

Kako vidimo barve

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Kakšne barve je žogica?



- Kakšna barva je rumena, oranžna?
(kaj pomeni “oranžna,” kako opišemo barvo?)

Barve



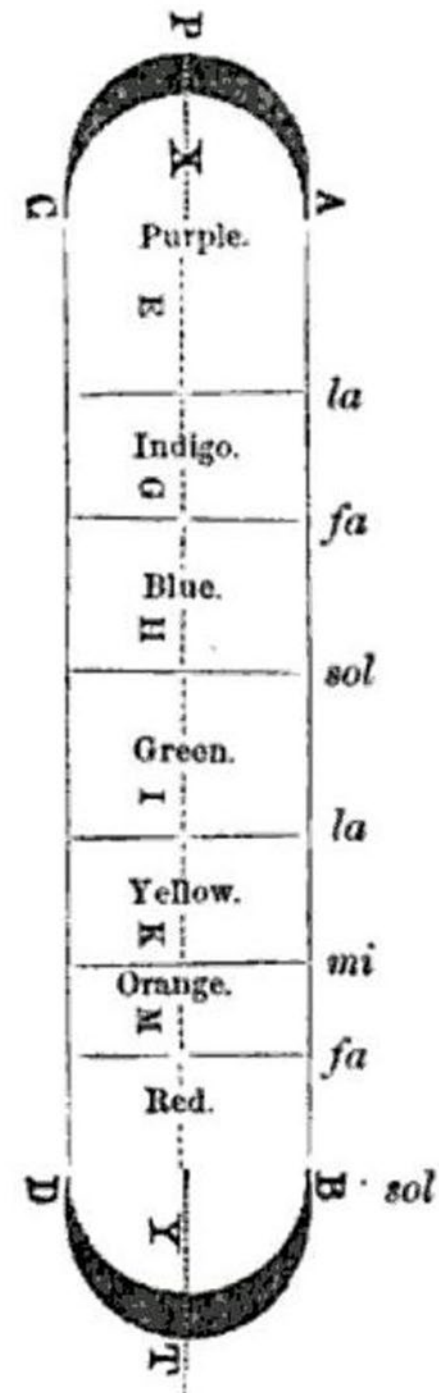
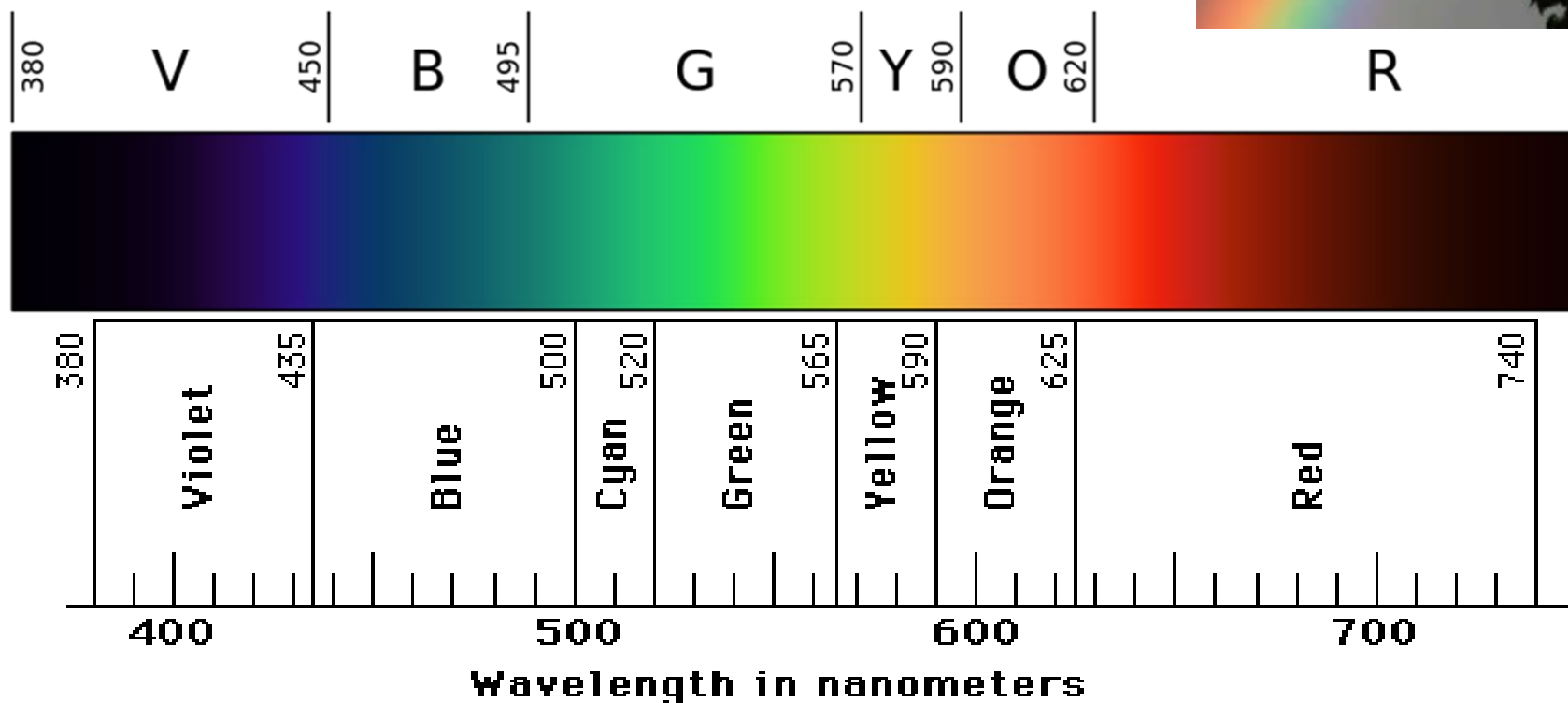
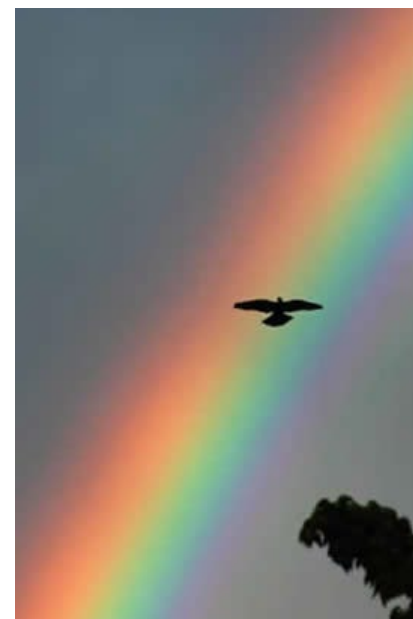
Barve

Mavrične, spektralne, monokromatične
barve – VALOVNA DOLŽINA



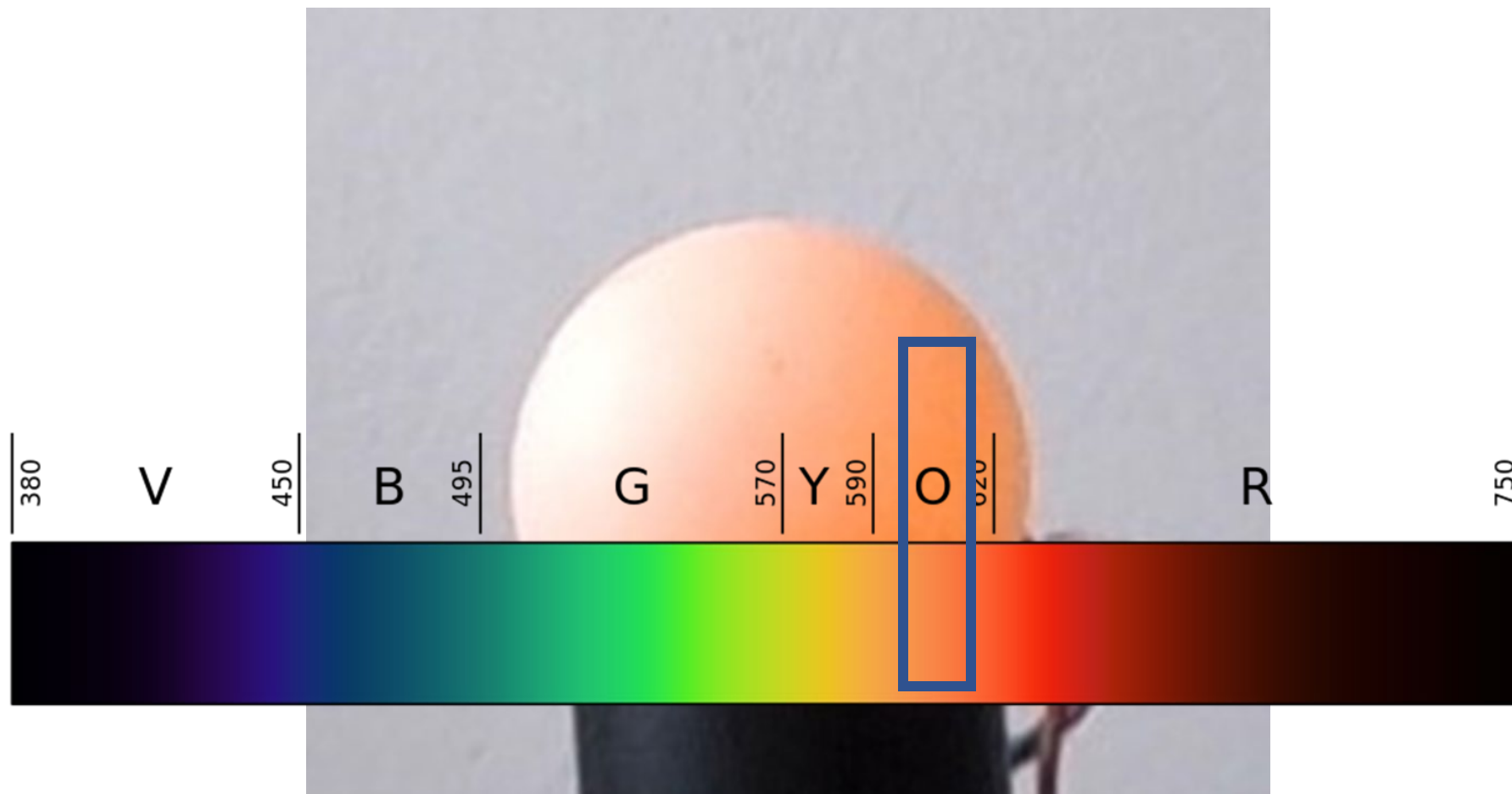
Barve

Mavrične, spektralne, monokromatične barve – VALOVNA DOLŽINA

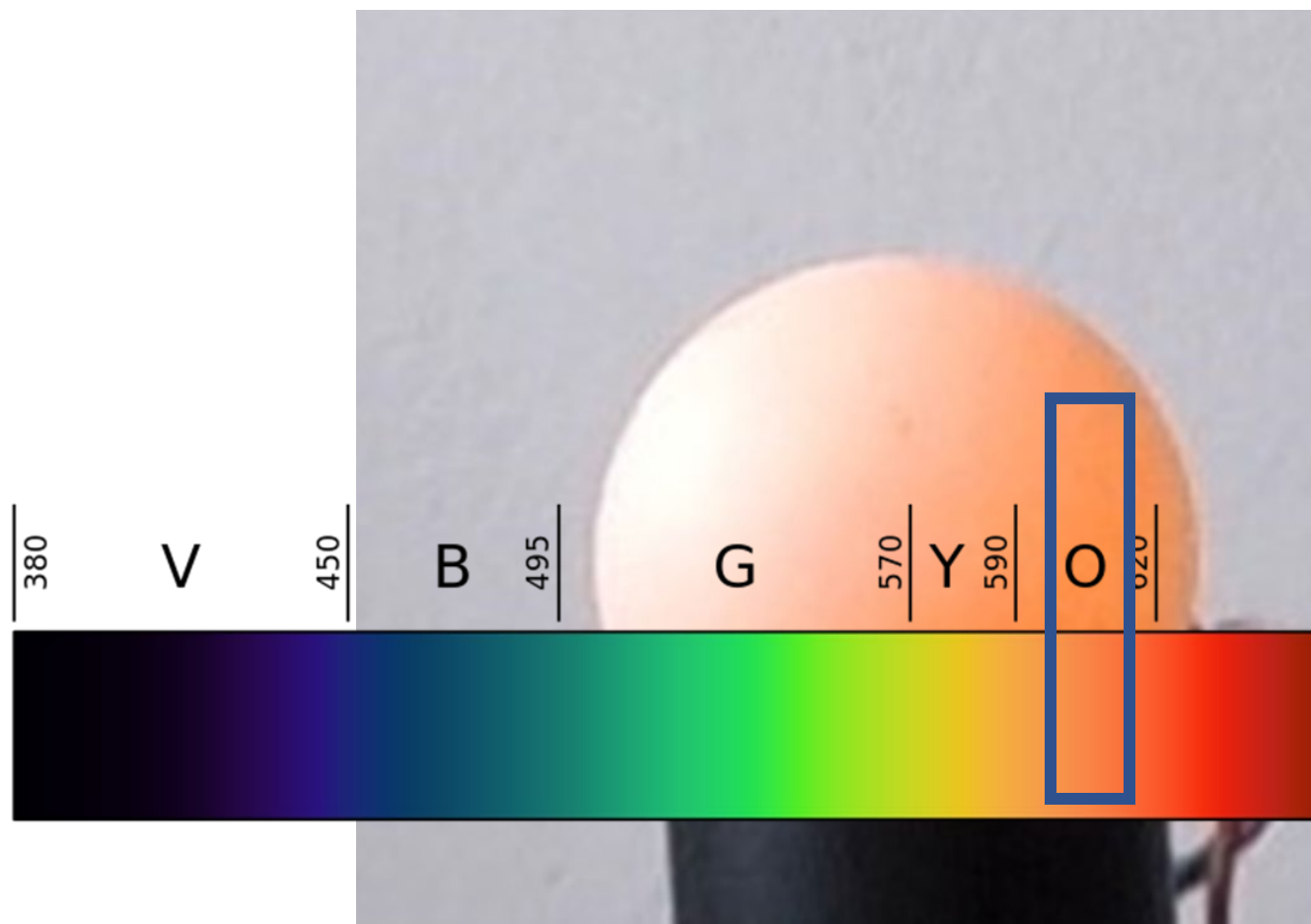


Kakšne barve je?

barva z valovno dolžino 610 nm



Kakšne barve je?



The screenshot shows a Windows 'Colors' dialog box. The 'Custom' tab is selected. The color model is set to RGB. The Red value is 254, Green is 147, and Blue is 79. The Hex value is #FE934F. A color swatch shows the selected orange color.

