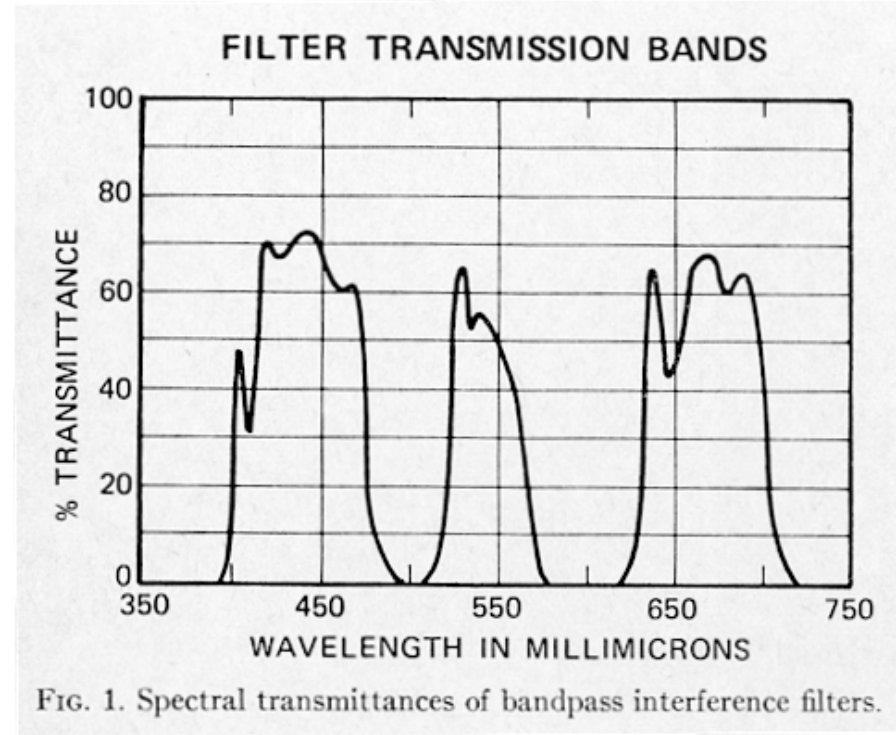
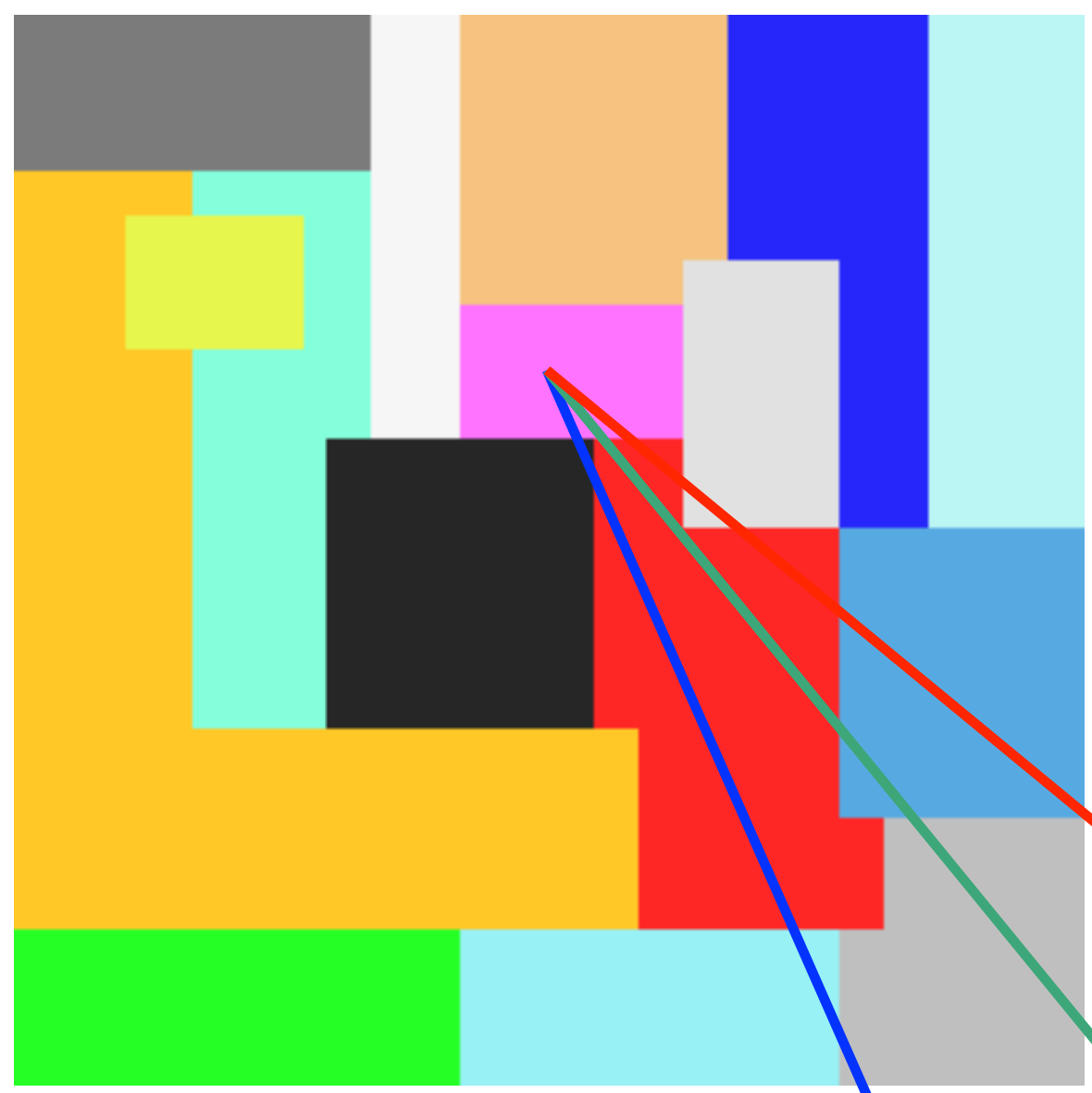
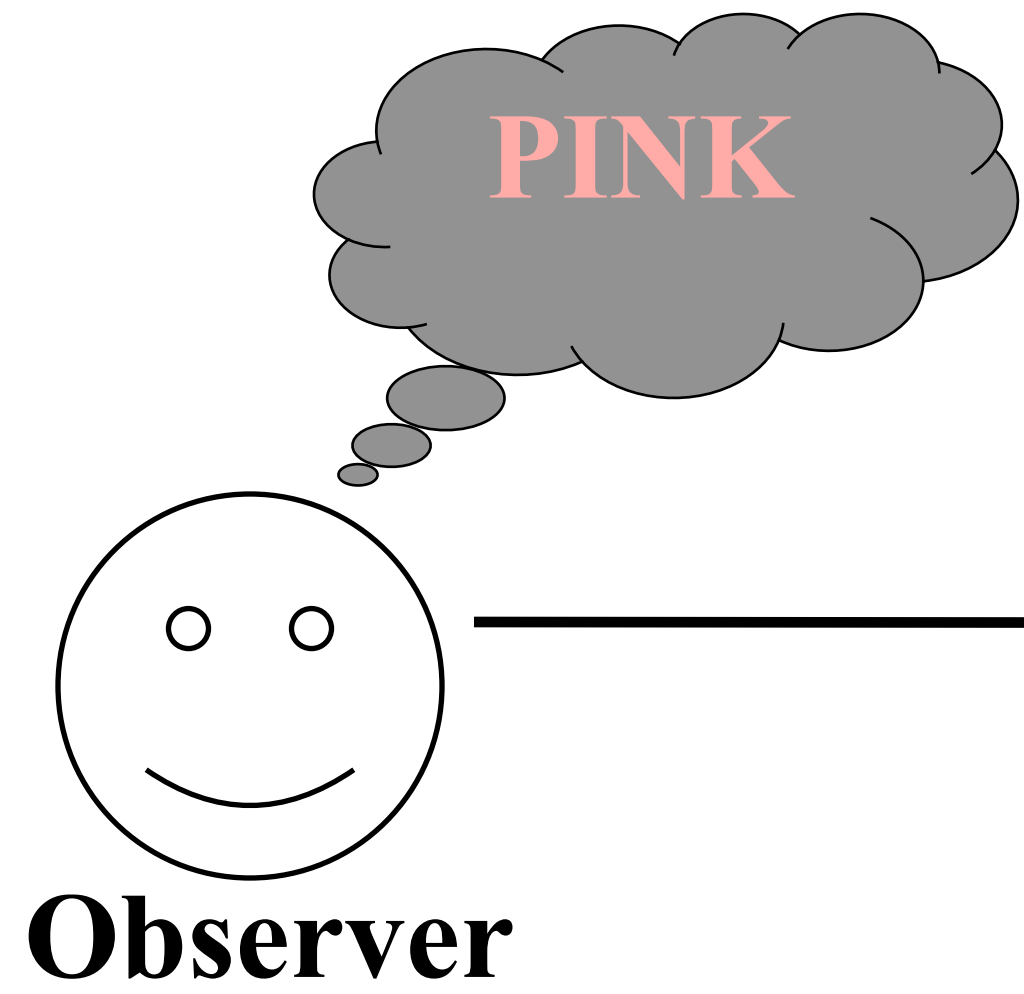


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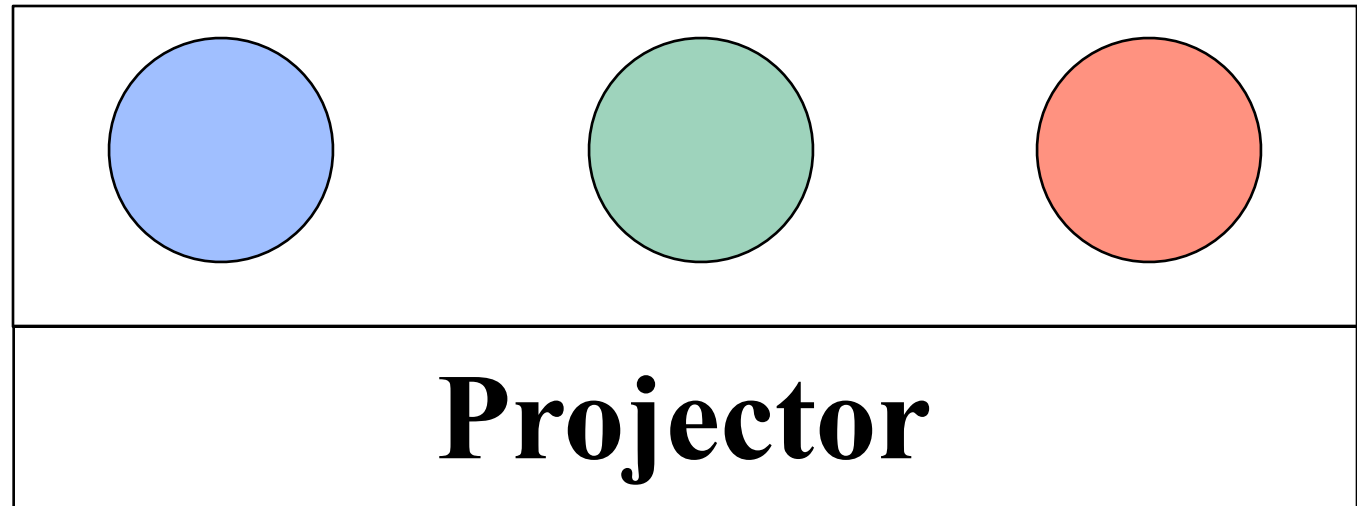


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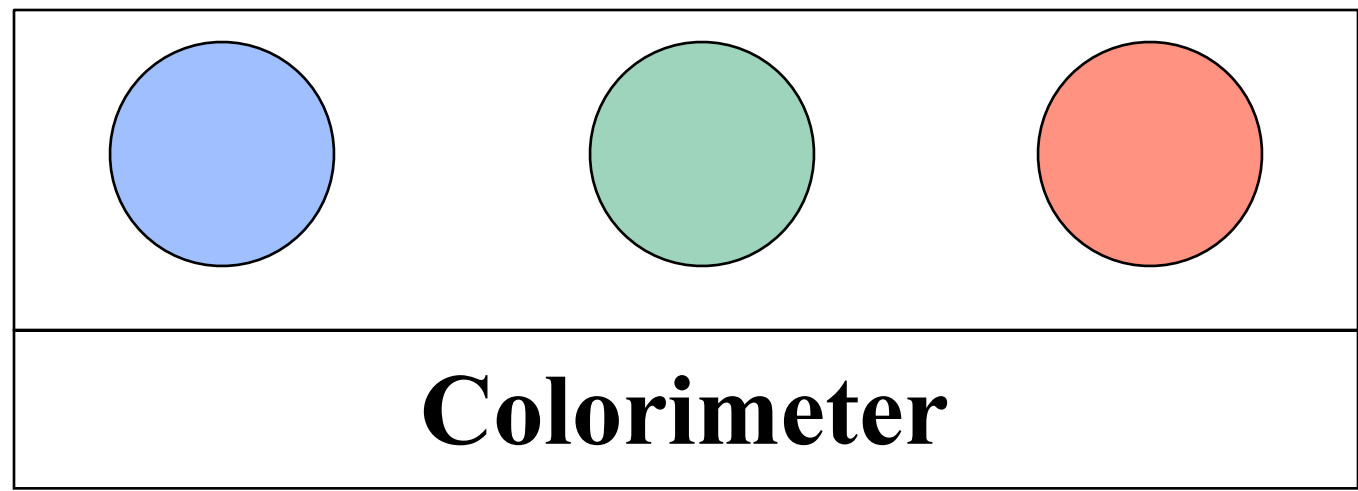


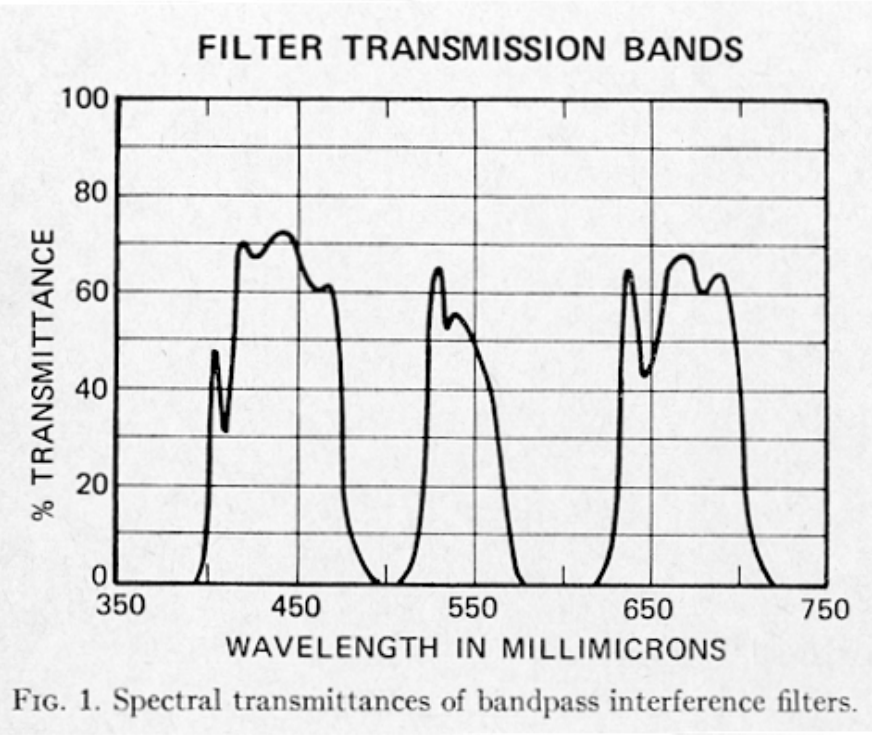
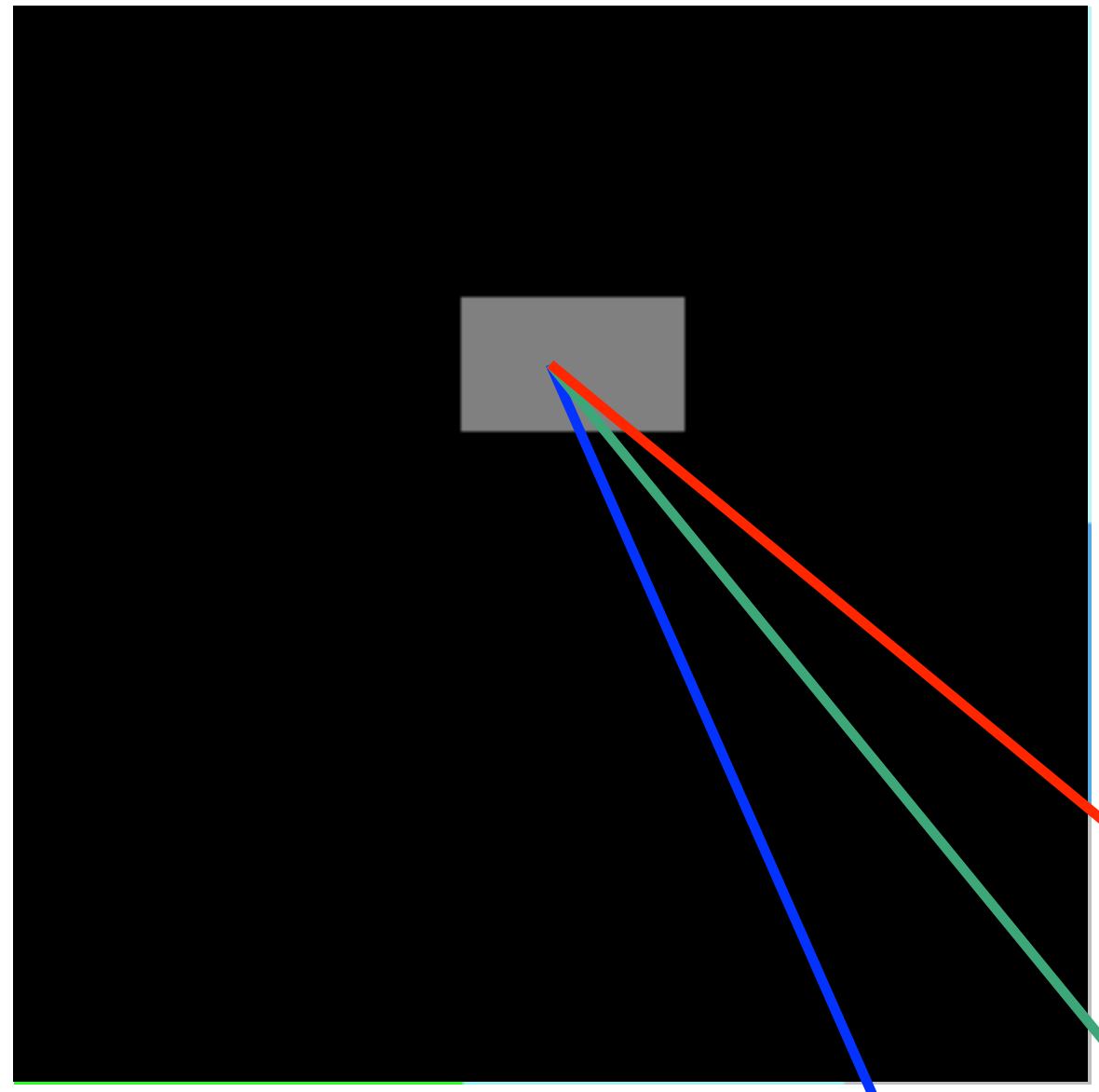
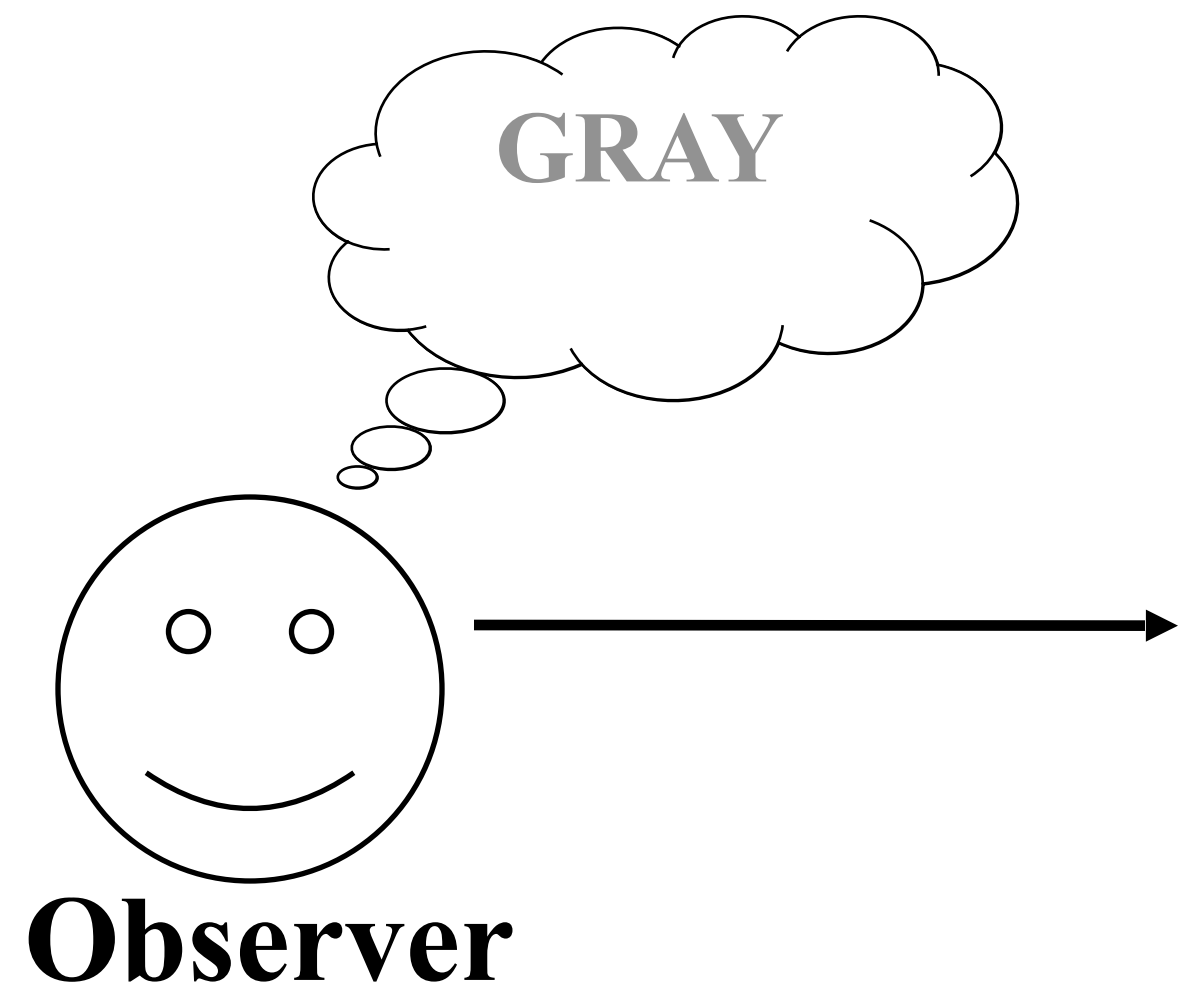


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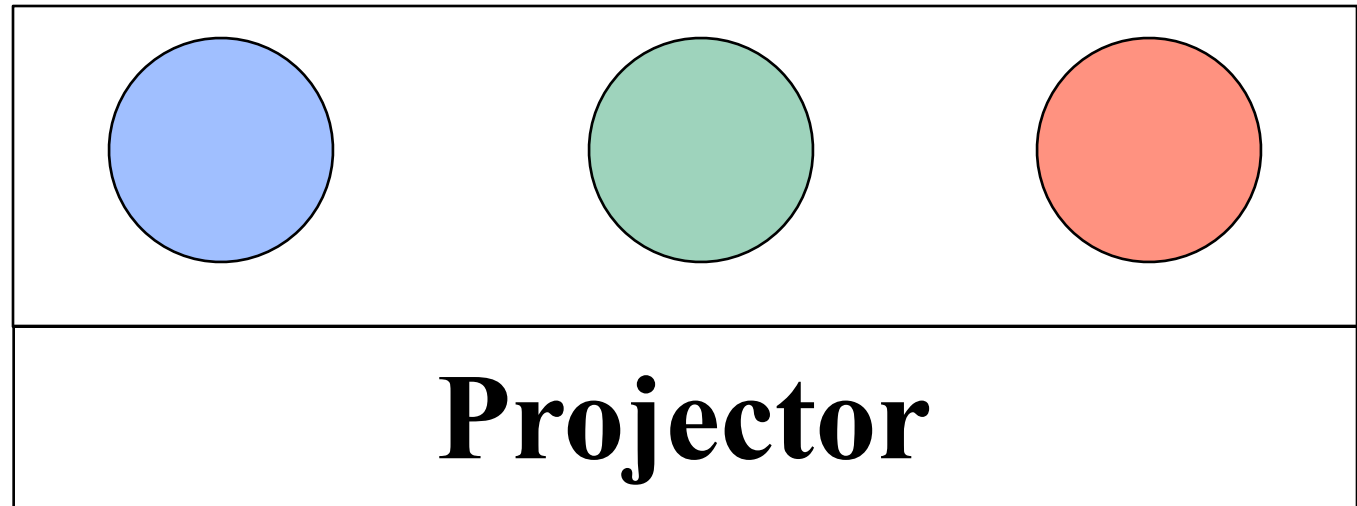


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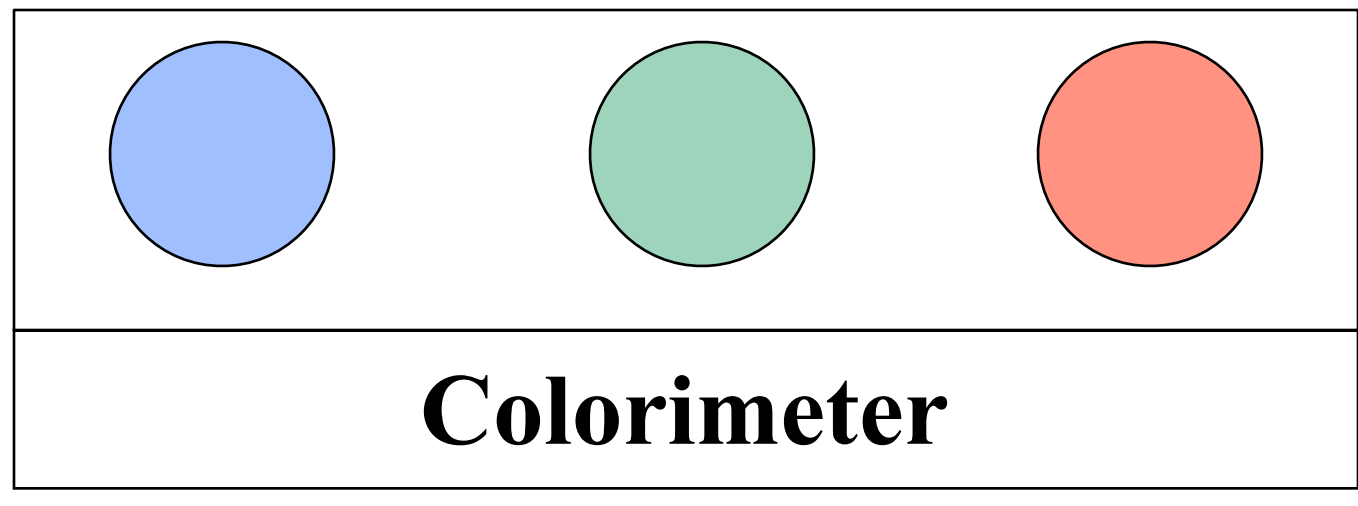


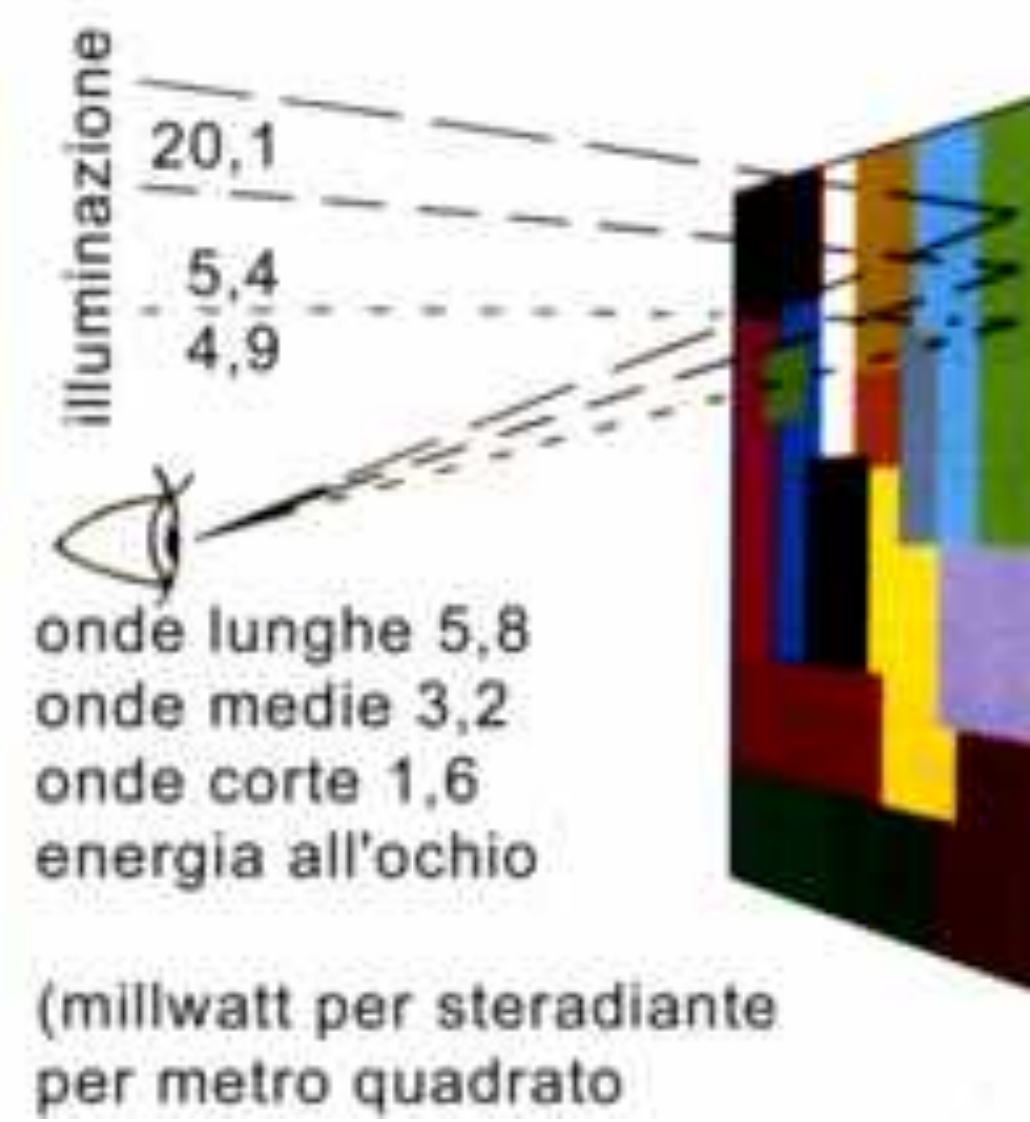
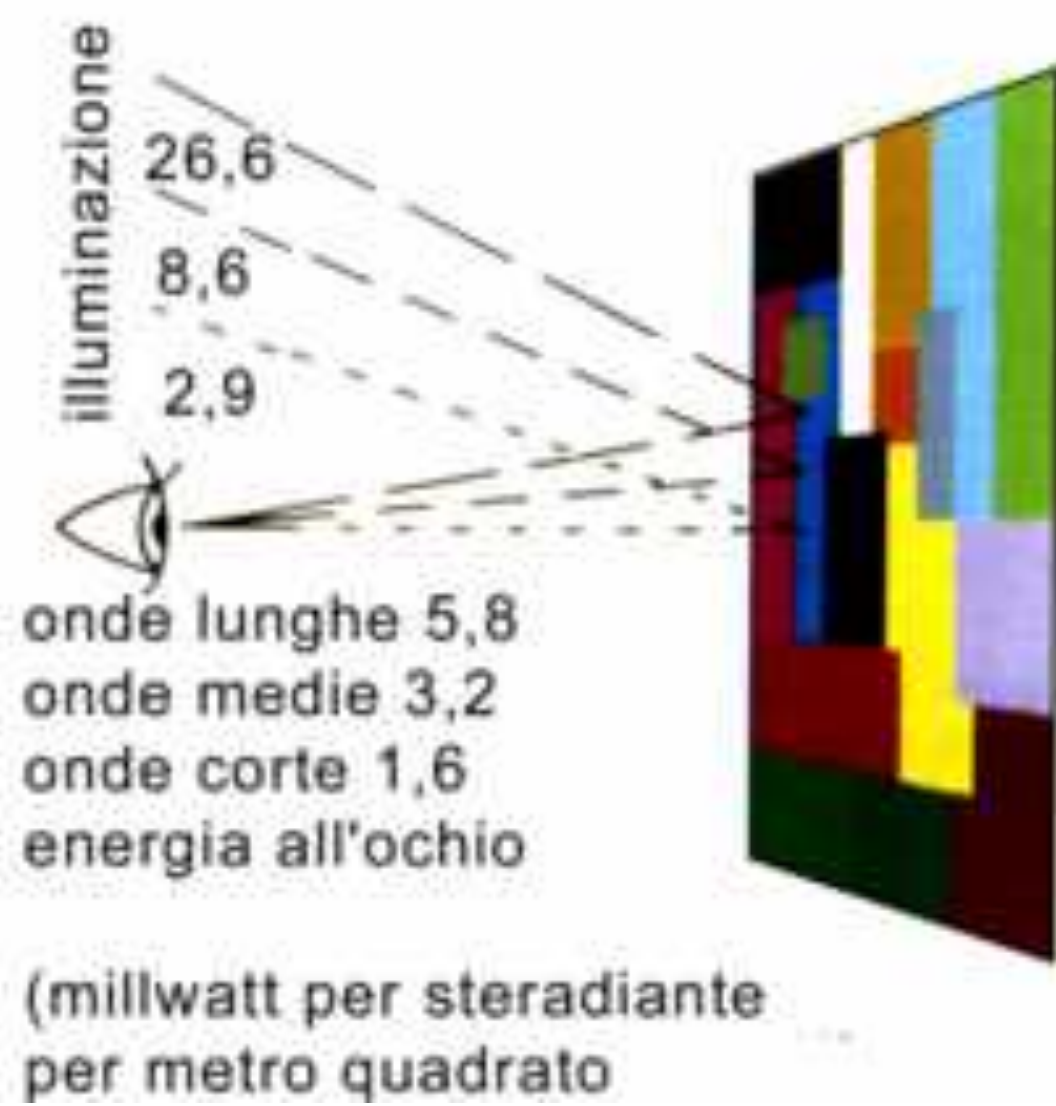
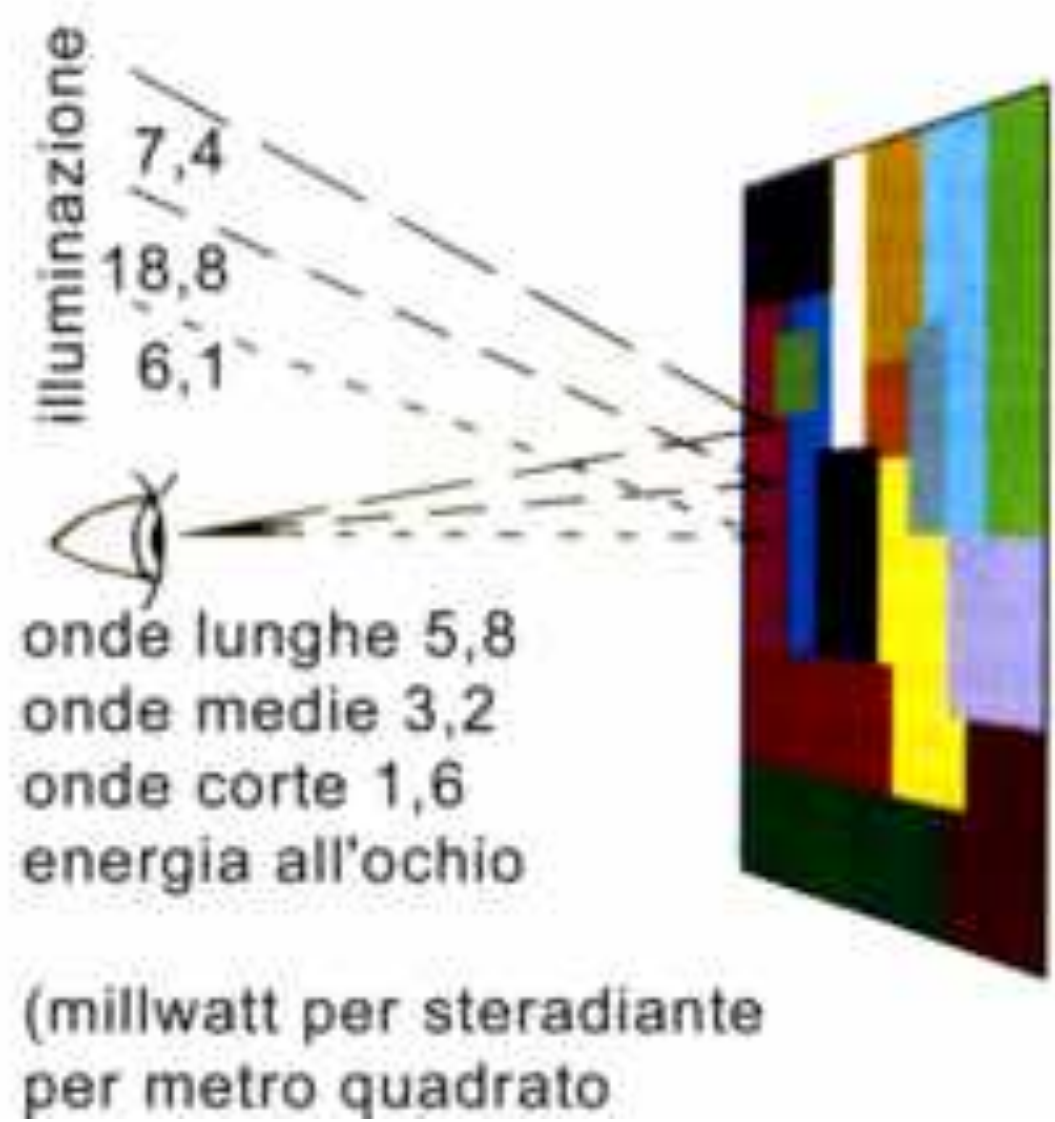


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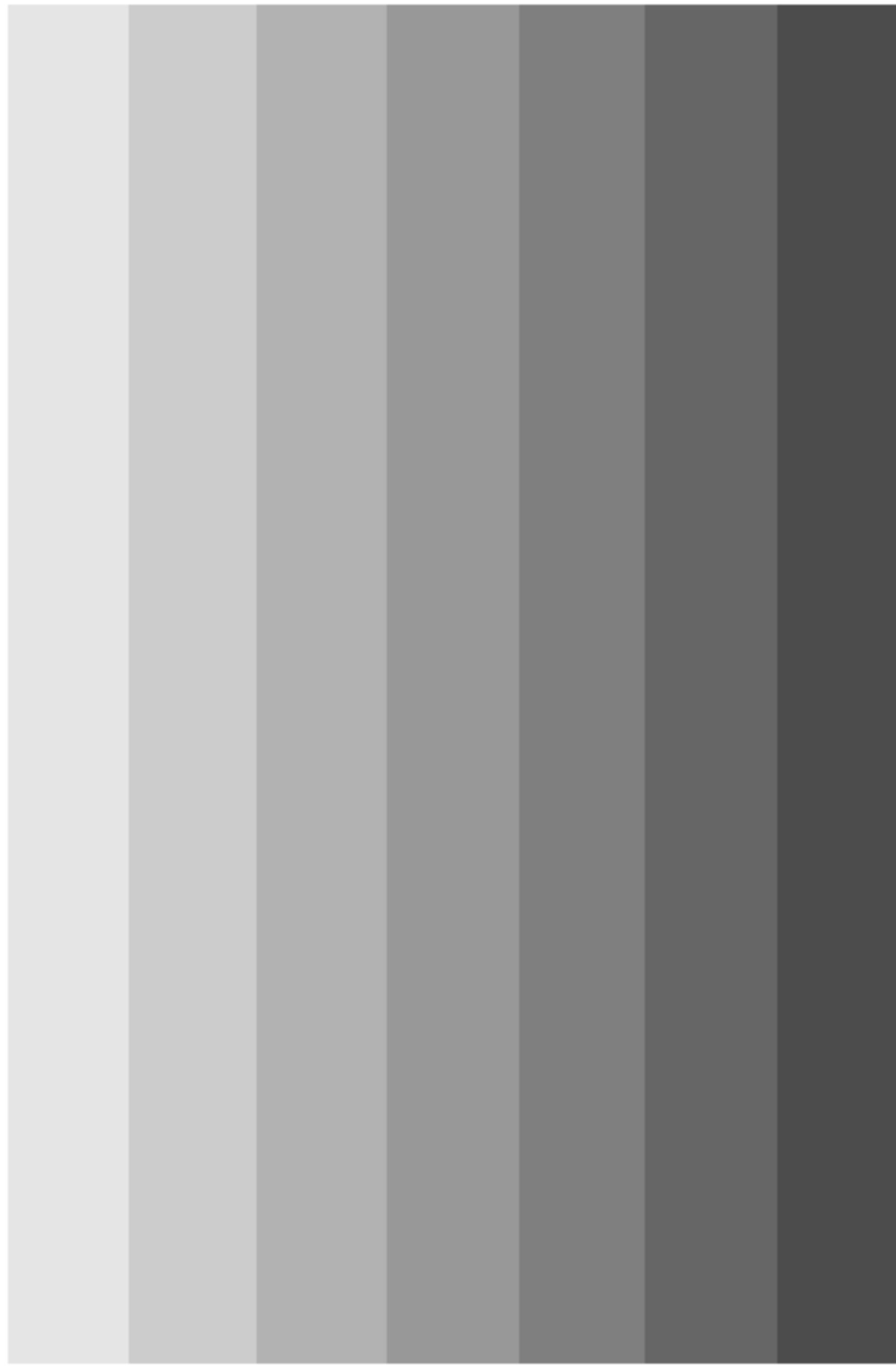
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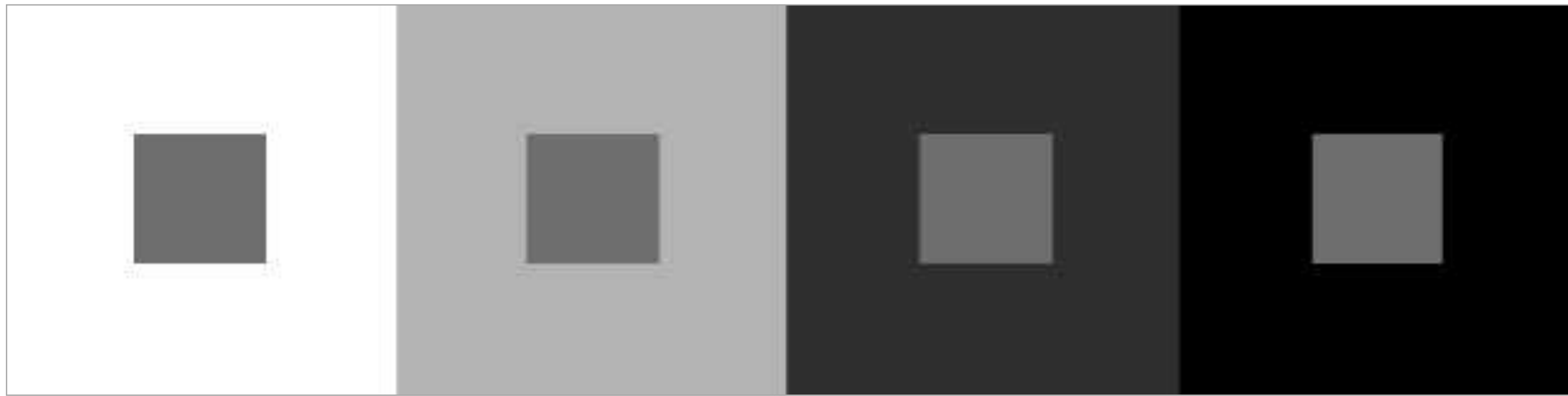


# **Effetto Cornsweet**

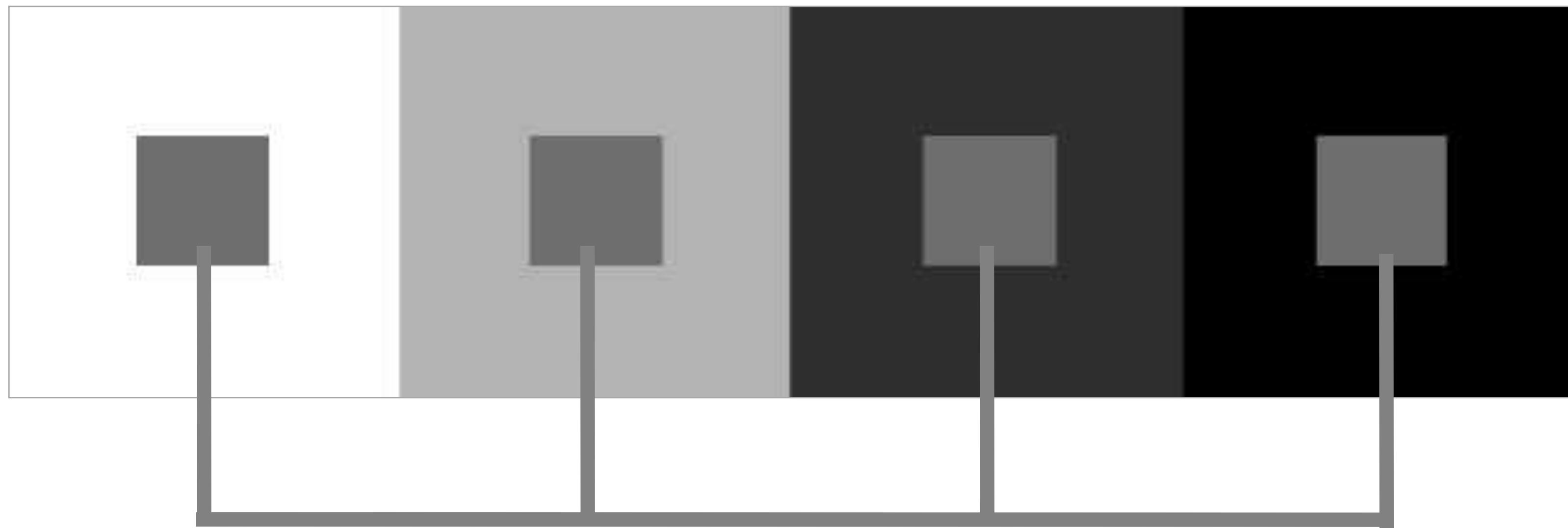


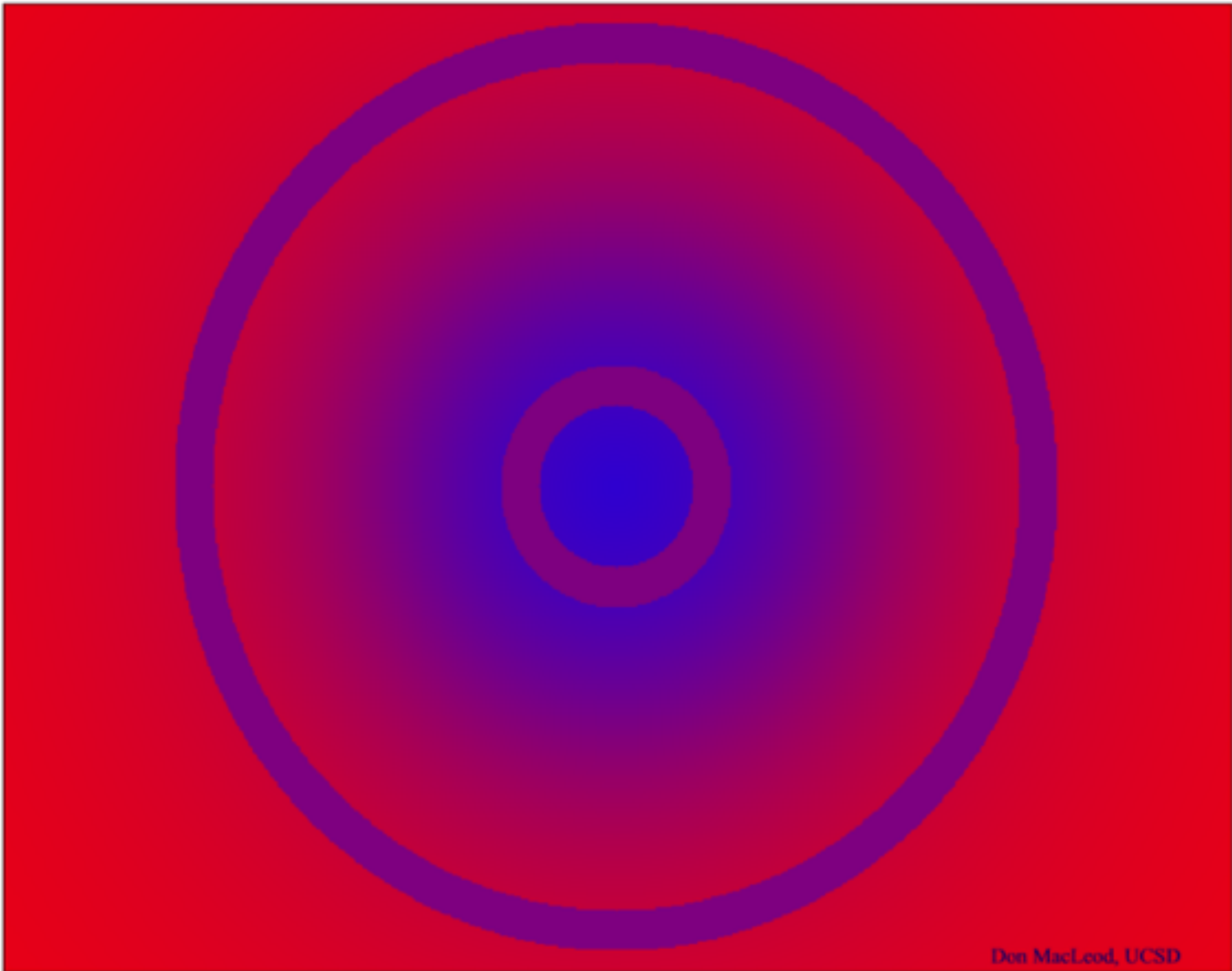
# Contrasto di simultaneità

# Contrasto di simultaneità

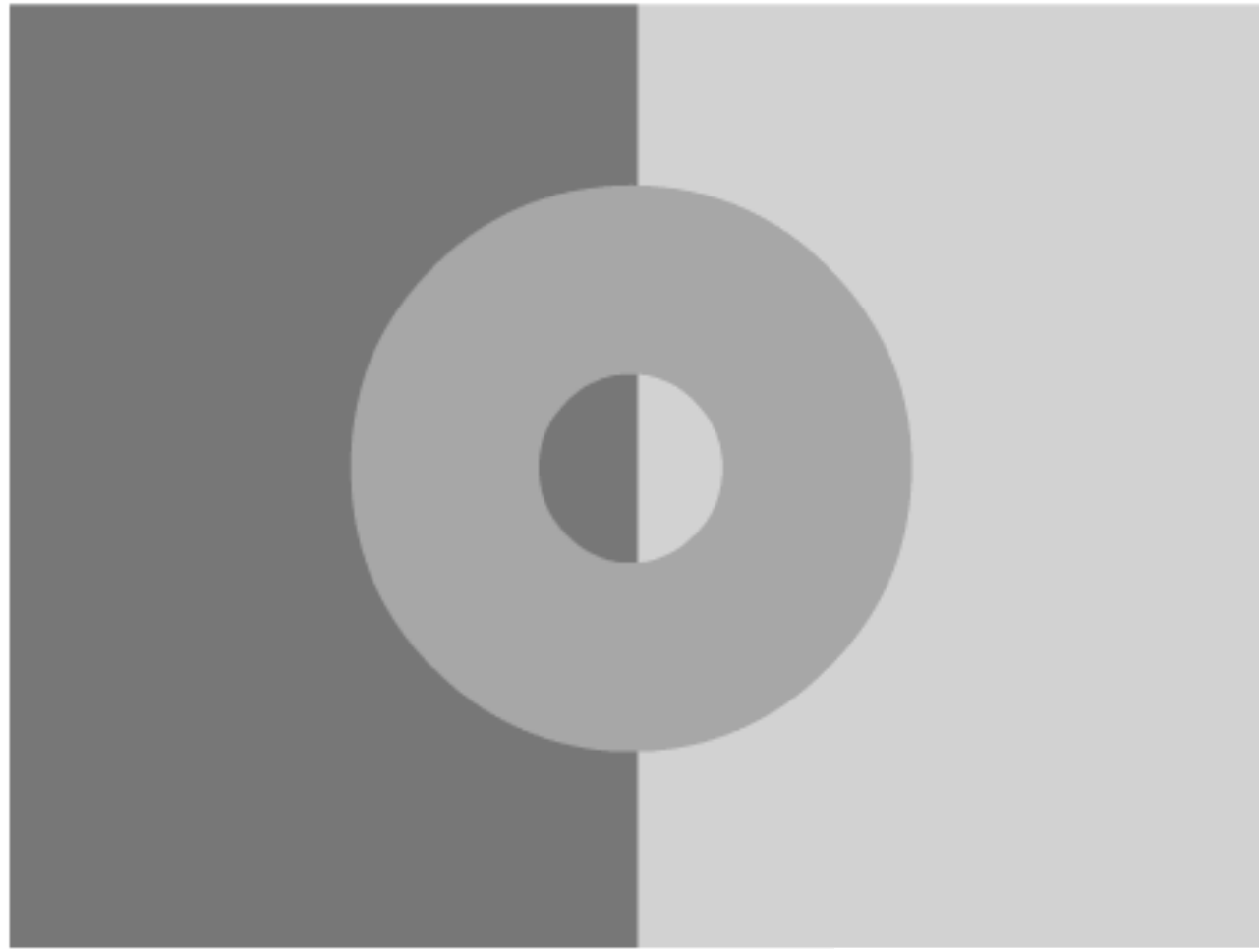


# Contrasto di simultaneità

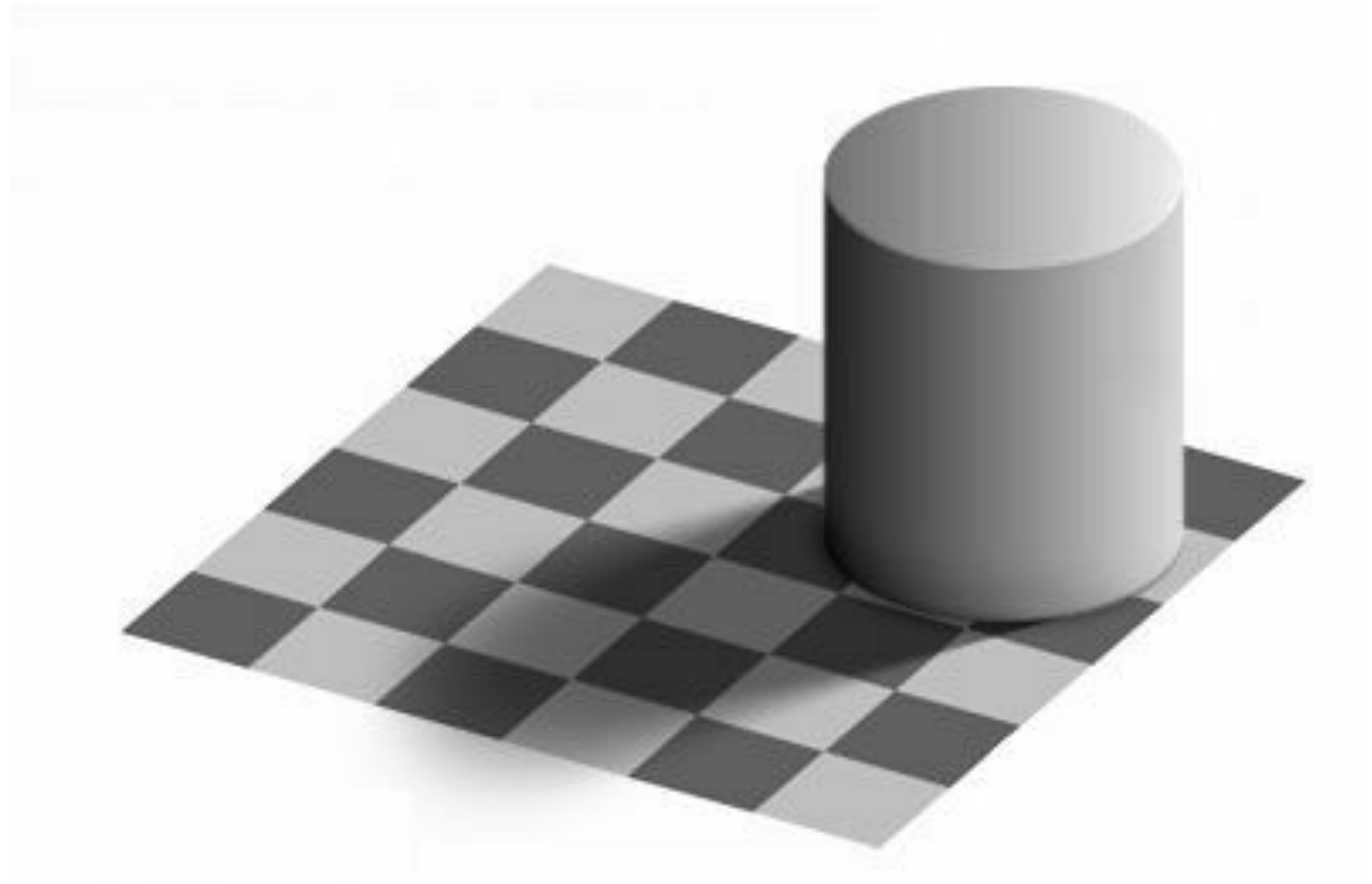




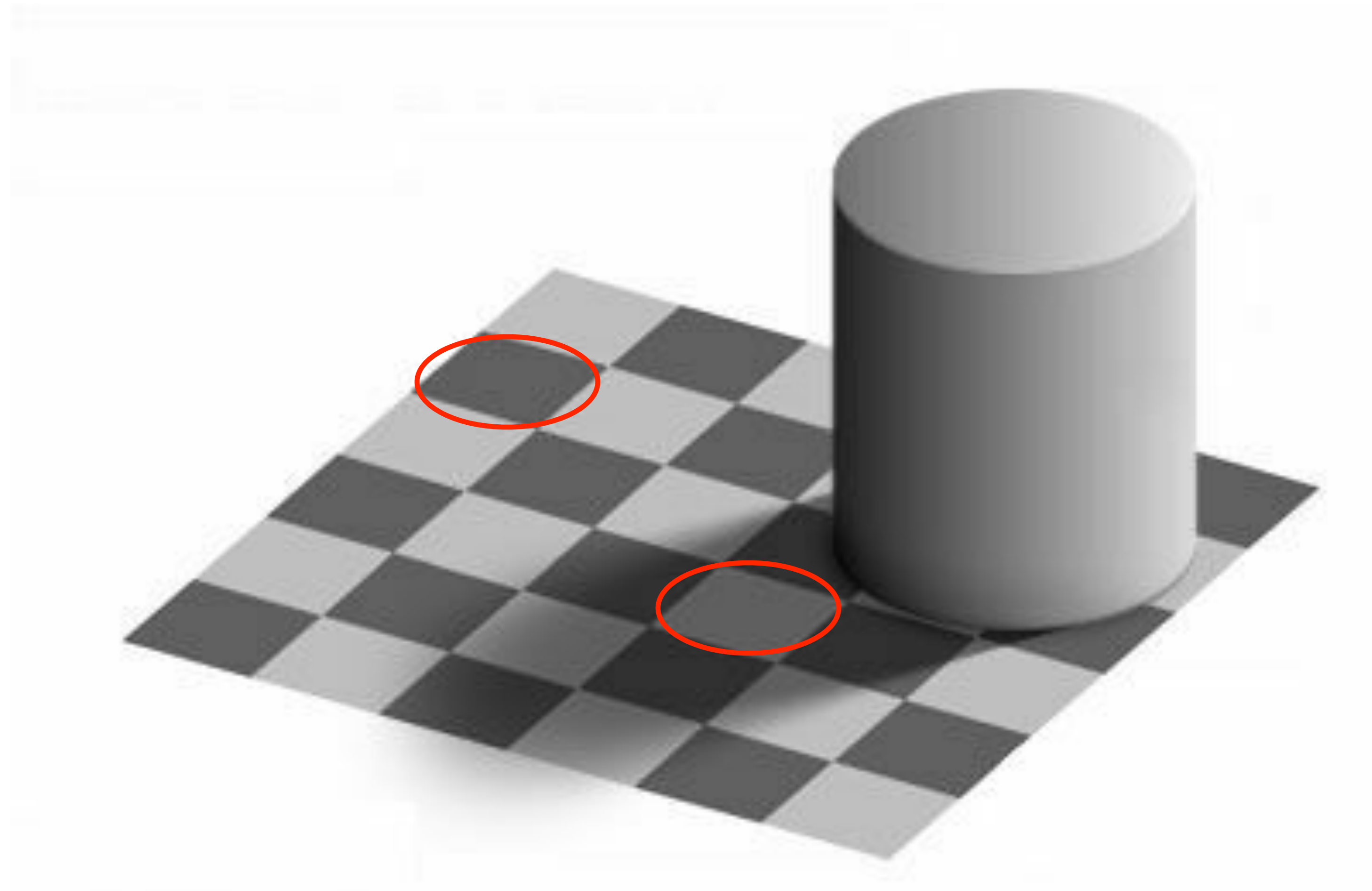
# Koffka ring



# Configurazione 3D

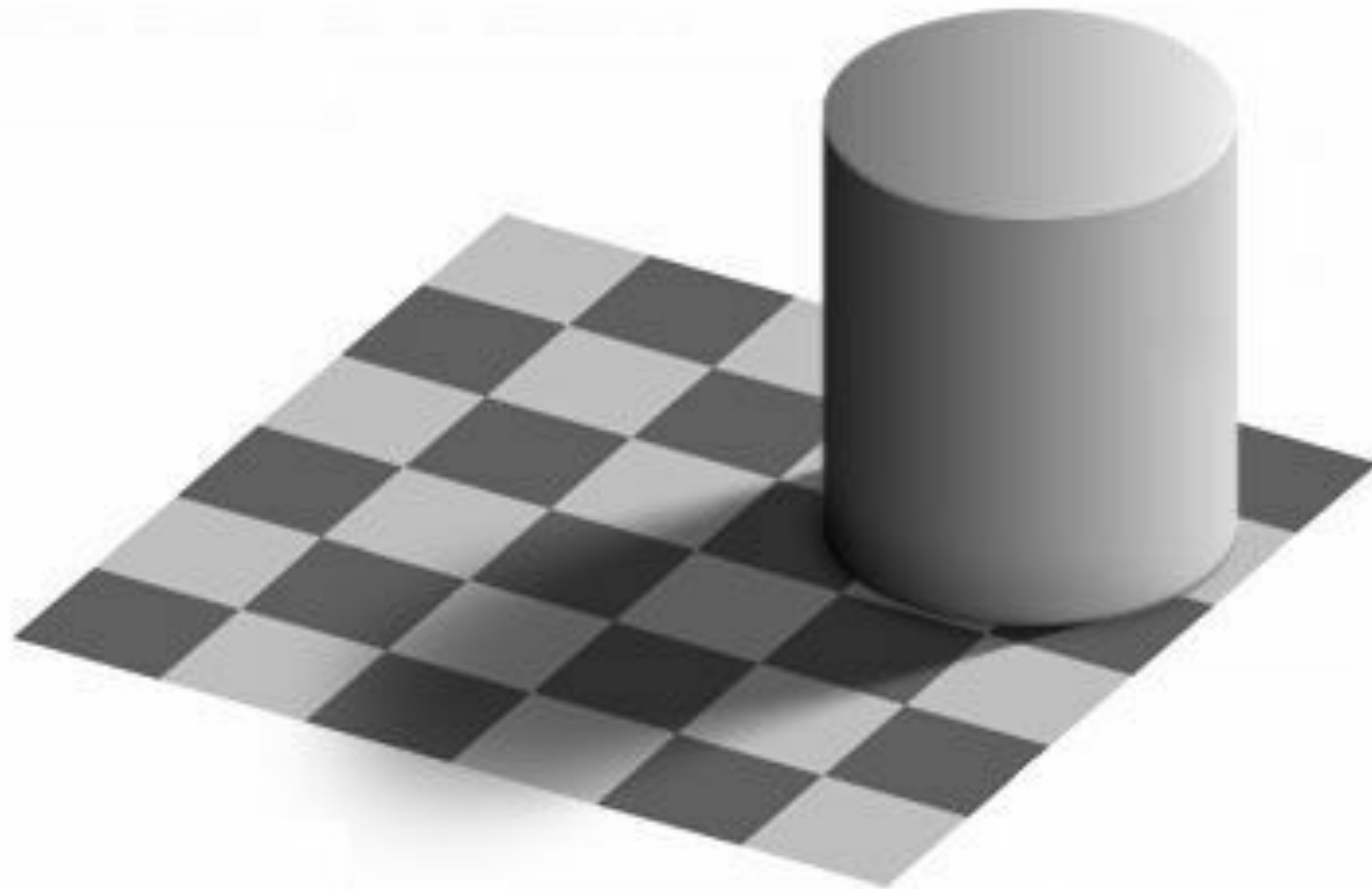


# Configurazione 3D

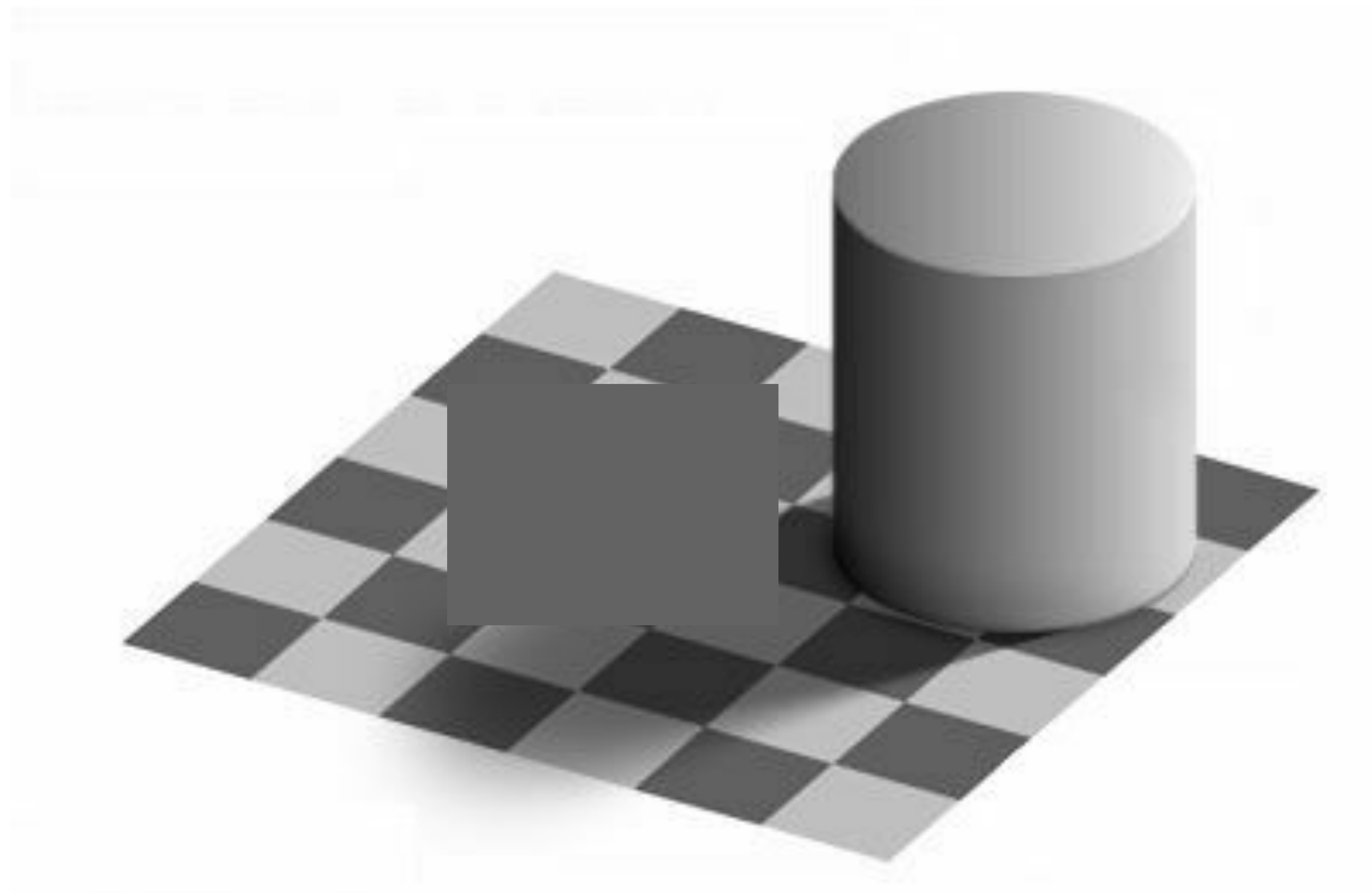




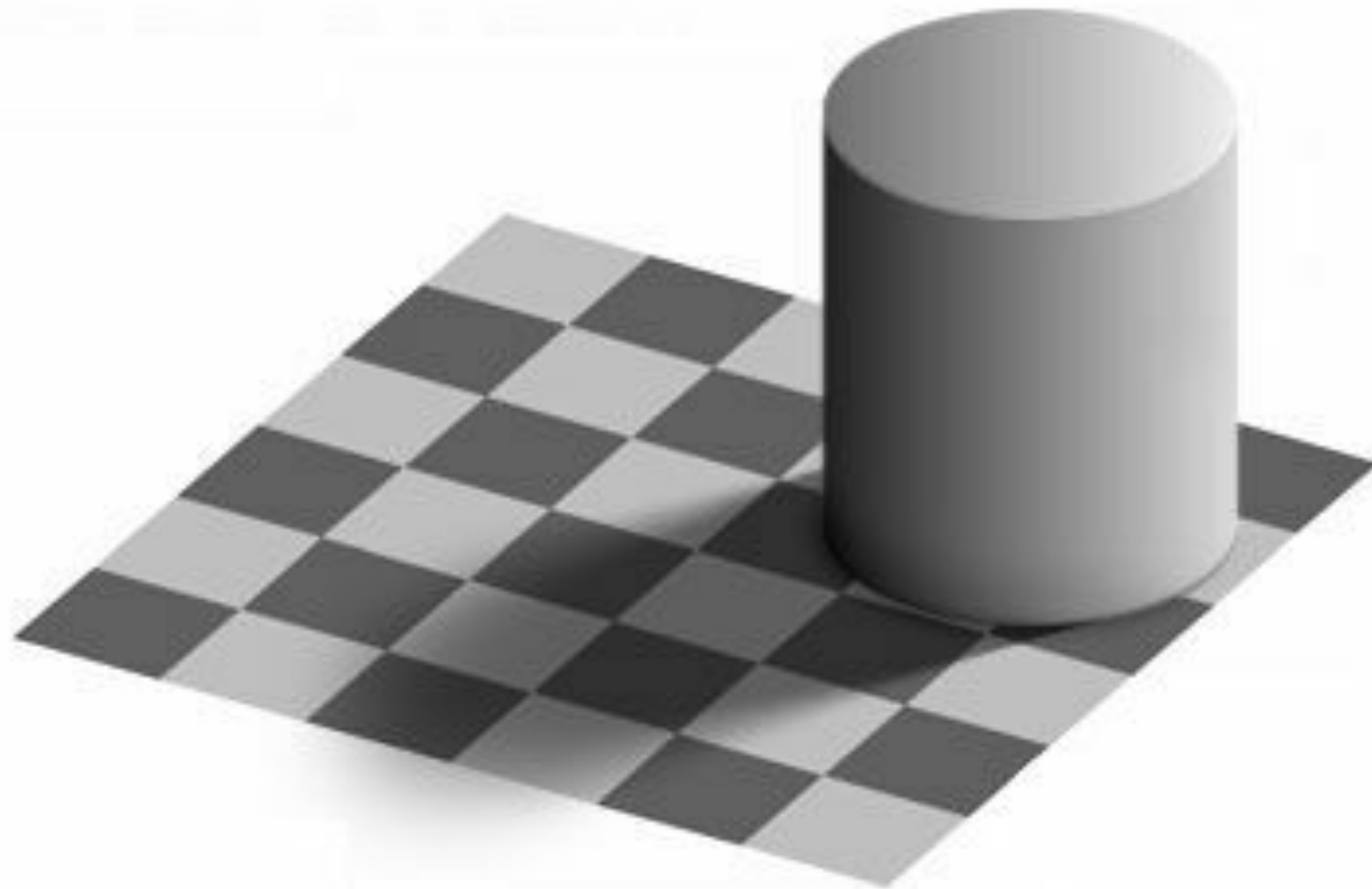
# Configurazione 3D



# Configurazione 3D



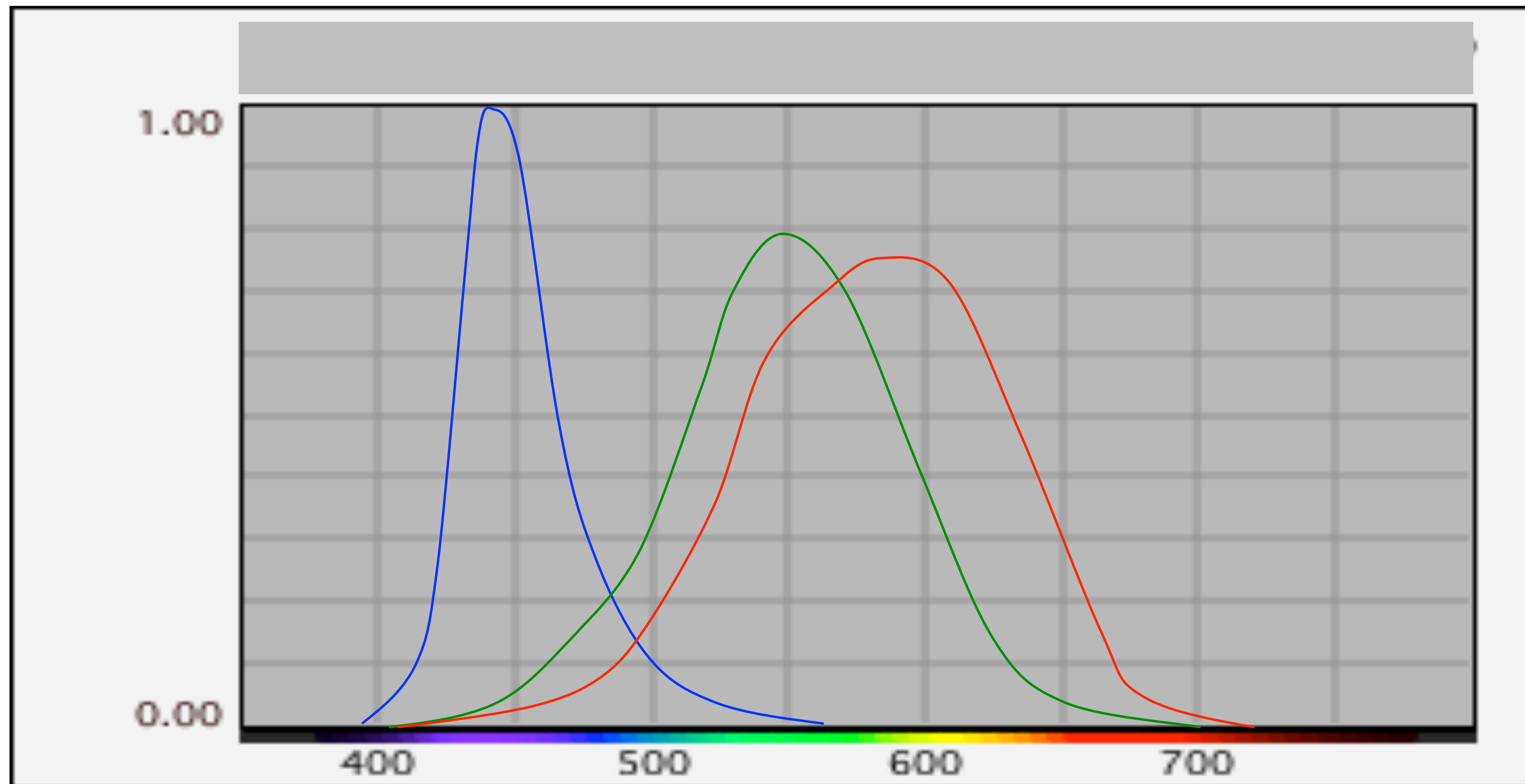
# Configurazione 3D



**Perché la  
computazione  
spaziale ?**

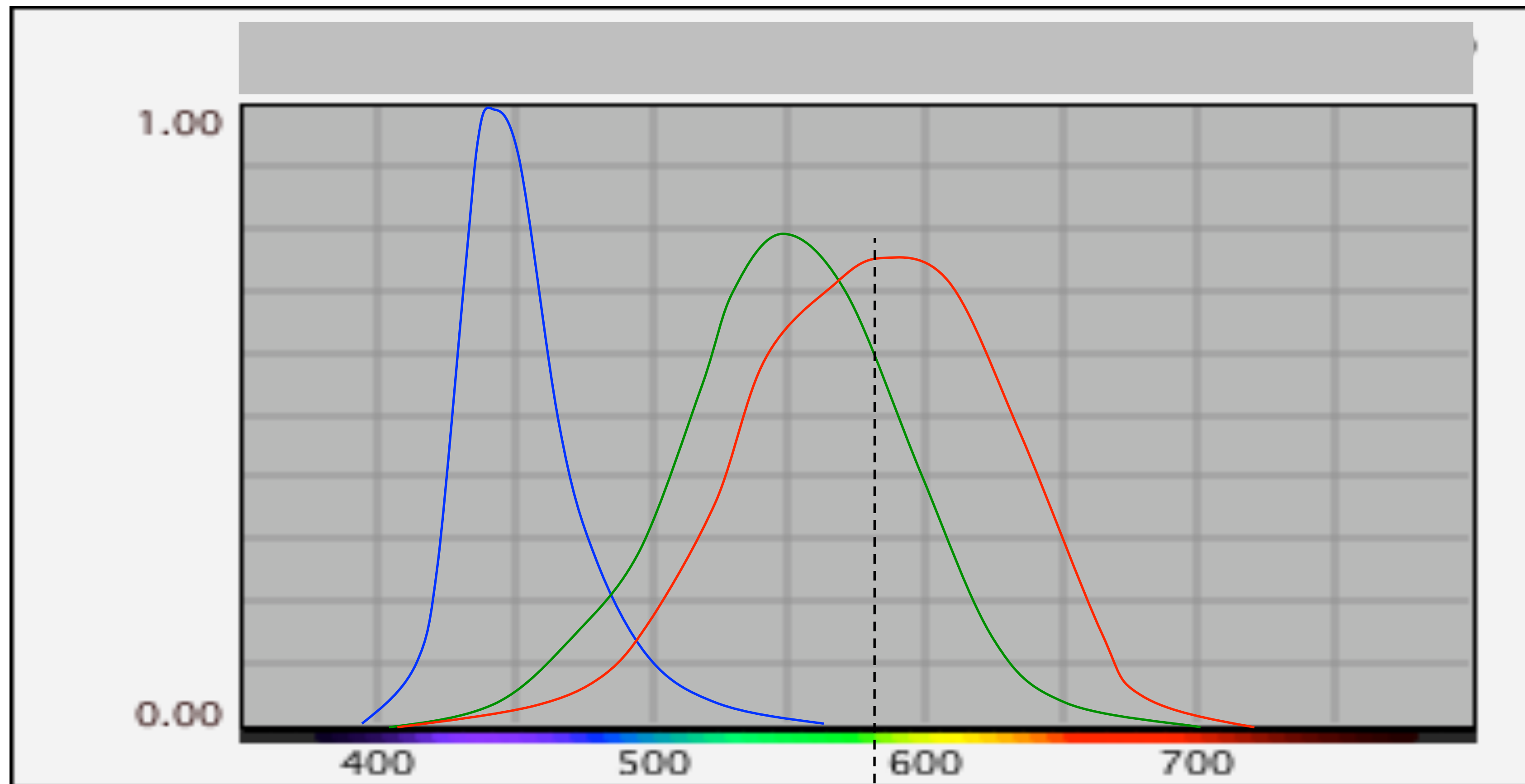
# Sensibilità spettrale dei coni

(normalizzate)