Property	Value
Color model	RGB
Red	254
Green	147
Blue	79
Hex	#FE934F
Transparency	0%

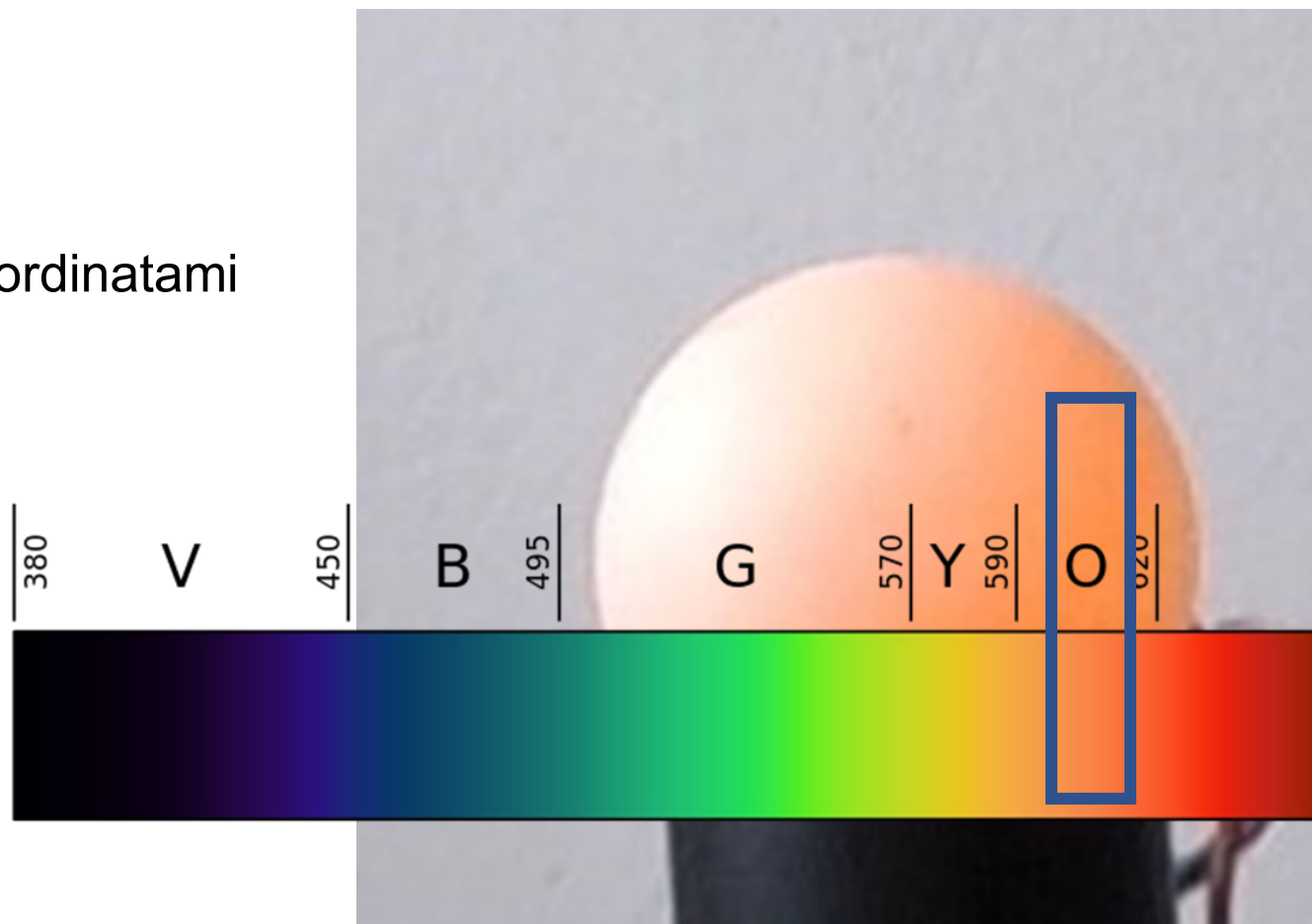
Kakšne barve je?

barva s koordinatami

R = 254

G = 147

B = 79

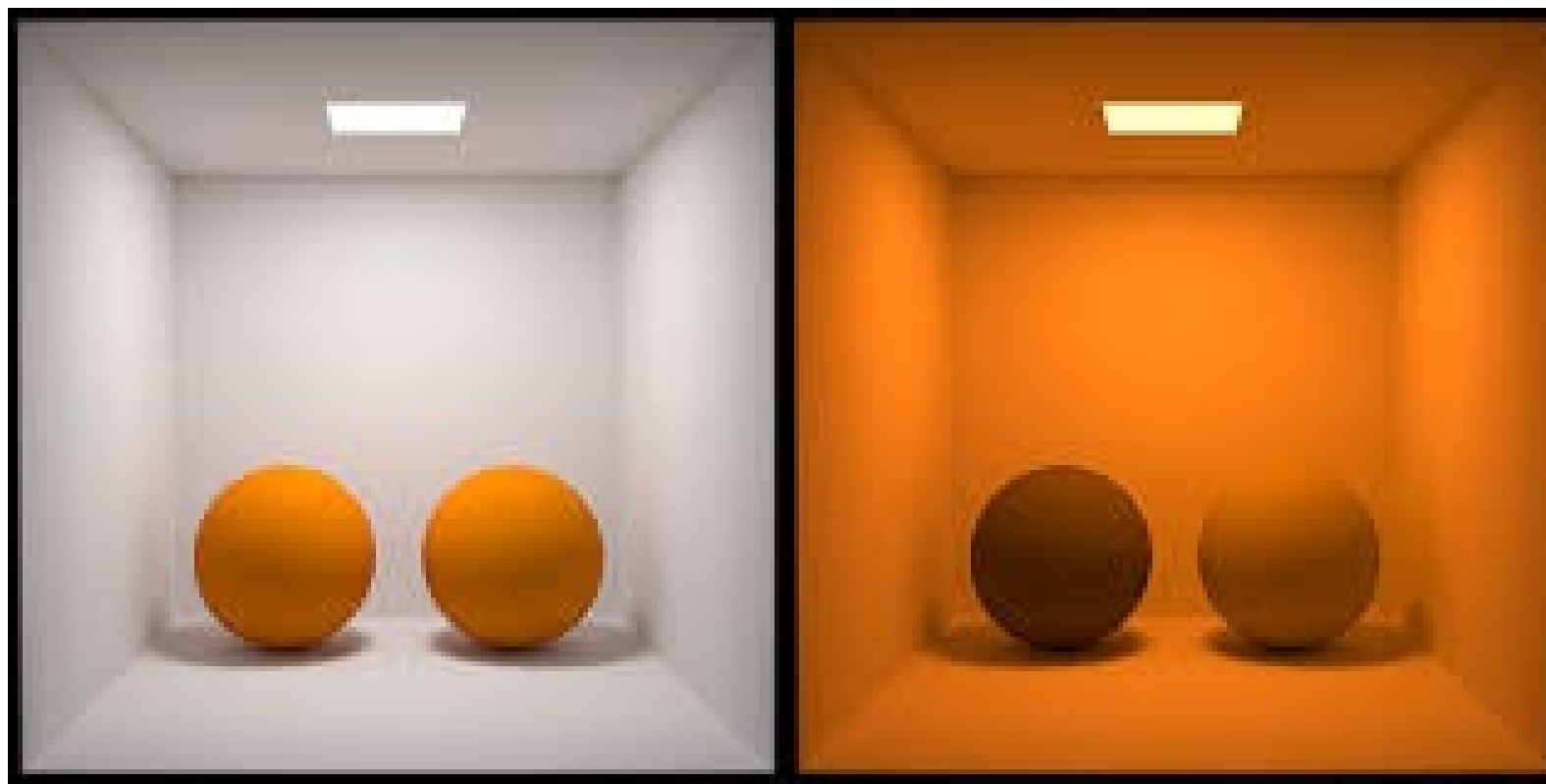


The screenshot shows a 'Colors' dialog box with the following settings:

- Standard Custom
- Color model: RGB
- Red: 254
- Green: 147
- Blue: 79
- Hex: #FE934F
- Transparency: 0%
- Buttons: OK, Cancel, New, Current

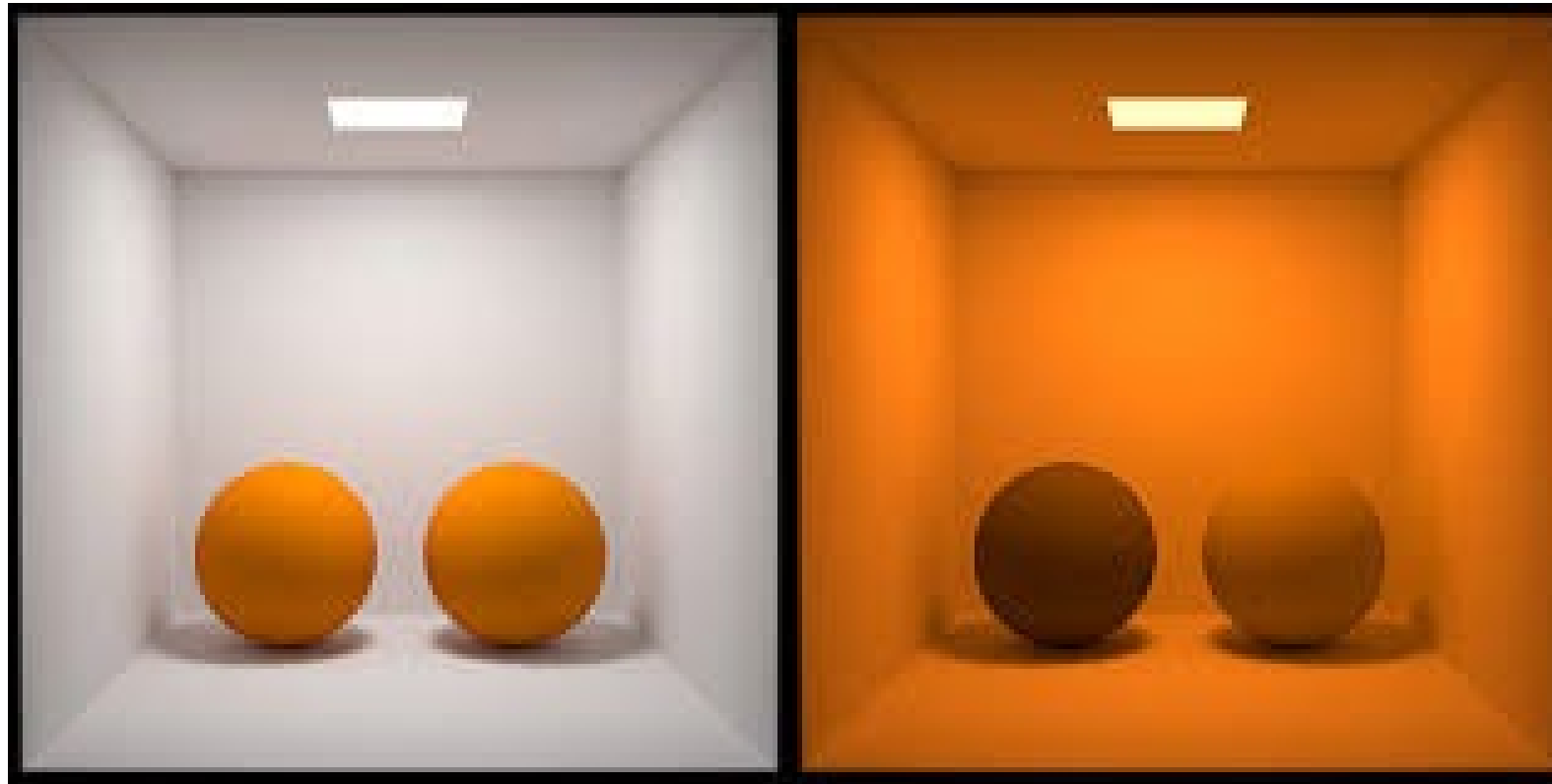


telesi osvetljeni z D65



telesi osvetljeni z
D65 (levo) in natrijevo svetilko (desno)

Metamerizem

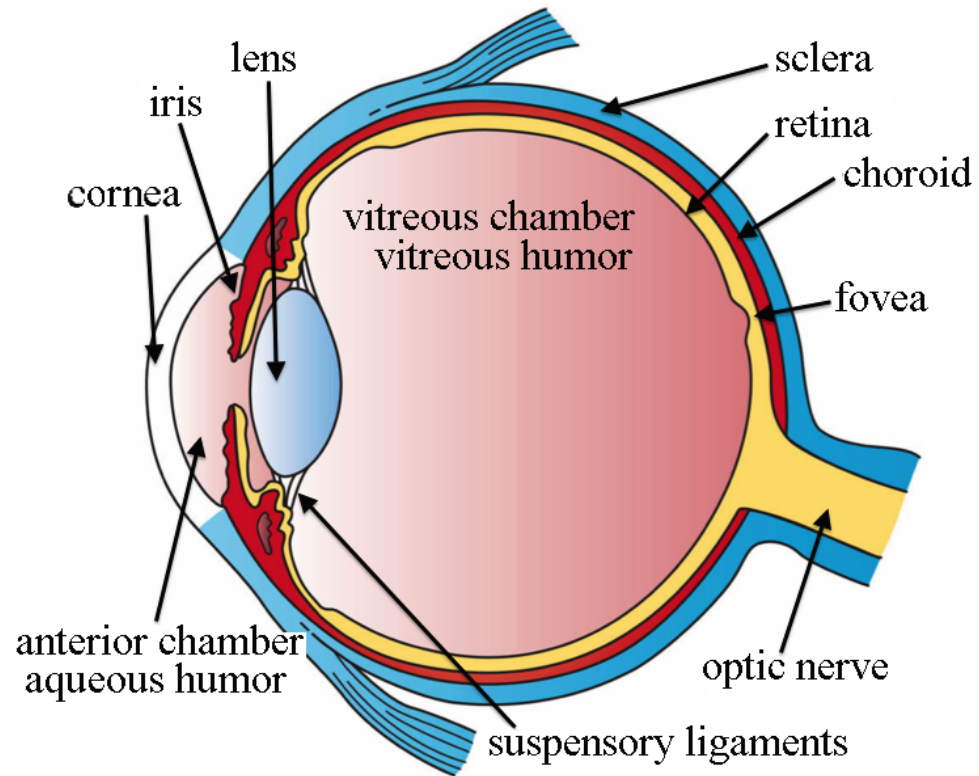


Metamerni telesi osvetljeni z
D65 (levo) in natrijevo svetilko (desno)

Kaj je barva?