# Sensibilità spettrale dei coni

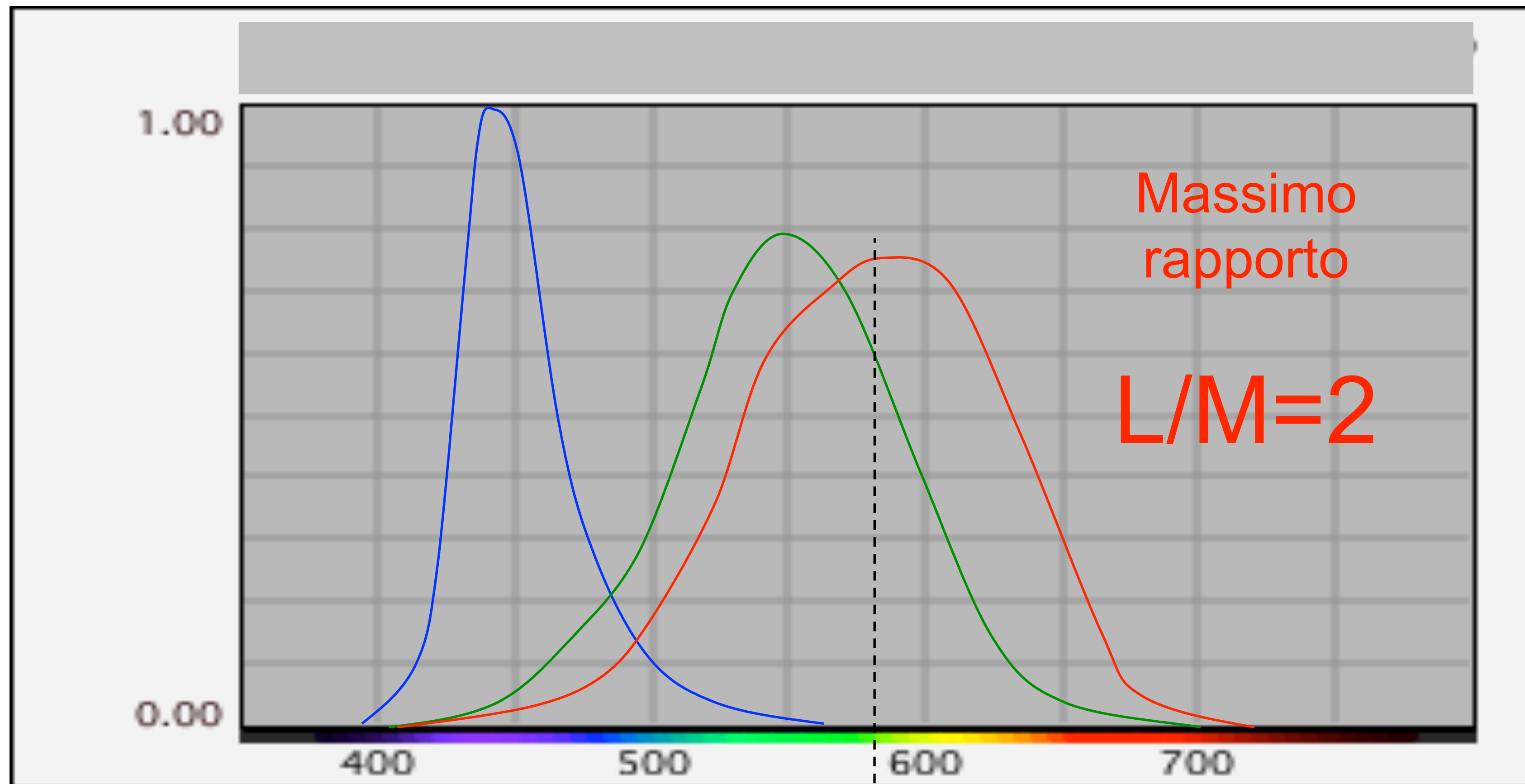
(normalizzate)



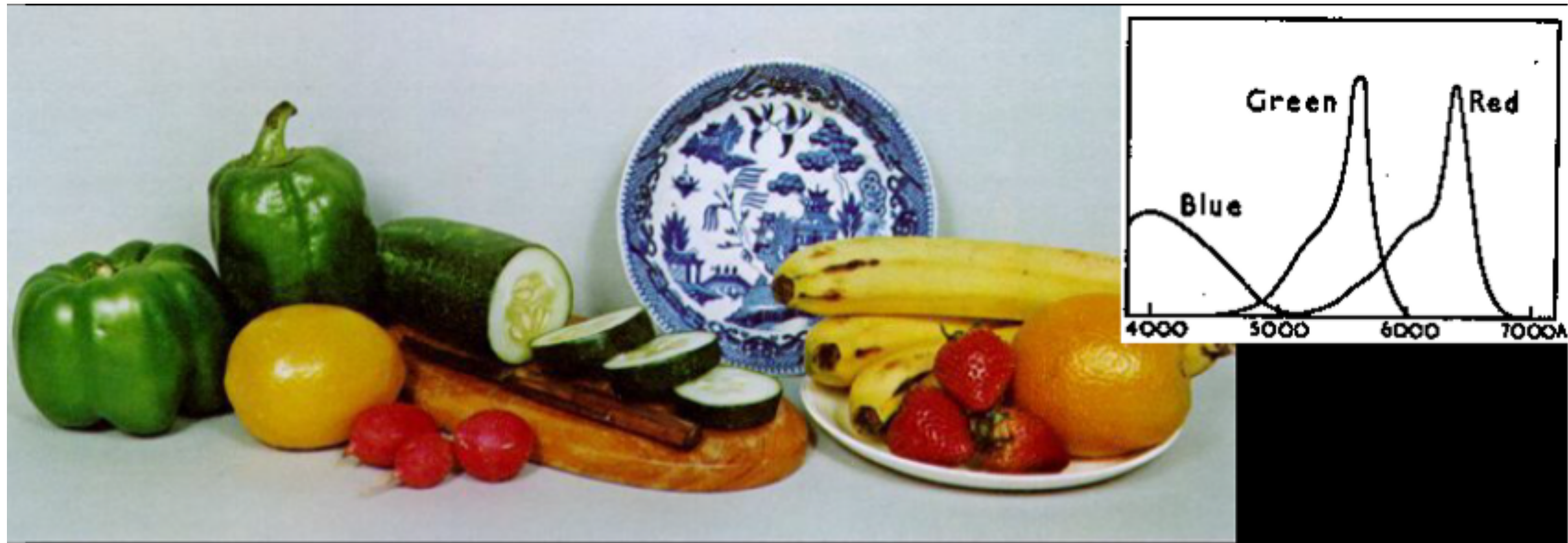
Il picco di sensibilità del **rosso** cade nel **verde**

# Sensibilità spettrale dei coni

(normalizzate)



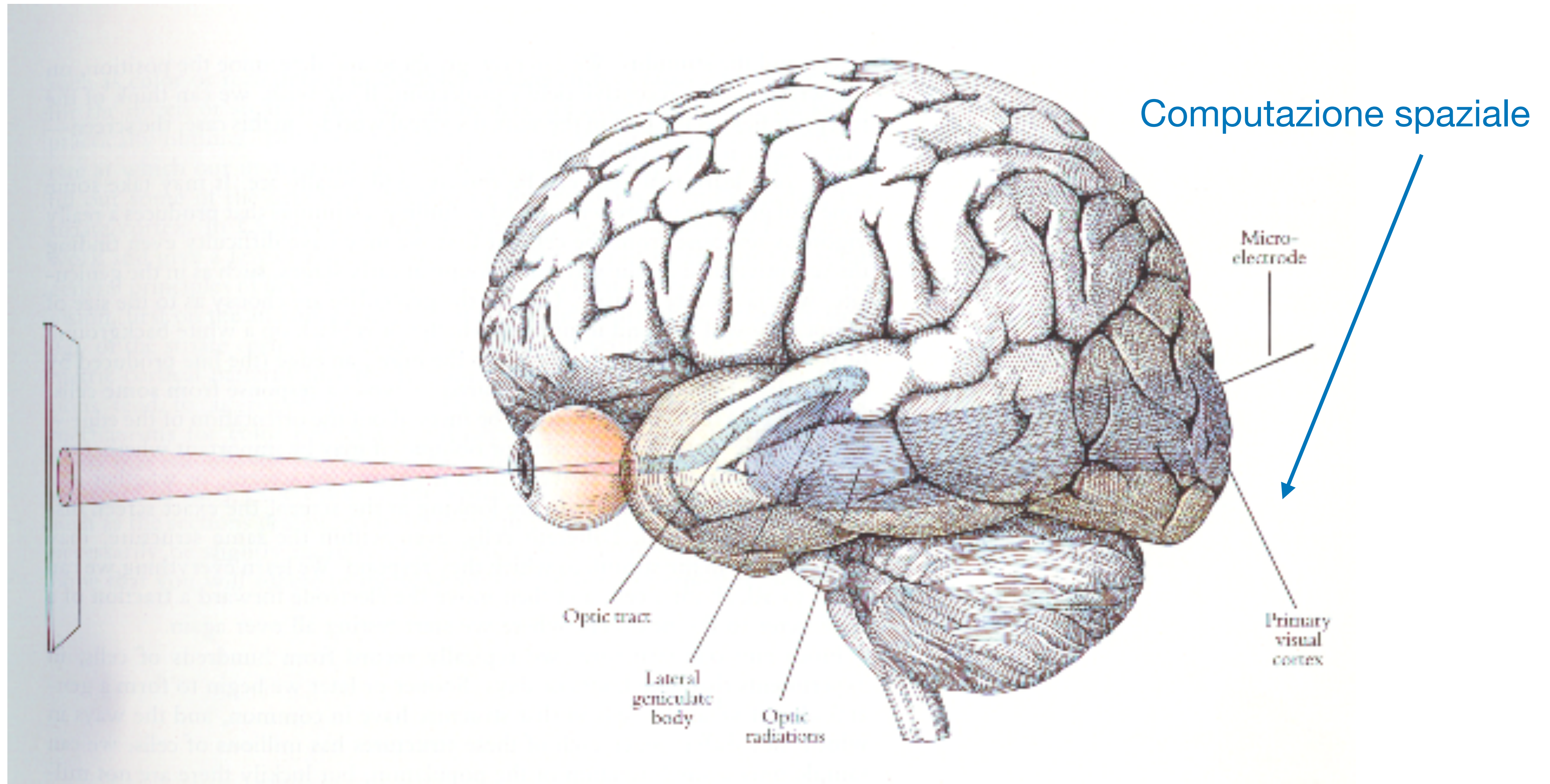
Il picco di sensibilità del **rosso** cade nel **verde**



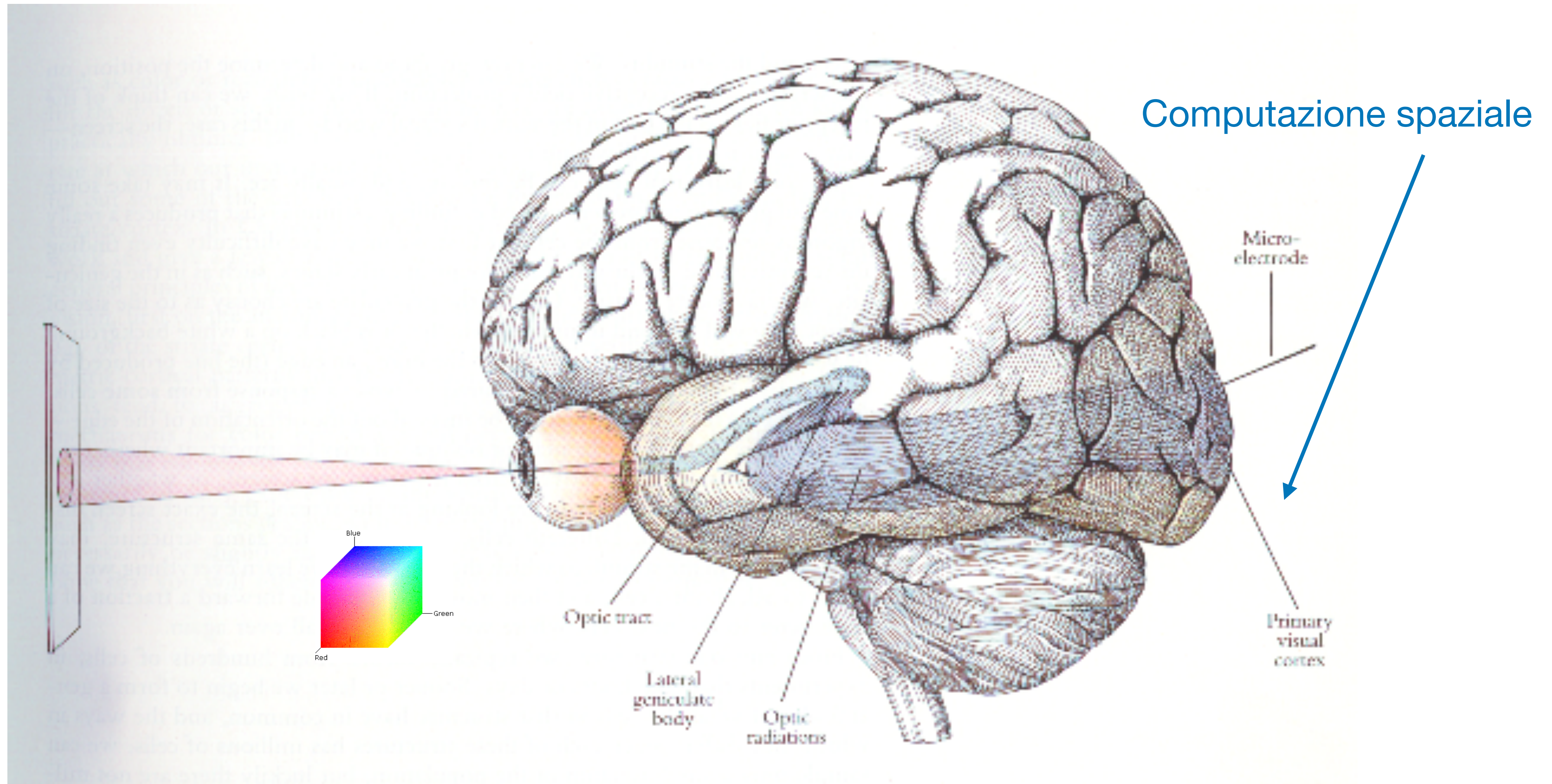
Courtesy J.J. McCann



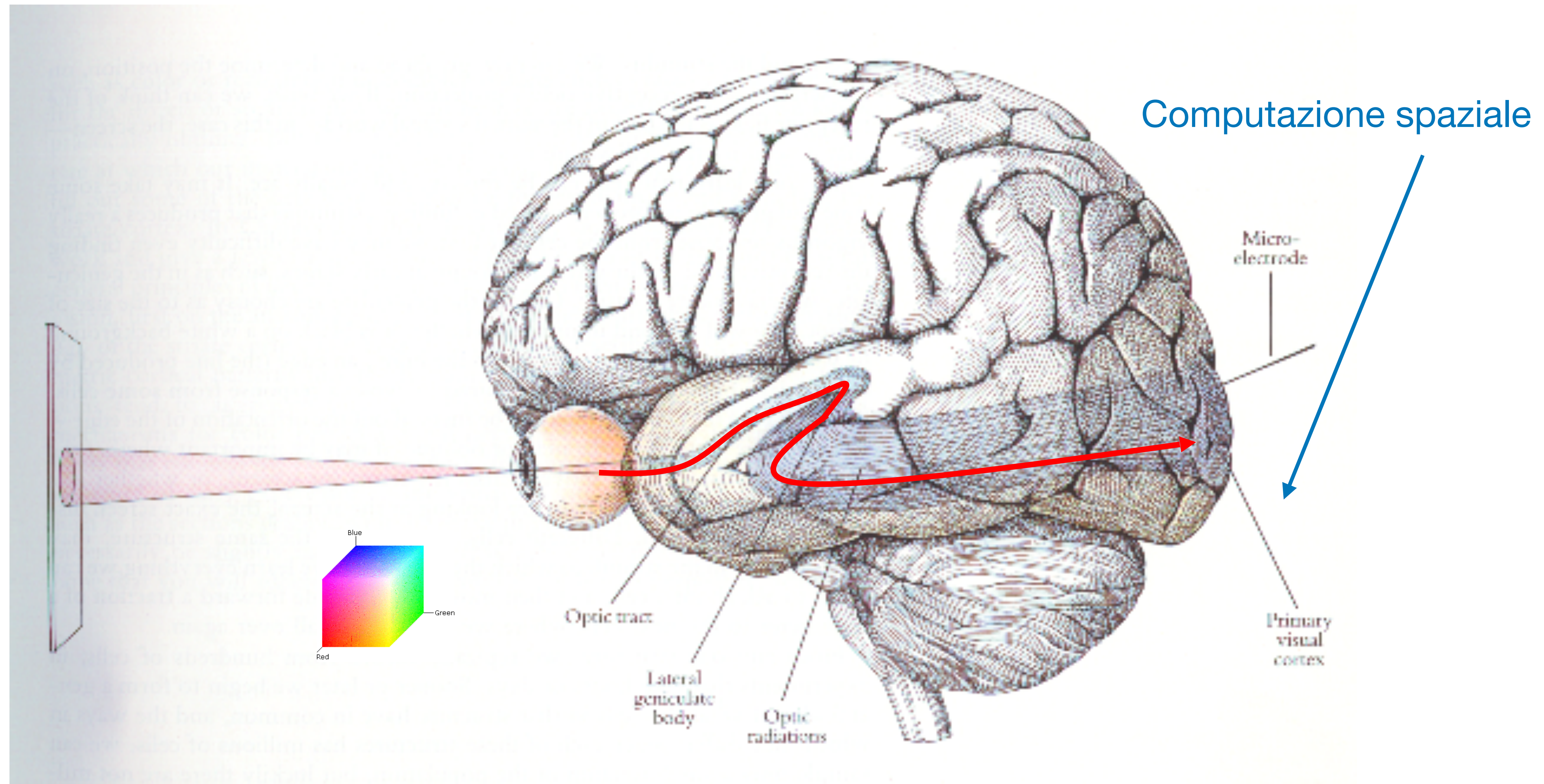
# La nascita della sensazione di colore



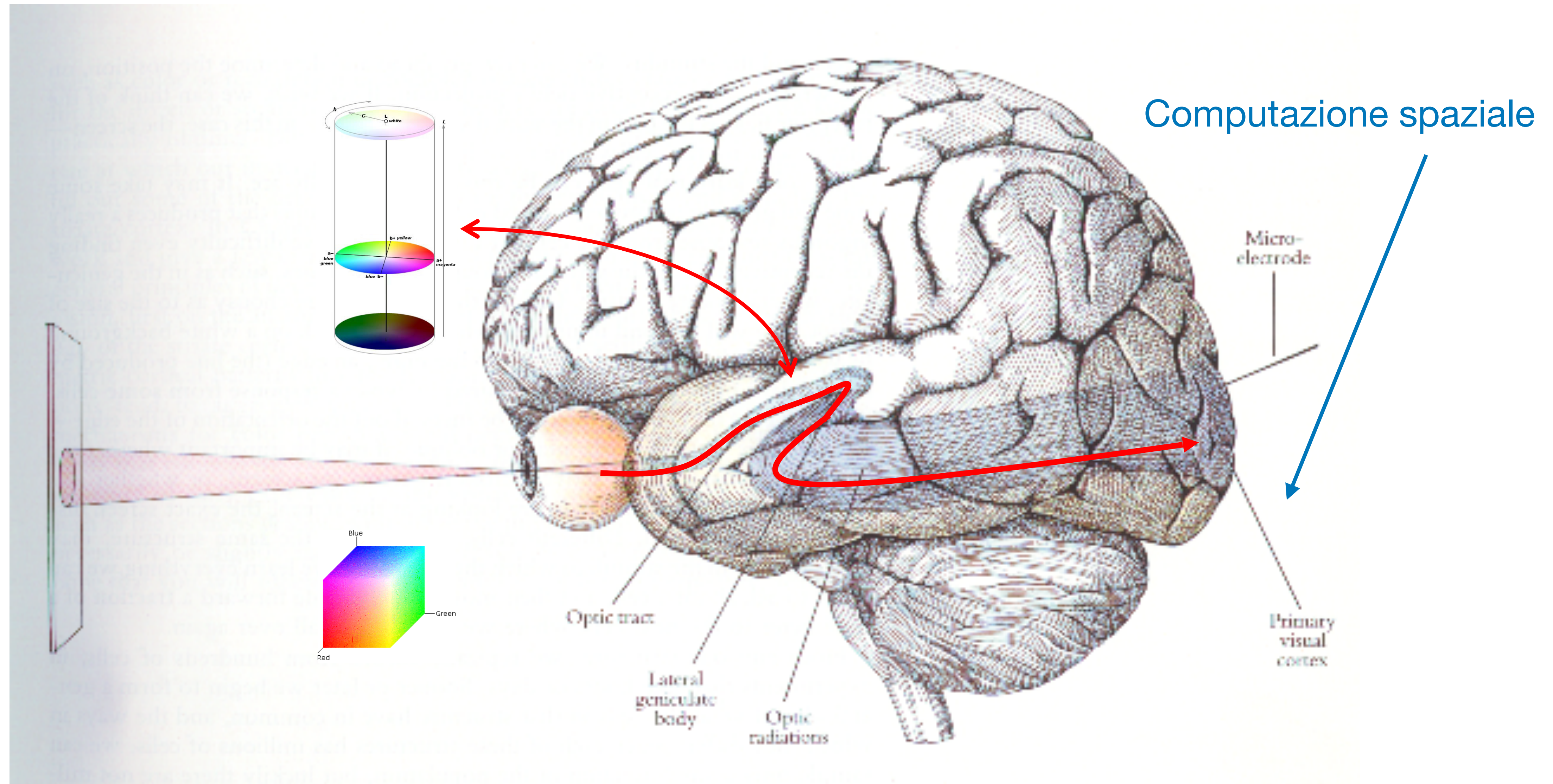
# La nascita della sensazione di colore



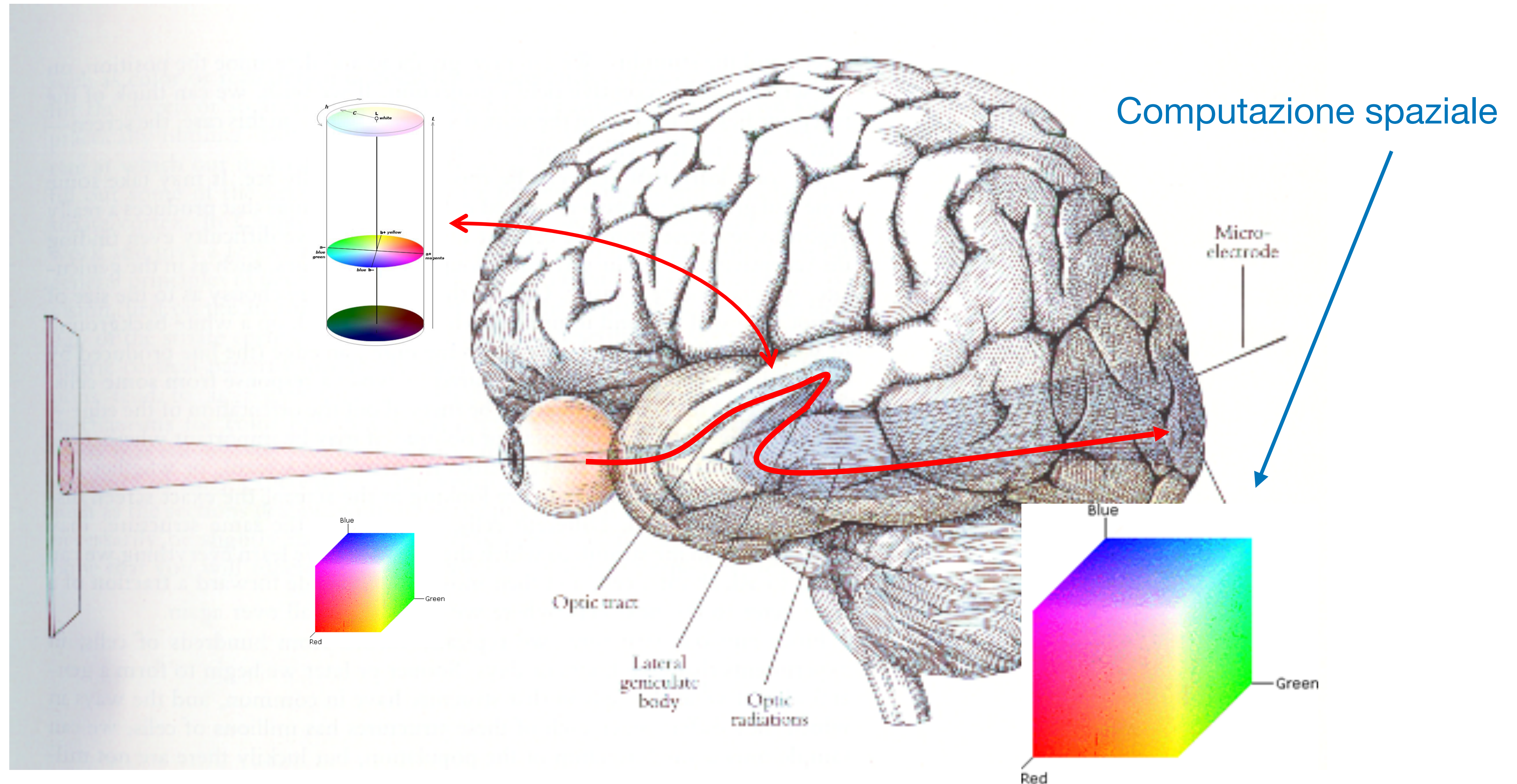
# La nascita della sensazione di colore



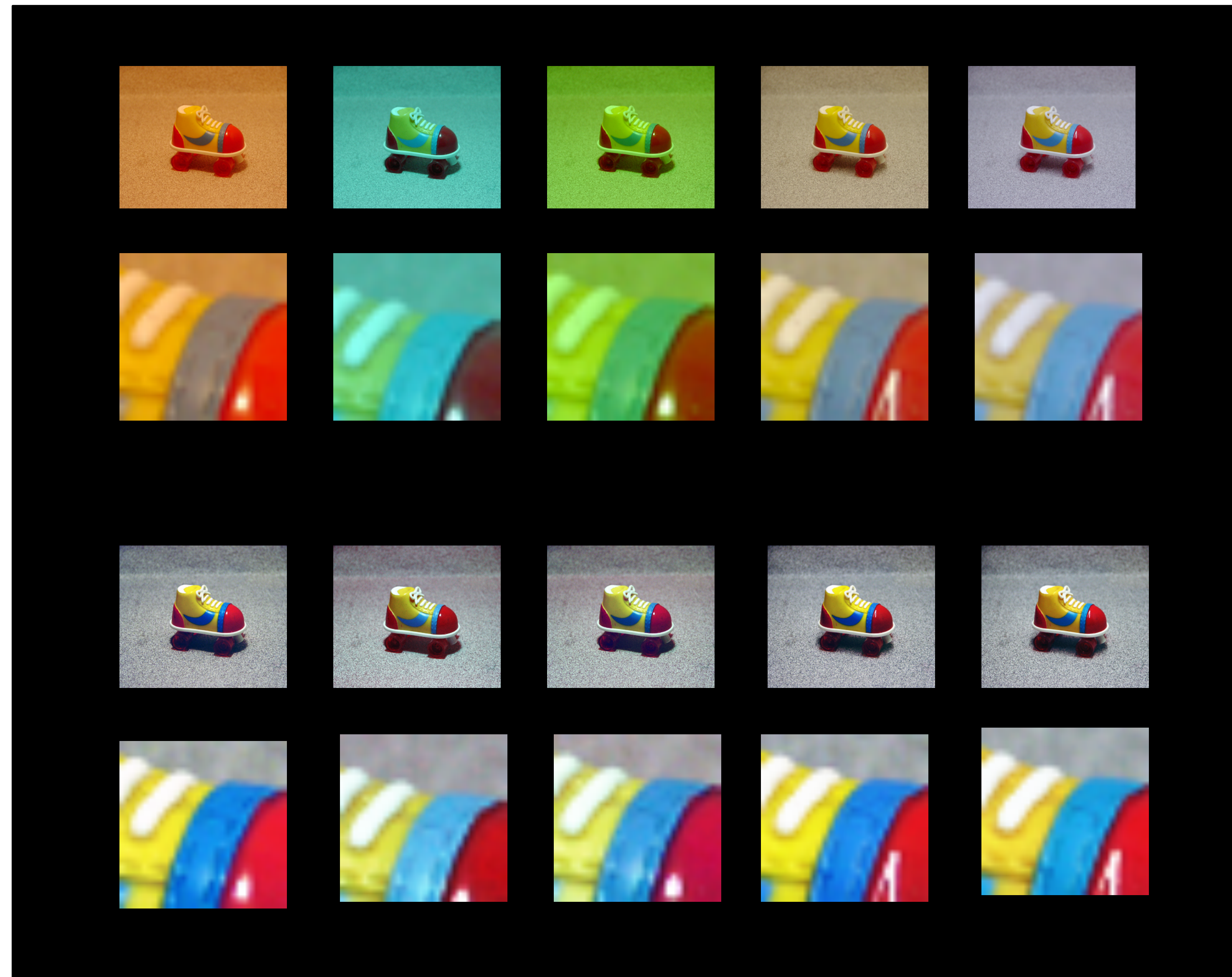
# La nascita della sensazione di colore



# La nascita della sensazione di colore



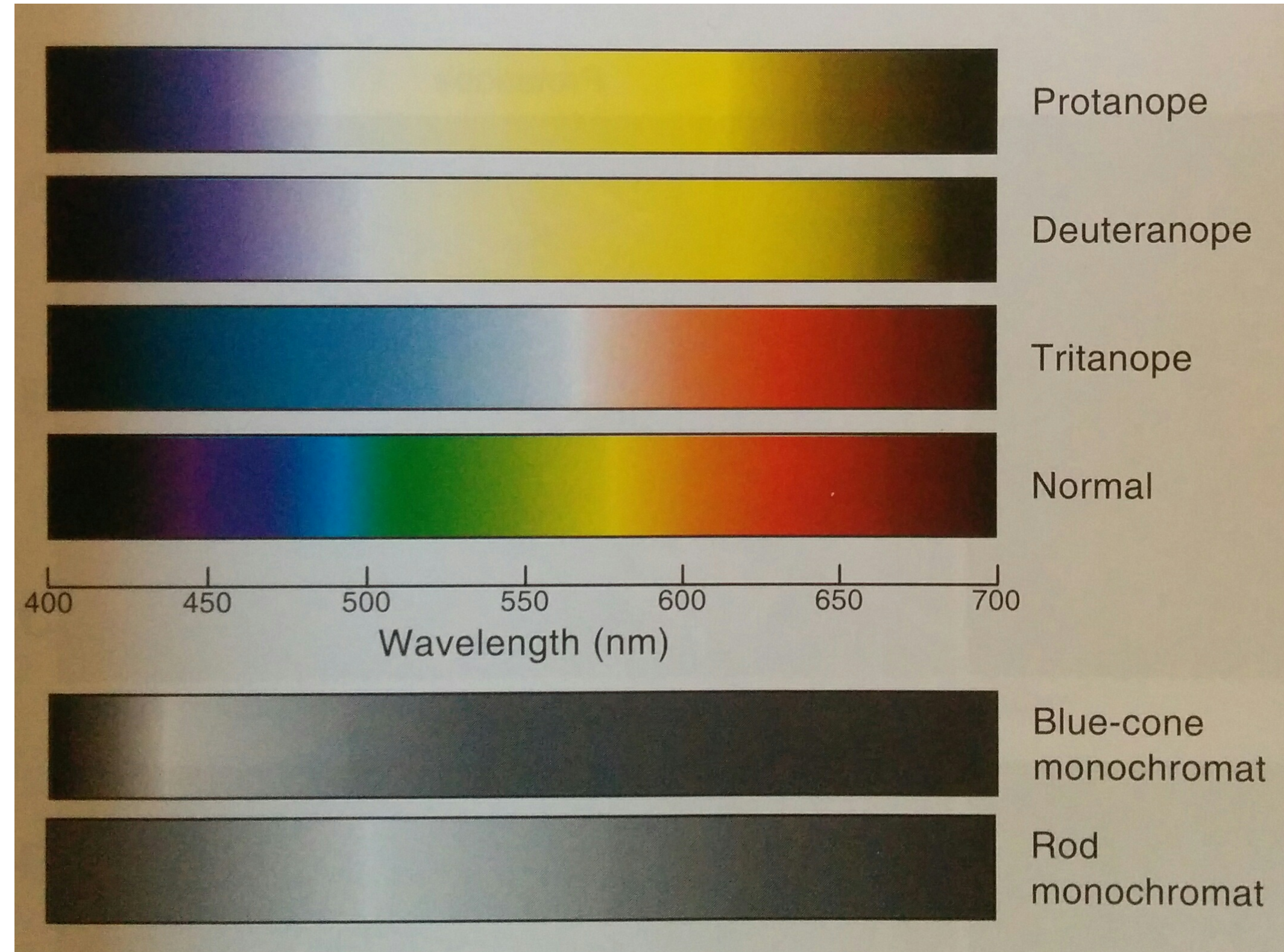
# Costanza Cromatica



**E i daltonici ?**

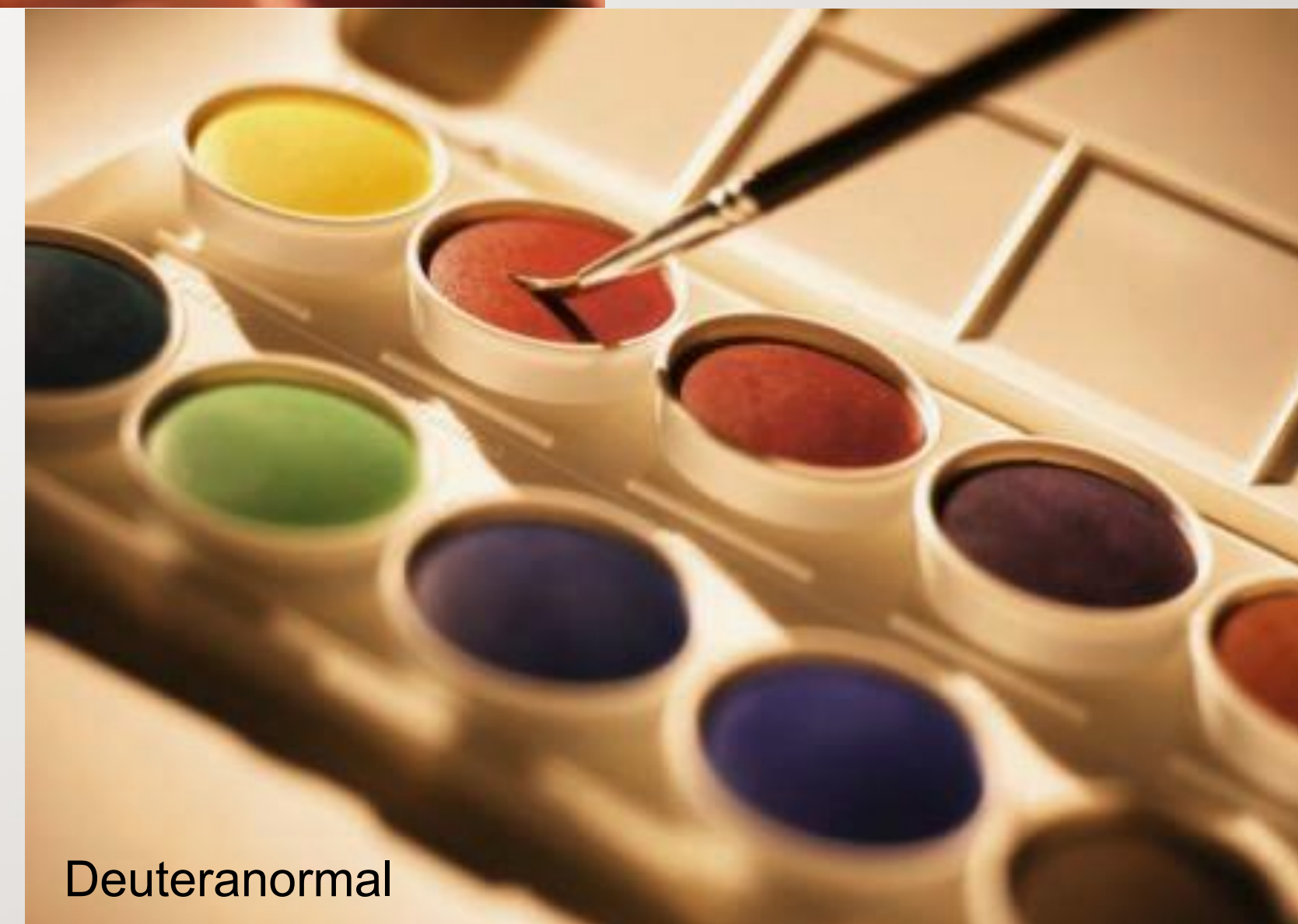
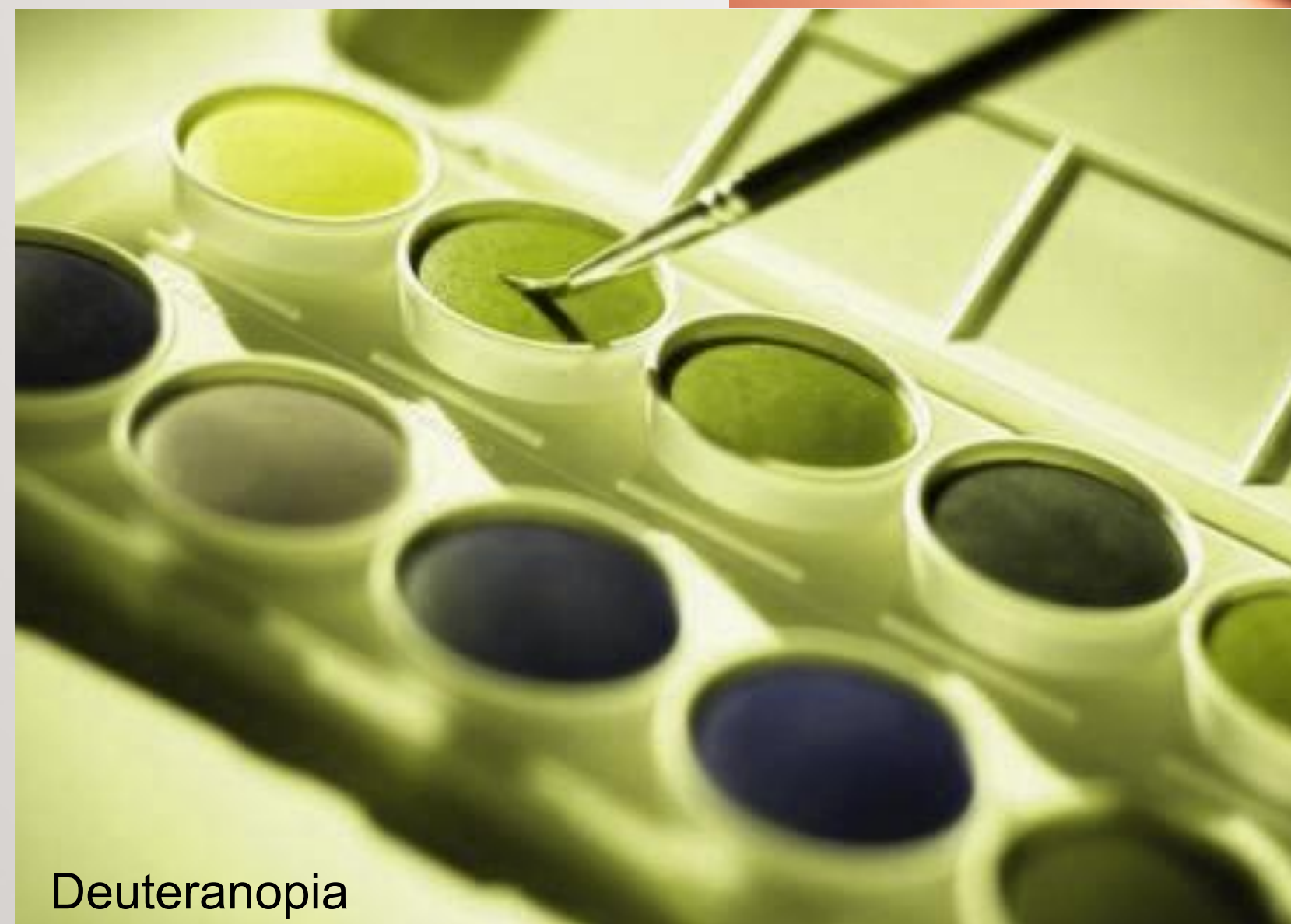
# Daltonismo

- Discromatopsia (o tricromia alterata)
- Acromatopsia
  
- Rosso
  - Protanomalia
  - Protanopia
- Verde
  - Deuteranomalia - Deuteranopia
- Blu
  - Tritanomalia
  - Tritanopia

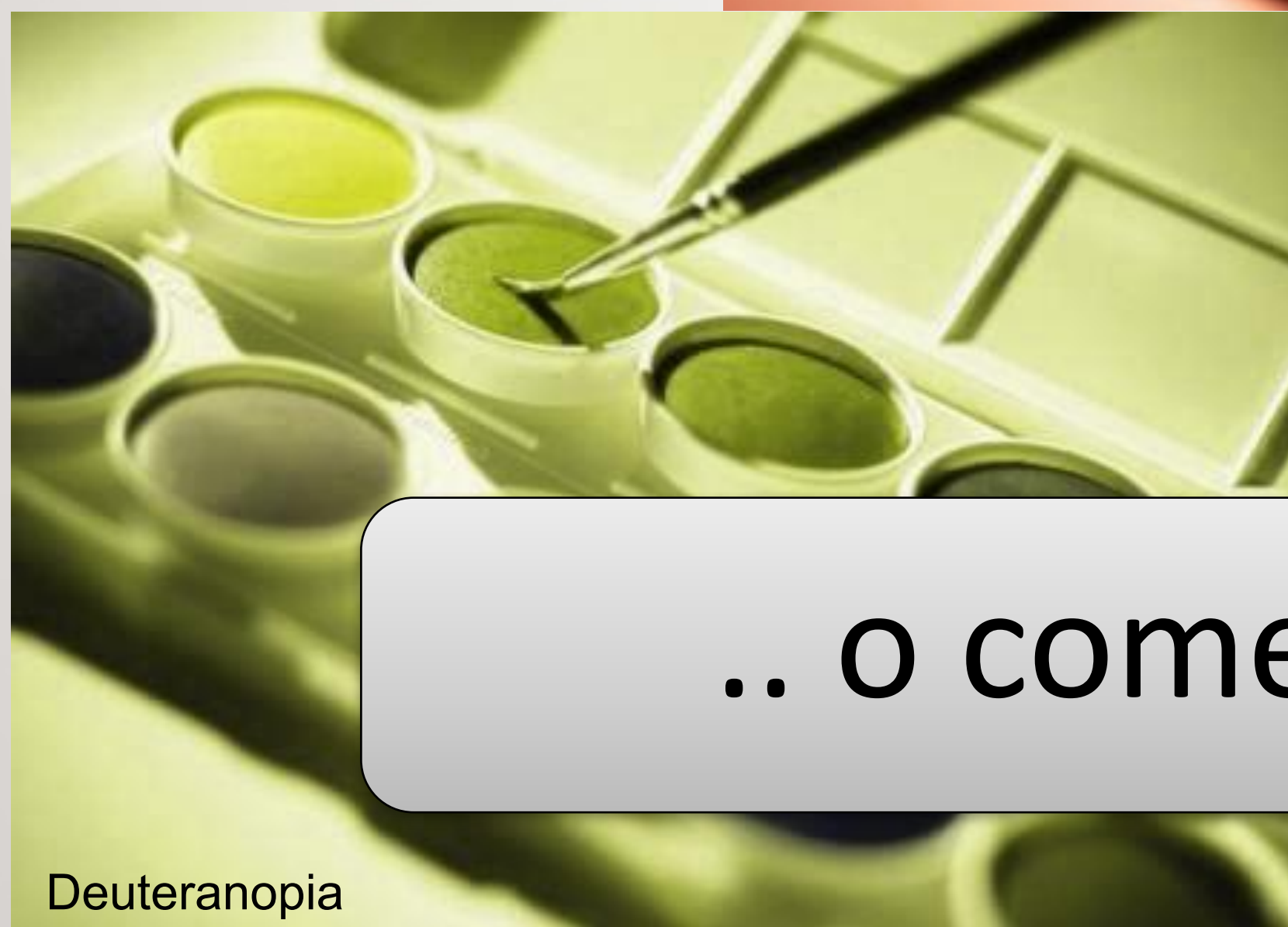




# E' come vedono i daltonici ?



# E' come vedono i daltonici ?



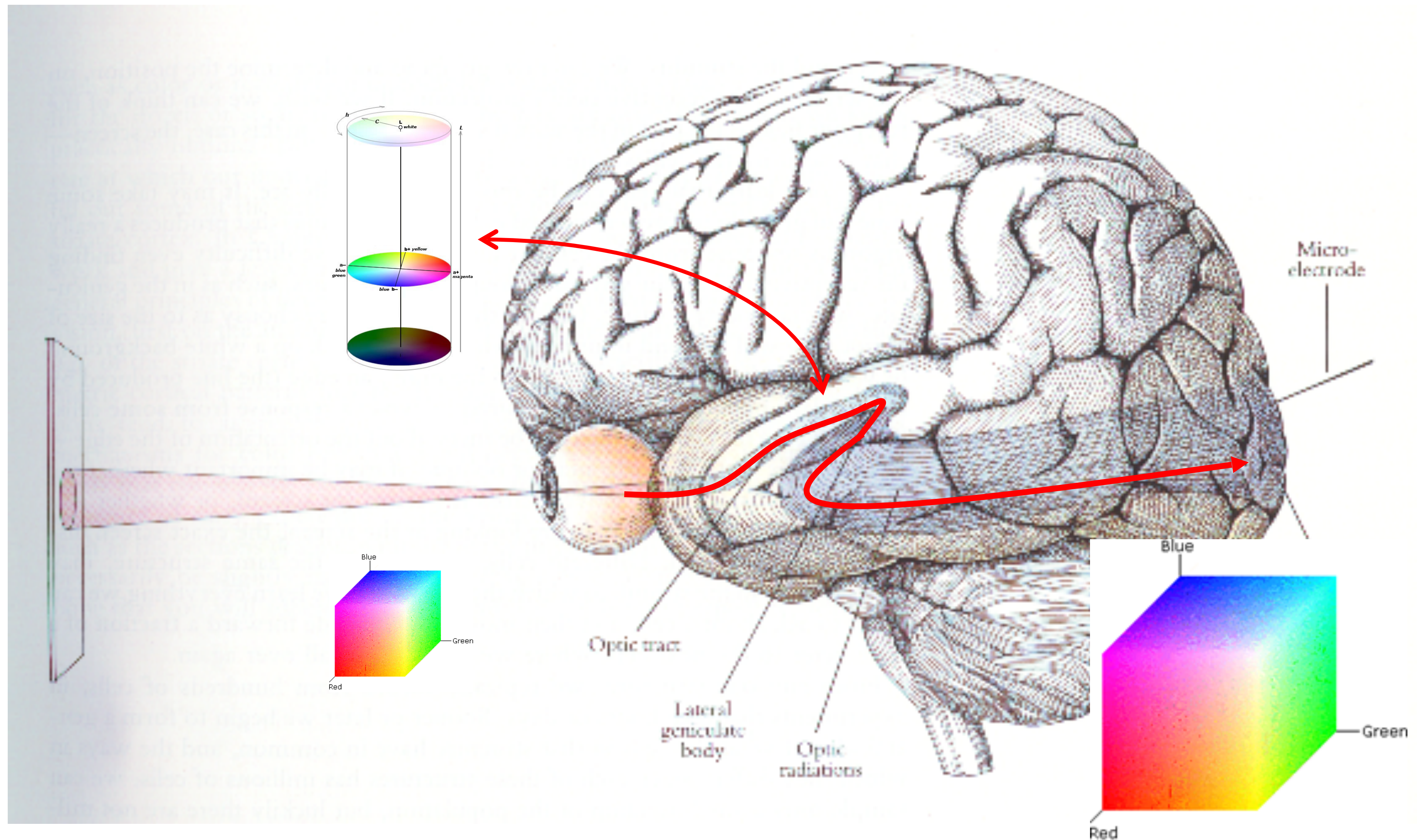
Deuteranopia



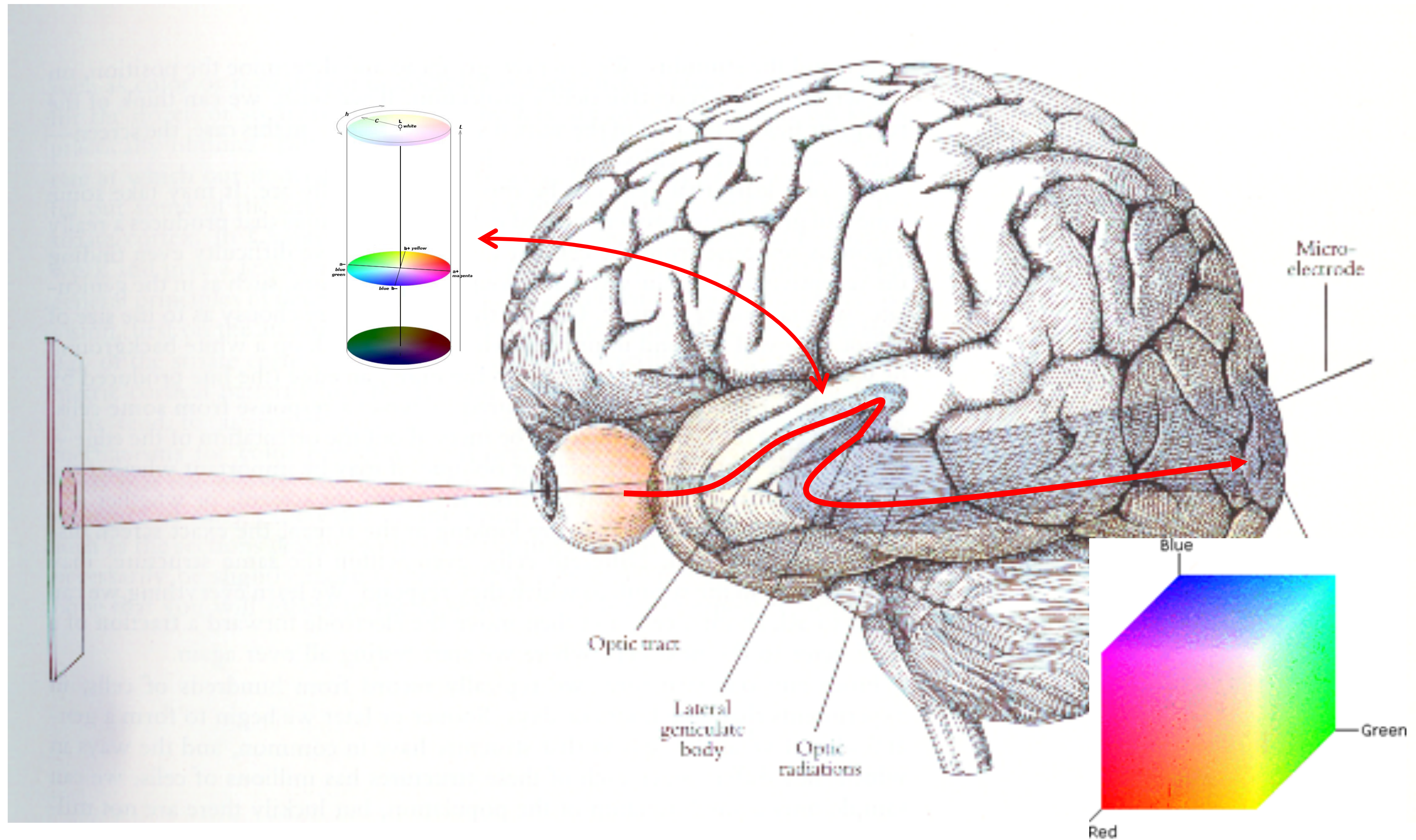
Deuteranormal

.. o come noi crediamo che vedano ?

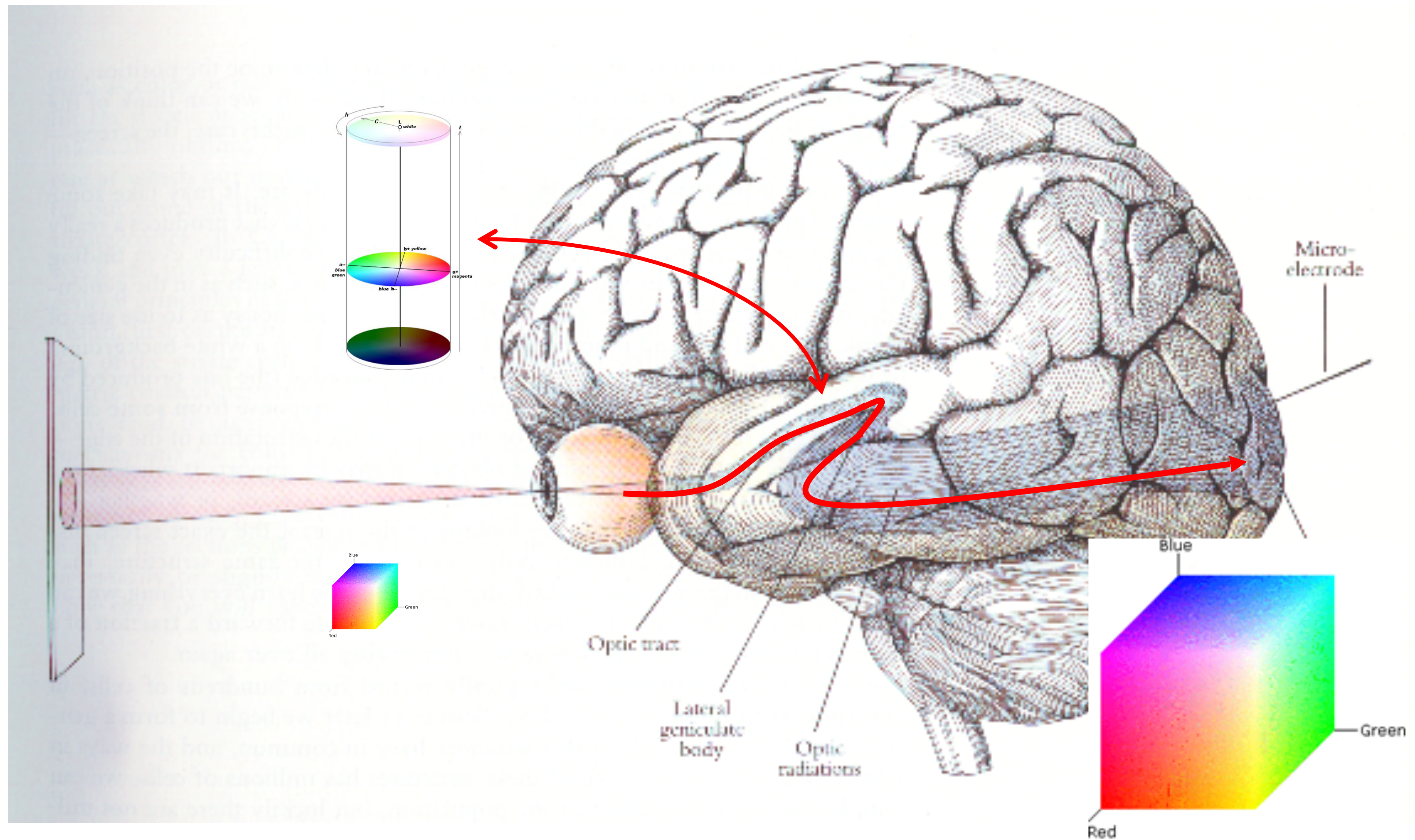
# La nascita della sensazione di colore



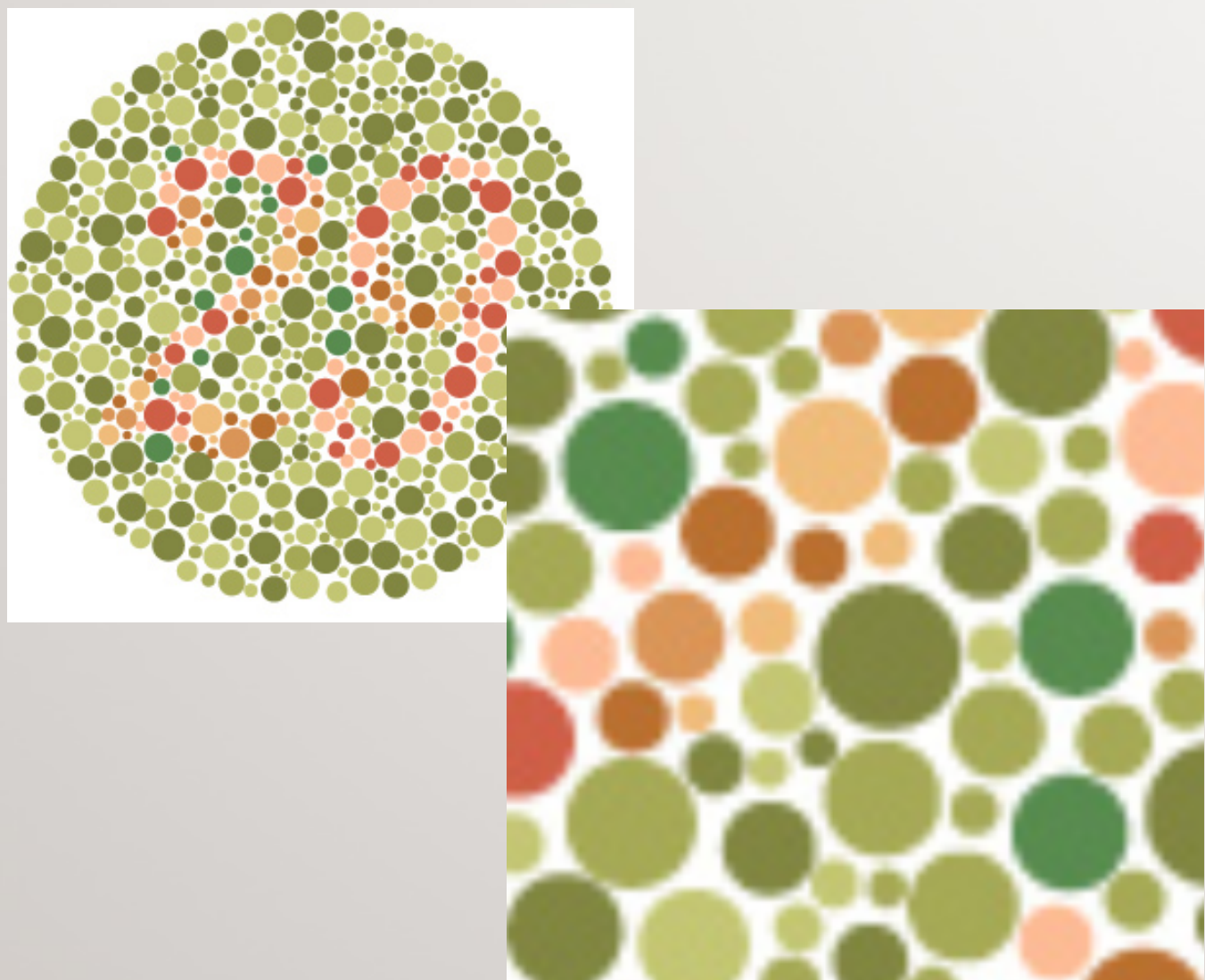
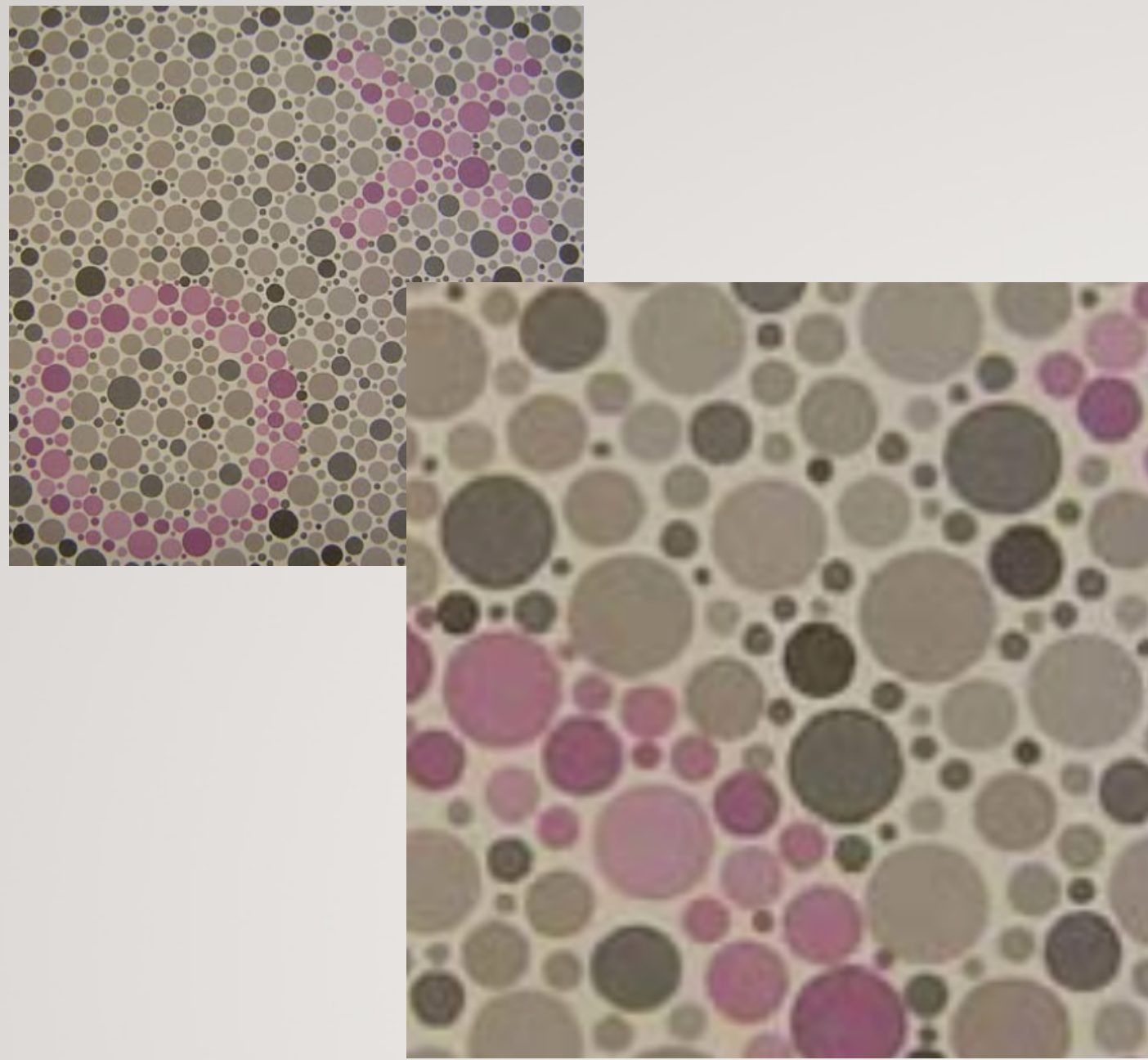
# La nascita della sensazione di colore



# La nascita della sensazione di colore



# Excluding edges

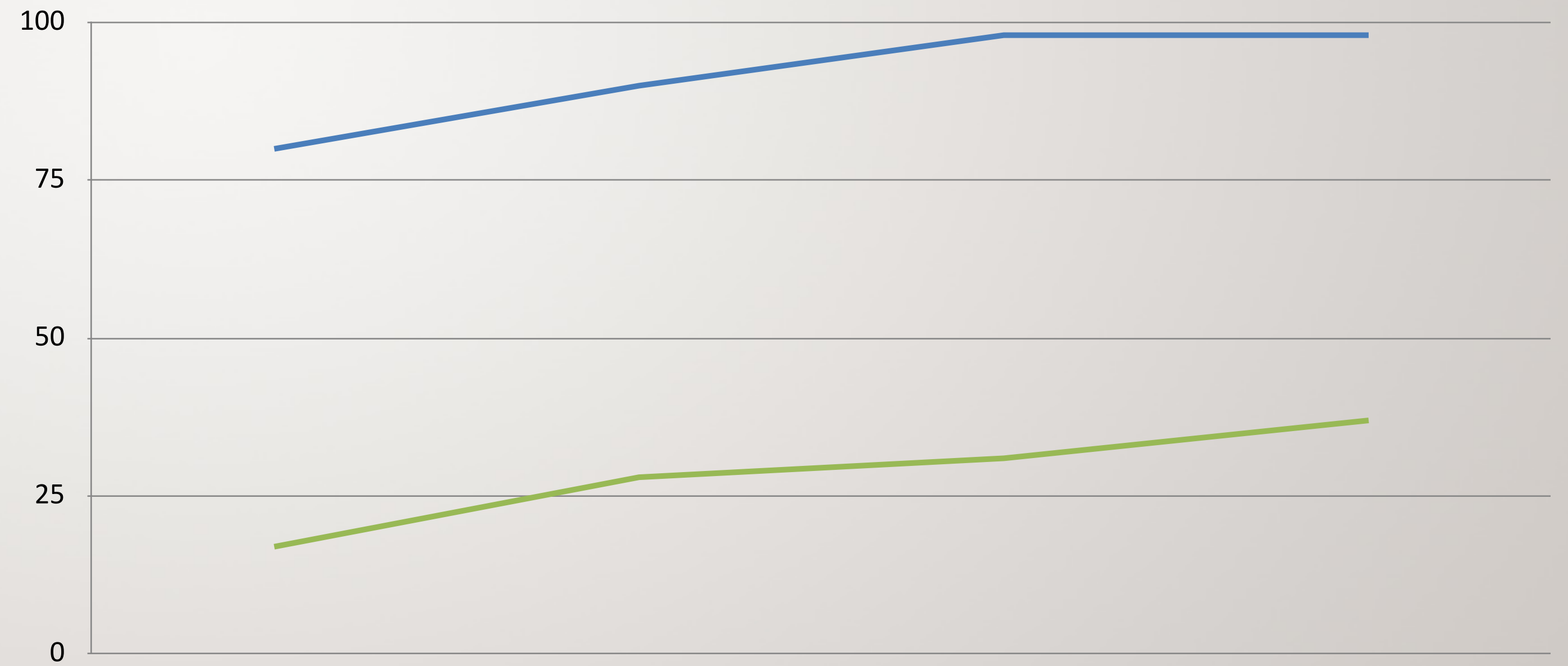
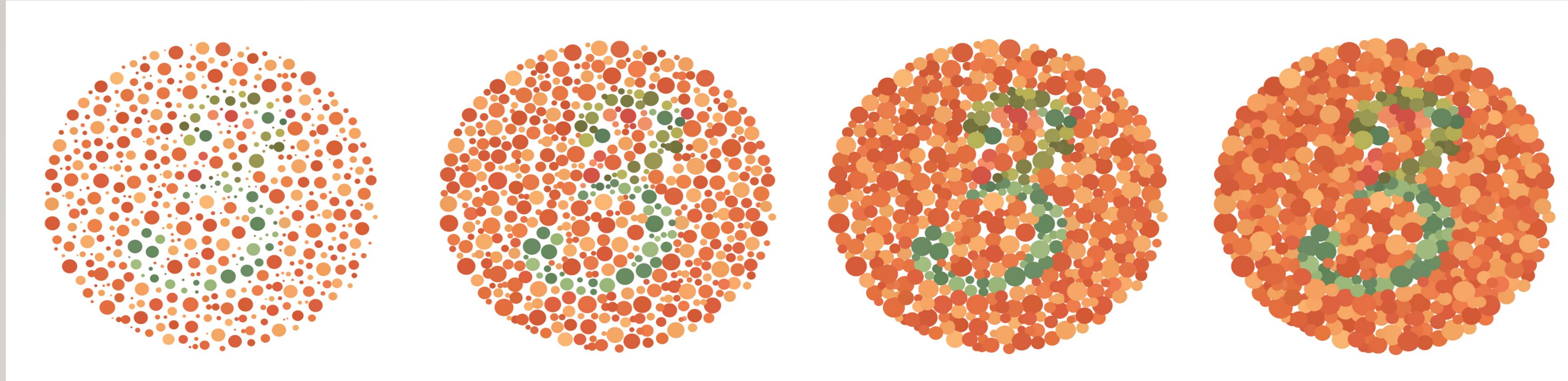