Barva je **občutek**, ki ga svetloba vzbudi v očesu. Monokromatičnim barvam pripišemo valovno dolžino. Ostale barve opišemo s spektrom.

oko



Premer 24 mm

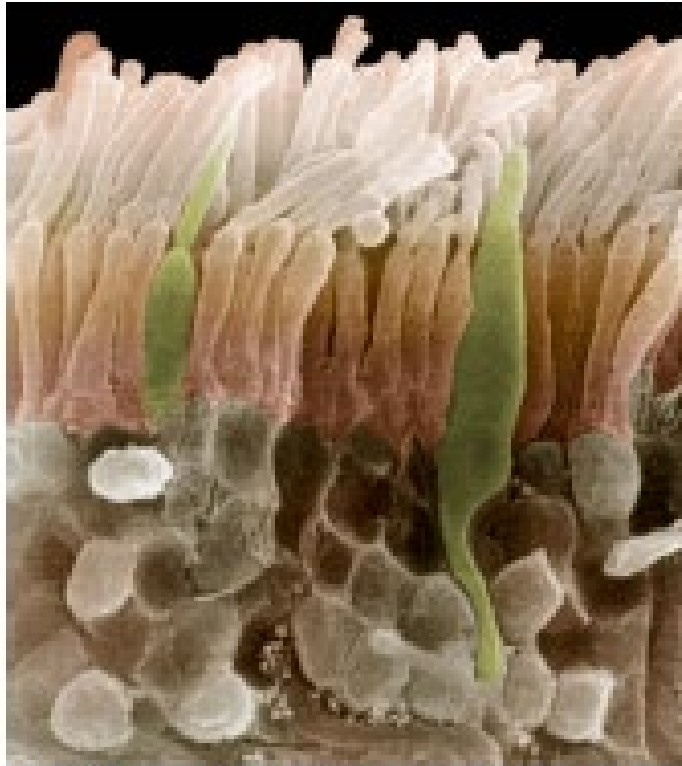
Prostornina 6 cm³

Masa 7,5 g

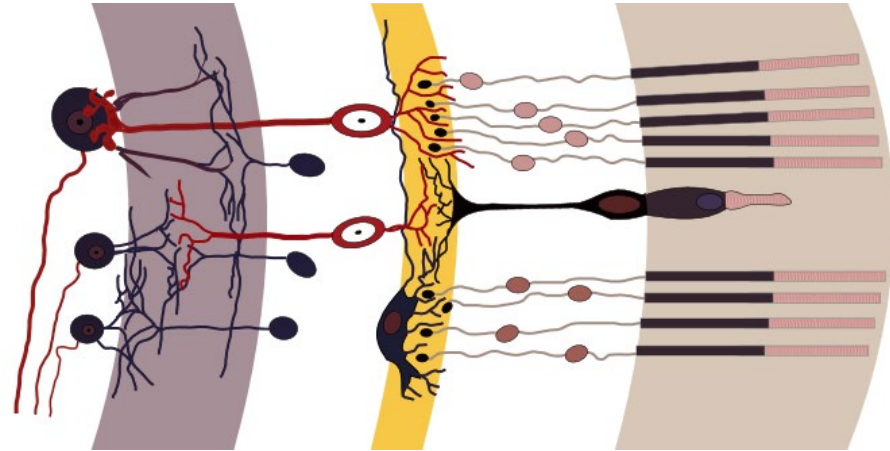
Lomnost roženice 43 d

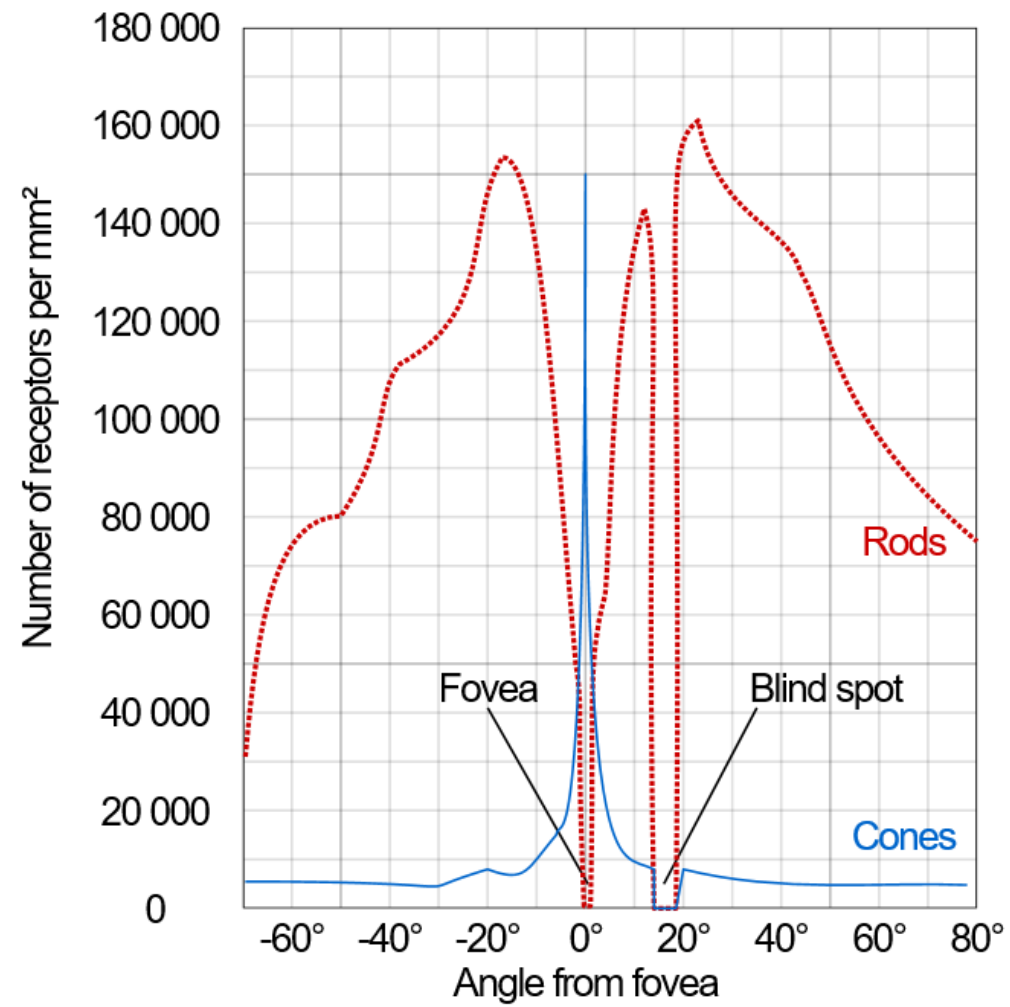
Variabilna lomnost 15 d

mrežnica

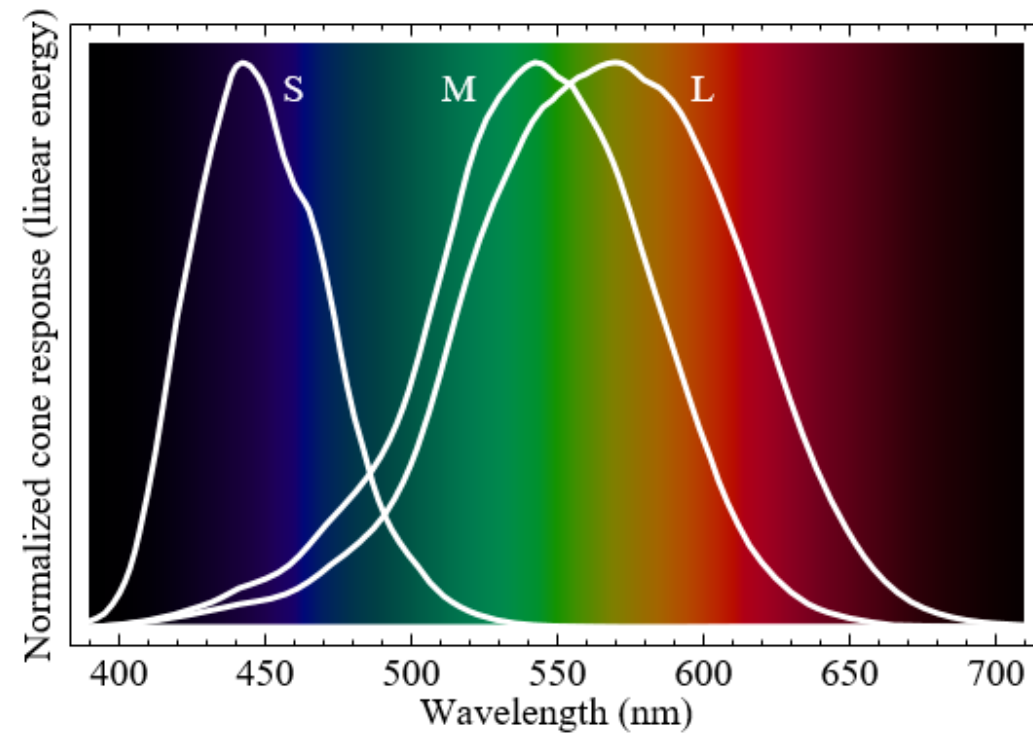
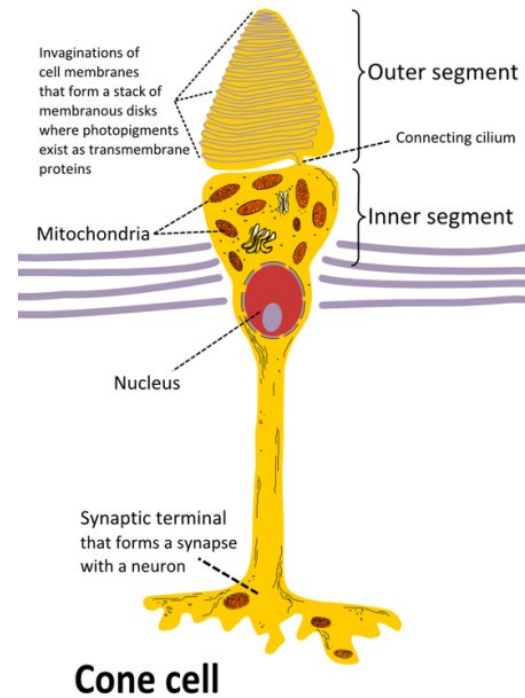


Rod (brown) and cone (green) cells
(© Visuals Unlimited, 2009)

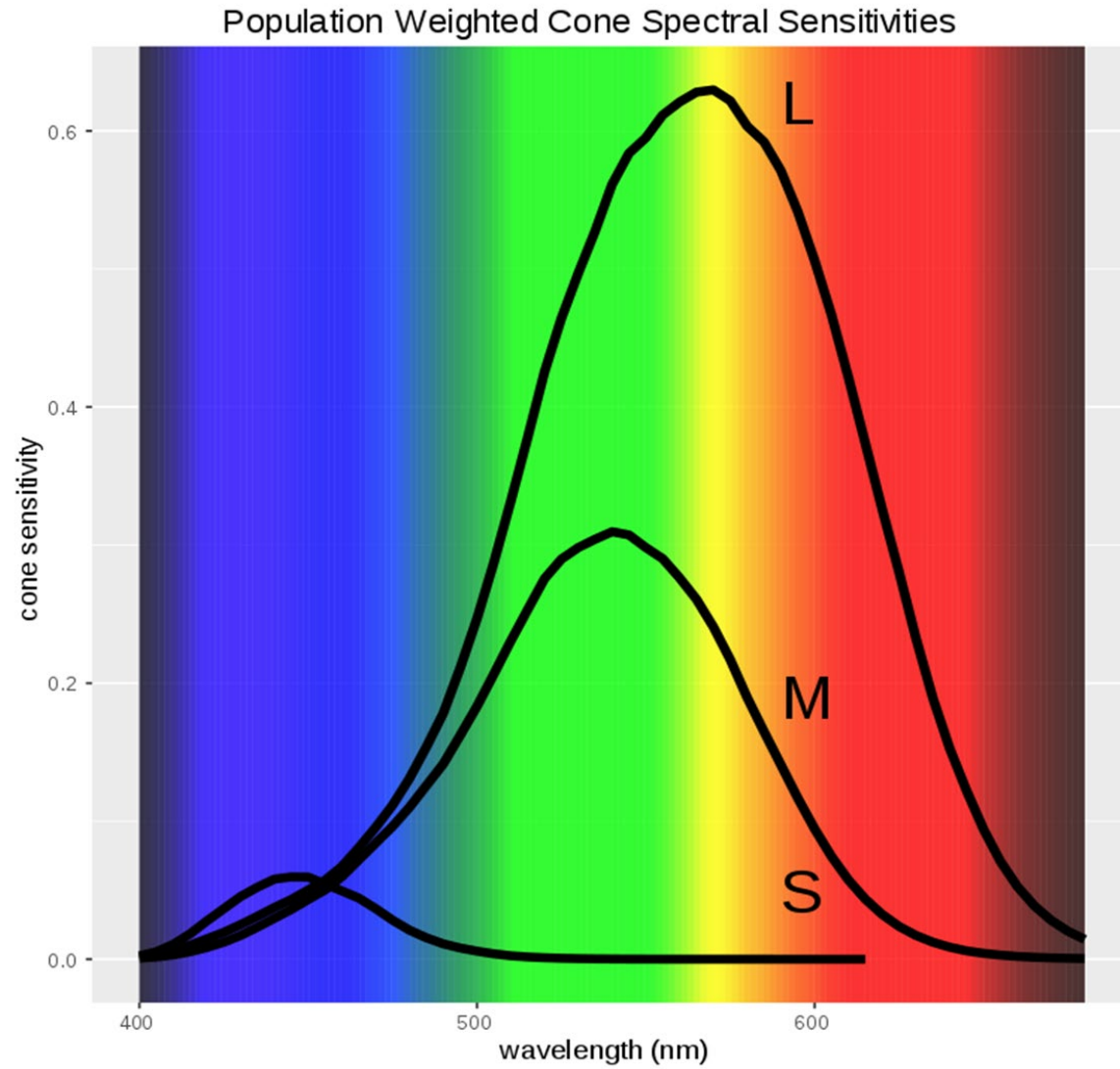




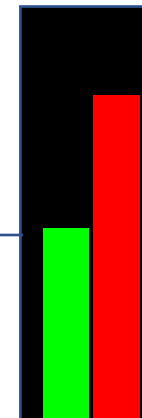
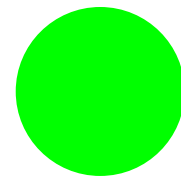
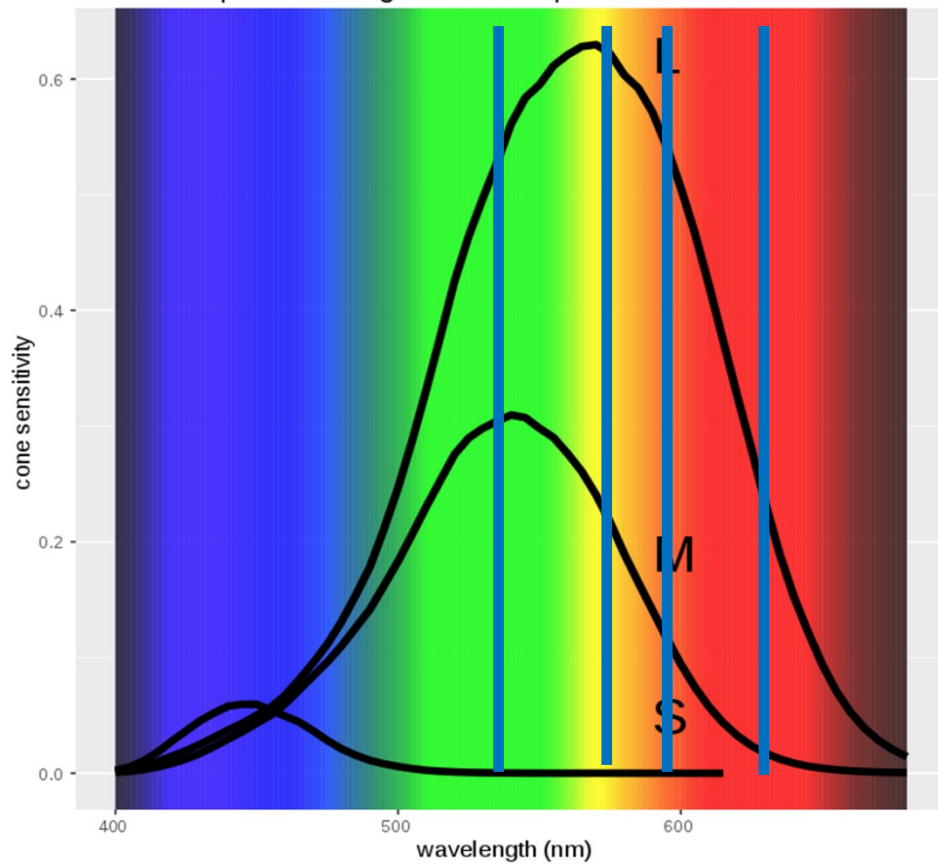
Čepnice