Small

Normal

Plus

Plus plus



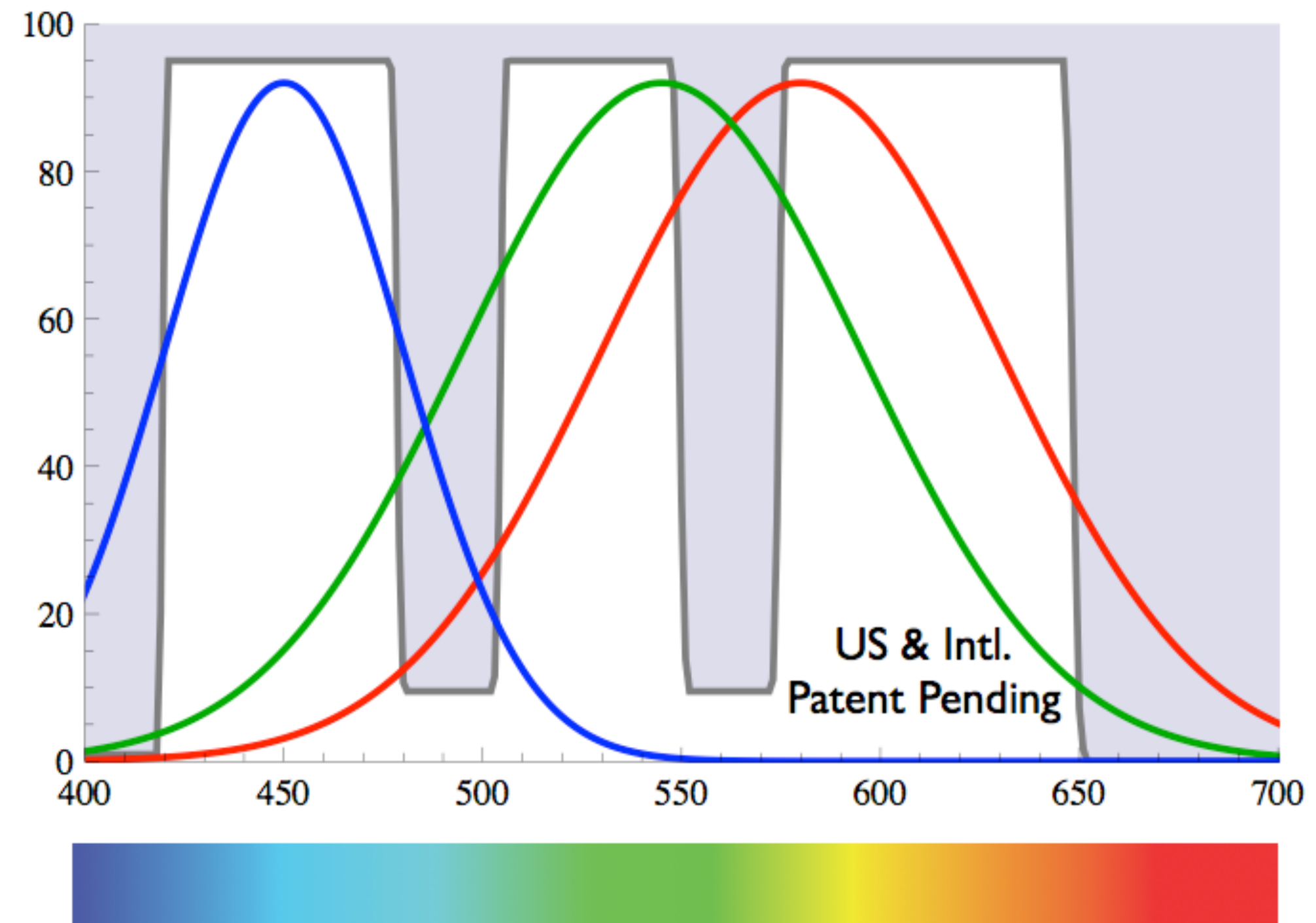
Small

Normal

Plus

Plus plus

# Daltonismo - enchroma



<http://enchroma.com/technology/>

EnChroma Cx

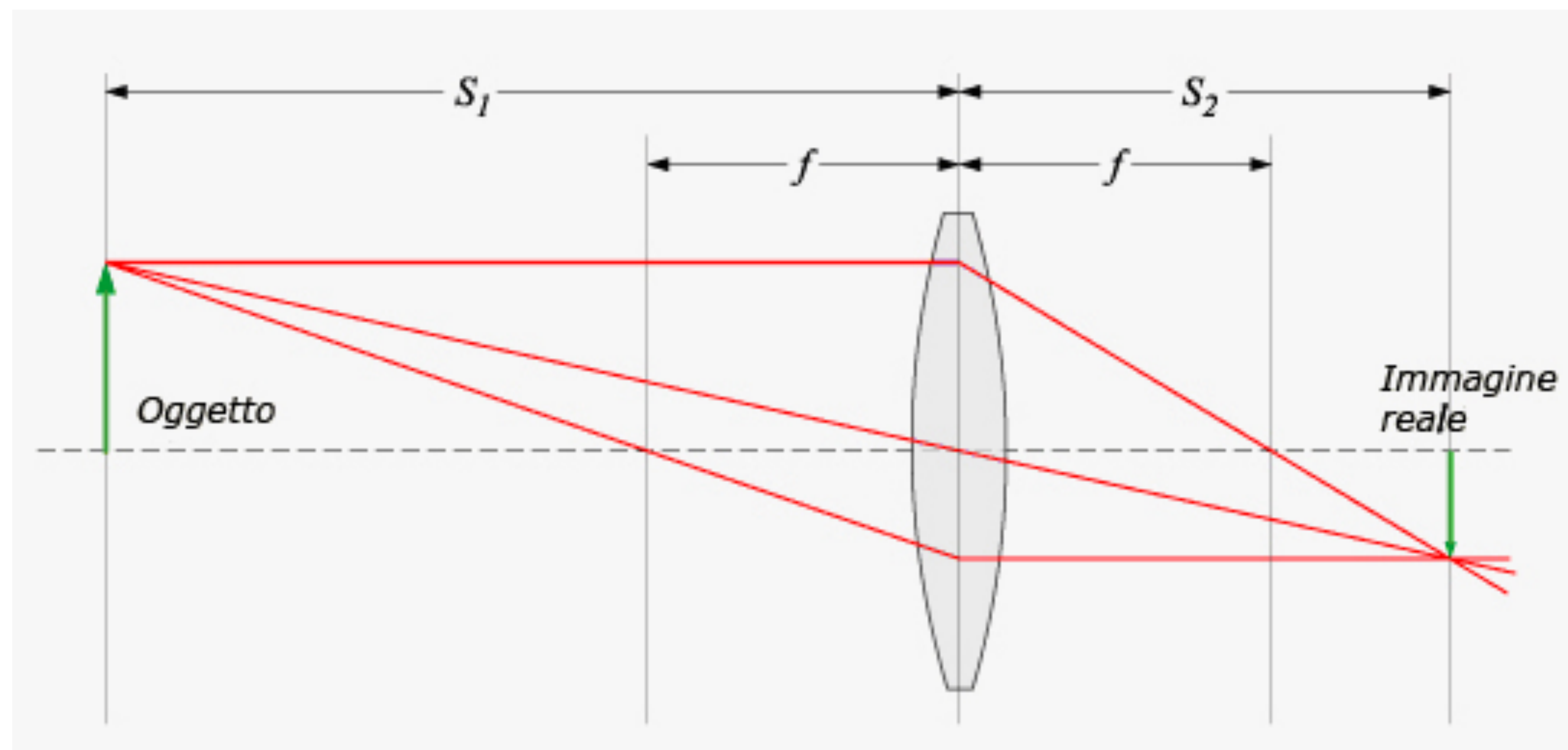


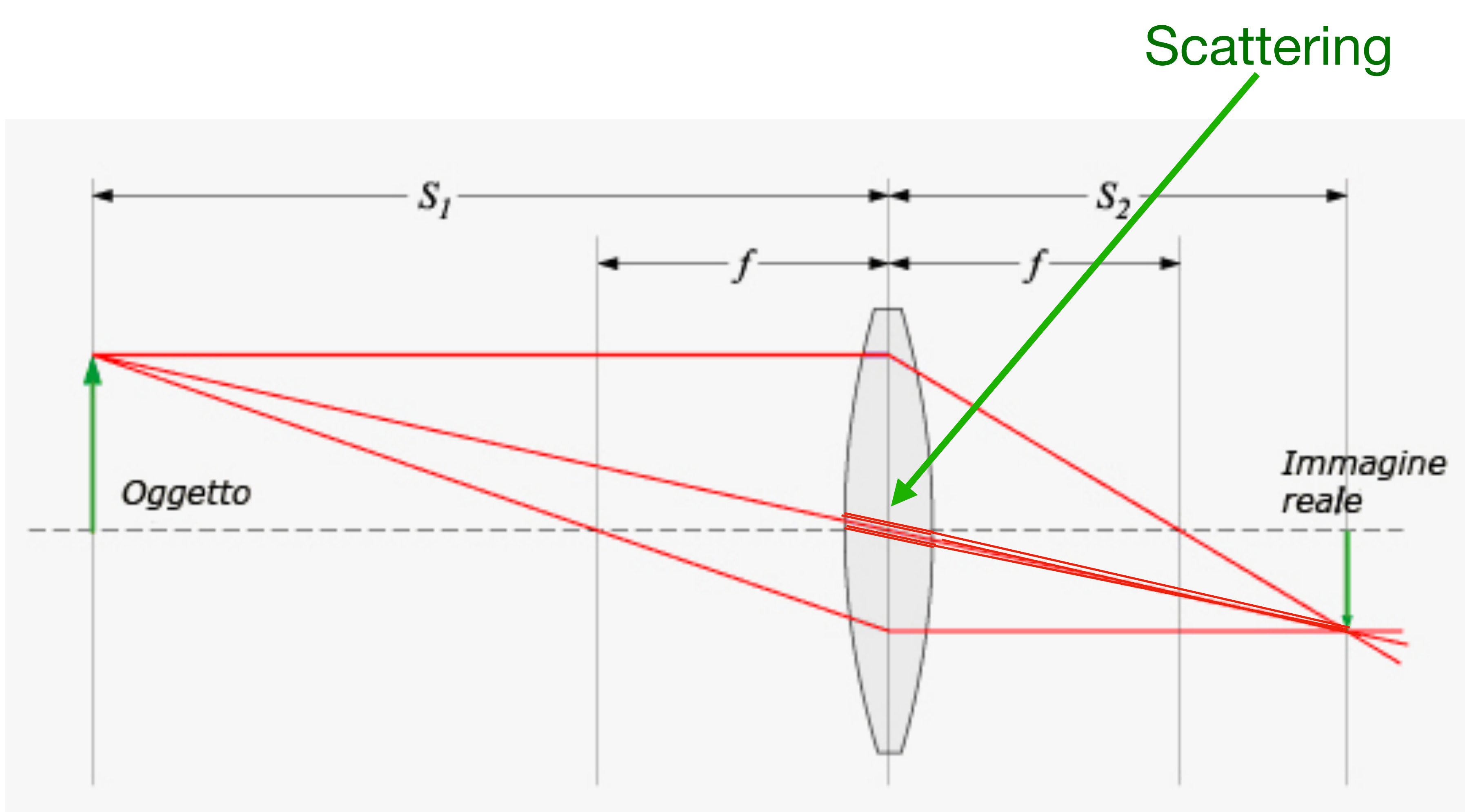
# Il problema del glare



# Il problema del glare

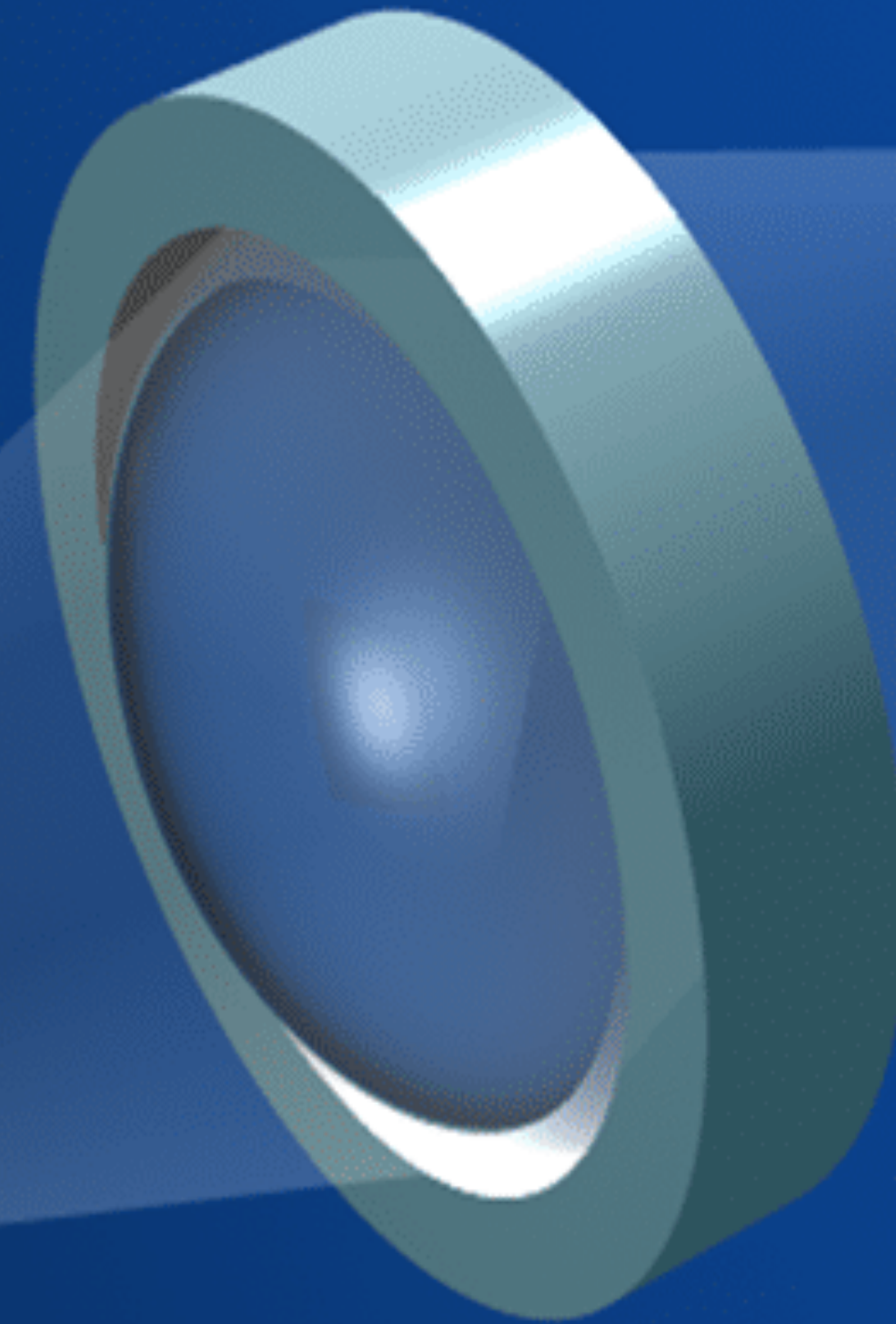






# Glare

POINT SOURCE

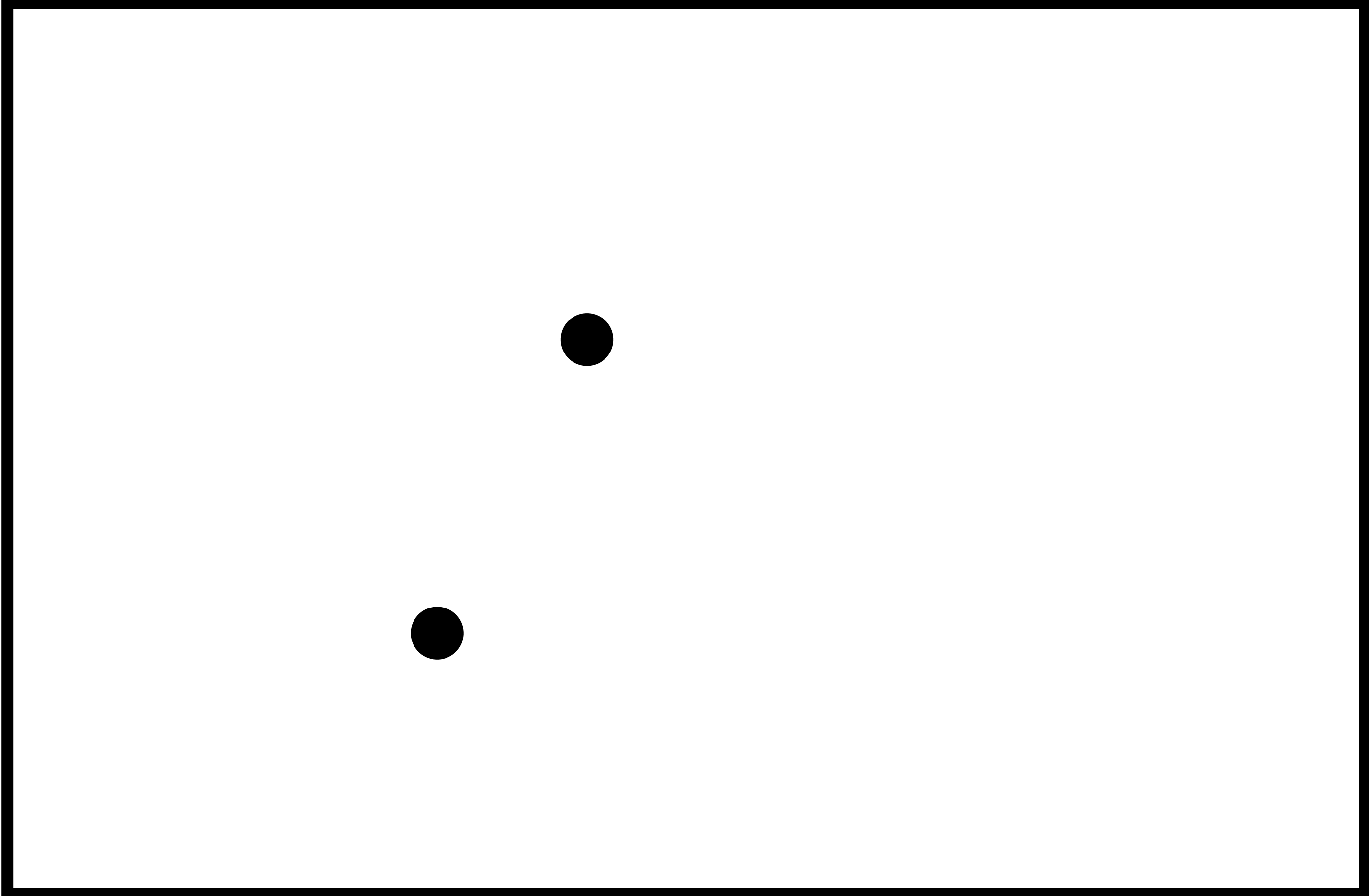


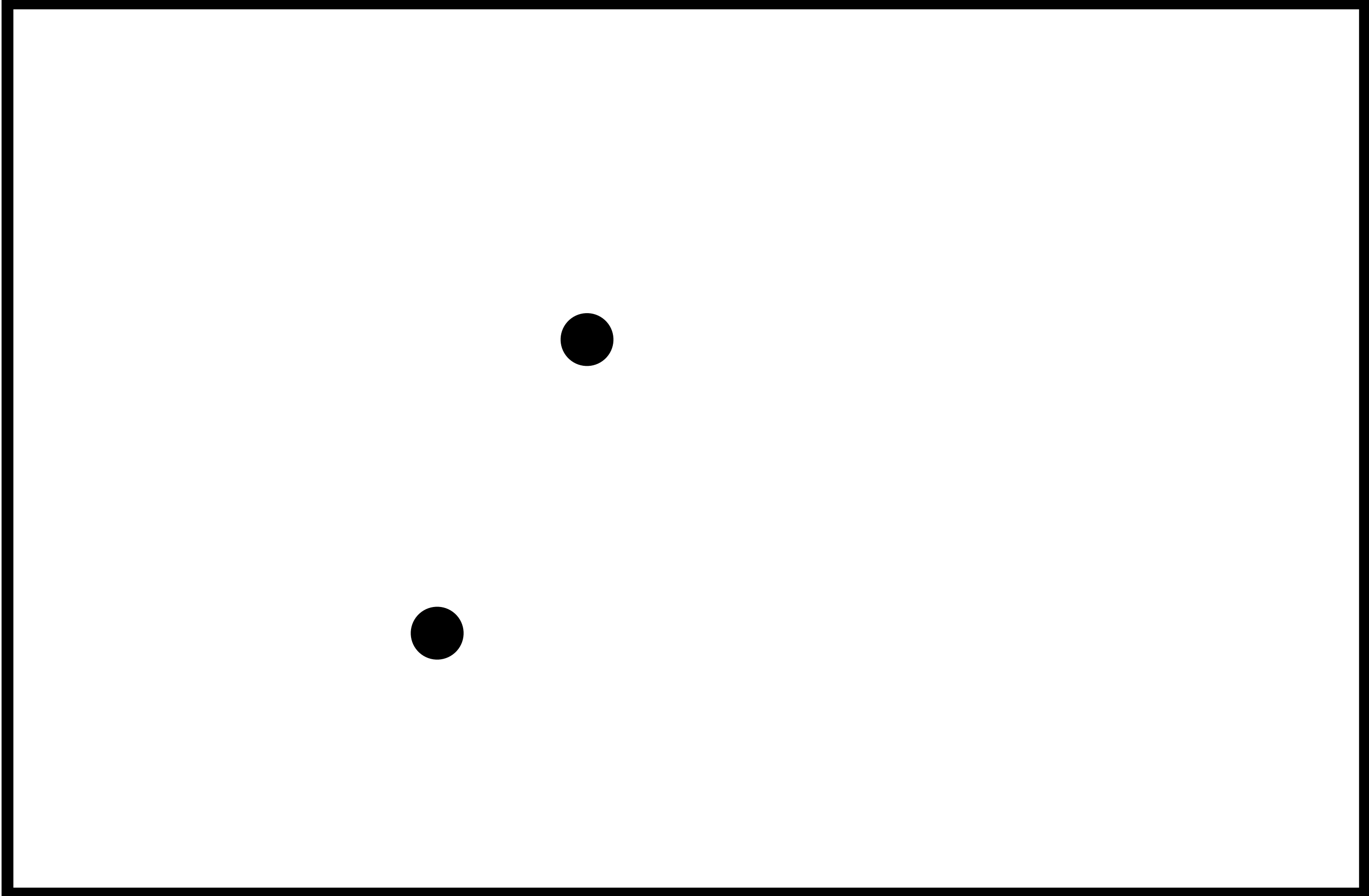
PSF

Systeme Optique

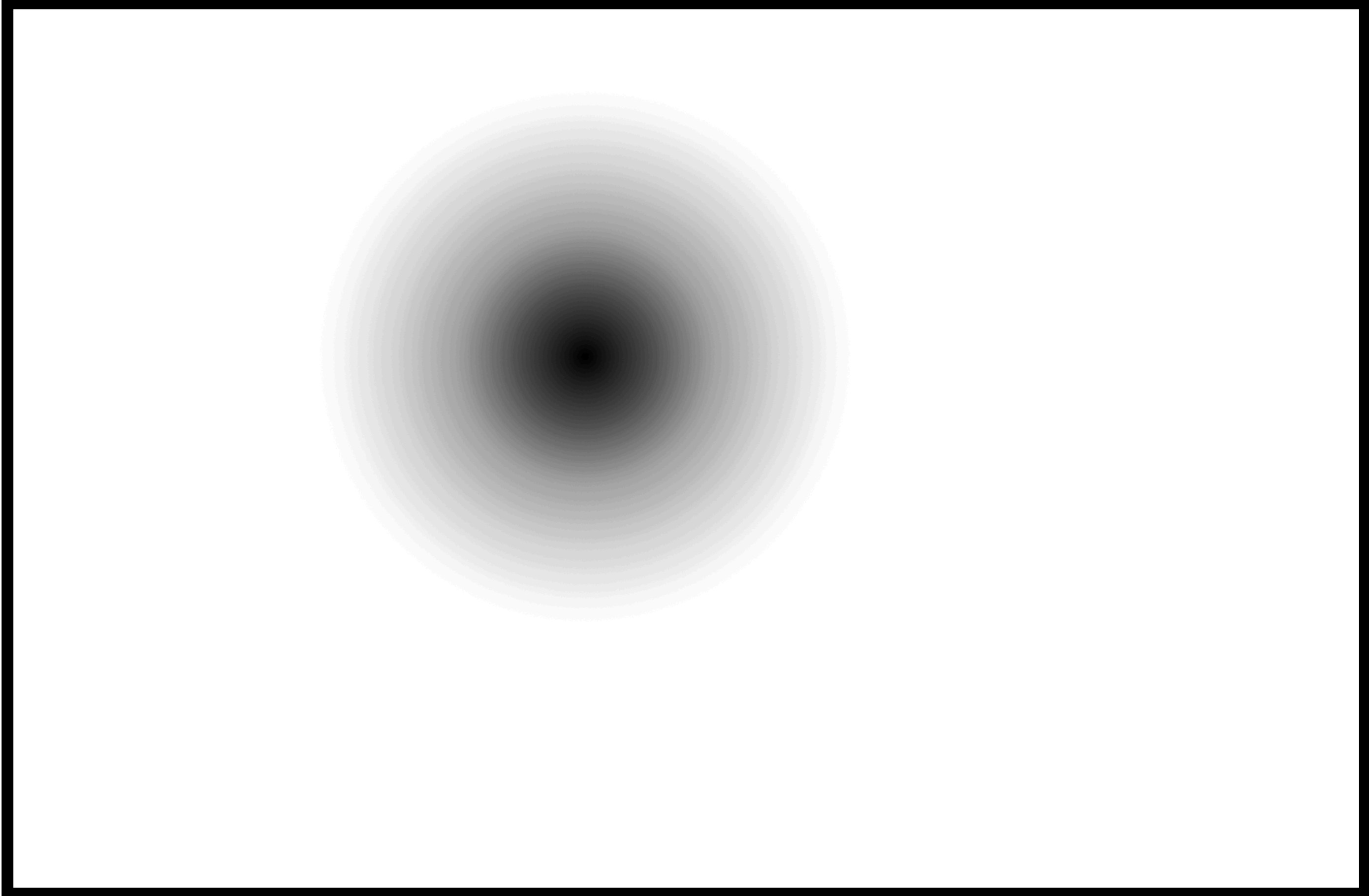
[www.gatinel.com](http://www.gatinel.com)

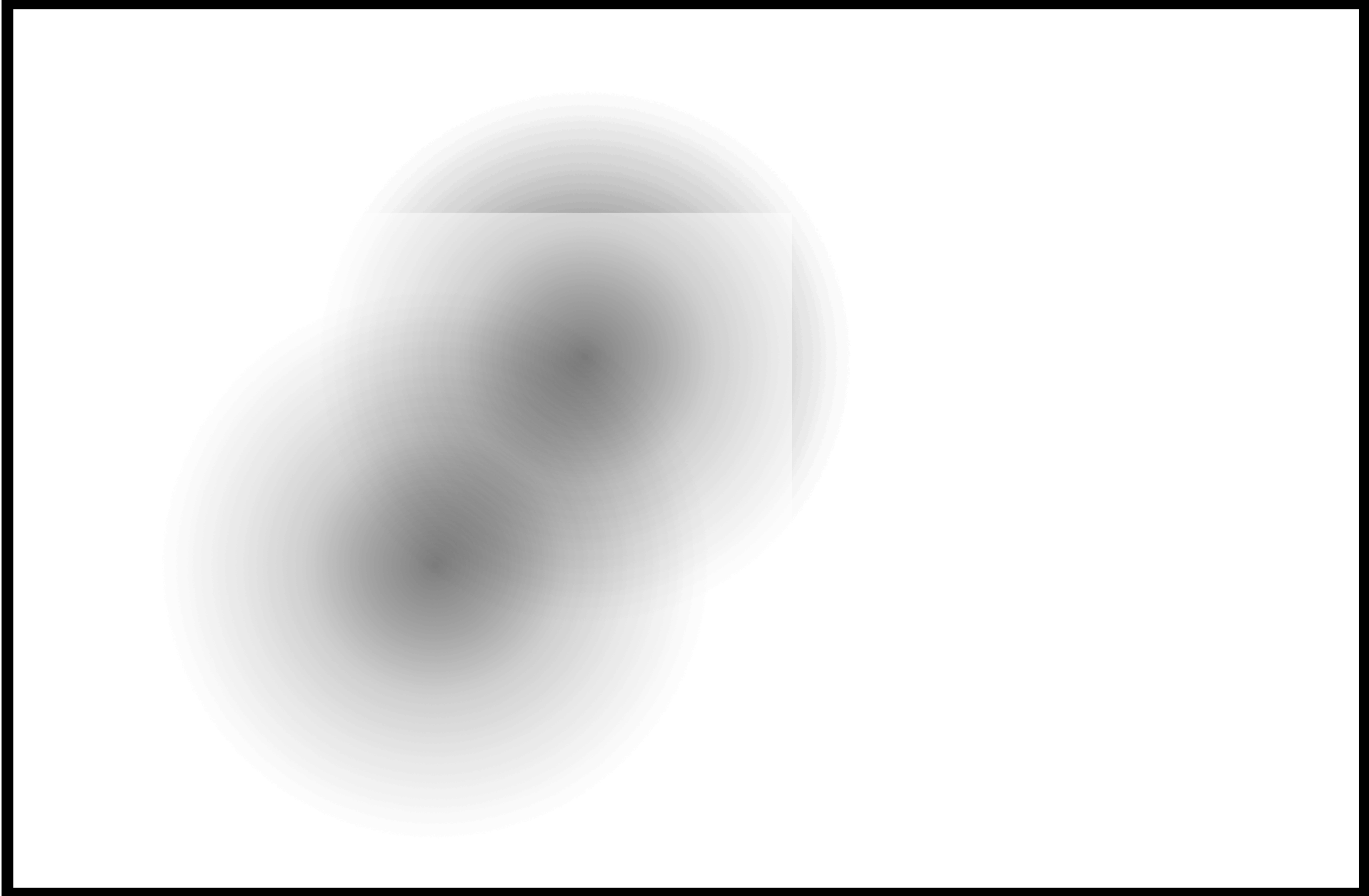


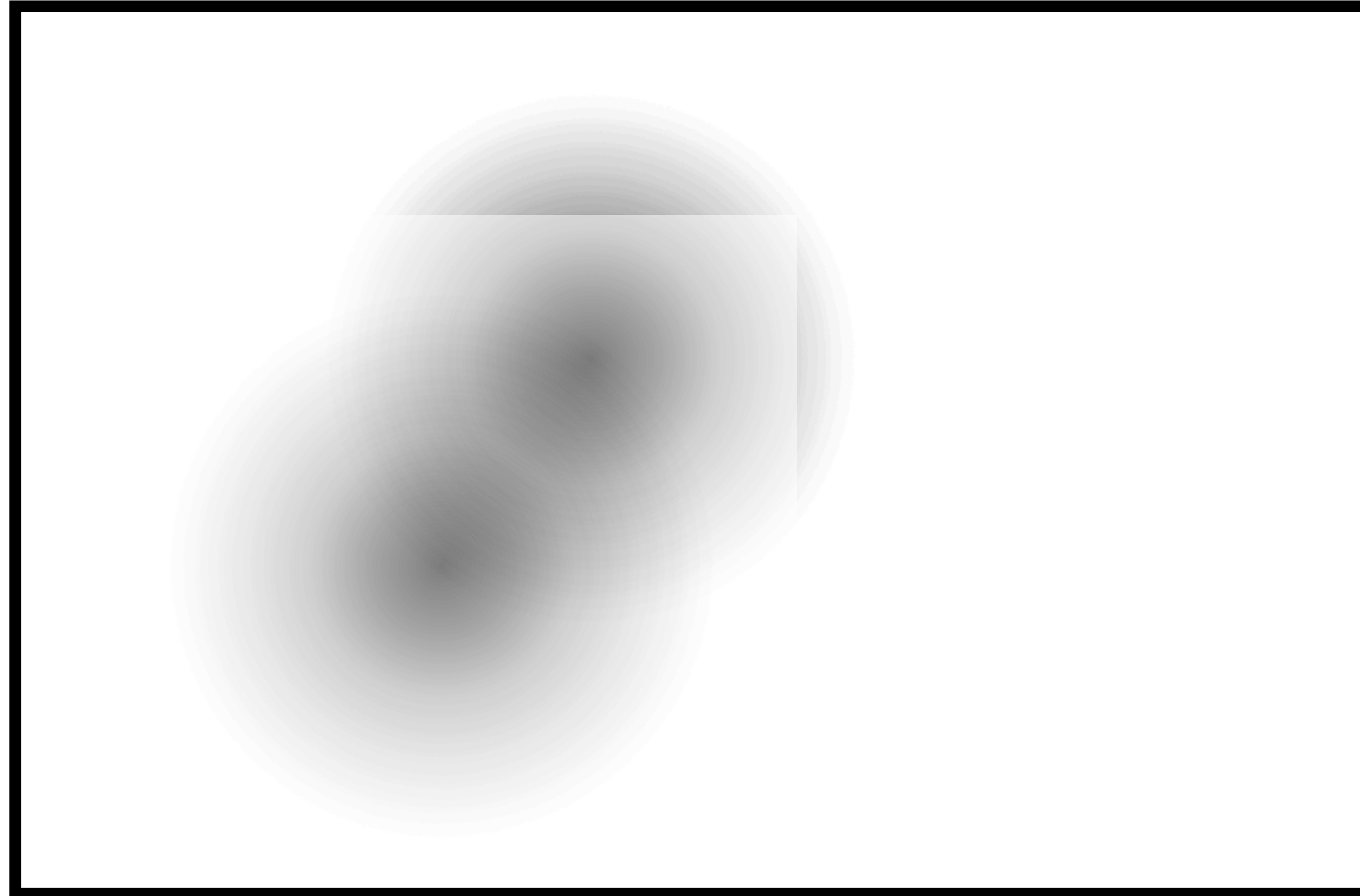












Non è eliminabile ed è sempre presente

[room]

[hall]



Aladdin A-light

# Scene setup

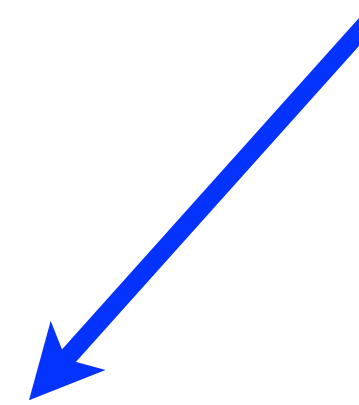


MCC2

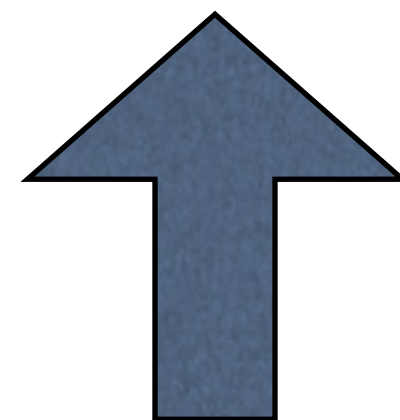
MCCI



Black cardboard  
shield



Aladdin A-light



Point of view

# Jpeg [fixed exposure]



Aladdin A-light [off-15.6 c/m<sup>2</sup>]

# Jpeg [fixed exposure]



[room]

[hall]

Aladdin A-light [469 c/m<sup>2</sup>]

# Jpeg [fixed exposure]



[room]

[hall]

Aladdin A-light [1980 c/m<sup>2</sup>]



# Jpeg [fixed exposure]



[room]

[hall]

Aladdin A-light [3950 c/m<sup>2</sup>]

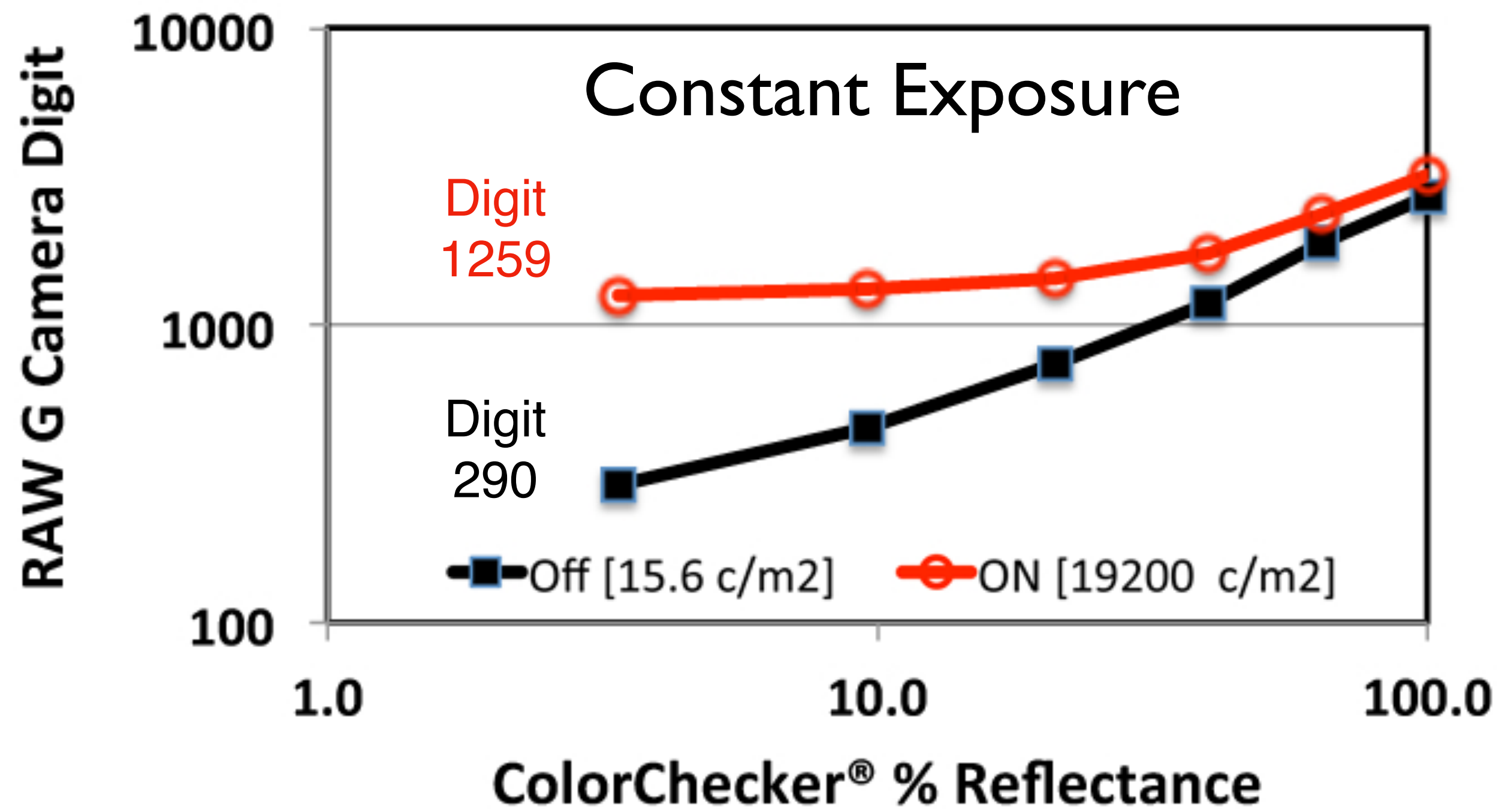
# Jpeg [fixed exposure]

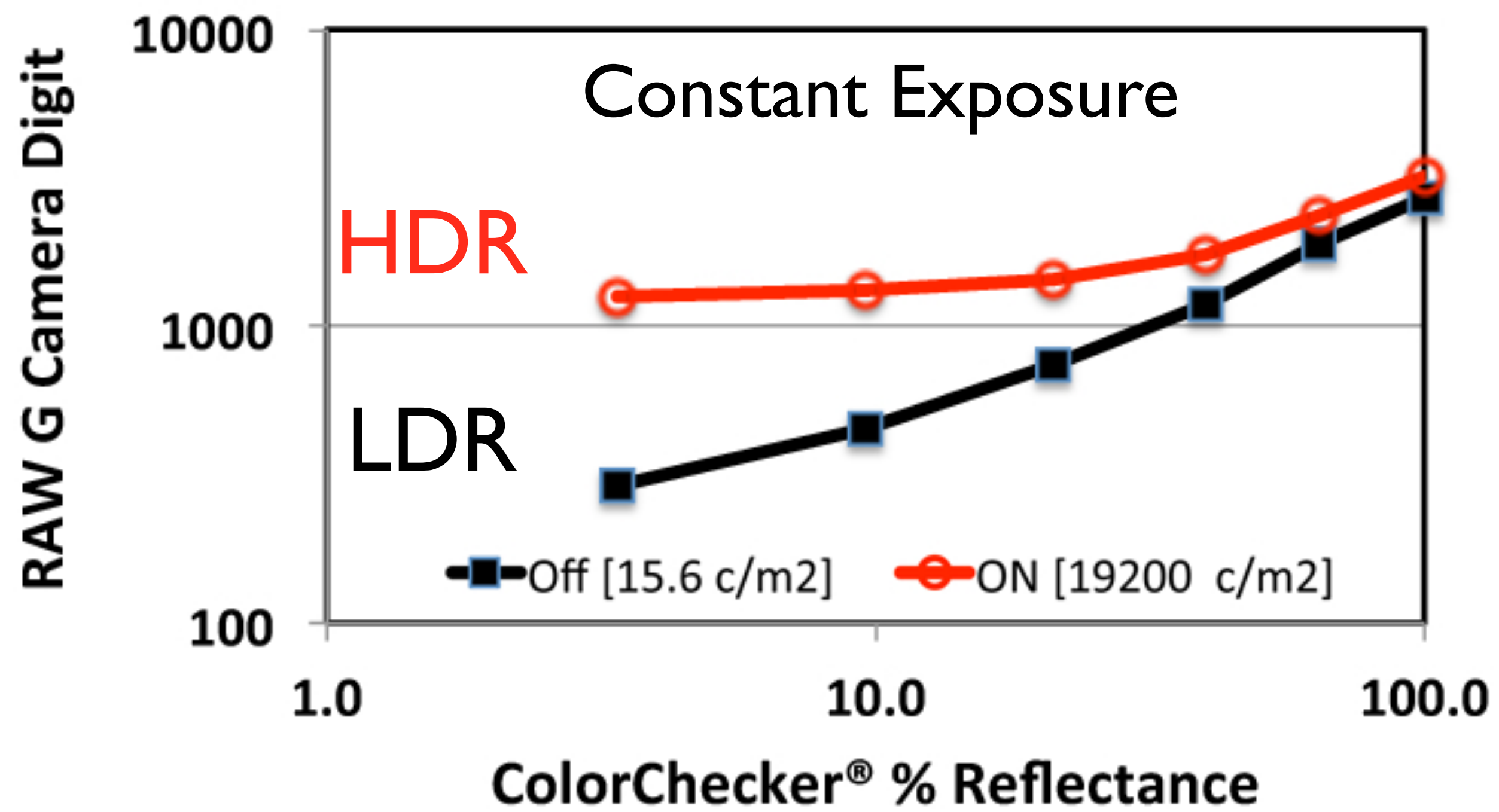


[room]

[hall]

Aladdin A-light [19200 c/m<sup>2</sup>]