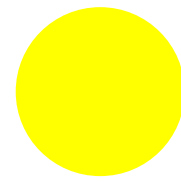
Občutljivost čepnic



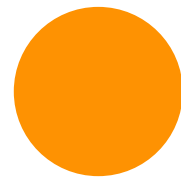
Population Weighted Cone Spectral Sensivities



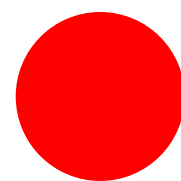
0,59



0,36

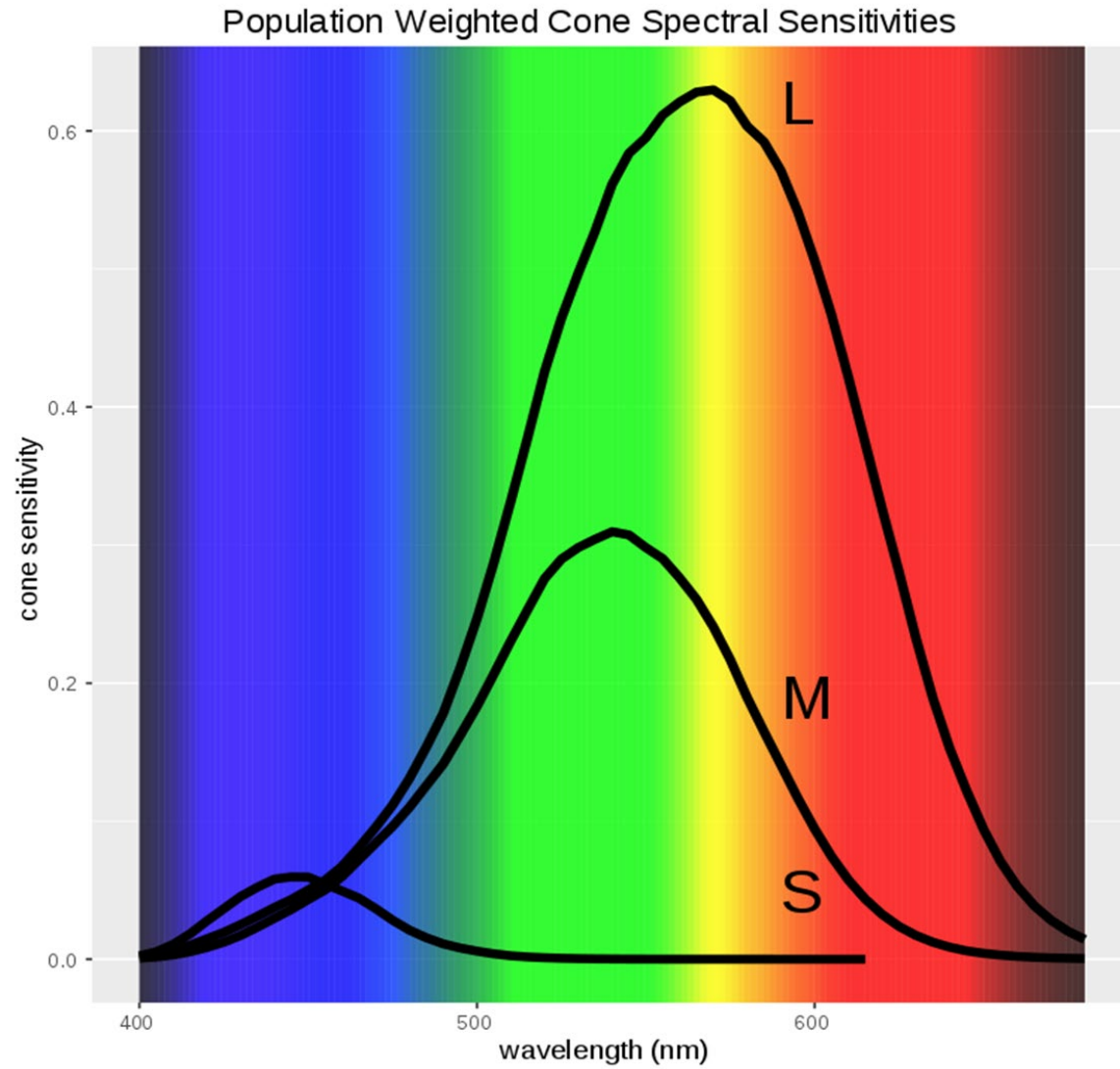


0,21

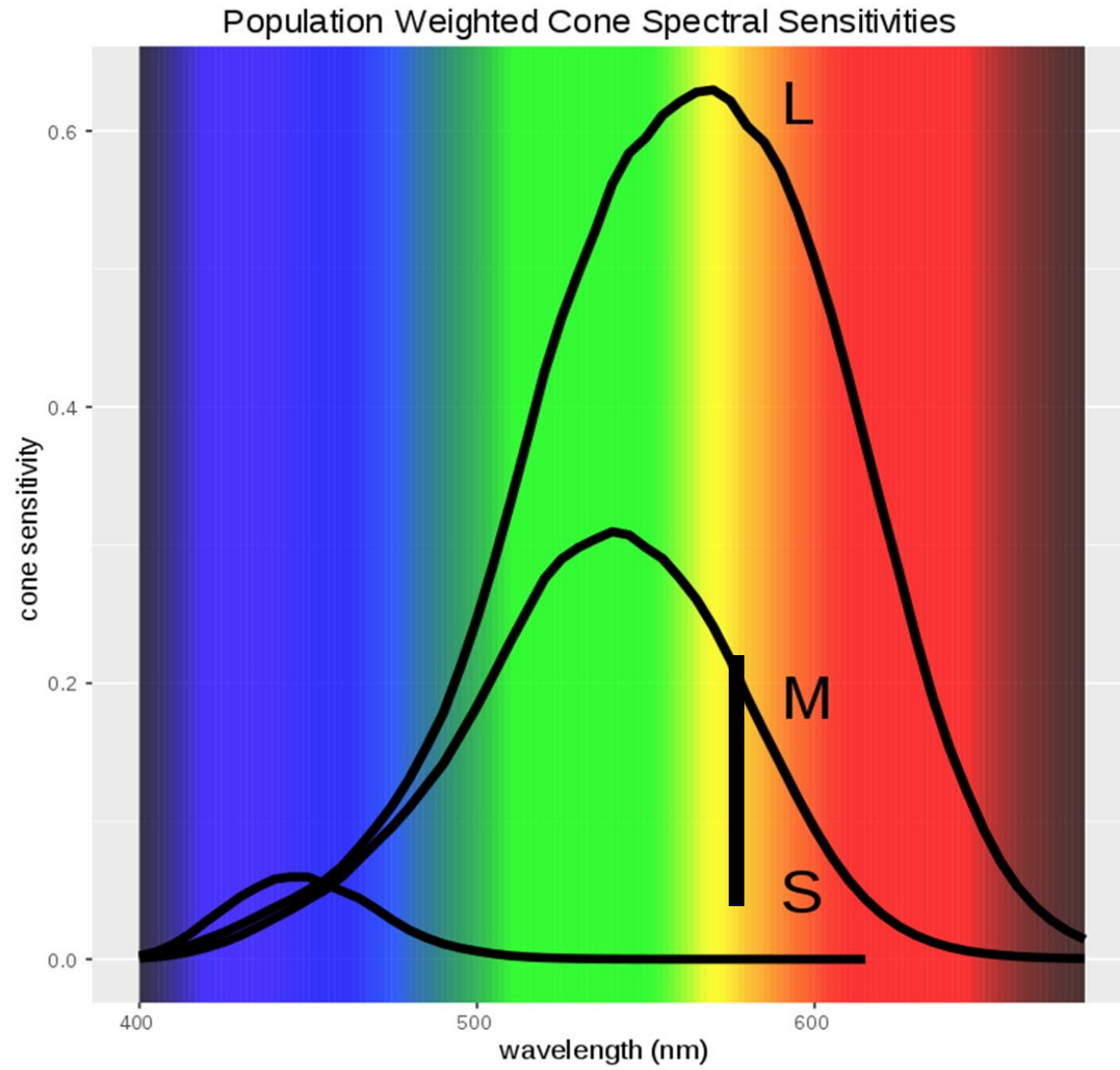


0,09

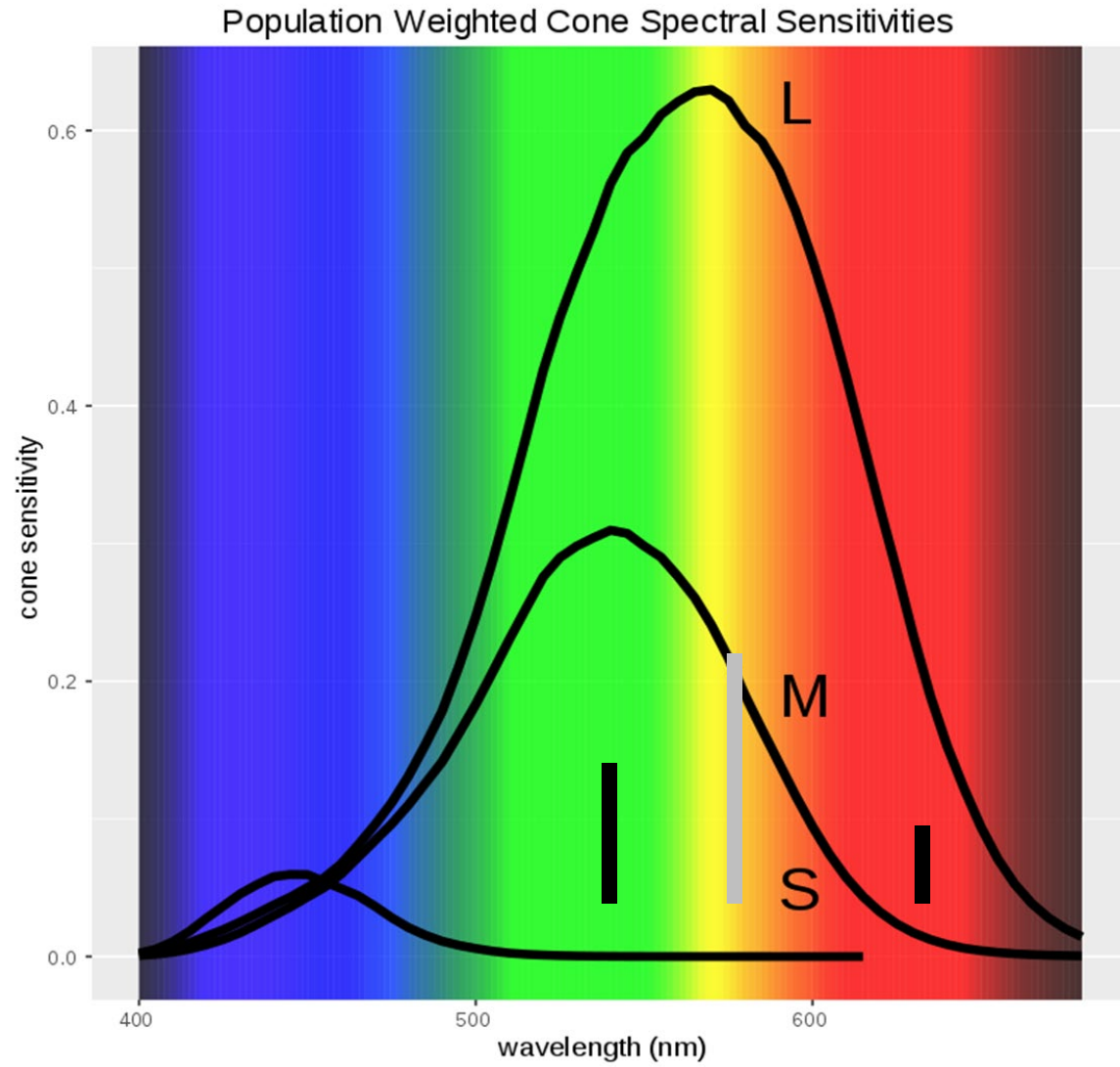
rumena



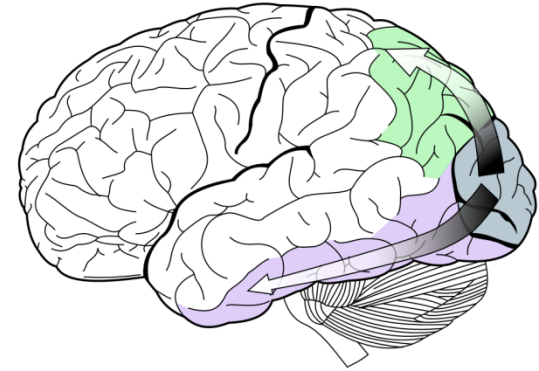
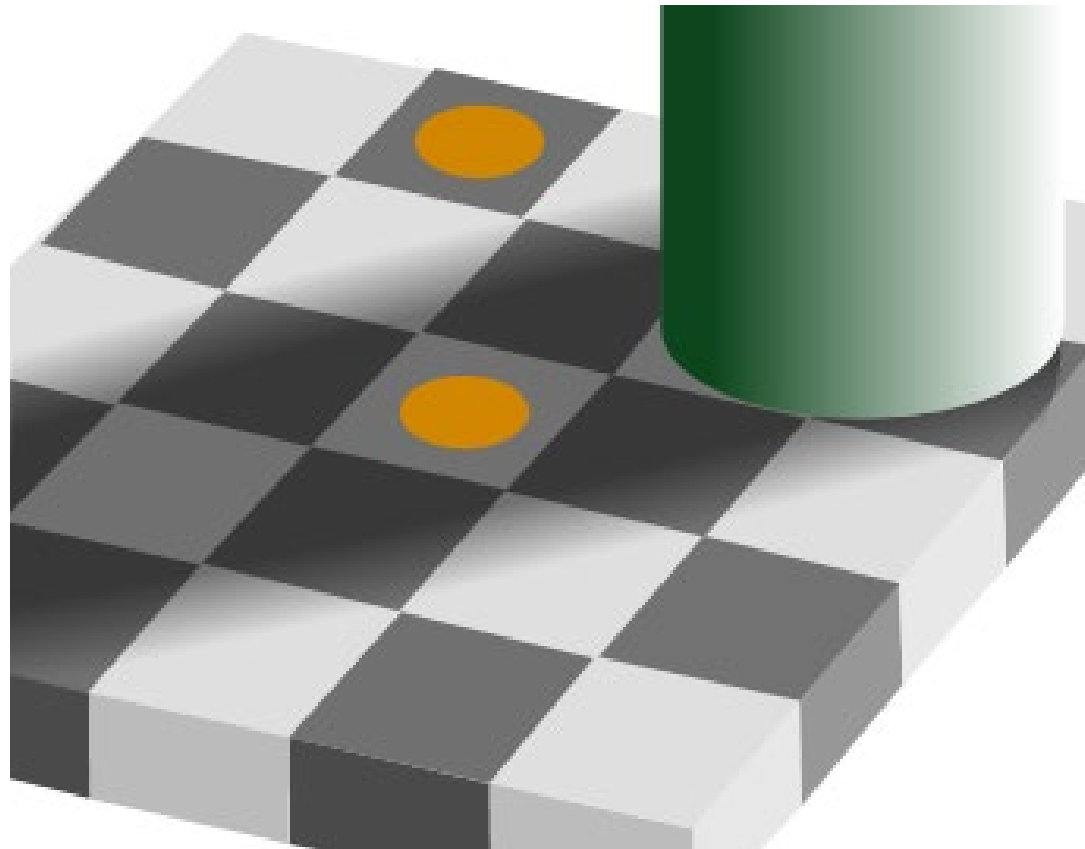
rumena