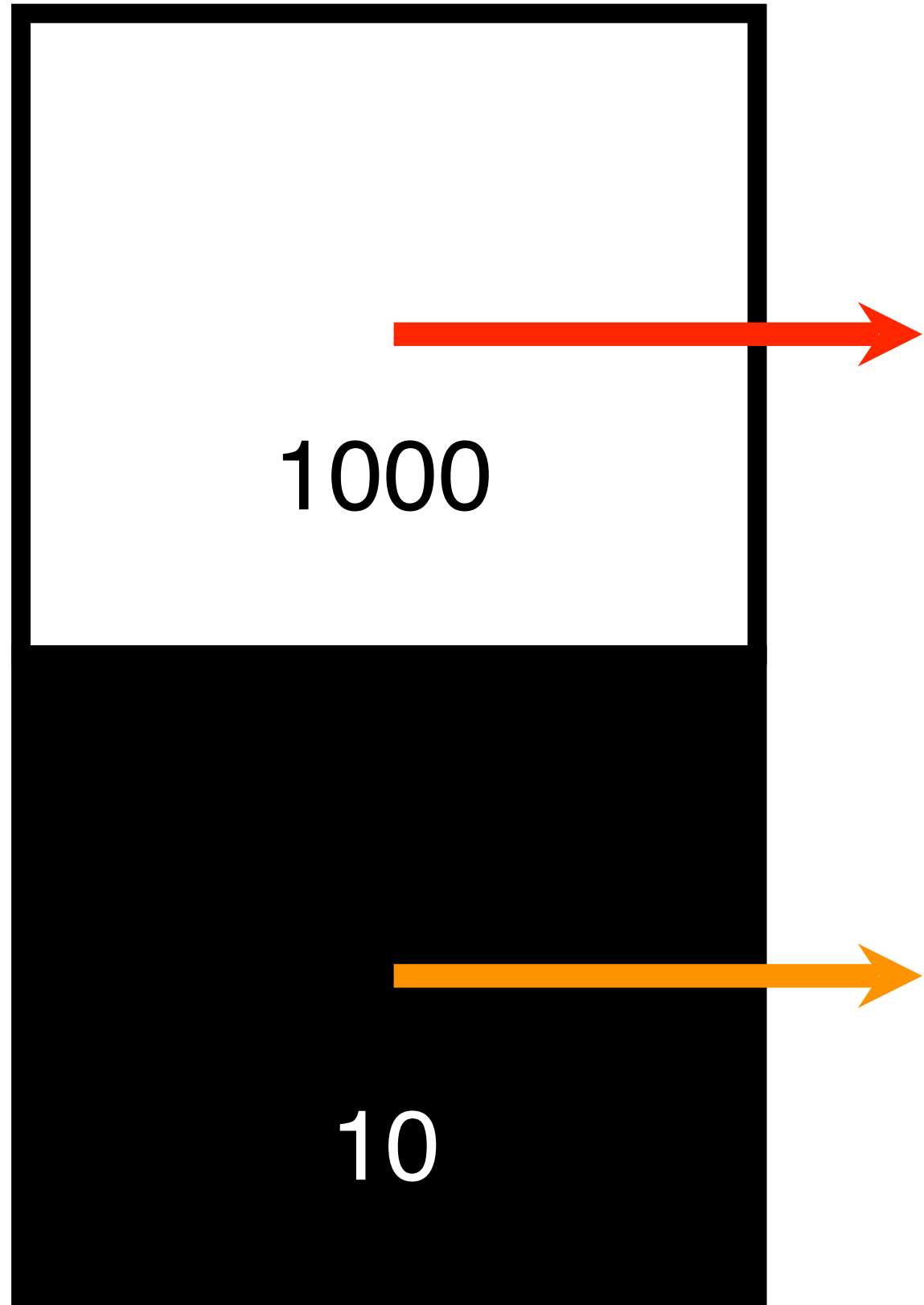




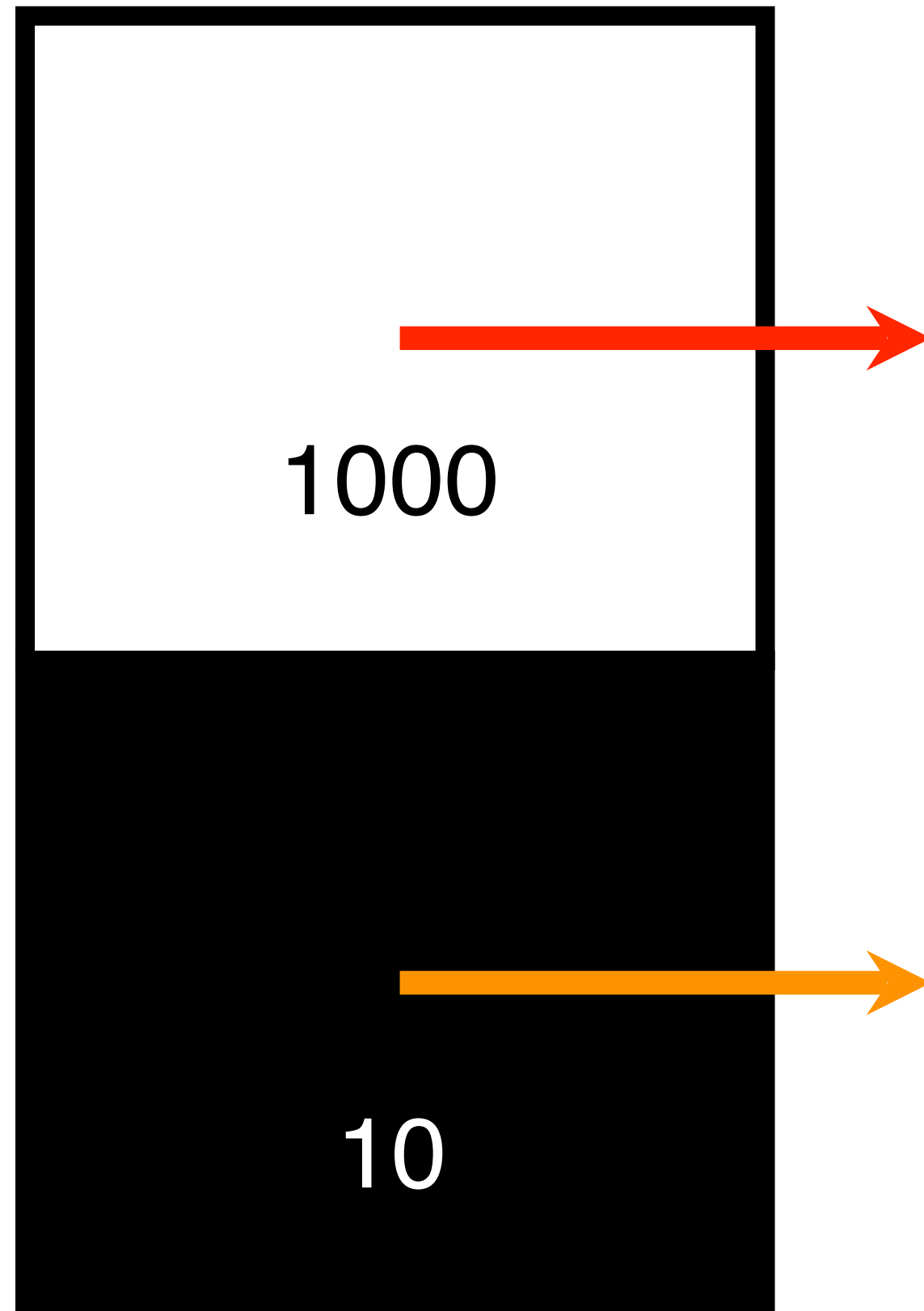
# Falsa idea

Glare vi sia solo in  
presenza di Highlights

Photo by Roy Thomson

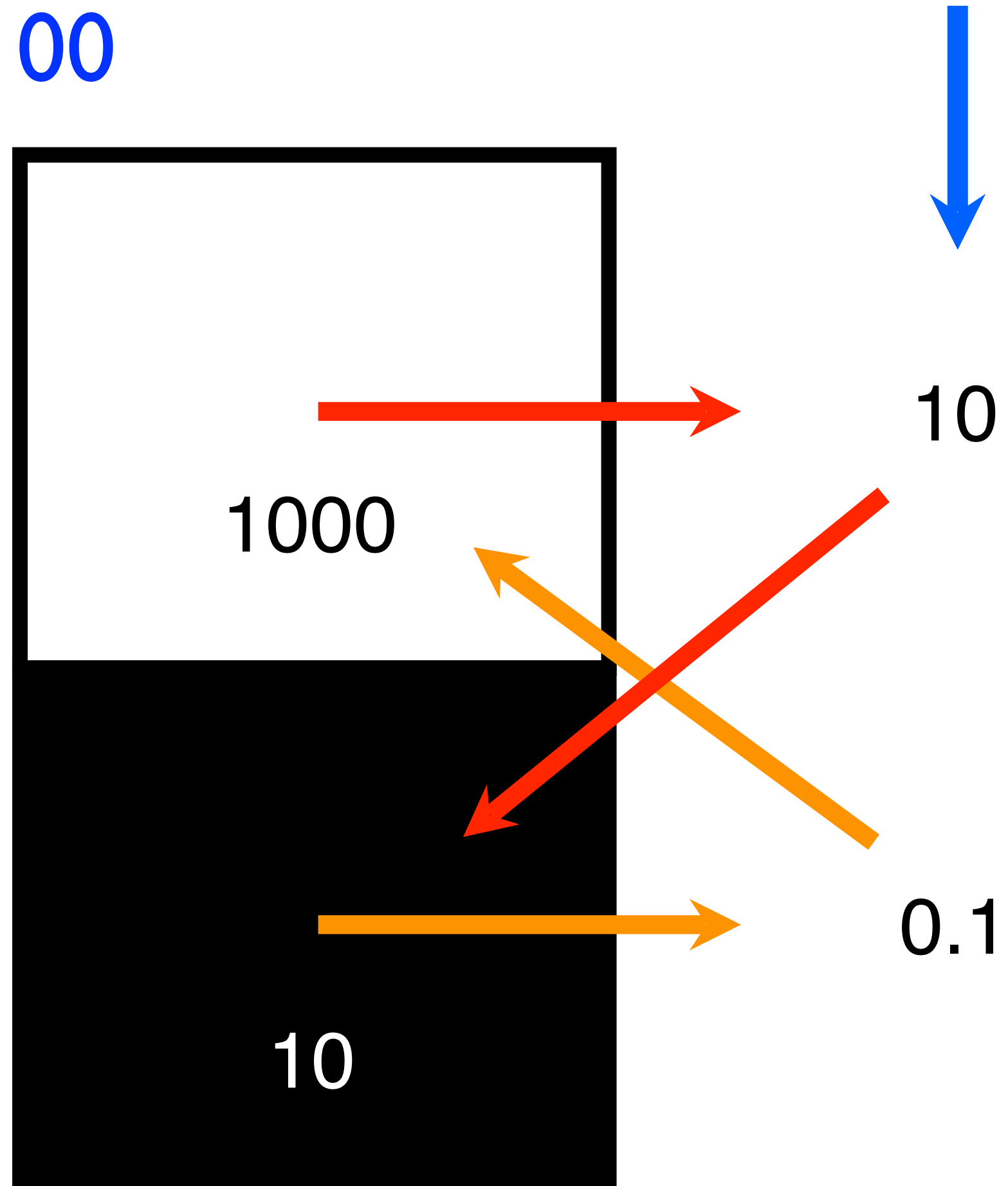


DR=100



1% arbitrary glare value

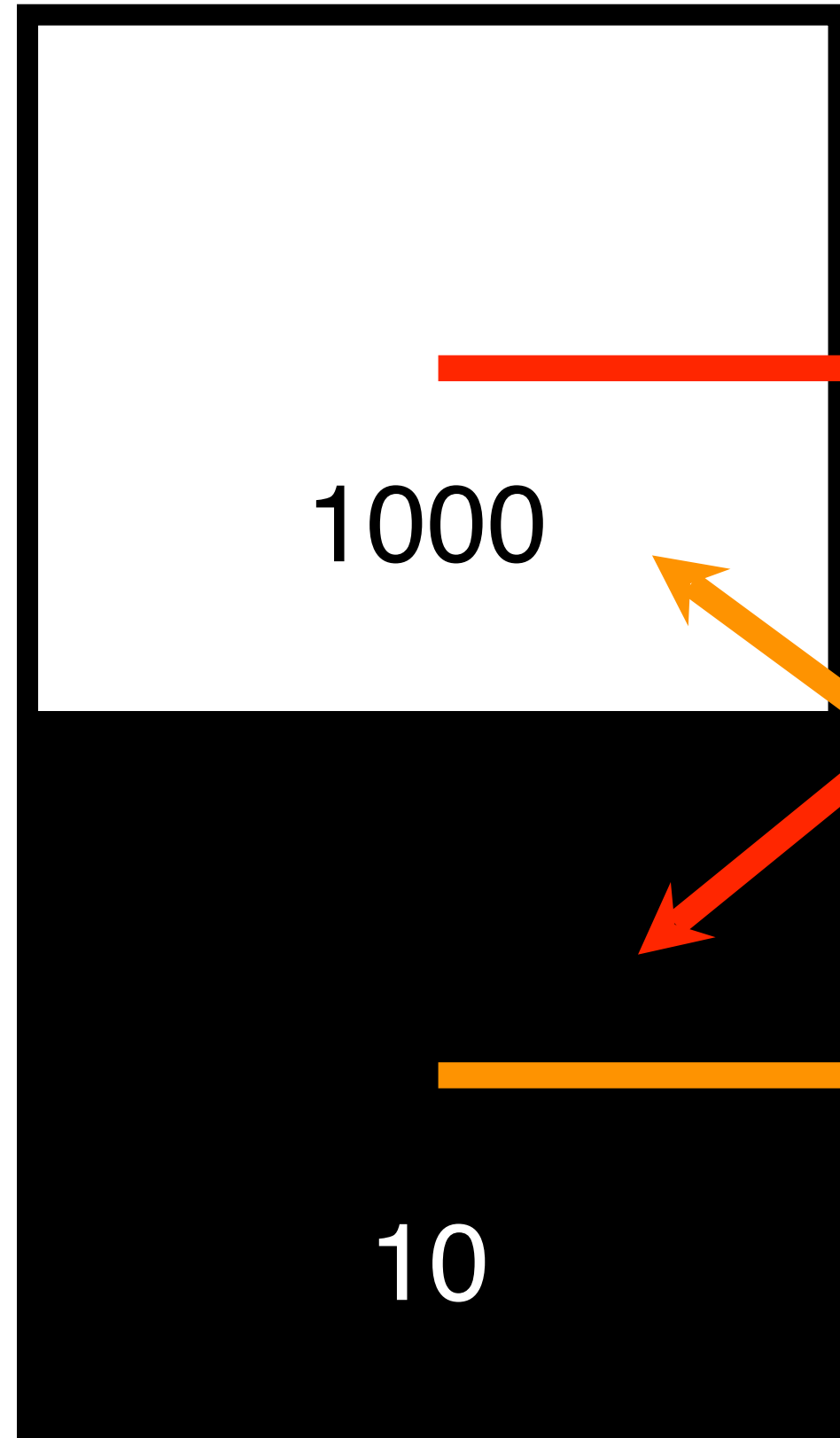
DR=100





1% arbitrary glare value

DR=100



10

$$0.1/1000 = 0.0001$$

0.1

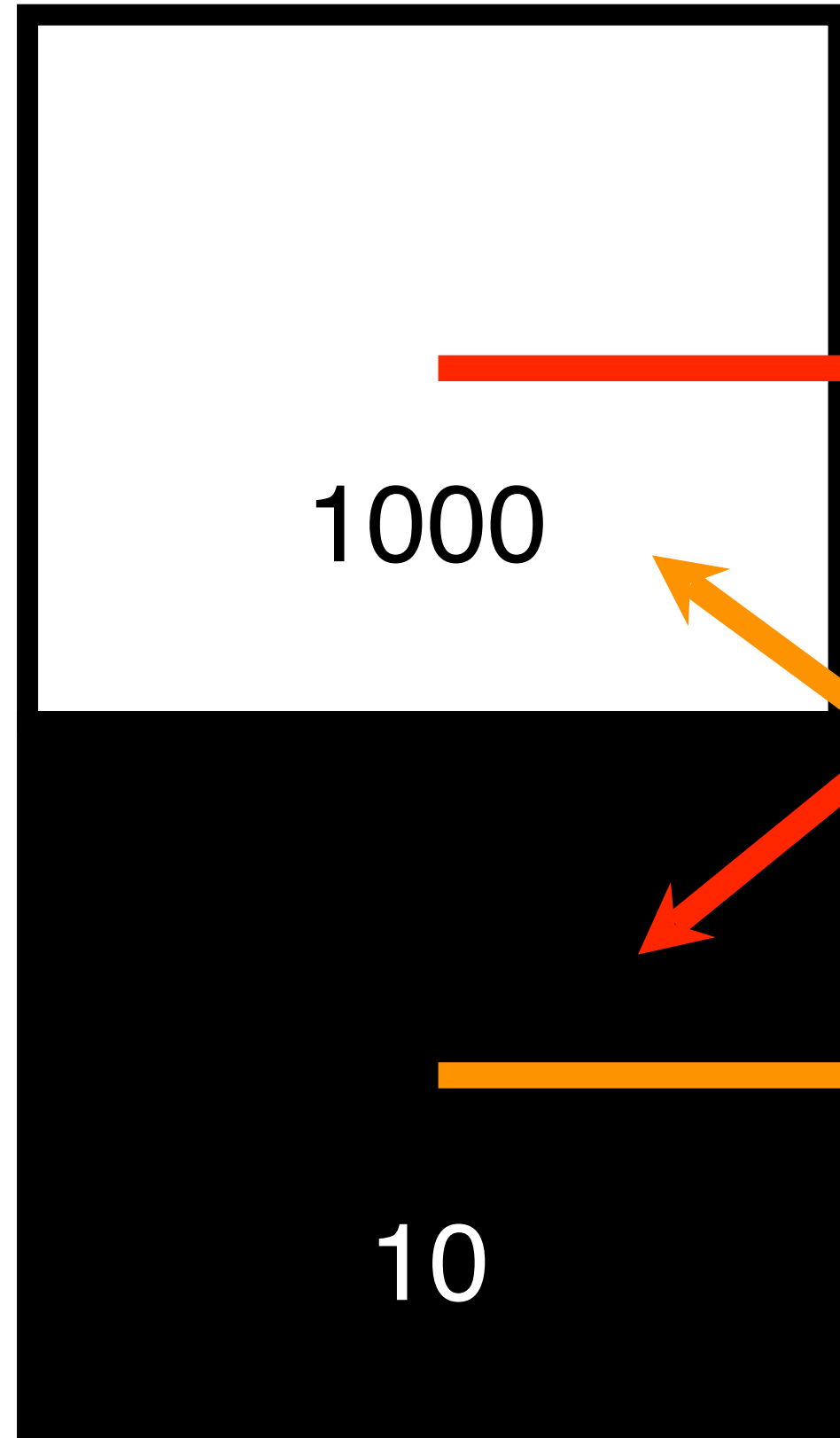
$$10/10 = 1$$

10

effect of glare

1% arbitrary glare value

DR=100



10

$$0.1/1000 = 0.0001$$

0.1

$$10/10 = 1$$

Overall effect:  
sum of millions contributions

effect of glare

# Acquisizione con lenti



# Acquisizione con lenti



Cosa arriva sul sensore ?



Using only Lib RAW data with linear calibration

Test for accurate scene measurements



1441



1441

1456



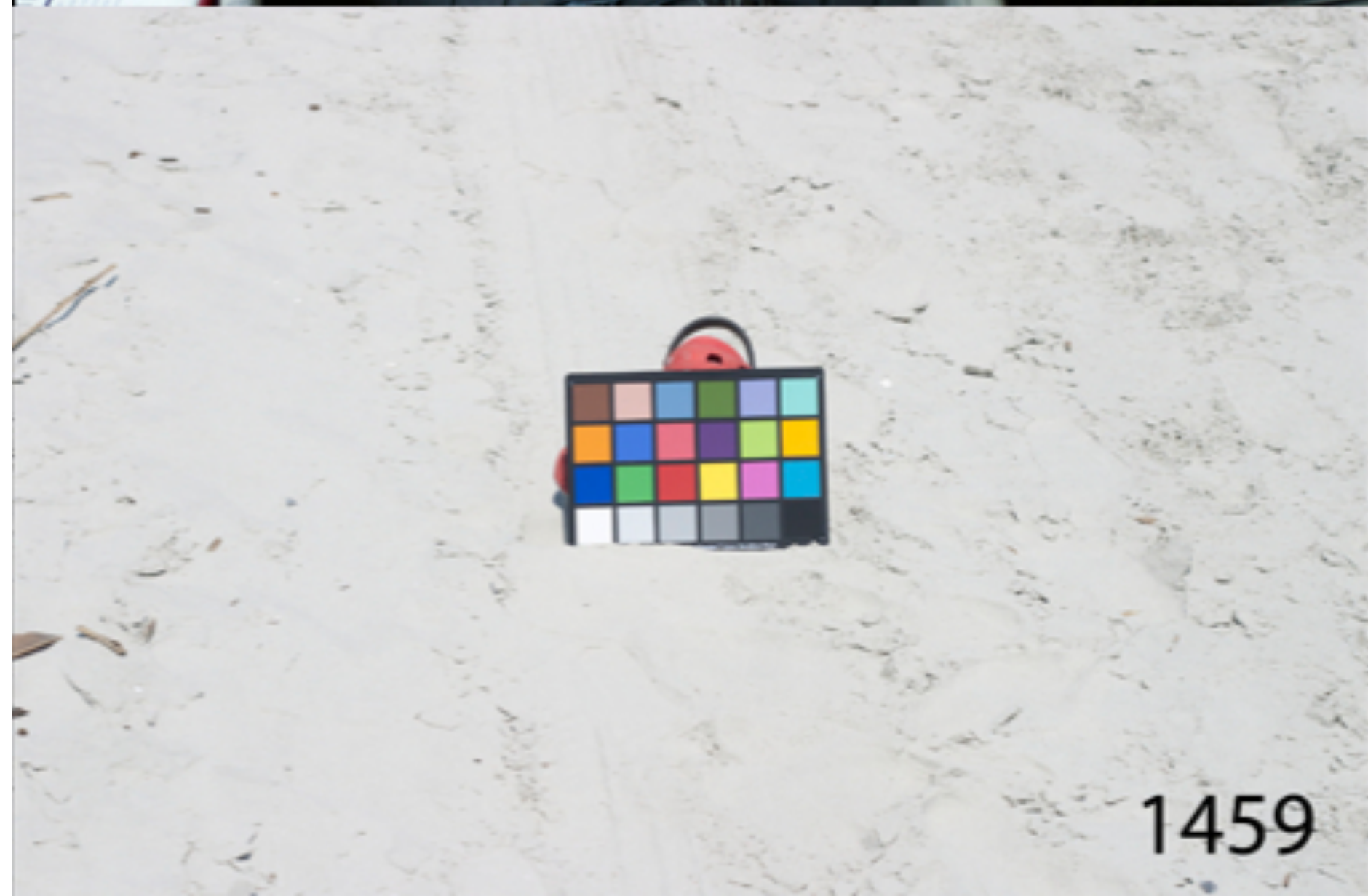


1459

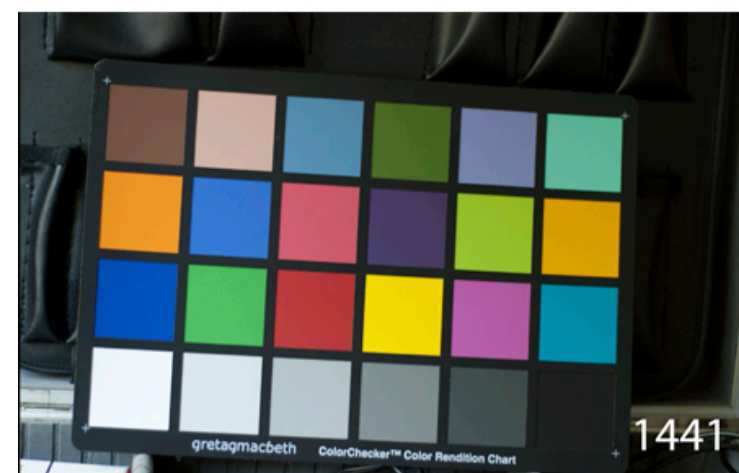
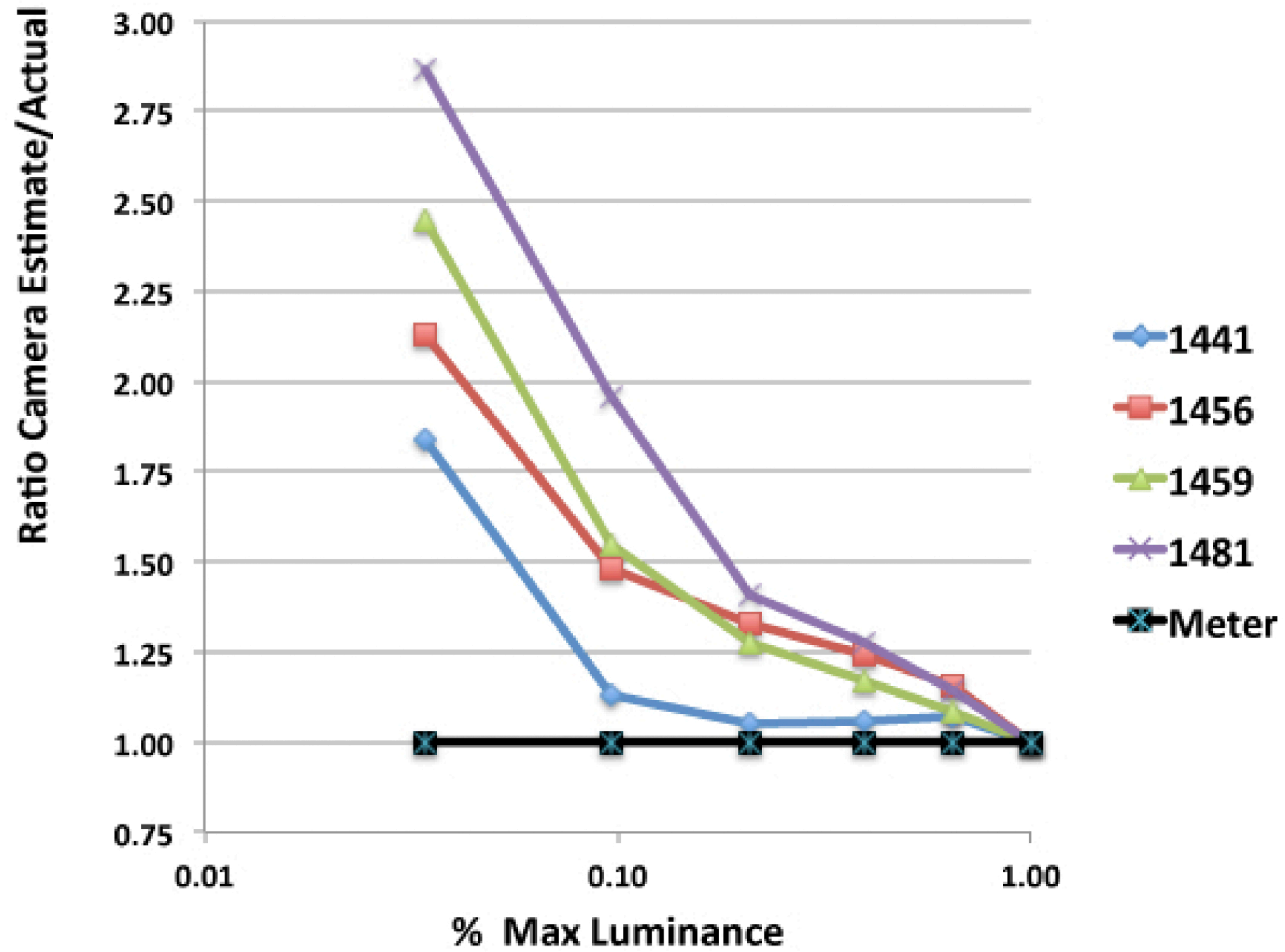


1481

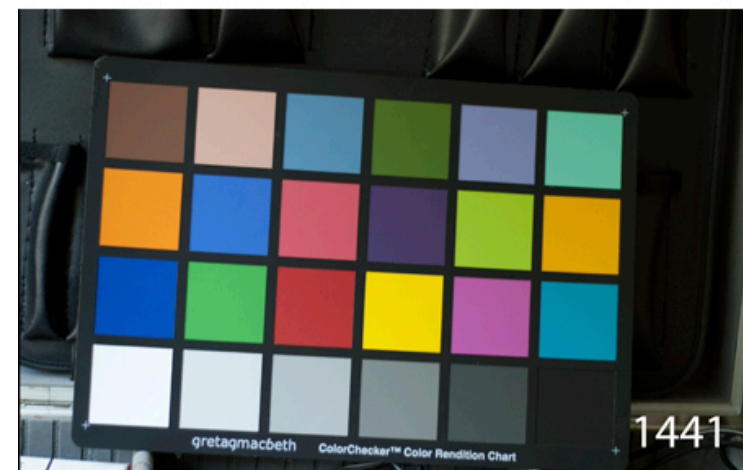
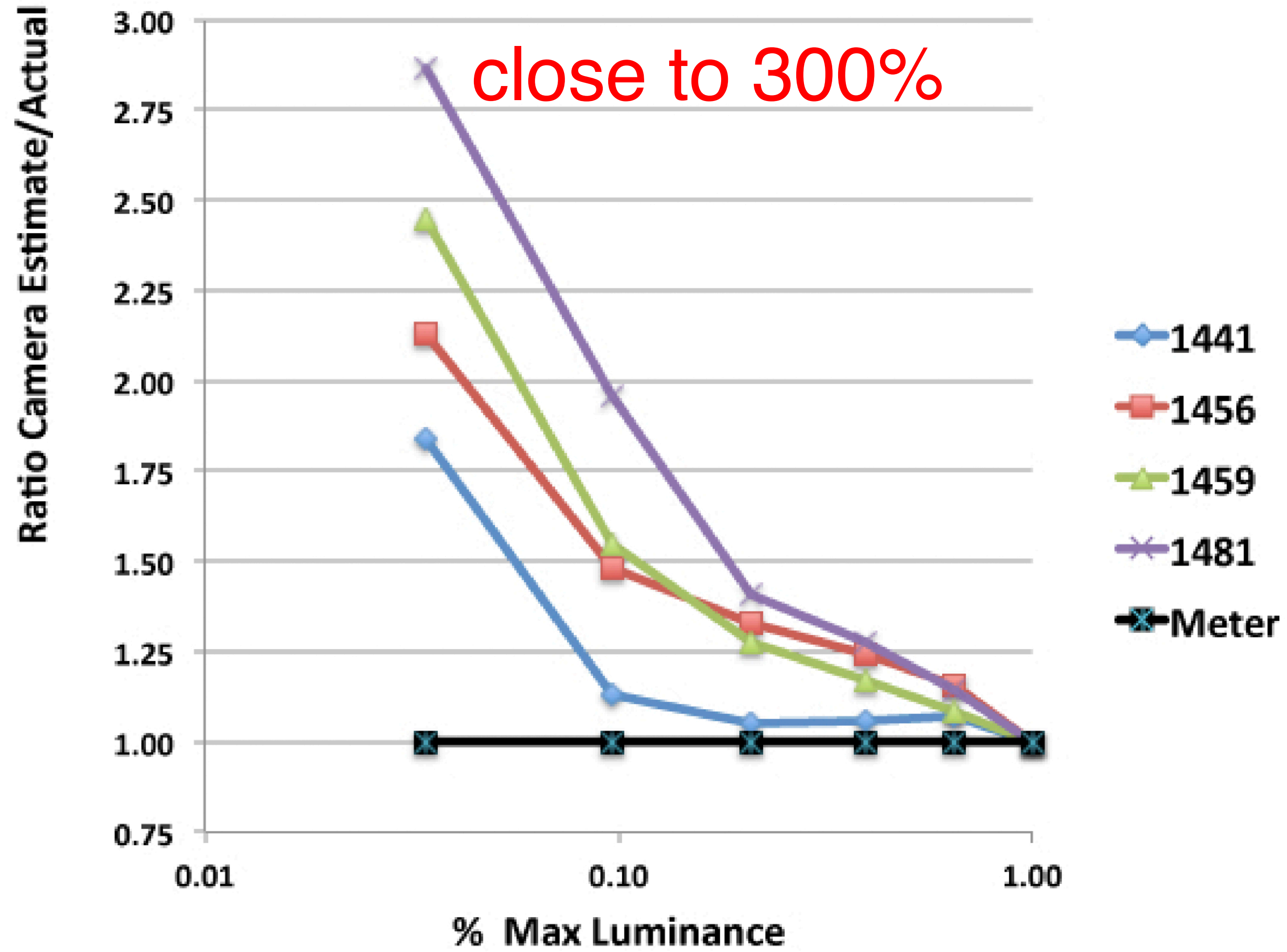
Do they look ok ?

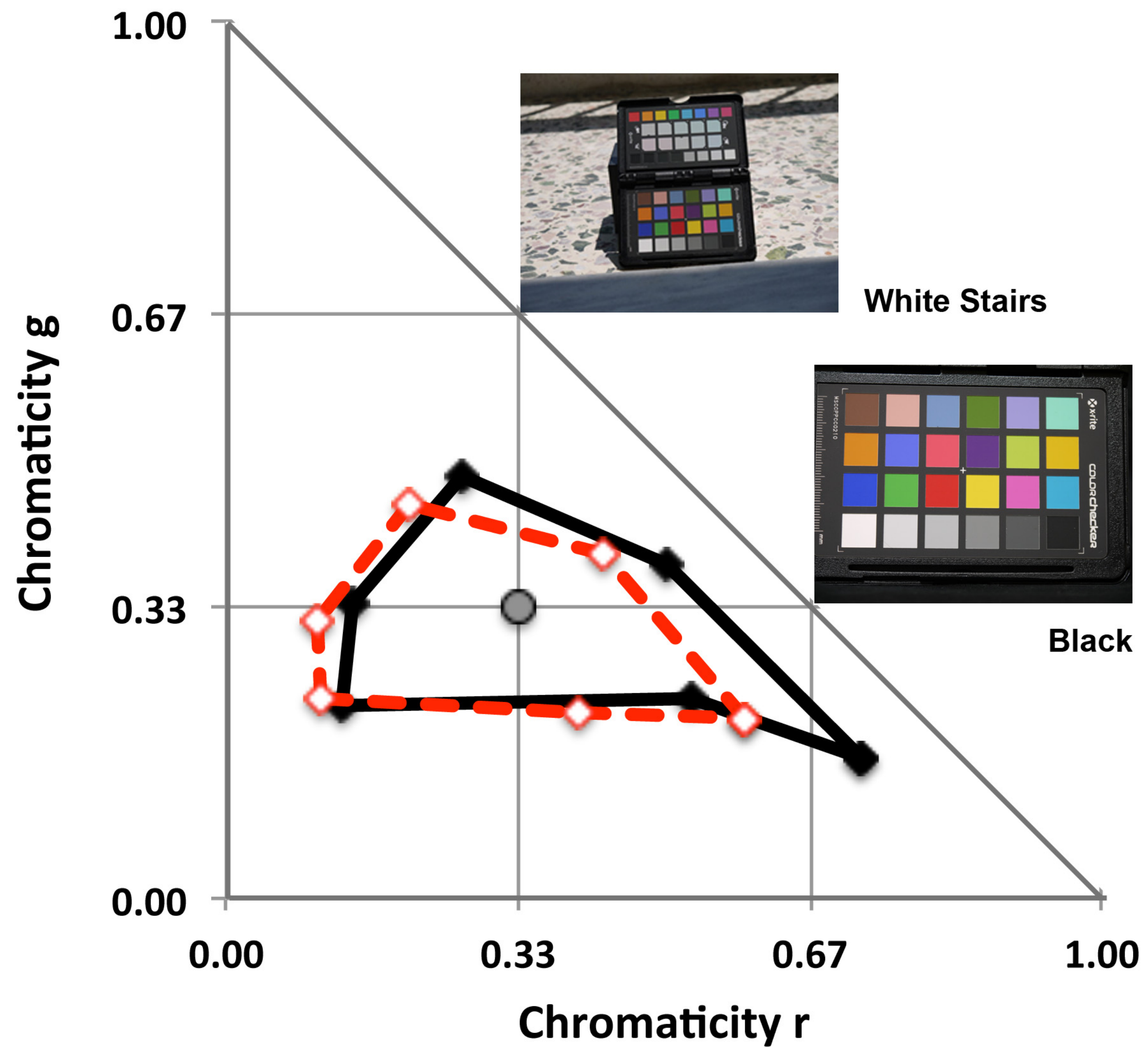


# Scene dependent camera responses

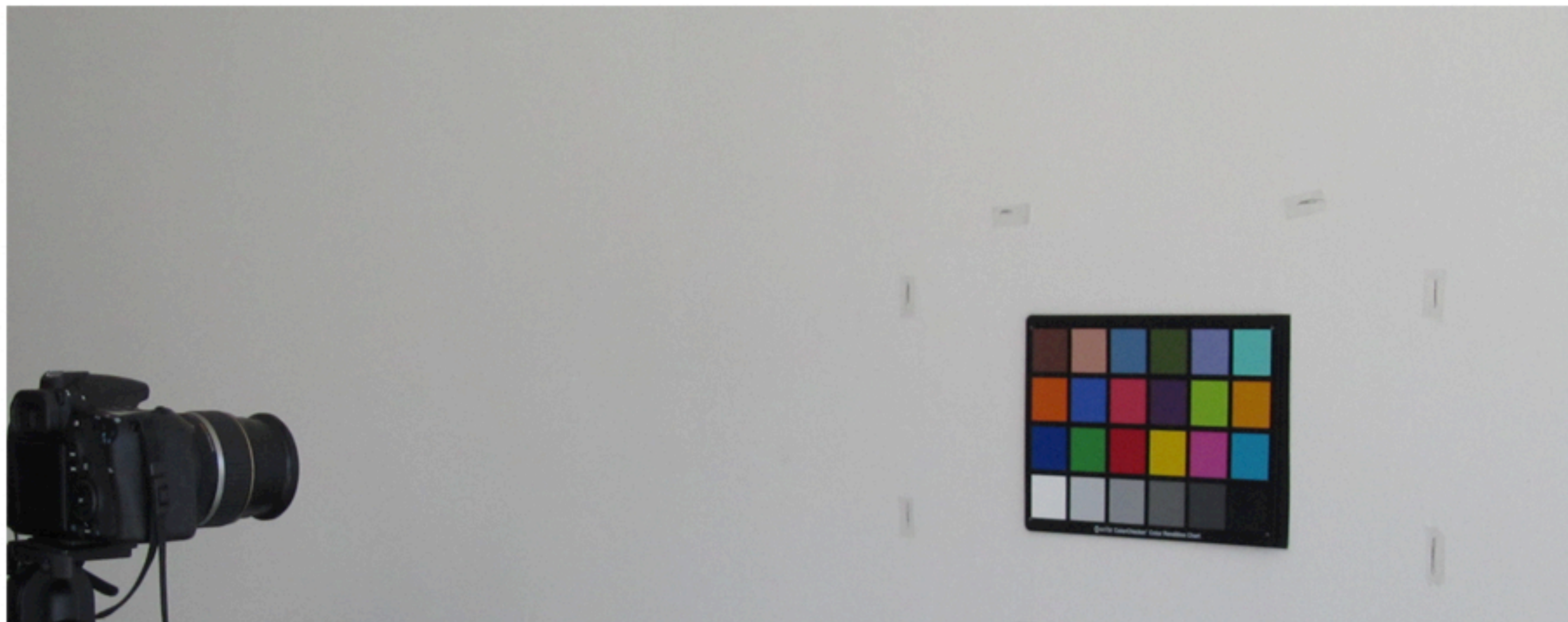
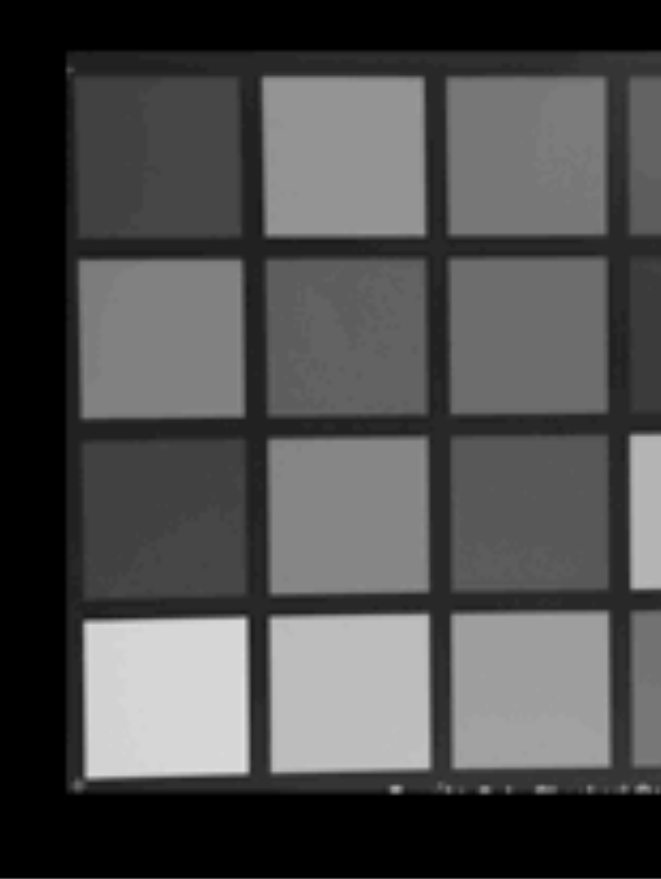
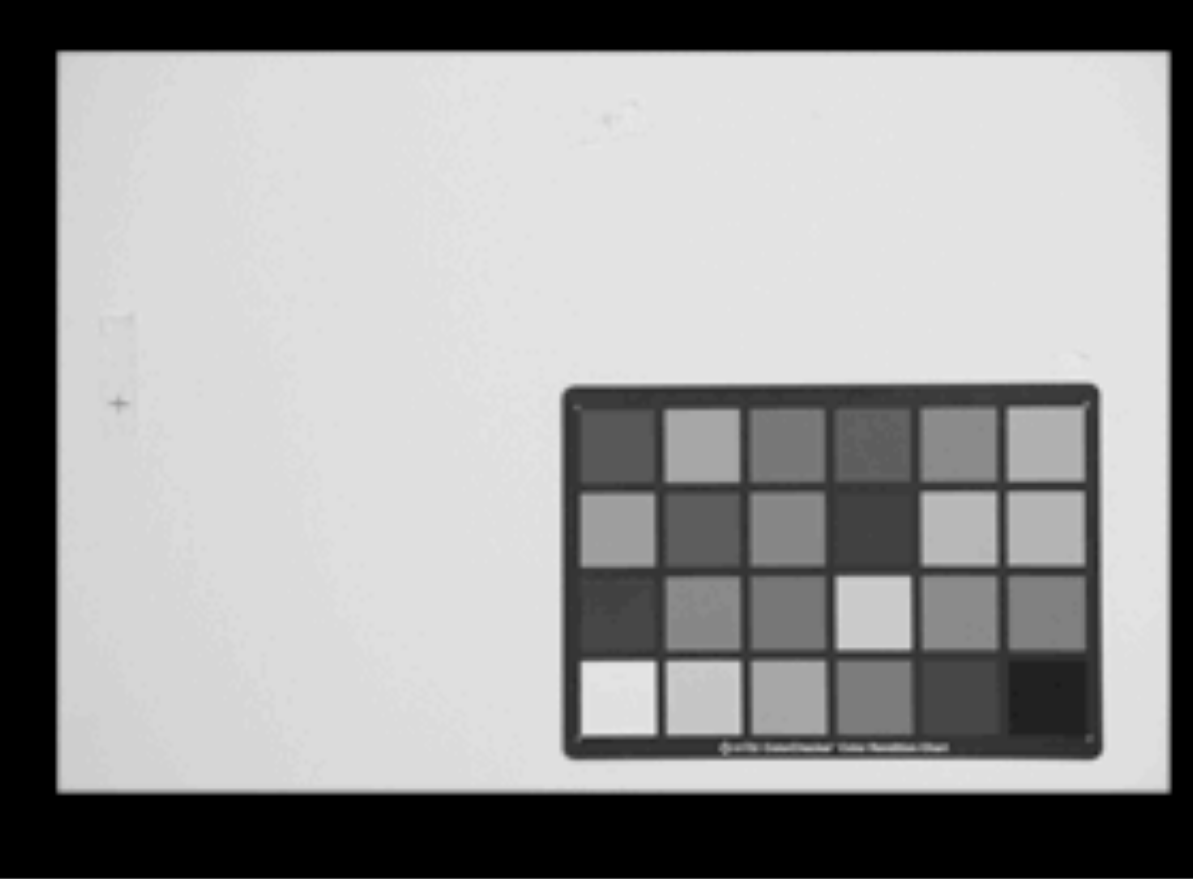
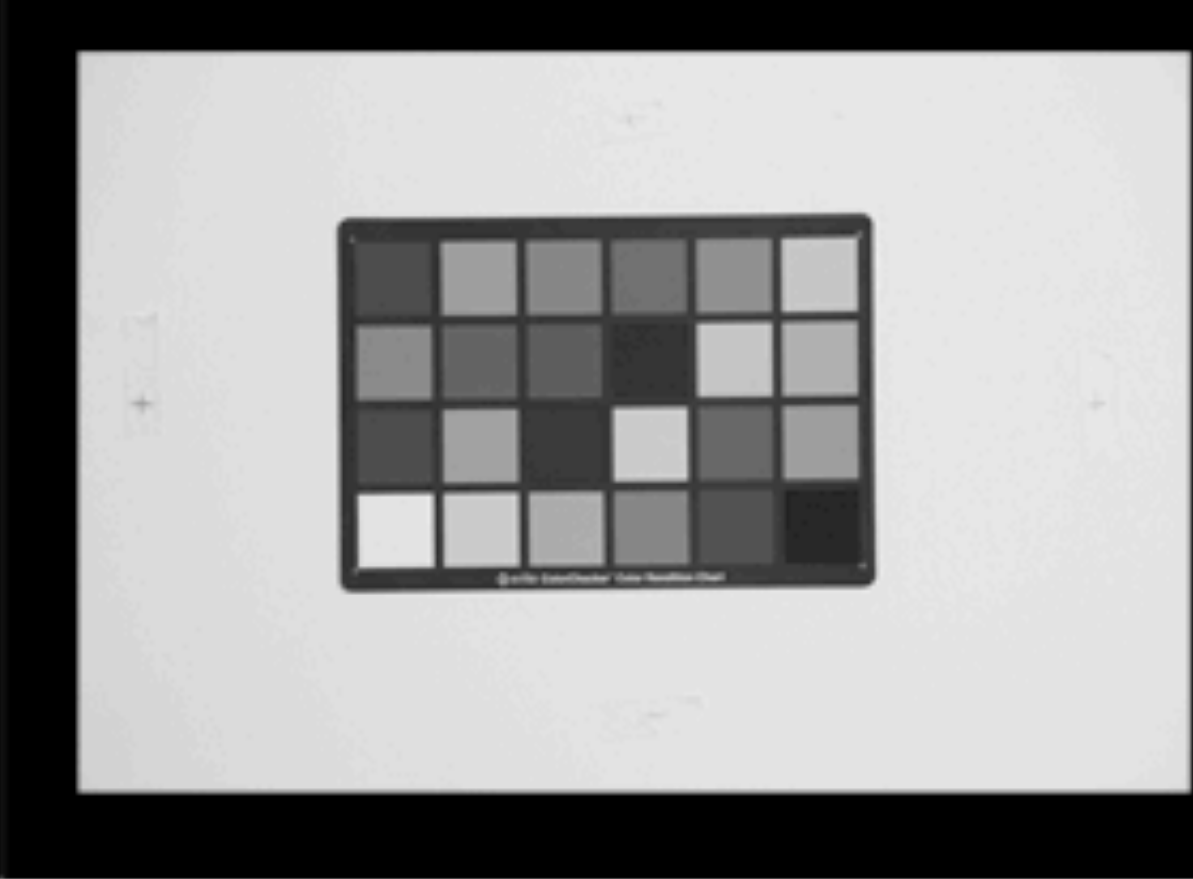
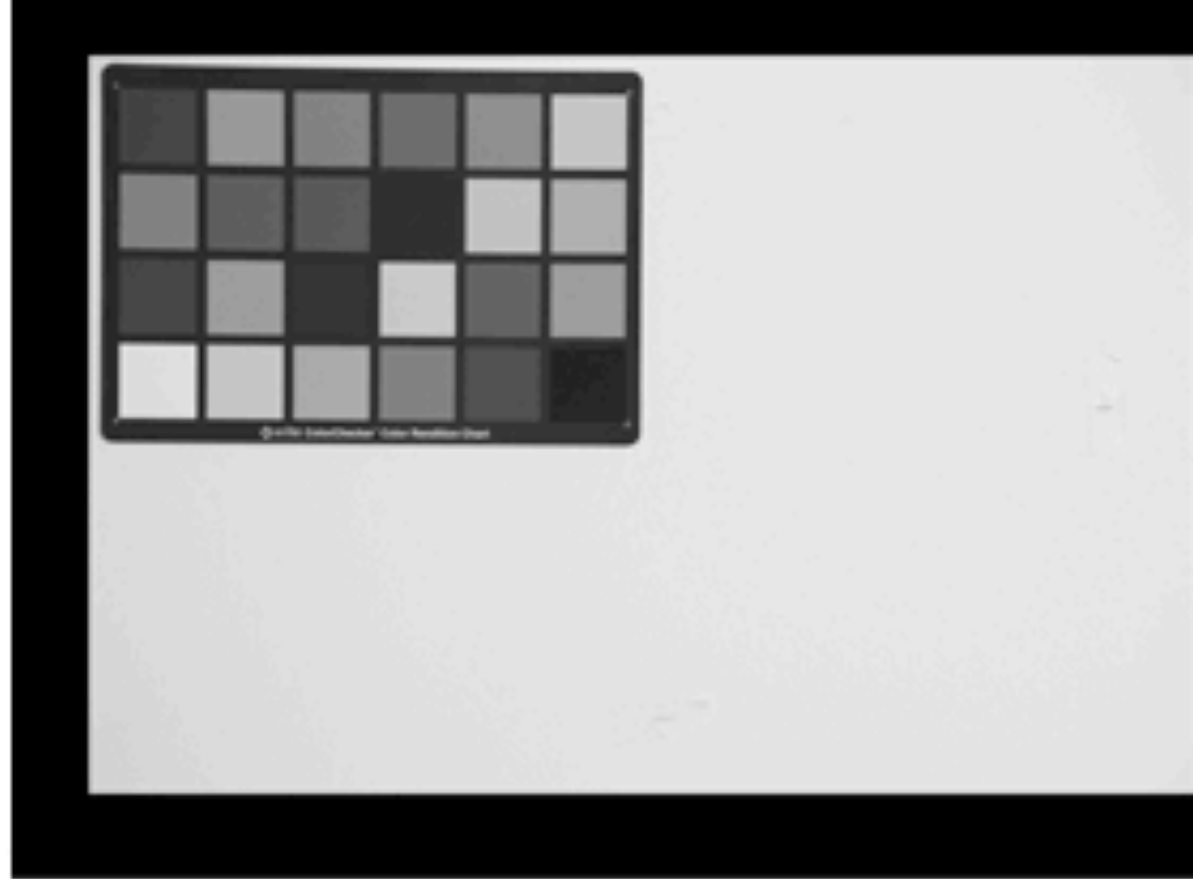