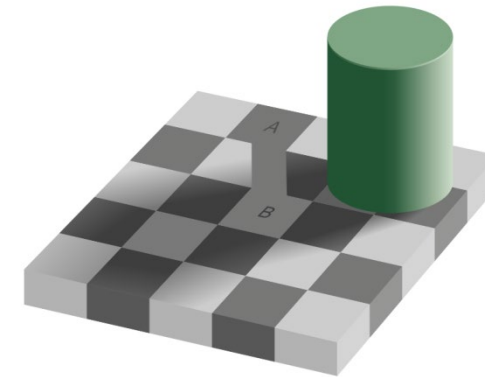
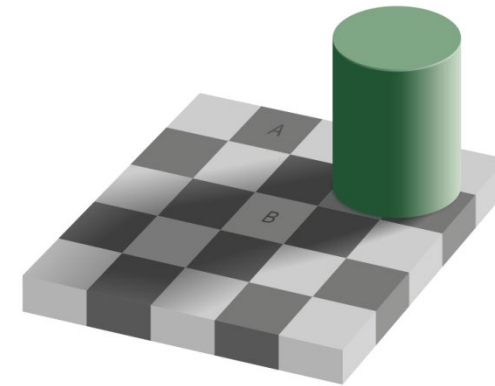
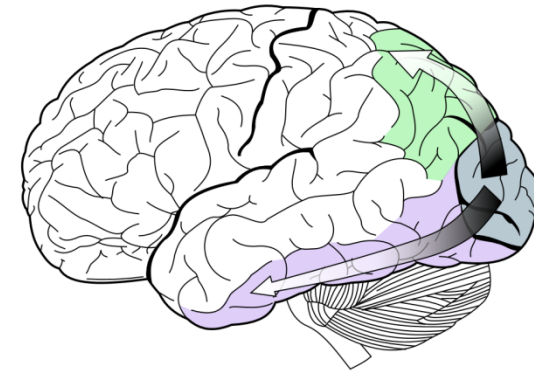
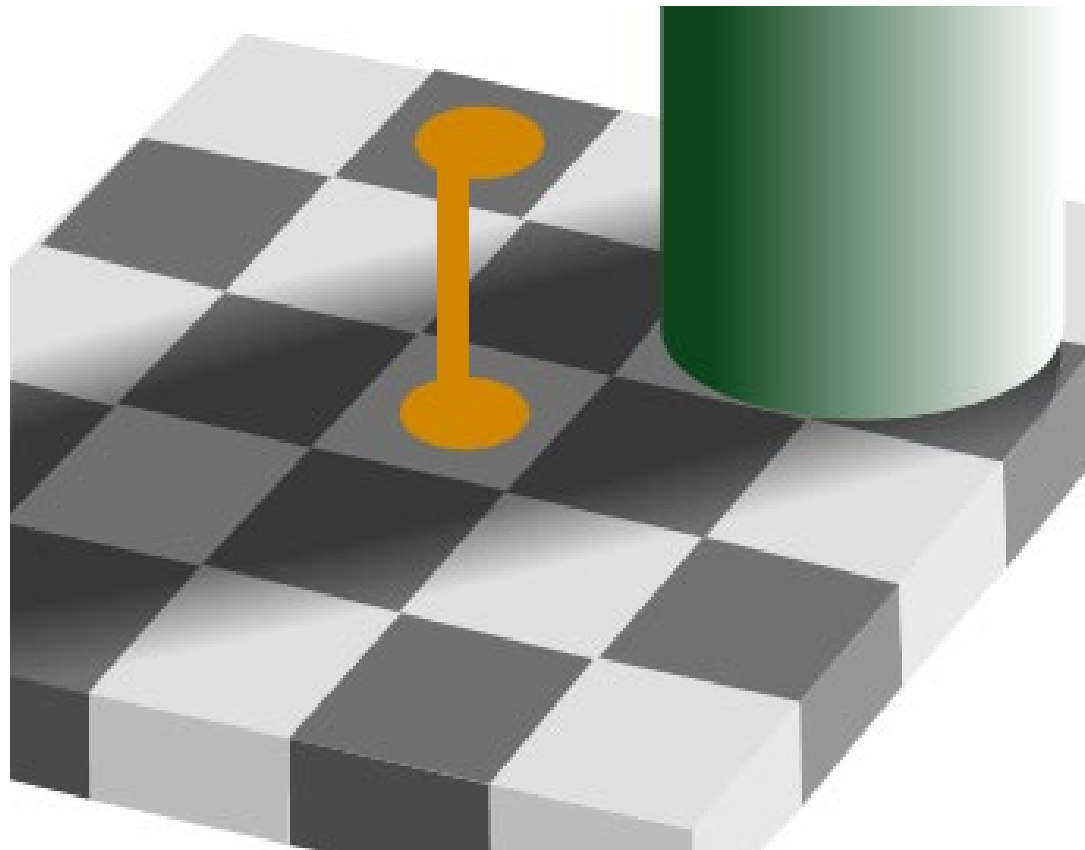
rumena



Percepcija



Percepcija

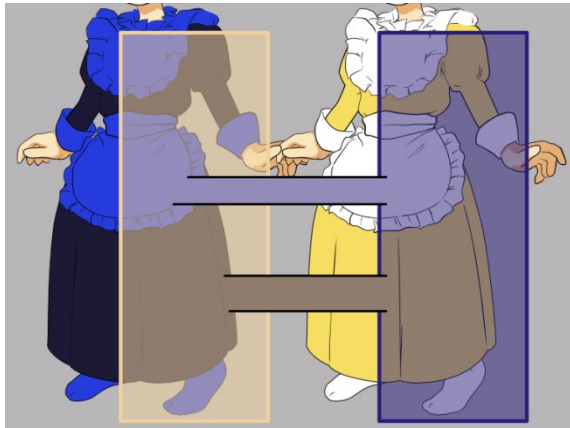


kakšne barve je obleka



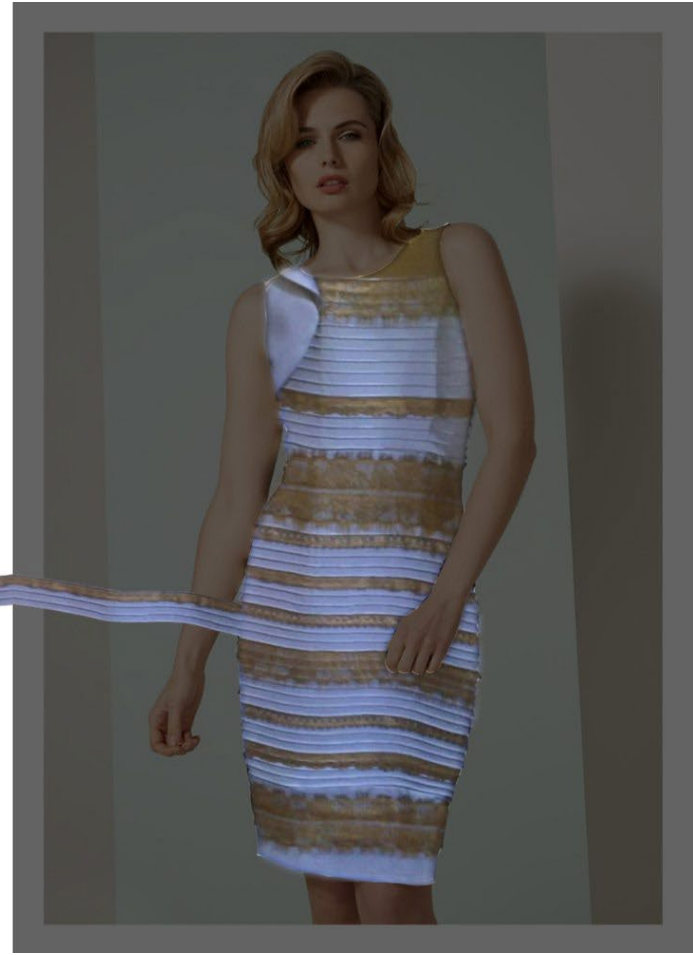
The dress

- viralno 26. 2. 2015
- Črno/modra ali belo/zlata



- Č/M z rumenkasto osvetlitvijo
- B/Z z modrikasto osvetlitvijo





Afterimage

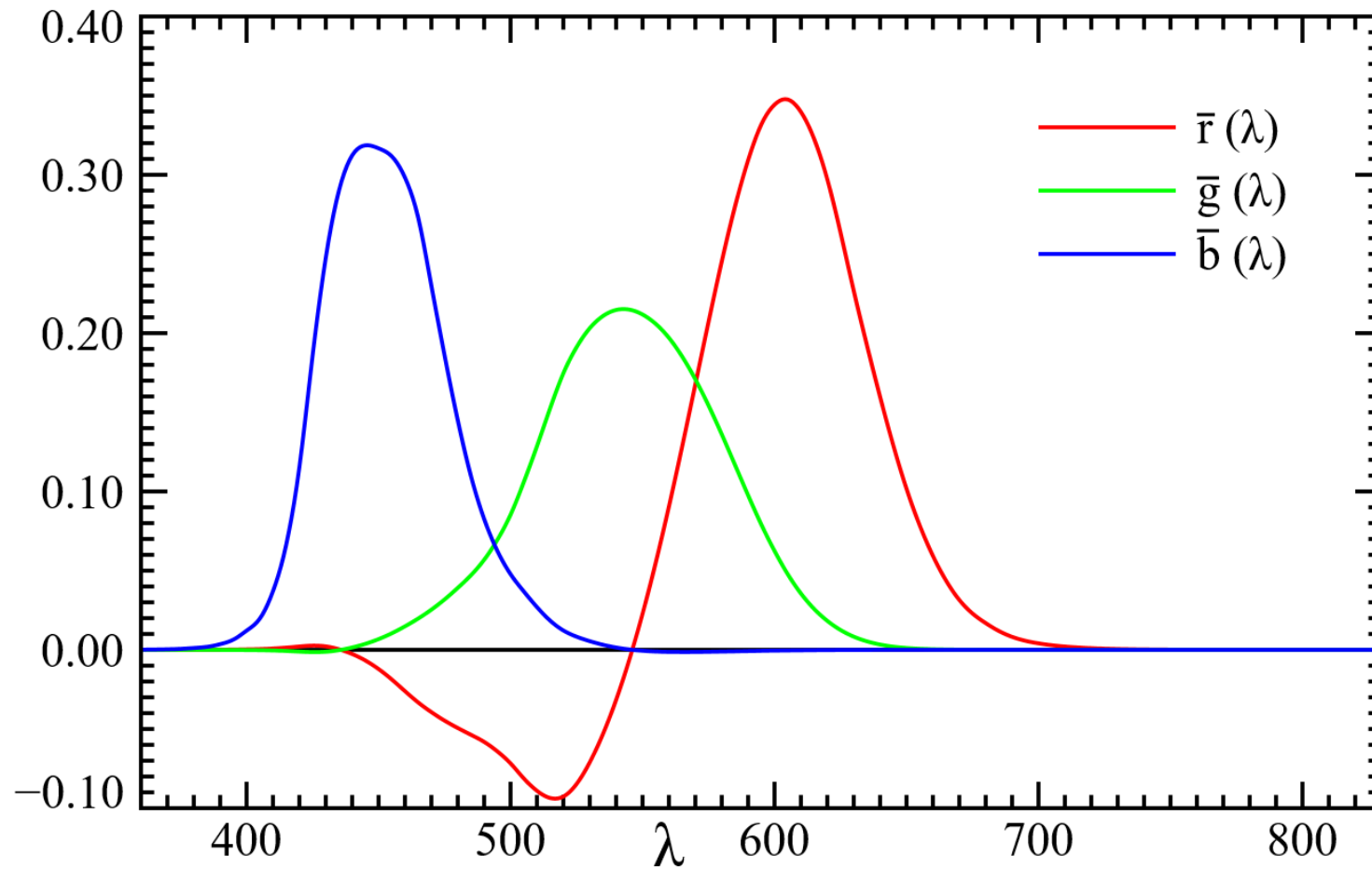
Afterimage

Barvni prostori

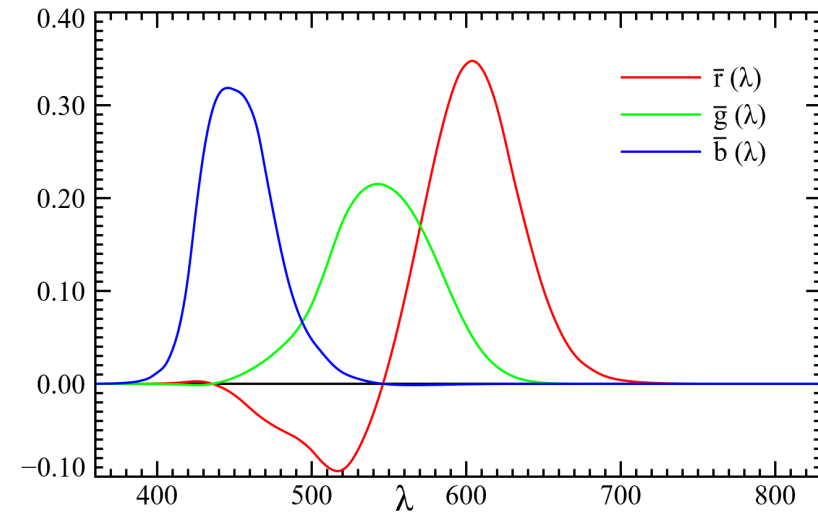
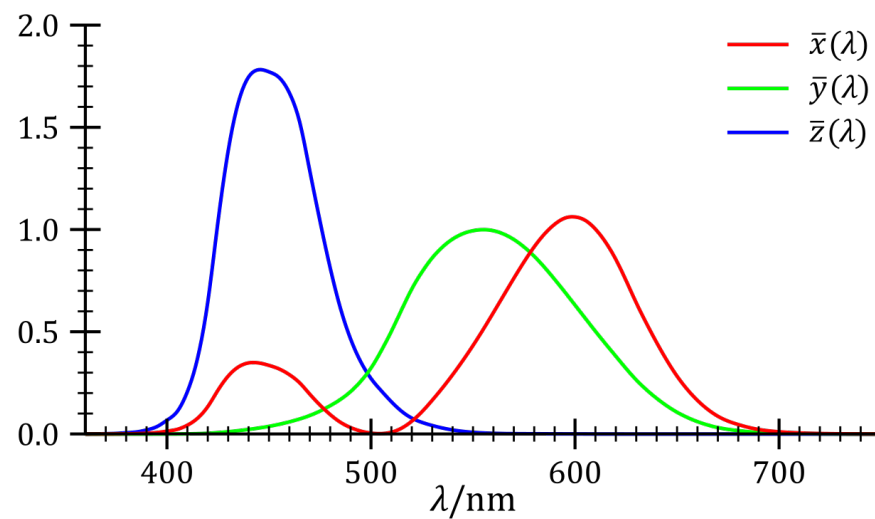
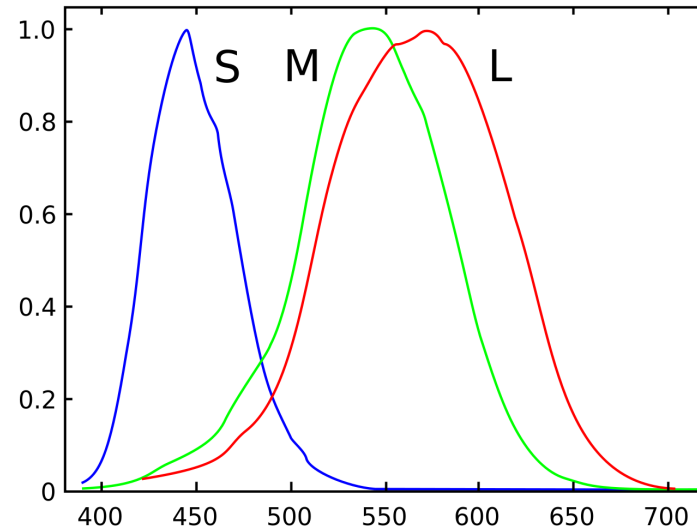
Poskus ujemanja barv

- Wright in Guild (1920ta)
- 3 različne primarne barve
 - Red (**R**): 700 nm
 - Green (**G**): 546,1 nm
 - Blue (**B**): 435,8 nm
- Opazujemo spektralno barvo
- S kombinacijo želimo doseči ujemanje

Rgb color matching functions

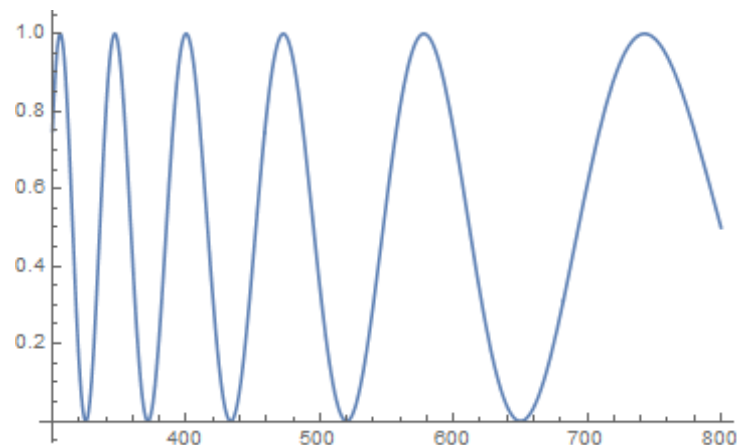
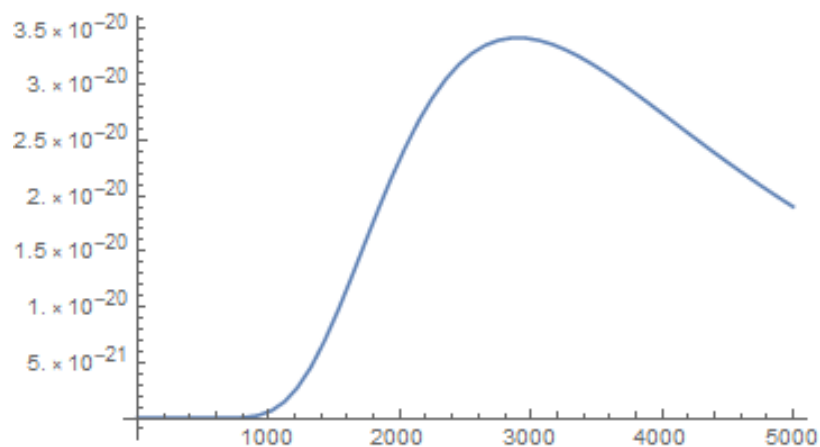


color matching functions



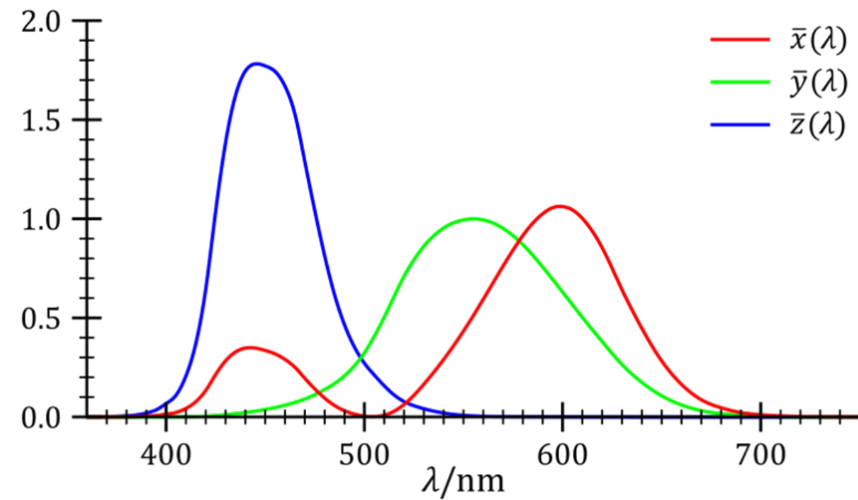
Kakšne barve je svetloba s spektralno svetlostjo $L(\lambda)$?

- npr. $L = I_0 \delta(\lambda - 580 \text{ nm})$
- ali



Barvni prostor CIE 1931

$$X = \int_{\lambda} L_{e,\Omega,\lambda}(\lambda) \bar{x}(\lambda) d\lambda,$$
$$Y = \int_{\lambda} L_{e,\Omega,\lambda}(\lambda) \bar{y}(\lambda) d\lambda,$$
$$Z = \int_{\lambda} L_{e,\Omega,\lambda}(\lambda) \bar{z}(\lambda) d\lambda.$$

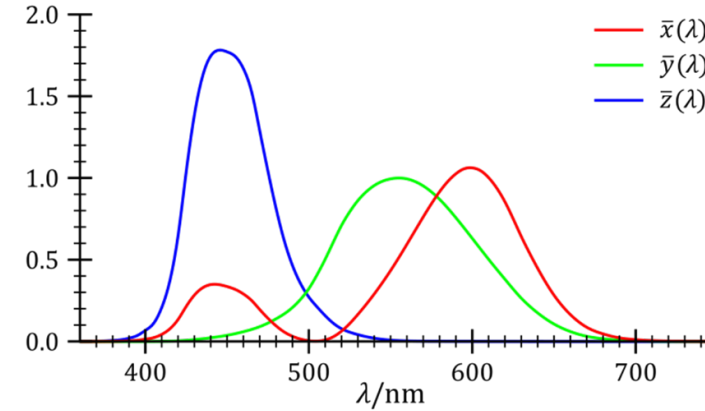


Barvni prostor CIE 1931

$$X = \sum_i L(\lambda_i) \bar{x}(\lambda_i) \Delta\lambda$$

$$Y = \sum_i L(\lambda_i) \bar{y}(\lambda_i) \Delta\lambda$$

$$Z = \sum_i L(\lambda_i) \bar{z}(\lambda_i) \Delta\lambda$$



λ, nm	$\bar{x}(\lambda)$	$\bar{y}(\lambda)$	$\bar{z}(\lambda)$
380	0,001368	0,000039	0,006450
385	0,002236	0,000064	0,010550
390	0,004243	0,000120	0,020050
395	0,007650	0,000217	0,036210
400	0,014310	0,000396	0,067850
405	0,023190	0,000640	0,110200
410	0,043510	0,001210	0,207400
415	0,077630	0,002180	0,371300
420	0,134380	0,004000	0,645600
425	0,214770	0,007300	1,039050
430	0,283900	0,011600	1,385600
435	0,328500	0,016840	1,622960
440	0,348280	0,023000	1,747060
445	0,348060	0,029800	1,782600
450	0,336200	0,038000	1,772110
455	0,318700	0,048000	1,744100

- $X = \sum_i L(\lambda_i) \bar{x}(\lambda_i) \Delta\lambda$
- $Y = \sum_i L(\lambda_i) \bar{y}(\lambda_i) \Delta\lambda$ - luminanca
- $Z = \sum_i L(\lambda_i) \bar{z}(\lambda_i) \Delta\lambda$
- barvni koordinati (kromatičnost)
- $x = \frac{X}{X+Y+Z}$ in $y = \frac{Y}{X+Y+Z}$
- in $z = 1 - x - y$

kromatičnost

saturacija



barva, barvni odtenek



0

60

120

180

240

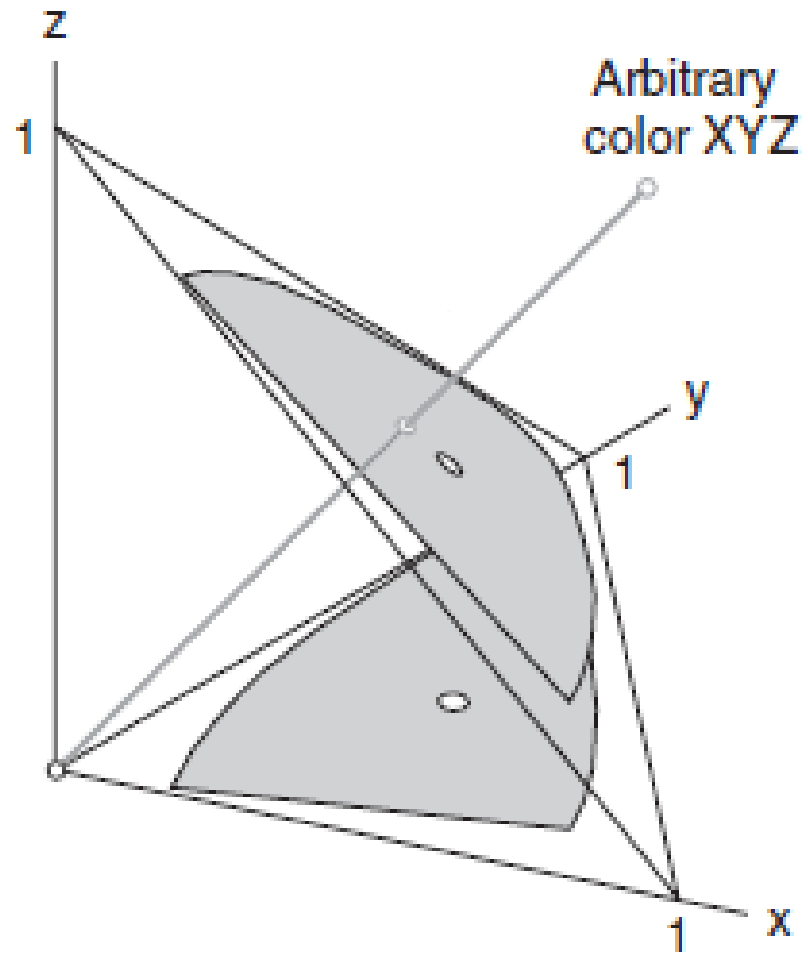
300

360

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

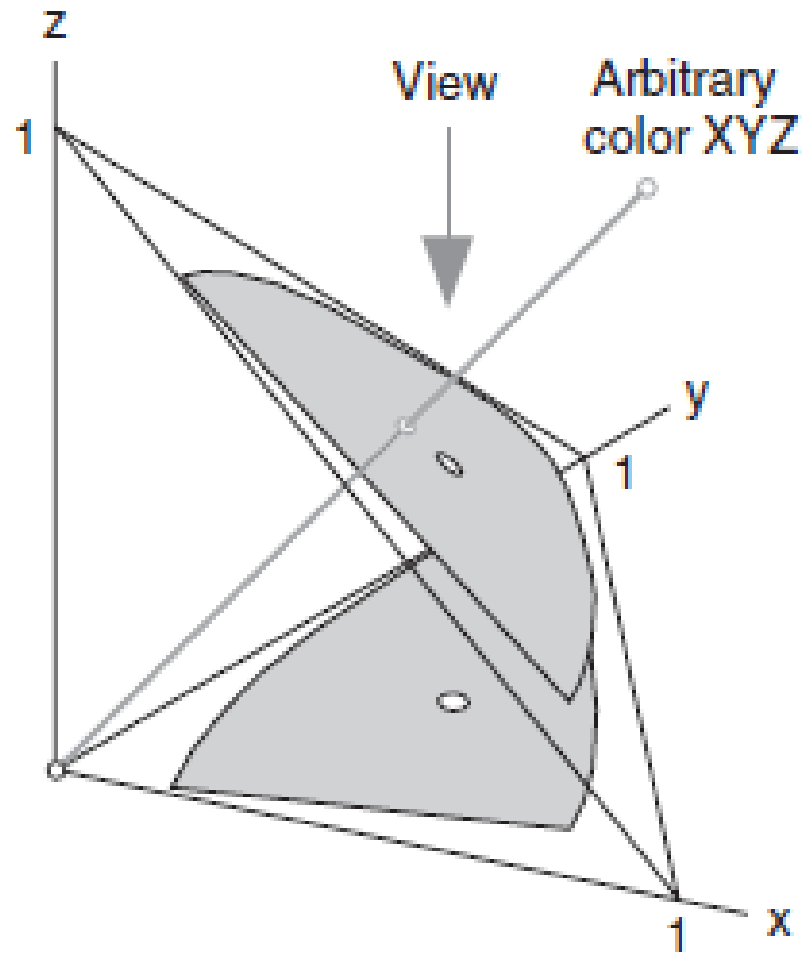
$$z = 1 - x - y$$



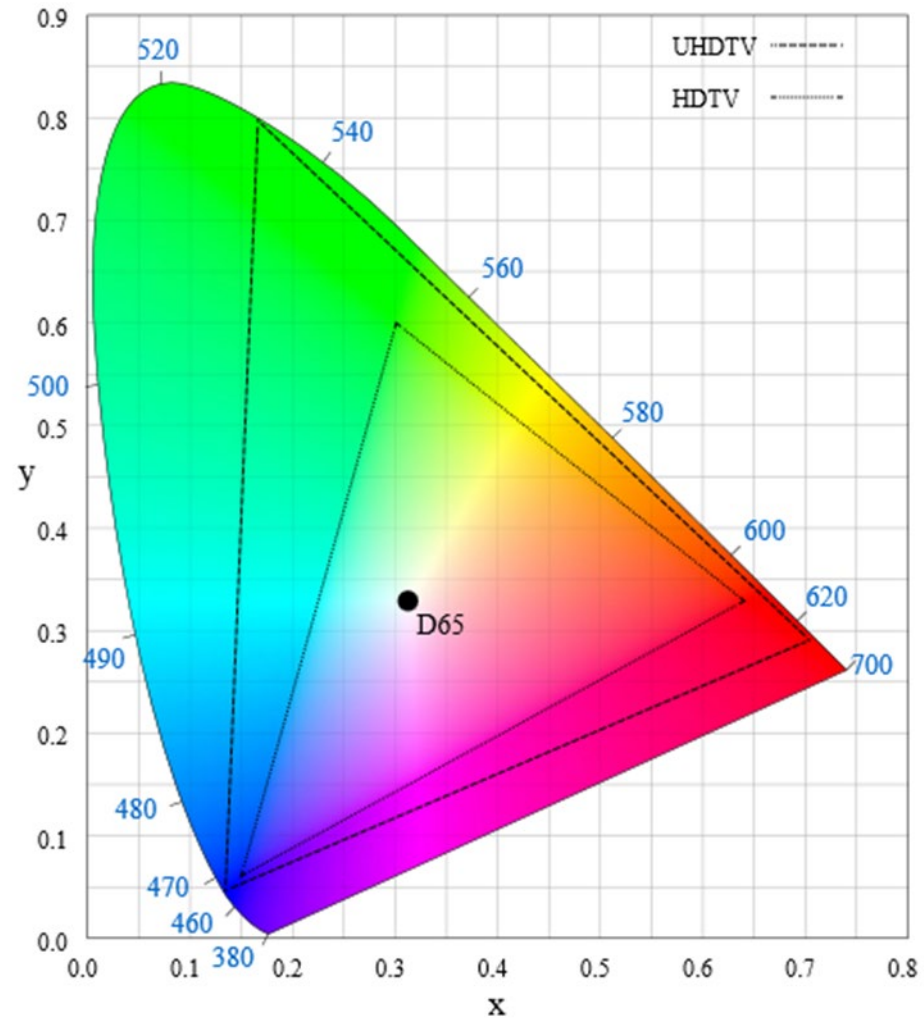
$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = 1 - x - y$$