# Scene dependent camera responses





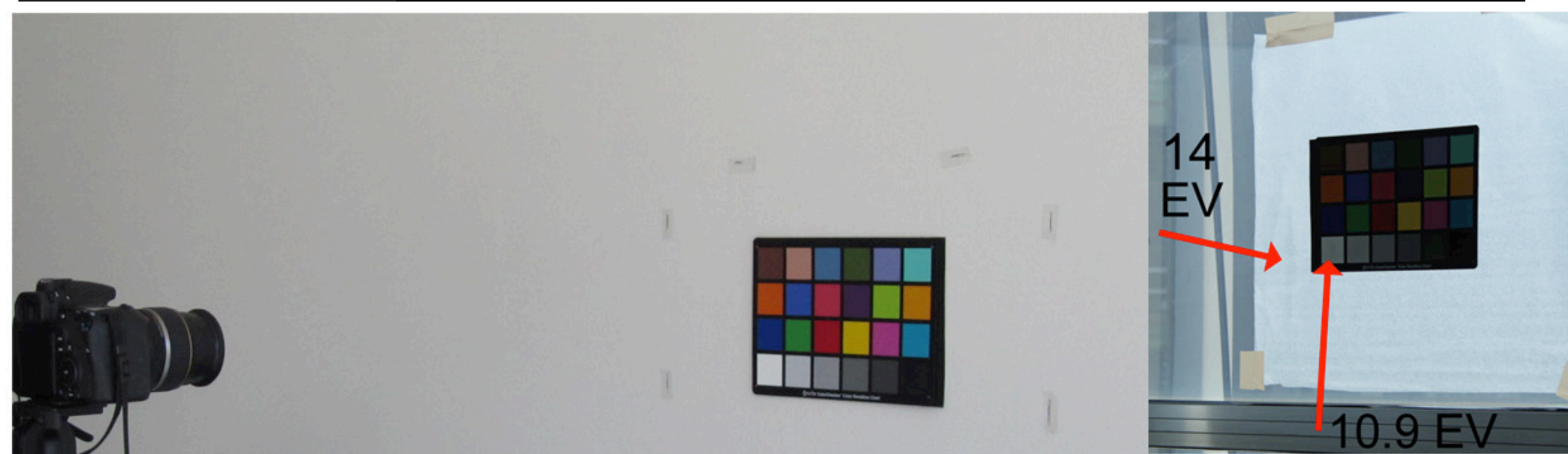
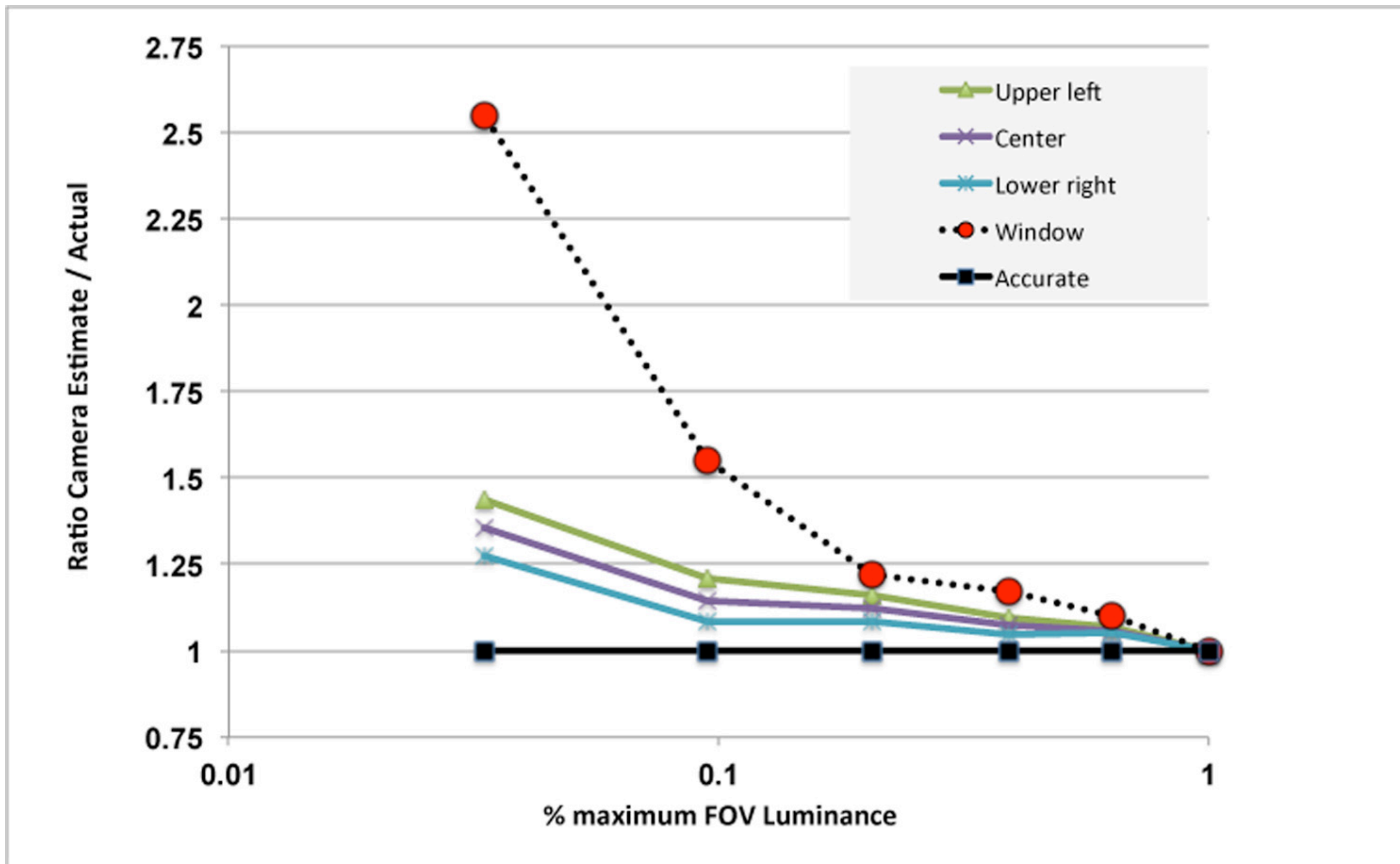
Black    White Stairs    G3



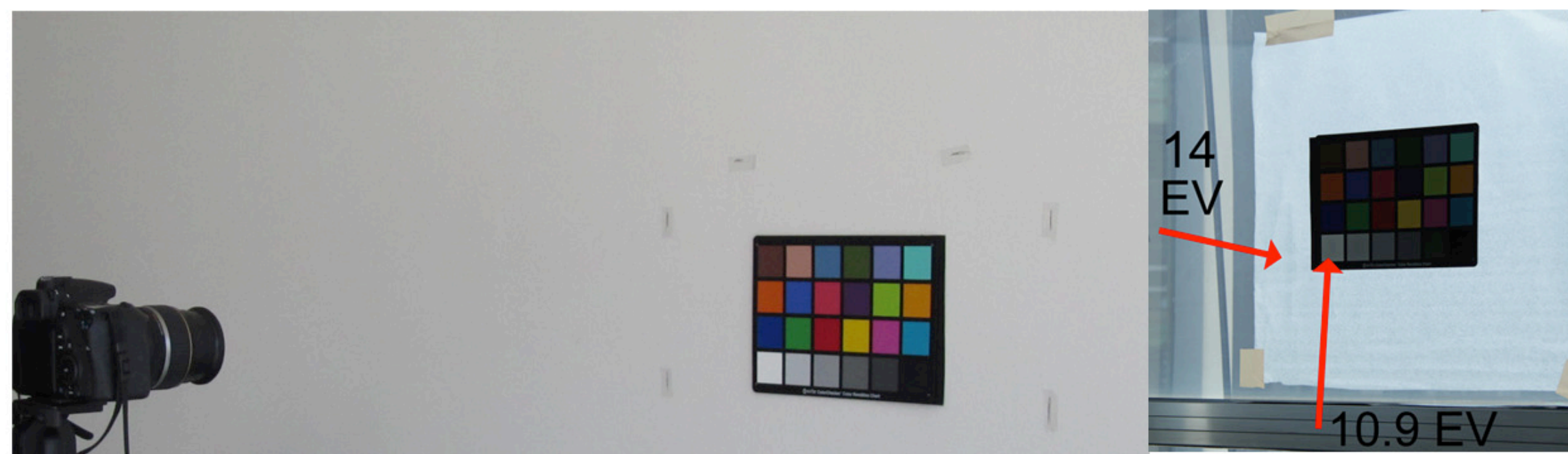
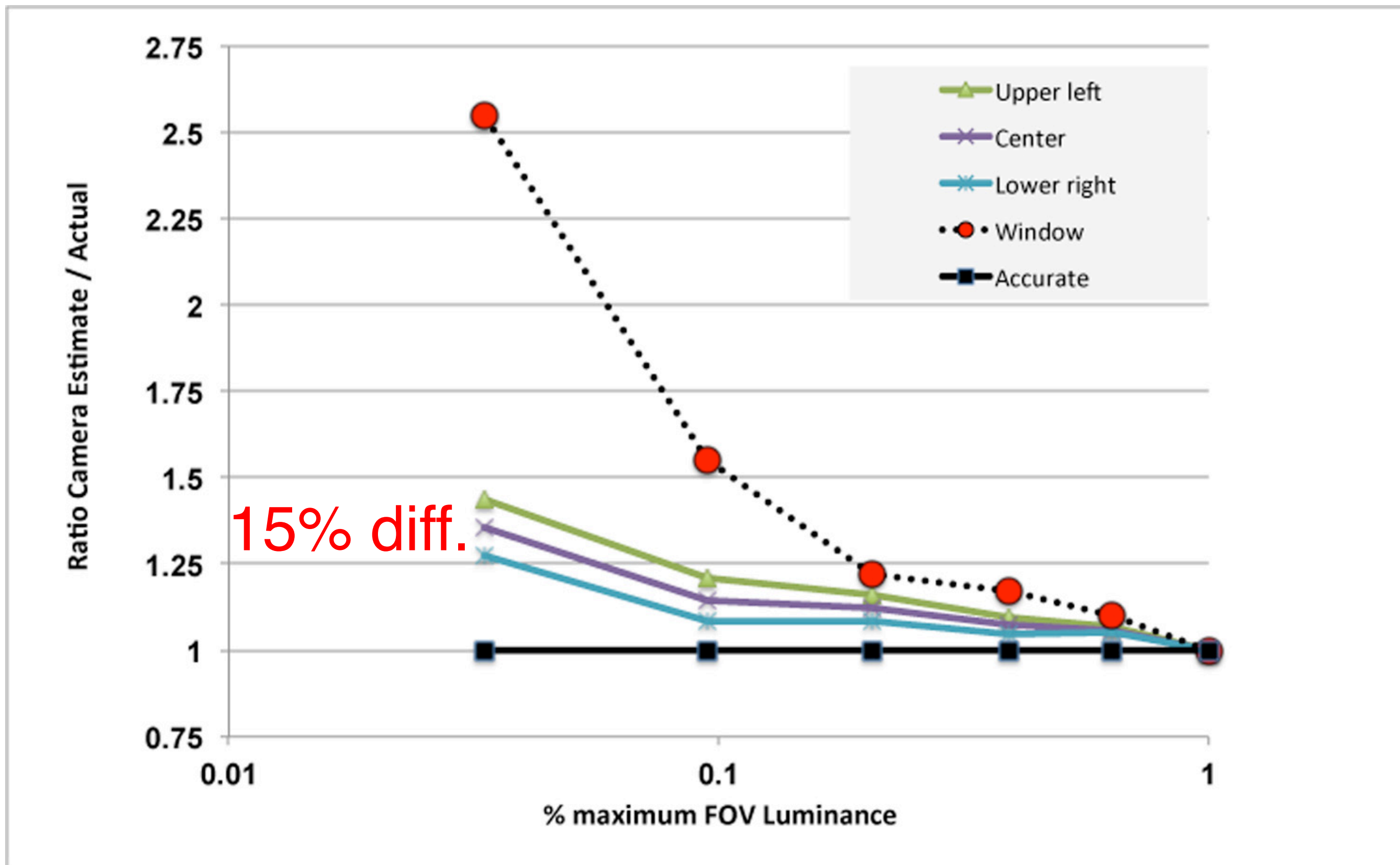
14 EV




10.9 EV







**Grandissima differenza  
nella misura ma  
praticamente invisibile  
per il nostro sistema  
visivo**



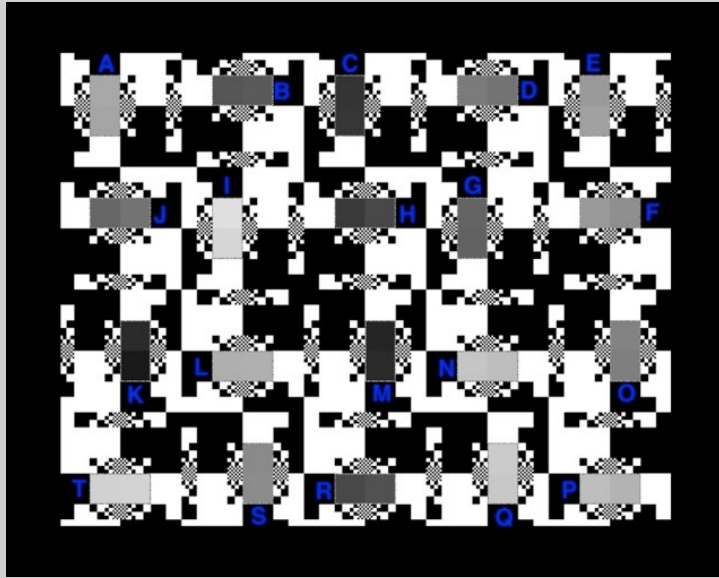
**Del perché la visione dei colori è spaziale e del perché non possiamo misurare colore e spettro con una macchina che usi un obiettivo**

**Alessandro Rizzi**  
**Dipartimento di Informatica**  
**Università degli Studi di Milano**

**Venerdì 18 Novembre 2022**

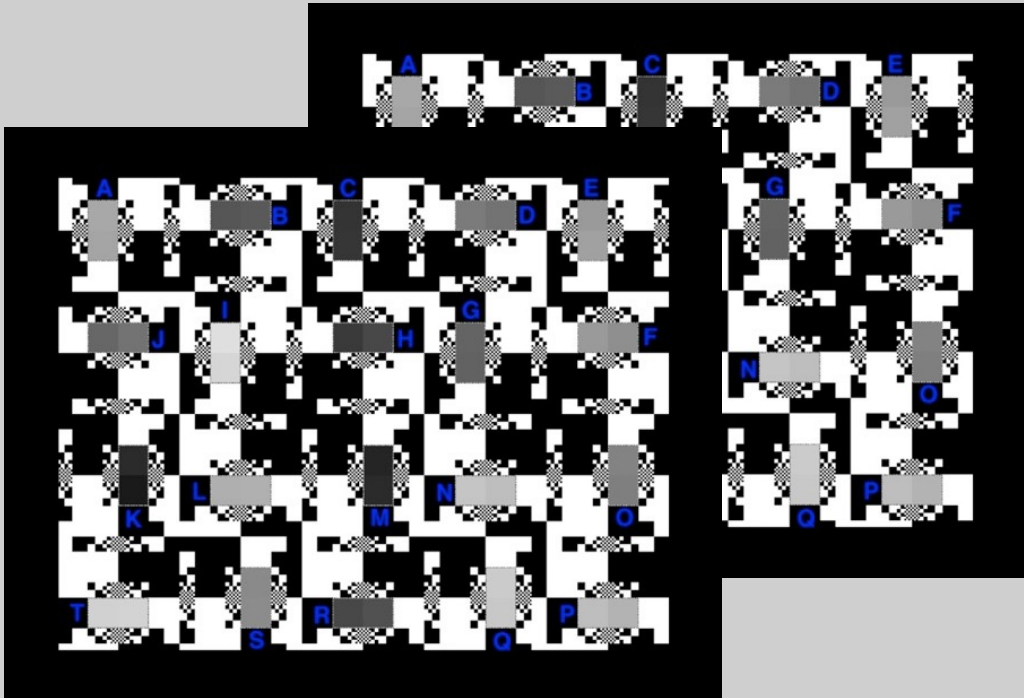
# Double Density Film Transparencies

Single =



2.7 log<sub>10</sub> range

Double =  
(superimposed)



5.4 log<sub>10</sub> range

Target	Max cd/m <sup>2</sup>	Min cd/m <sup>2</sup>	Range:1	%Average cd/m <sup>2</sup>	O.D. Min	O.D. Max	O.D. Range
Single Contrast	6,680	13.6	490	50.01%	0.20	2.89	2.69
Double Contrast	4,215	0.018	239,883	50.00%	0.40	5.78	5.38

# Glare nell'occhio

## CIE Veiling Glare Standard

J. Vos and T. van den Berg (1999) collected a series of measurements for the 1999 CIE report. We used the formula referred to as number eight. The formula is:

$$L_{eq} / E_{gl} = \left[ 1 - 0.08 * (A / 70)^4 \right] * \left[ \frac{9.2 * 10^6}{[1 + (\theta / 0.046)^2]^{1.5}} + \frac{1.5 * 10^5}{[1 + (\theta / 0.045)^2]^{1.5}} \right] +$$
$$+ \left[ 1 - 1.6 * (A / 70)^4 \right] * \left\{ \left[ \frac{400}{1 + (\theta / 0.1)^2} + 3 * 10^{-8} * \theta^2 \right] + p \left[ \frac{1300}{[1 + (\theta / 0.1)^2]^{1.5}} + \frac{0.8}{[1 + (\theta / 0.045)^2]^{0.5}} \right] \right\} + 2.5 * 10^{-3} * p$$

where  $\theta$  is the viewing angle from the point from which the light is spread causing the veiling glare, A is the age of the observer, and p is his/her iris pigmentation. In the calculation we used an age of 25 and brown Caucasian pigment.

We converted this formula into a convolution filter.

CIE (2002) 146 CIE equations for disability glare, 146/147: CIE Collection on Glare.

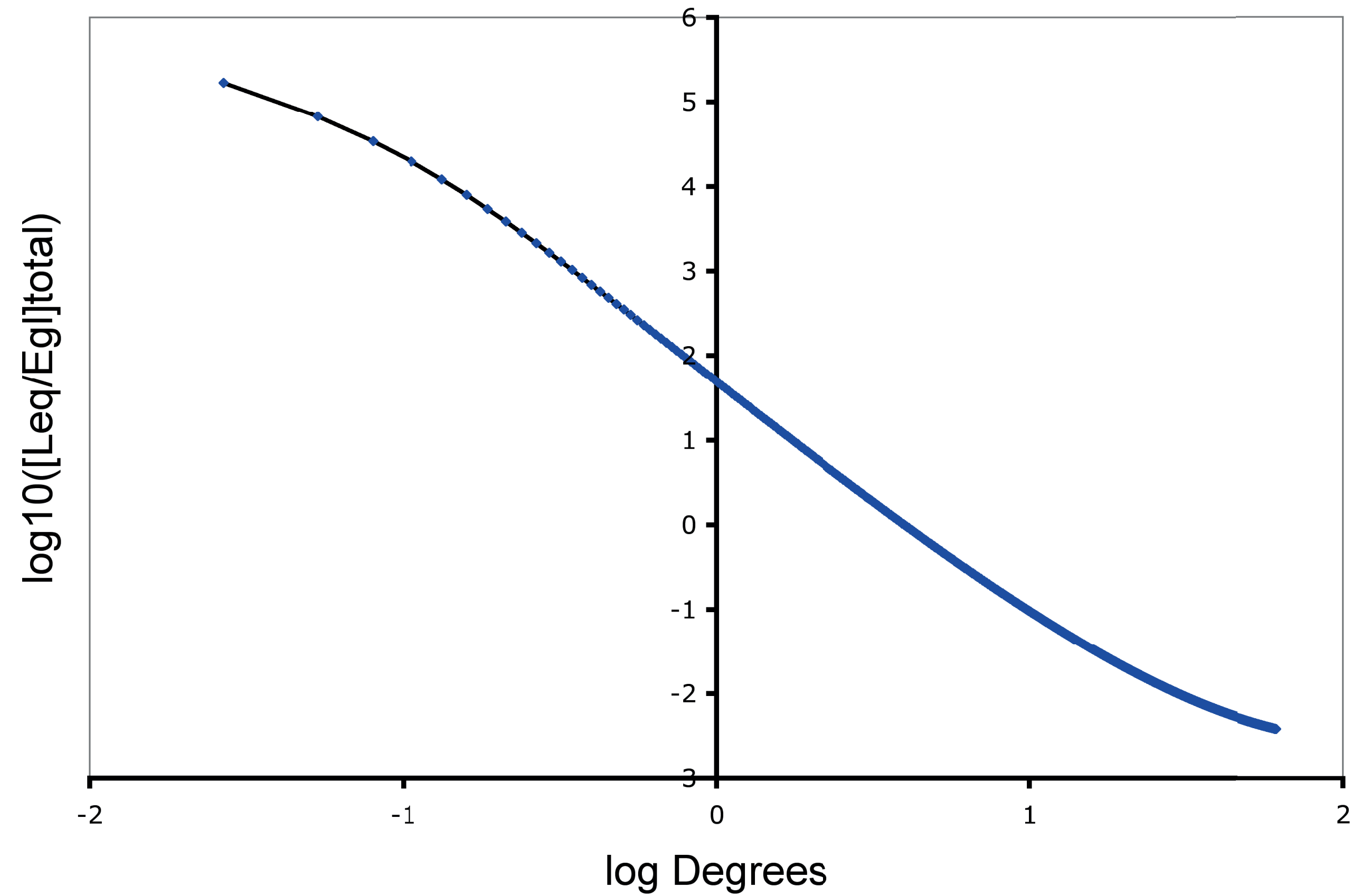
Franssen L & Coppens JE (2007) Straylight at the retina: Scattered papers, thesis, Universiteit van Amsterdam, <http://dare.uva.nl/record/215172>.

Vos J & van den Berg T (1999) Disability Glare, CIE Research note 135/1, ISBN 3 900734 97 6.

Vos J, Walraven J, & van Meeteren A (1976) Light Profiles of the Foveal Image of a Point Source, Vision Res, 16:215-219.

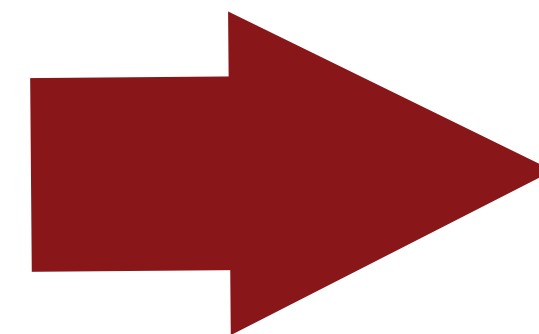
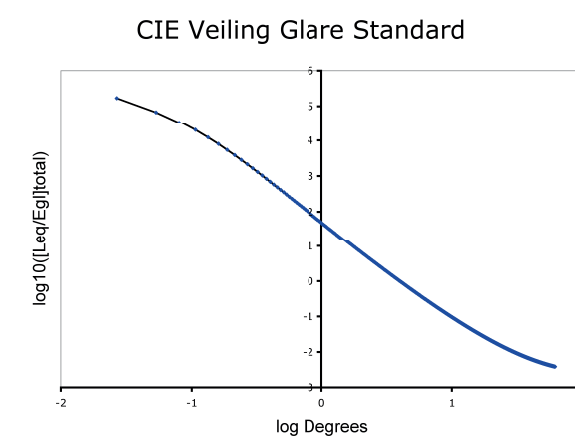
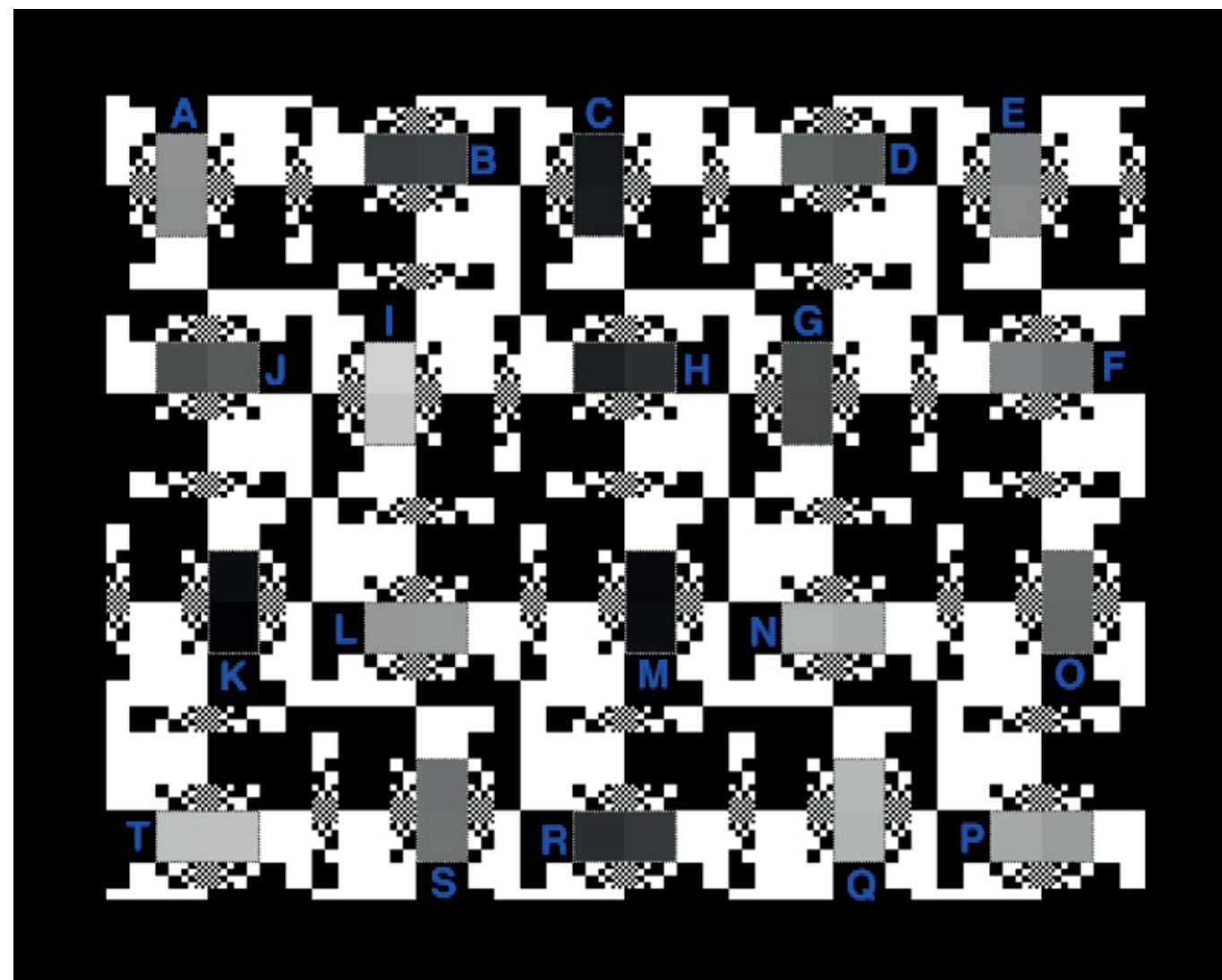
- B. CIE Glare Spread Function

CIE Veiling Glare Standard



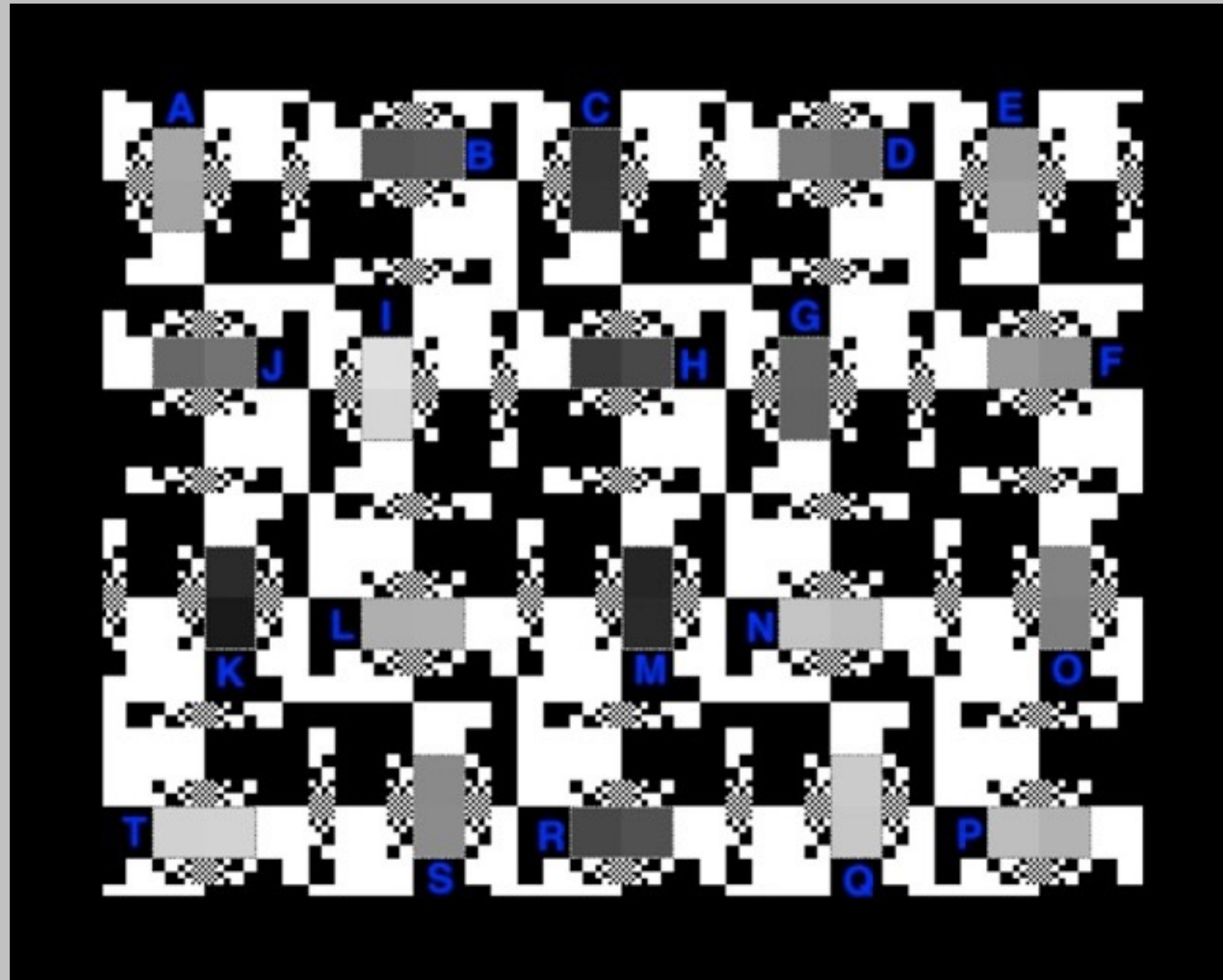
# Calcoliamo cosa arriva sulla retina

Scene

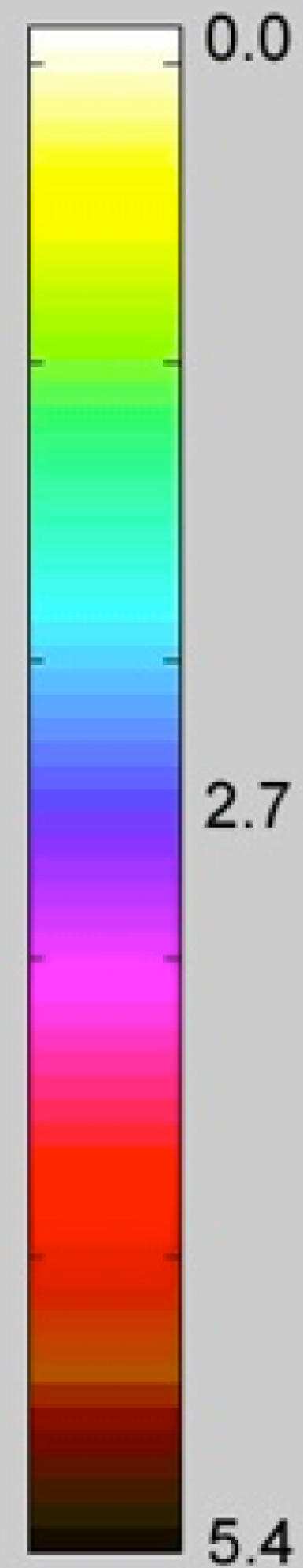


Retina

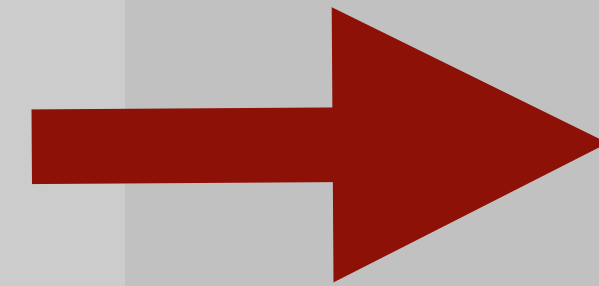




**Dynamic Range = 5.4 OD  
or 251,189:1**



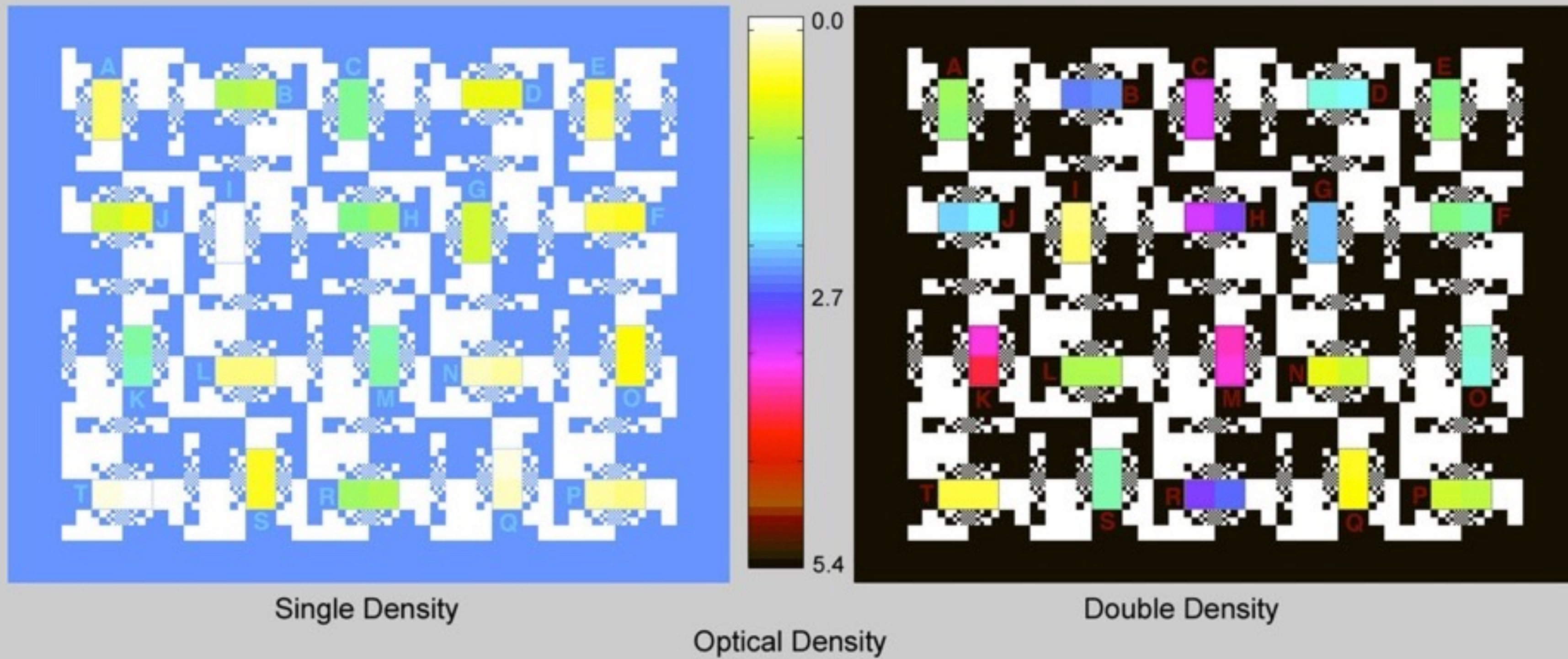
Optical Density



**False-color LookUpTable (LUT)**



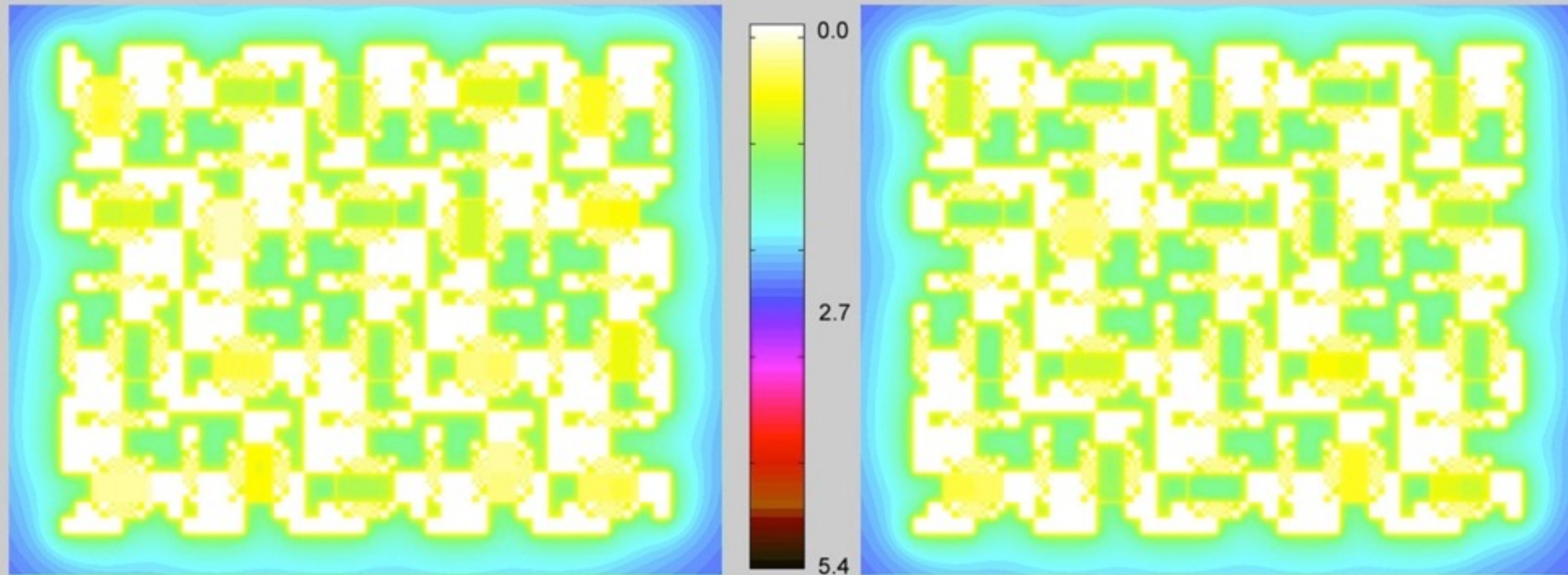
# Target Contrast



Range 500:1

Range 250,000:1

# Retinal Contrast



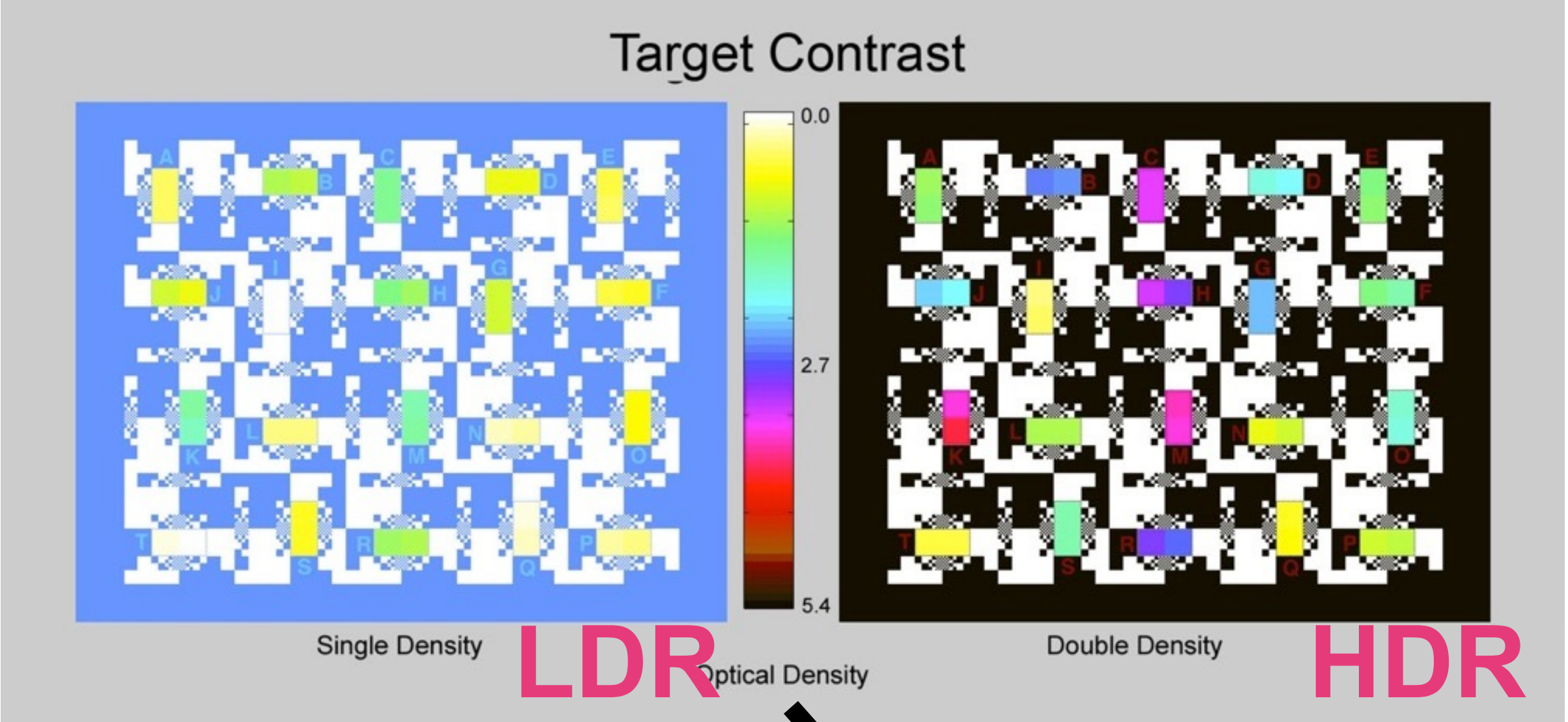
Single Density

Optical Density

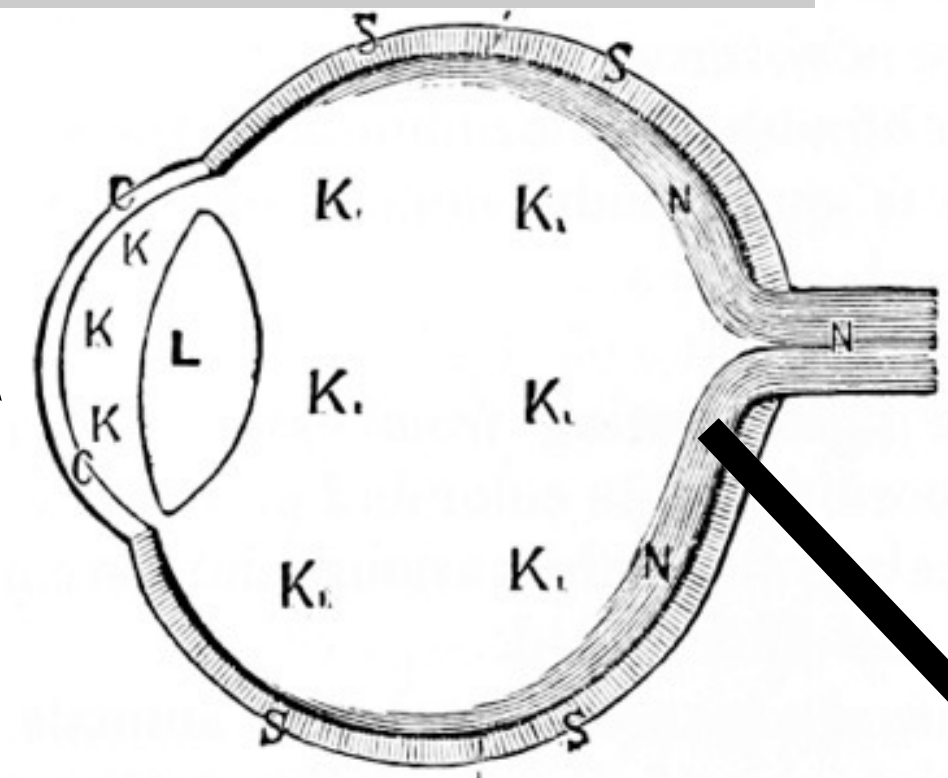
Double Density

Range 100:1

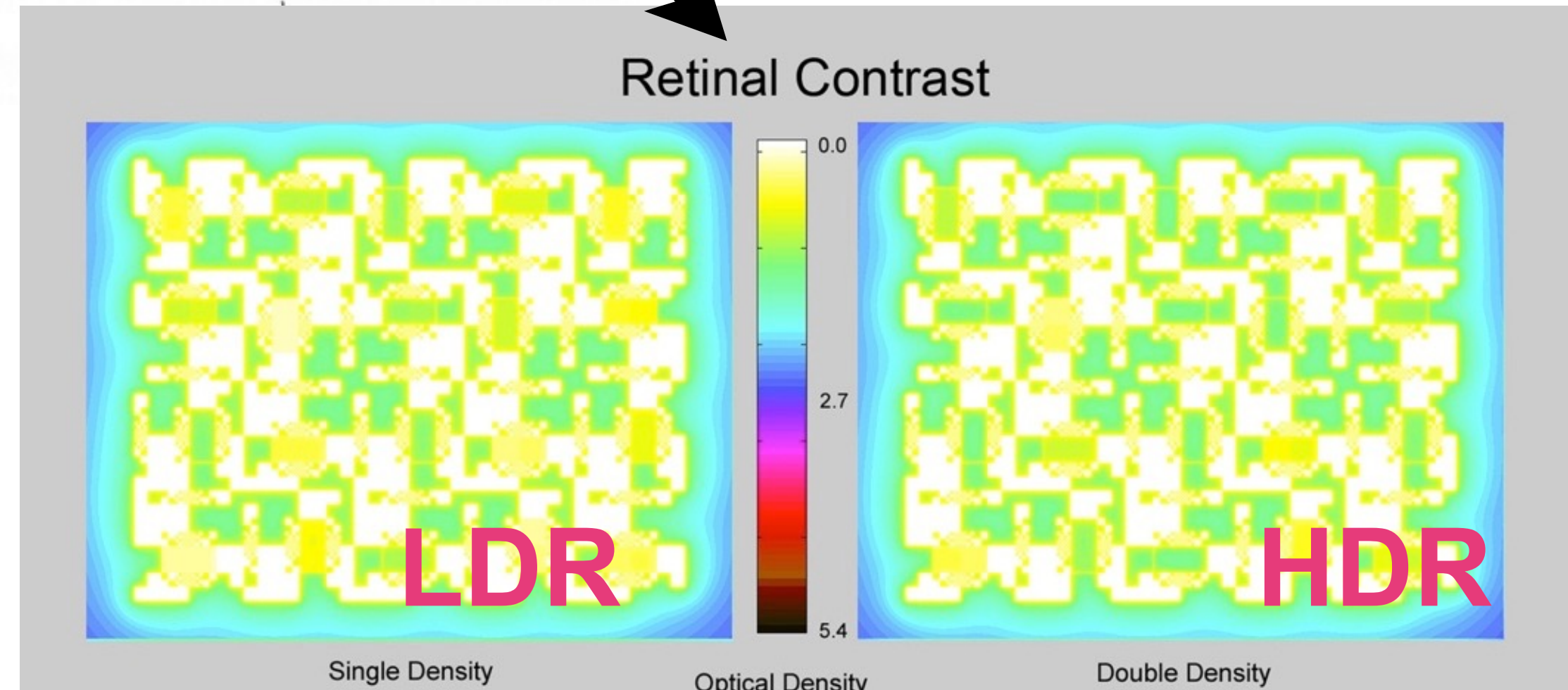
Range 150:1

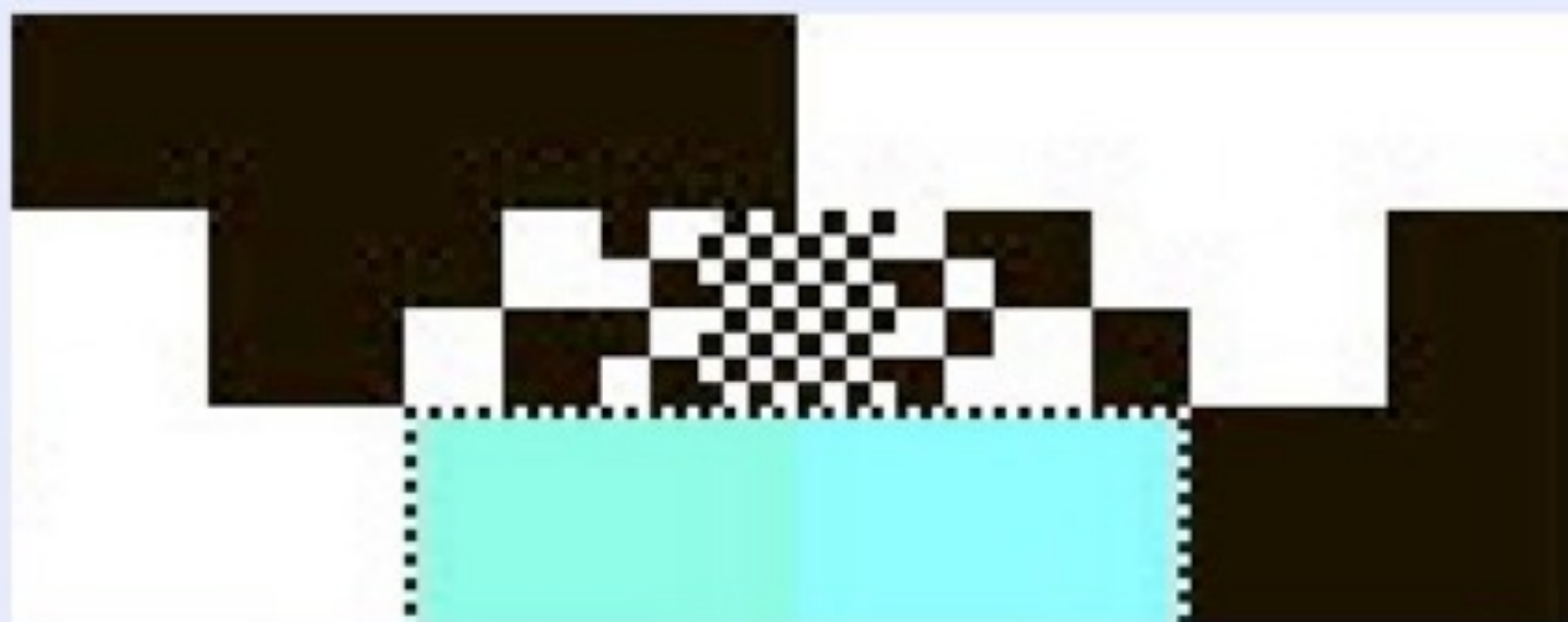
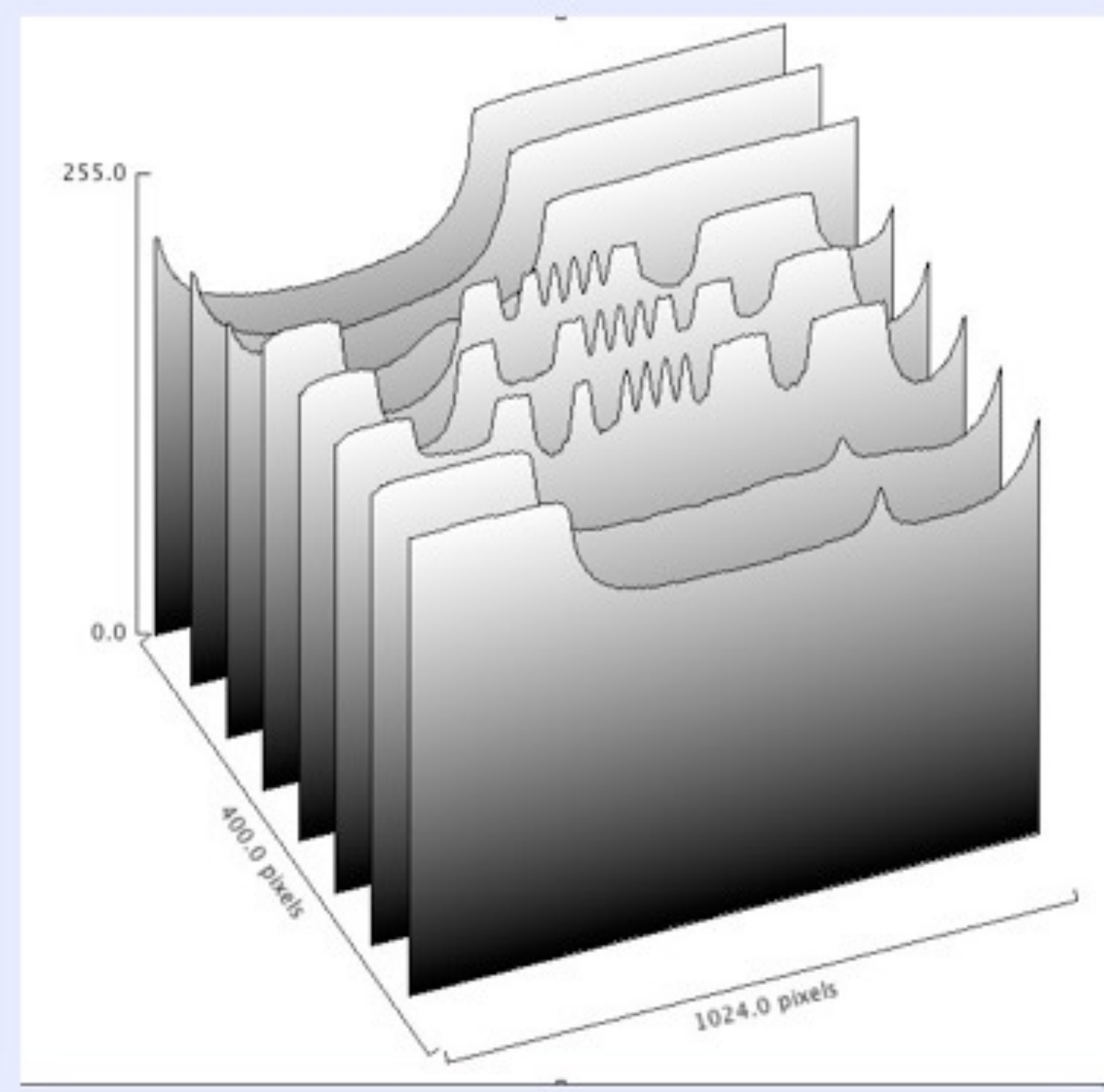
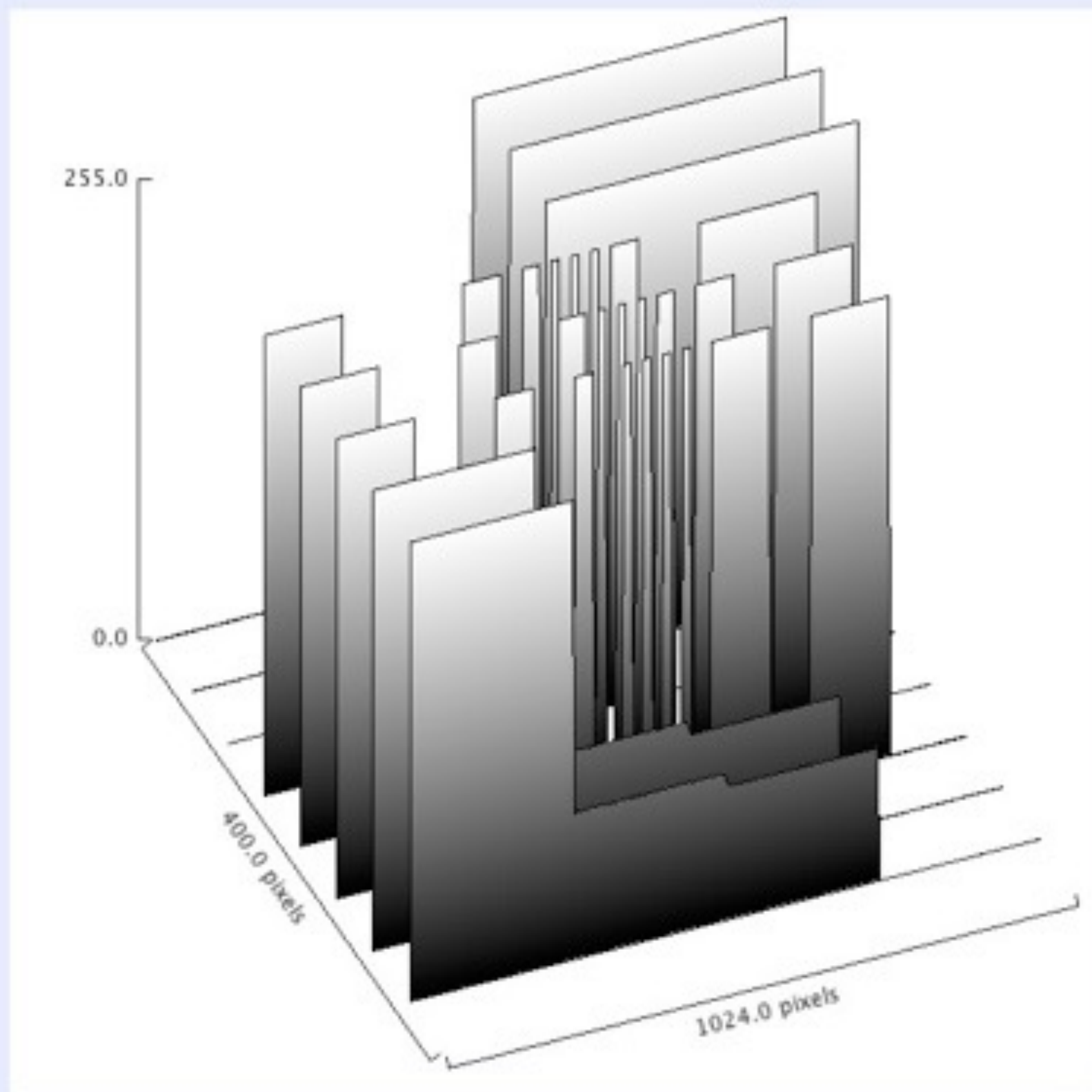


Scene Luminance



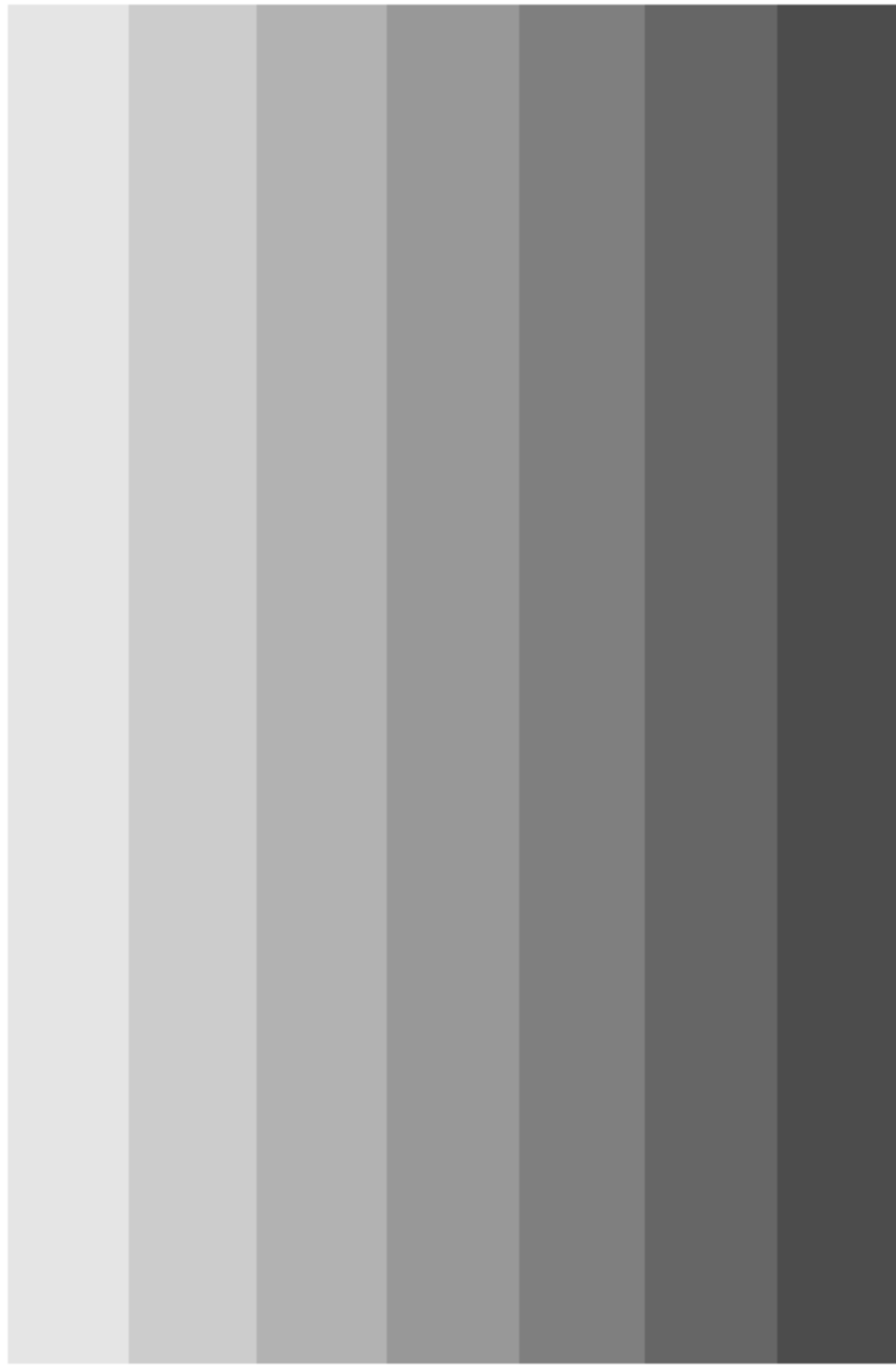
Retinal Luminance



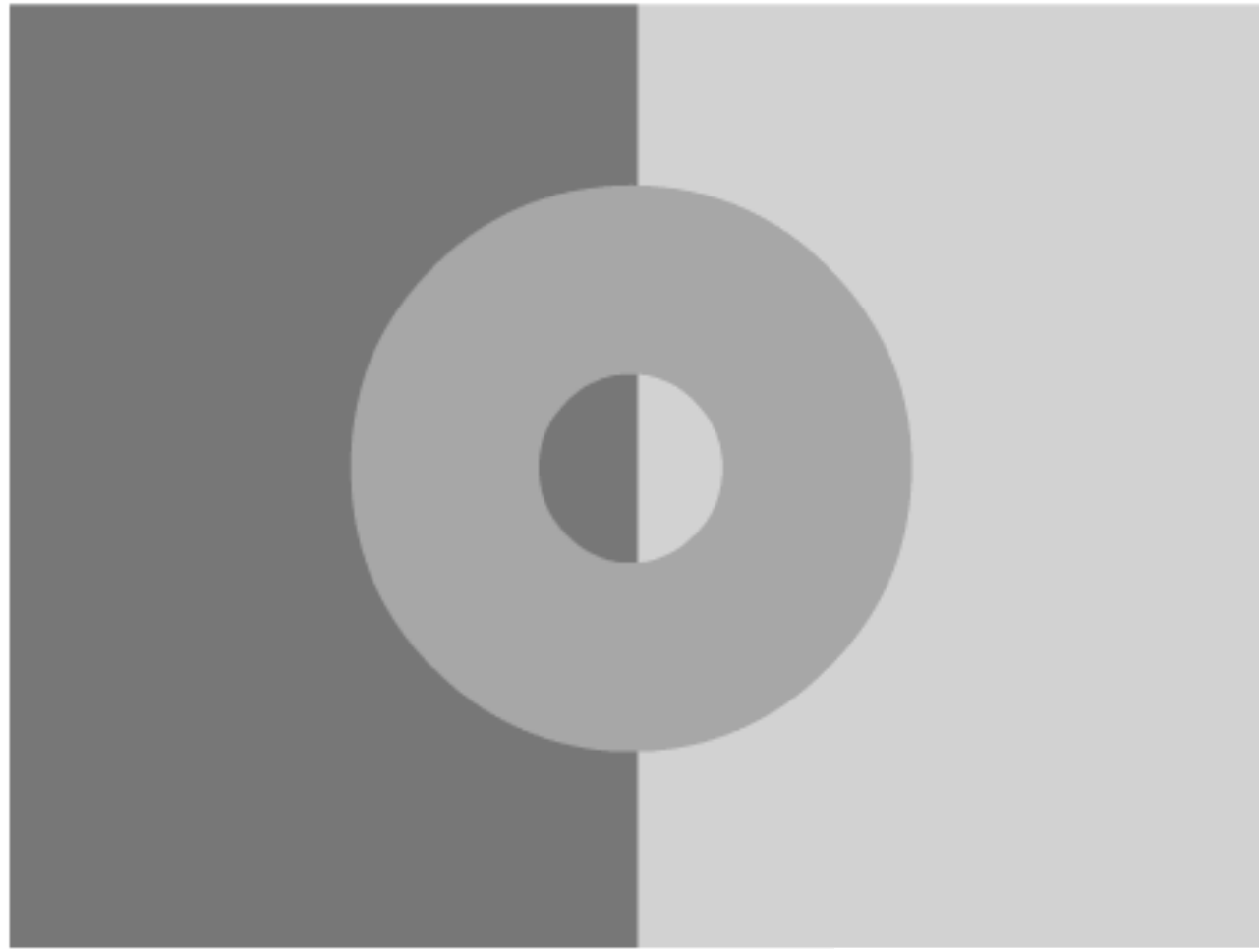


I bordi diventano gradienti sulla retina

# **Effetto Cornsweet**

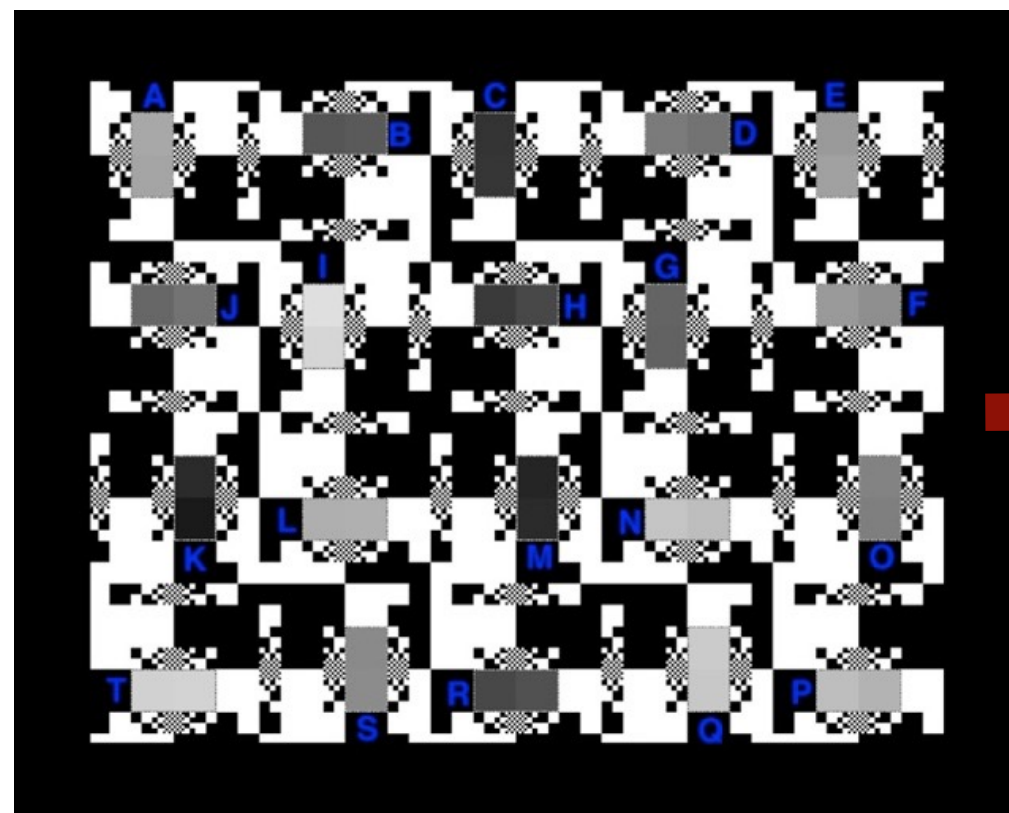


# Koffka ring



Scena

1,000,000:1



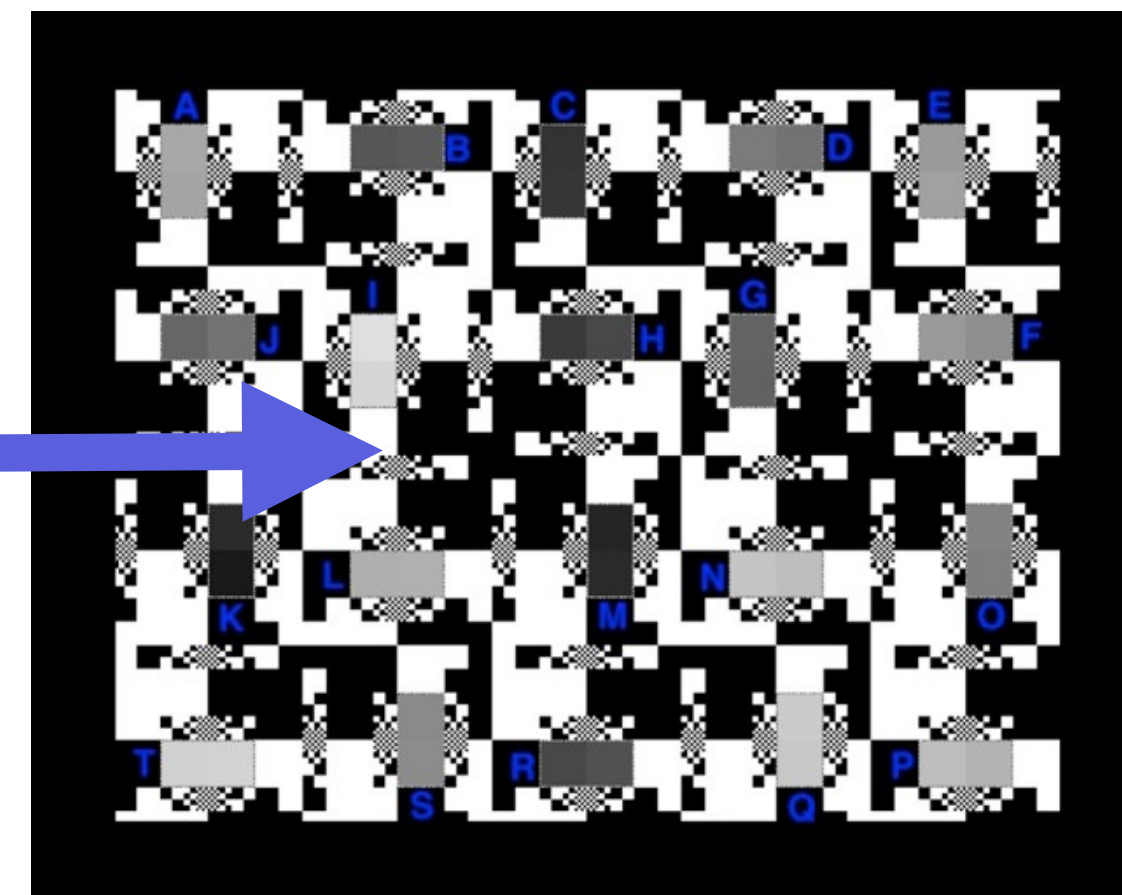
Retina

100:1



Apparenza

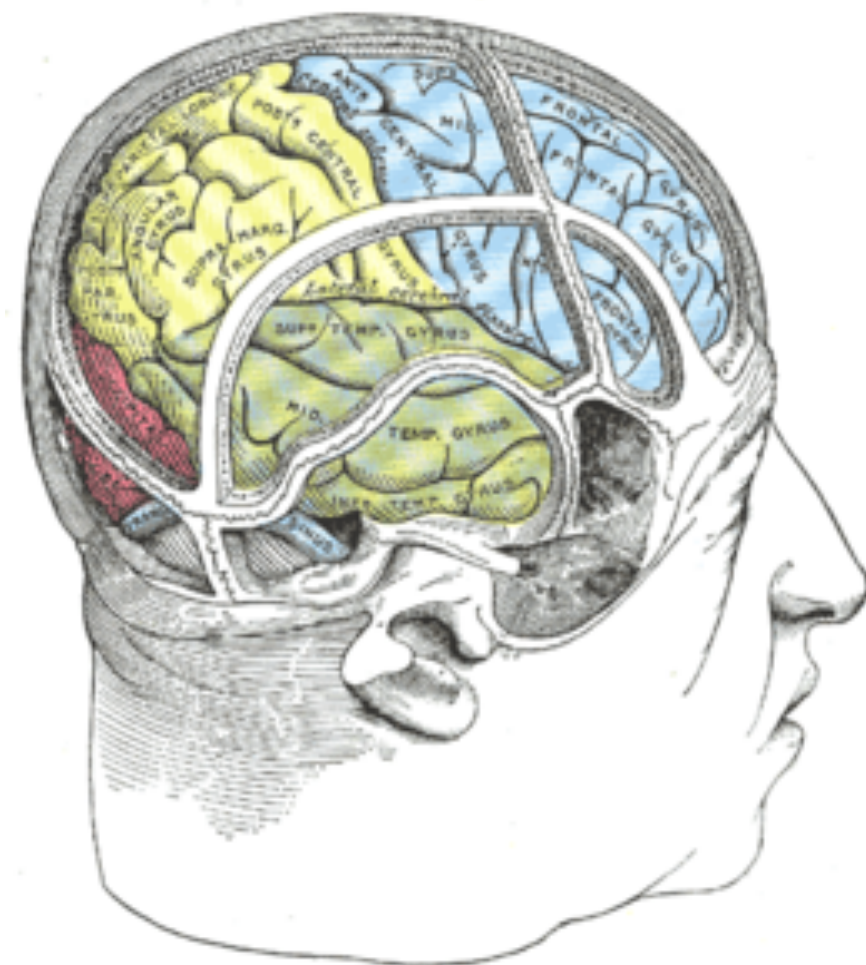
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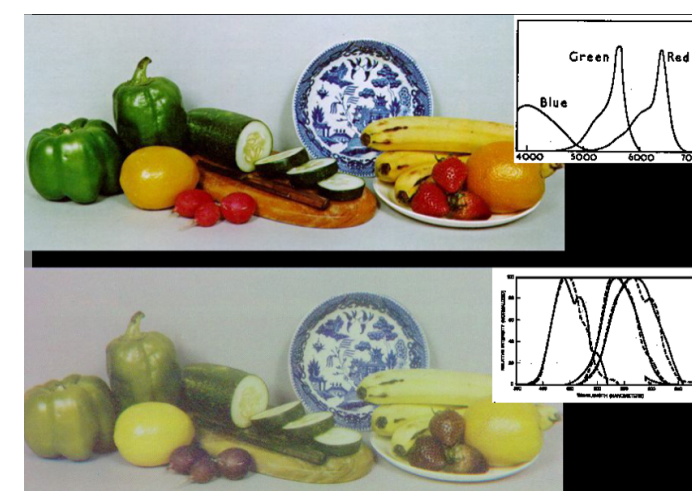
Glare

Computazione  
spaziale

Glare



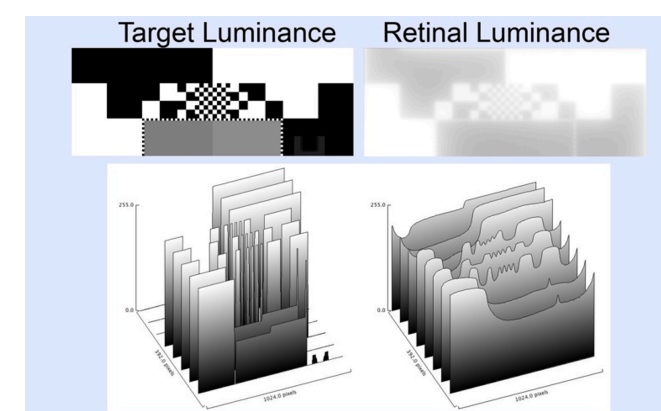
Computazione spaziale



Amplificazione saturazione




Costanza cromatica



Recupero bordi





Del perché la visione dei colori è spaziale e del perché non possiamo misurare colore e spettro con una macchina che usi un obiettivo

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Venerdì 18 Novembre 2022



Grazie

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