Barvni prostor



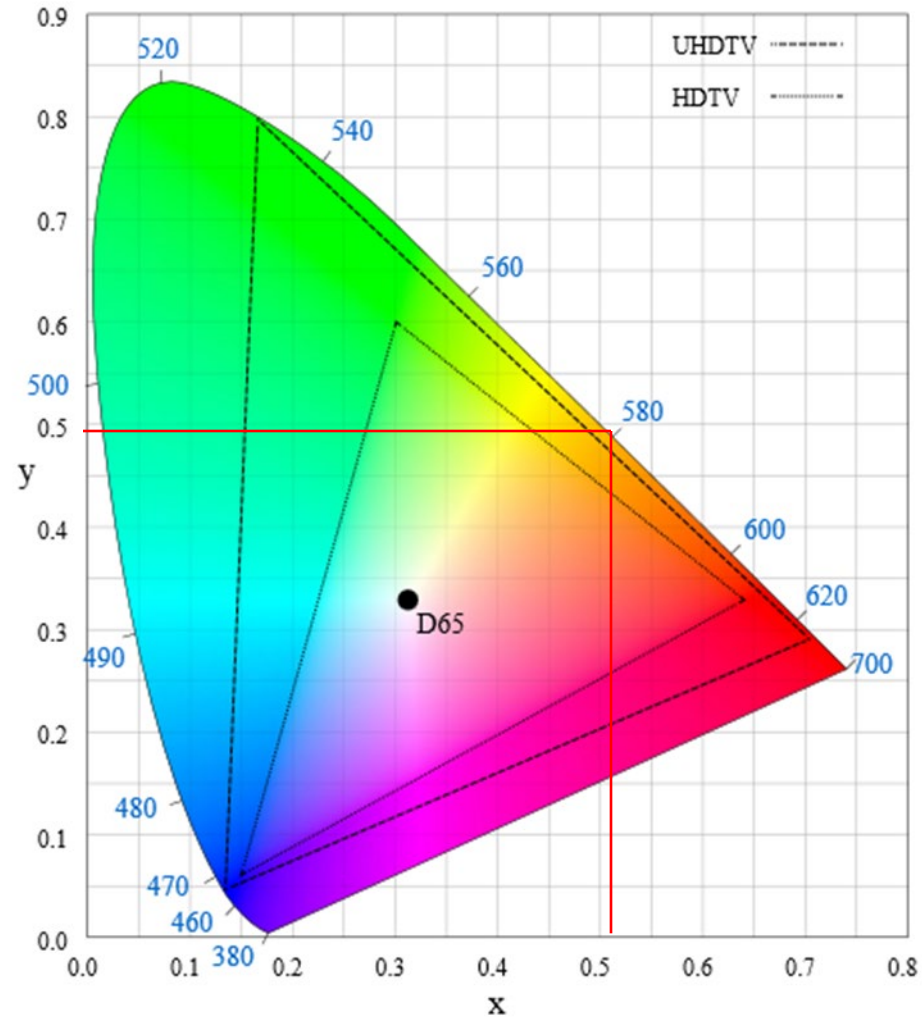
CIE 1931 color space

spekter rumene

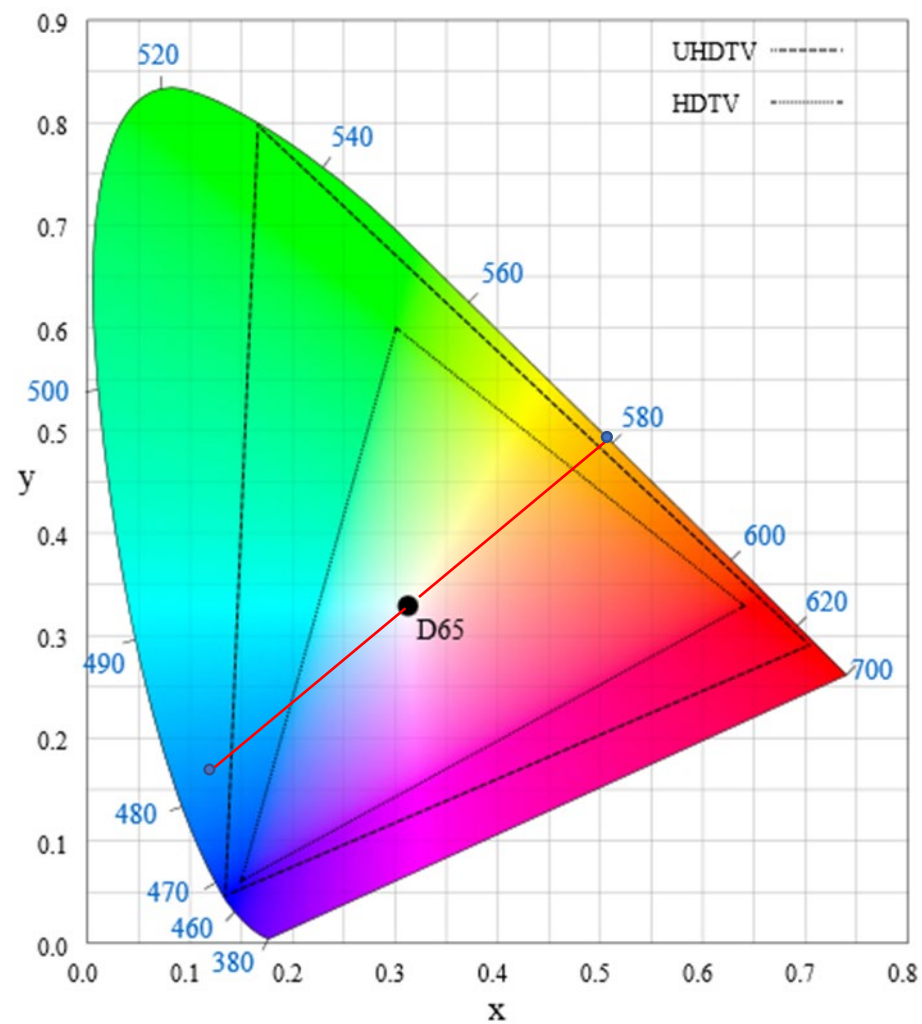
- $L = l_0 \delta(\lambda - 580 \text{ nm})$
- $\bar{x}(580 \text{ nm}) = 0,916300$
- $\bar{y}(580 \text{ nm}) = 0,870000$
- $\bar{z}(580 \text{ nm}) = 0,001650$
- $X \propto 0,9163, Y \propto 0,87, Z \propto 0,00165$
- $x = 0,91630/1,78795=0,512$
- $y = 0,487$

$\lambda, \text{ nm}$			
380	0,001368	0,000039	0,006450
385	0,002236	0,000064	0,010550
390	0,004243	0,000120	0,020050
395	0,007650	0,000217	0,036210
400	0,014310	0,000396	0,067850
405	0,023190	0,000640	0,110200
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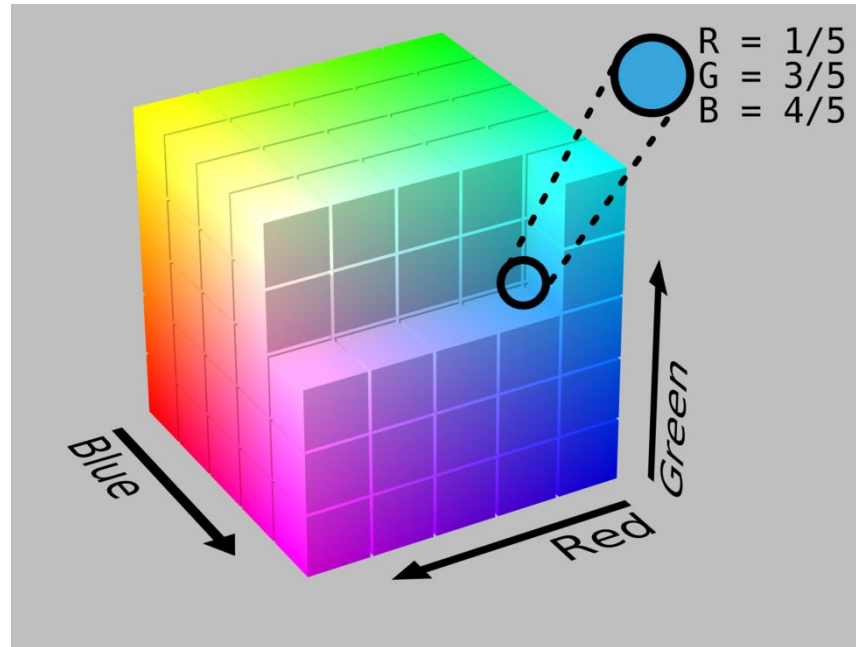
- $L = l_0 \delta(\lambda - 580 \text{ nm})$
- $\bar{x}(580 \text{ nm}) = 0,916300$
- $\bar{y}(580 \text{ nm}) = 0,870000$
- $\bar{z}(580 \text{ nm}) = 0,001650$
- $X = 0,9163, Y = 0,87, Z = 0,0016$
- $x = 0,512$
- $y = 0,487$



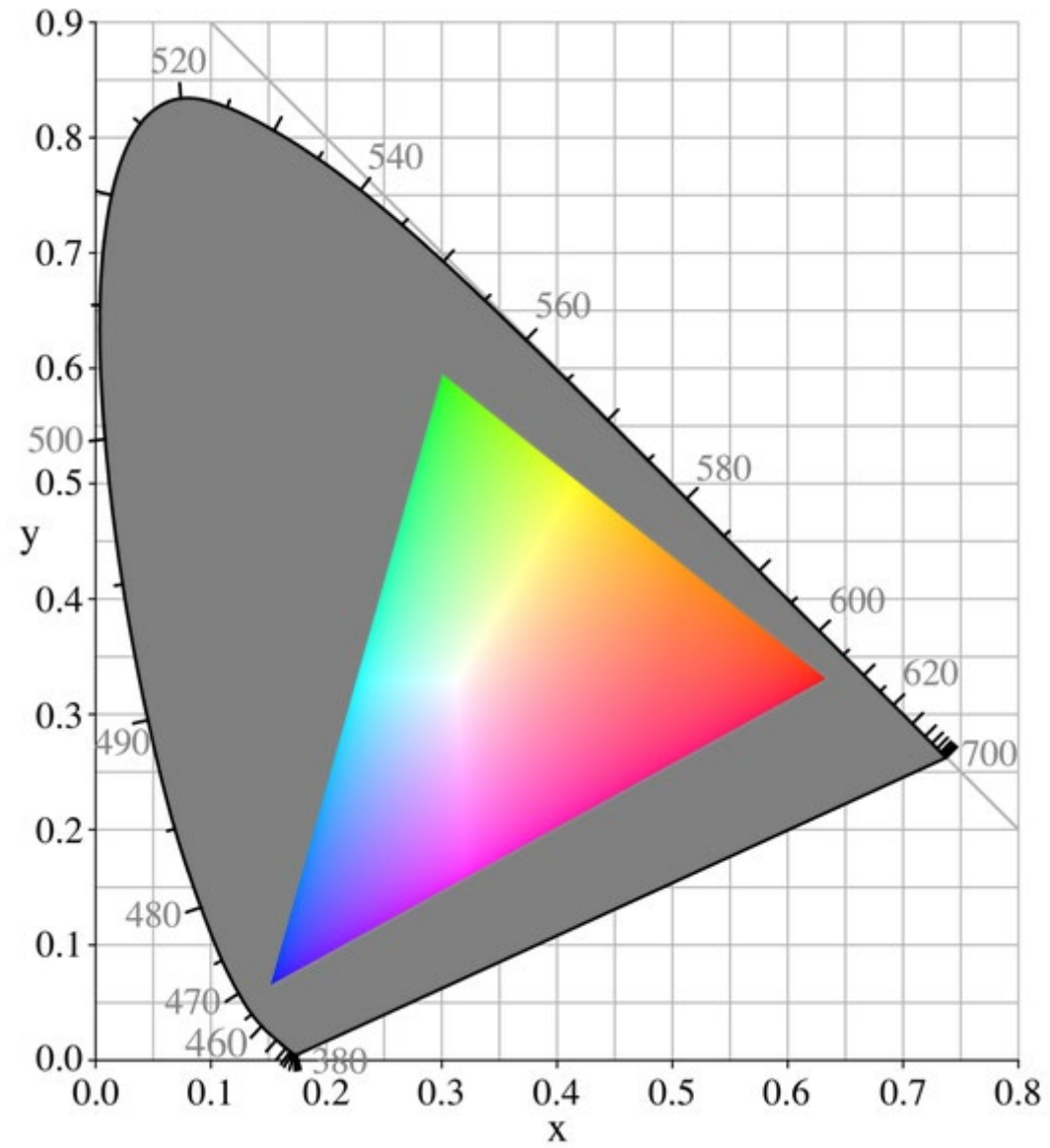
komplementarna barva



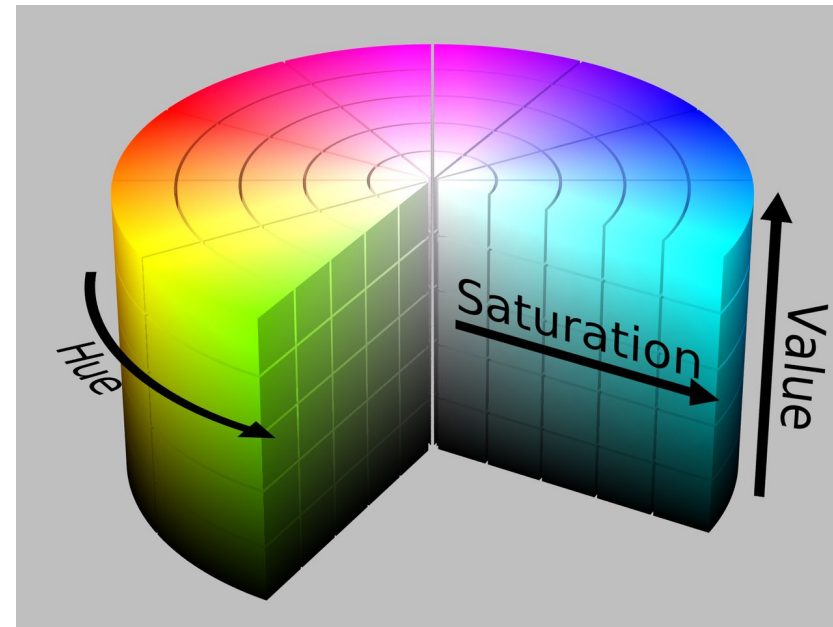
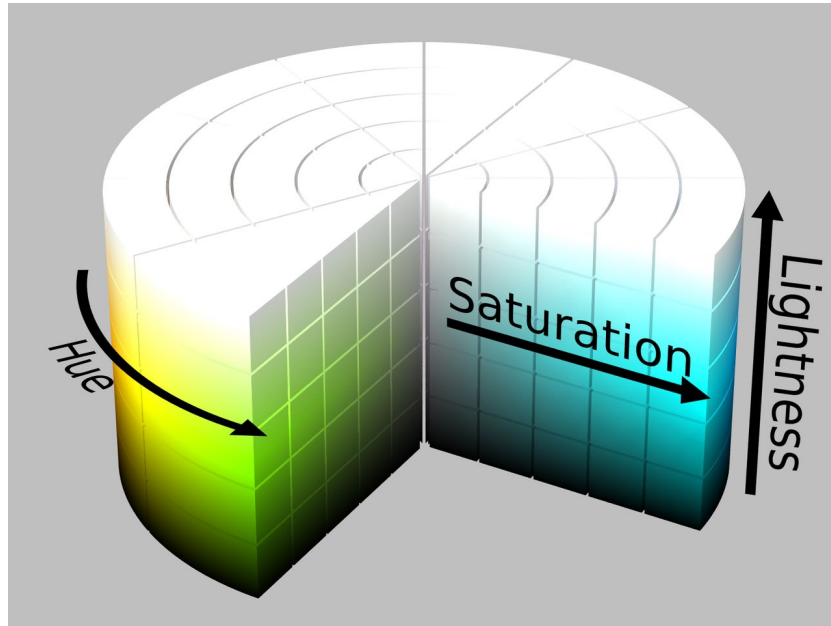
Prostor RGB



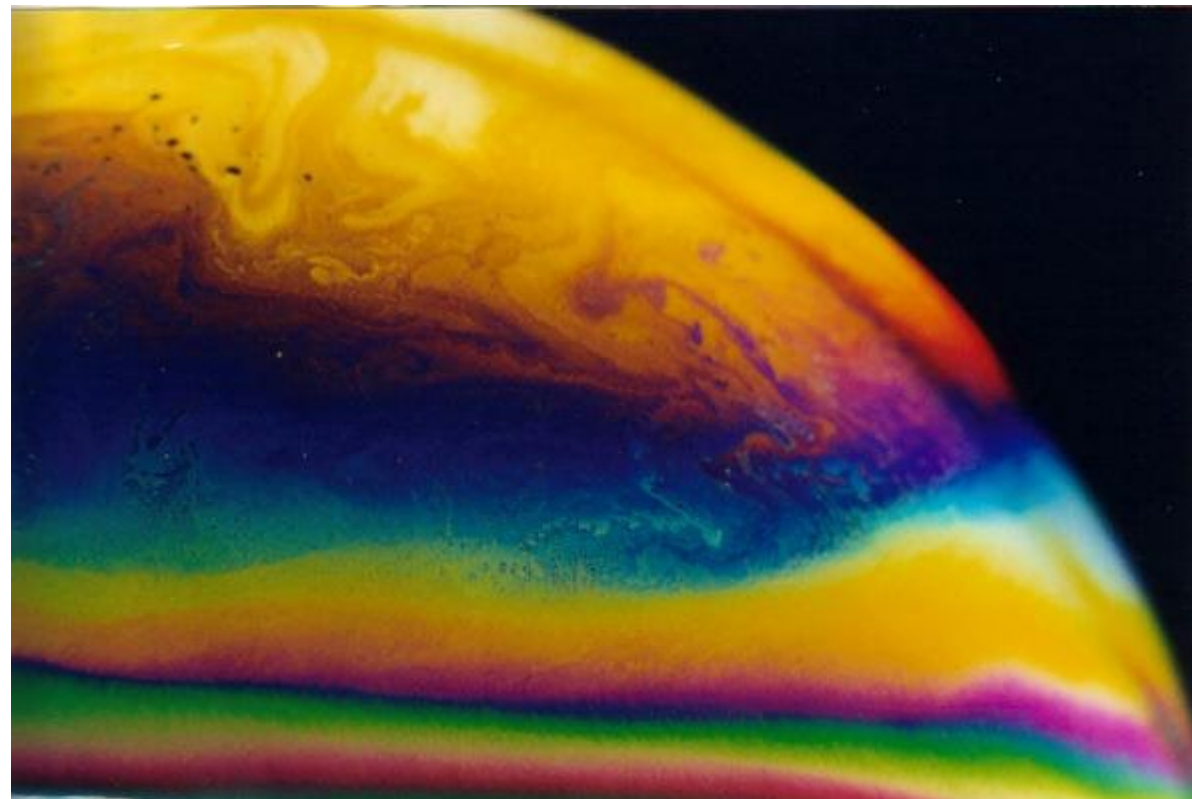
$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 0.418,47 & -0.158,66 & -0.082,835 \\ -0.091,169 & 0.252,43 & 0.015,708 \\ 0.000,920,90 & -0.002,549,8 & 0.178,60 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$



Prostora HSL in HSV



interferenca na opni



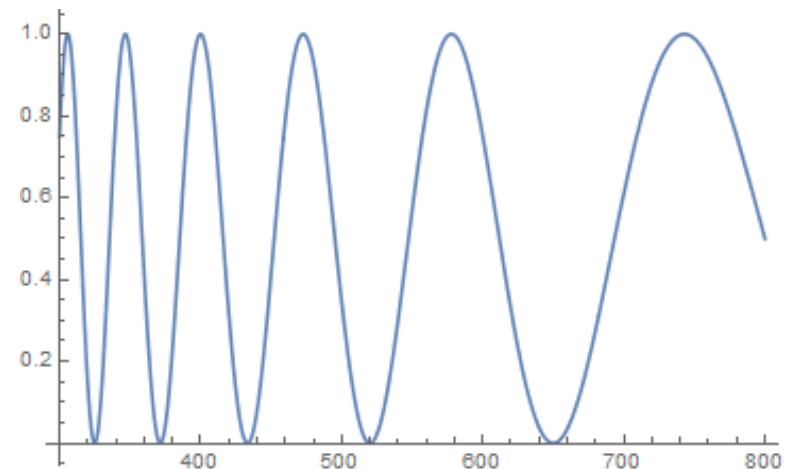
interferenca na opni

- $E = E_0 e^{ikz - i\omega t}$
- na prvi plasti se odbije $-\alpha E$
- od zadnje plasti se odbije $\alpha\beta e^{iks} E$
- in plast je debela d : $s = 2nd$
- ti valovanji interferirata in gostota energijskega toka $j \propto \overline{E^2}$
- $j \propto \alpha^2 E_0^2 \left[1 + \beta^2 - 2\beta \cos\left(\frac{2\pi s}{\lambda}\right) \right]$

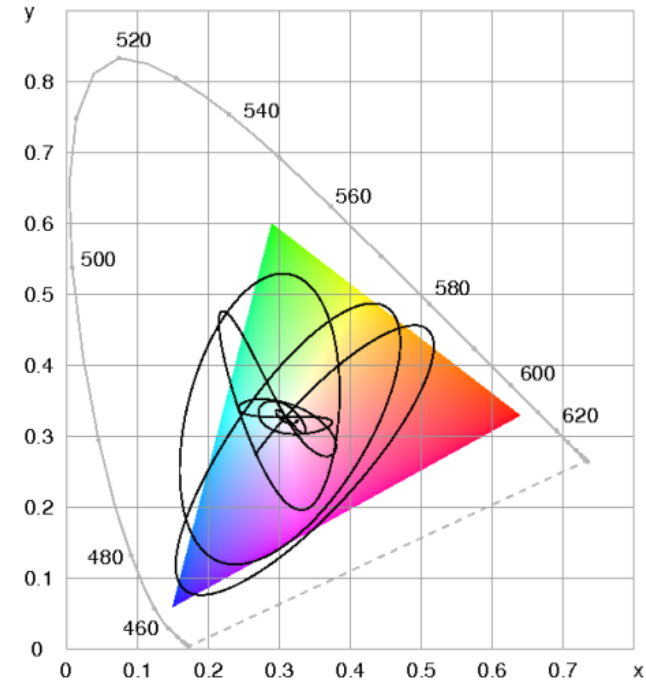
- na opno vpada bela svetloba D65, črno telo pri $T = 6504$ K:

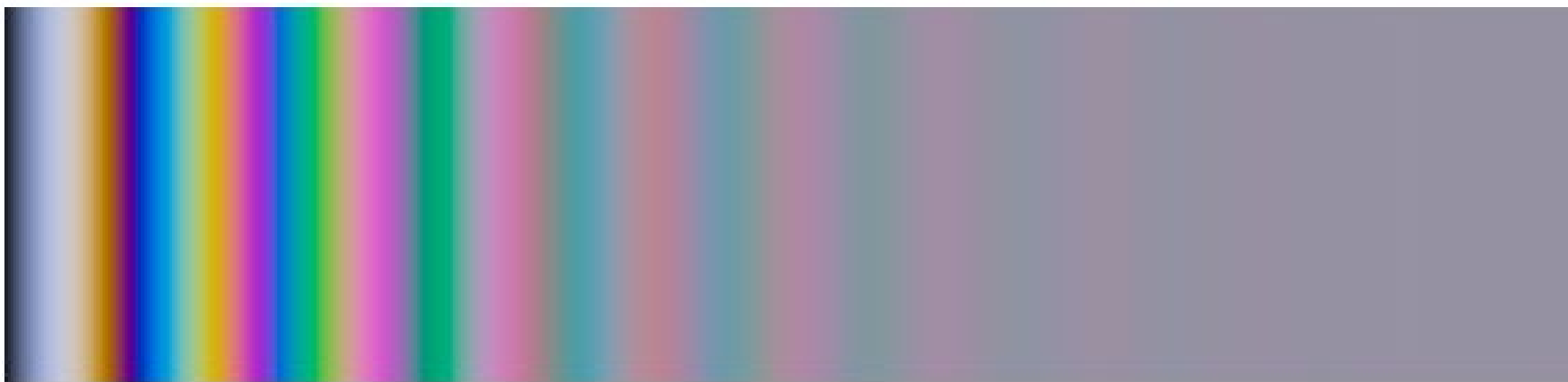
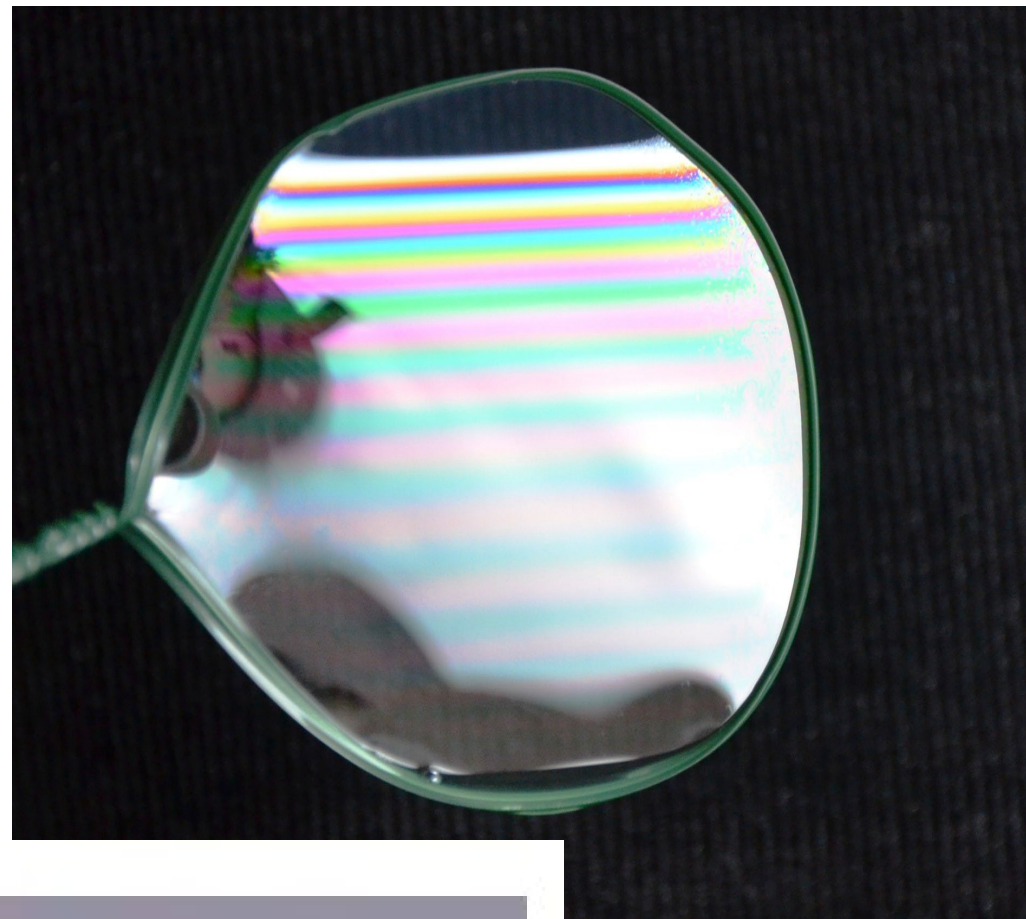
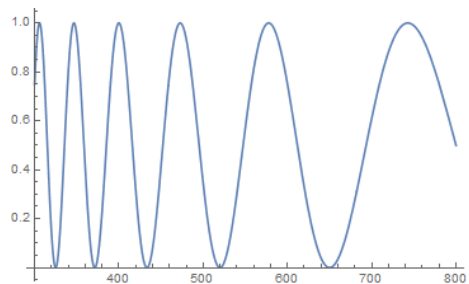
- $S(\lambda) \propto \left[\lambda^5 \left(\exp \left(\frac{hc}{\lambda kT} \right) - 1 \right) \right]^{-1}$

- $L(s, \lambda) = Sj = C \frac{1 + \beta^2 - 2\beta \cos\left(\frac{2\pi s}{\lambda}\right)}{\lambda^5 \left(\exp \frac{hc}{\lambda kT} - 1 \right)}$

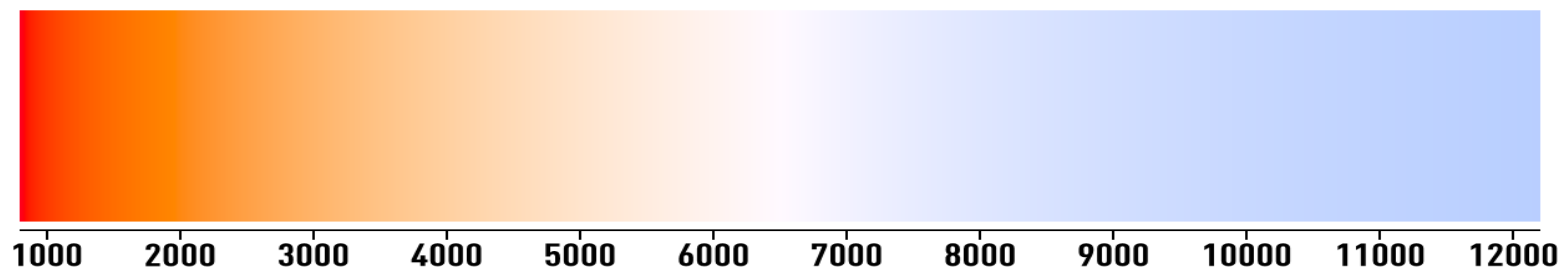
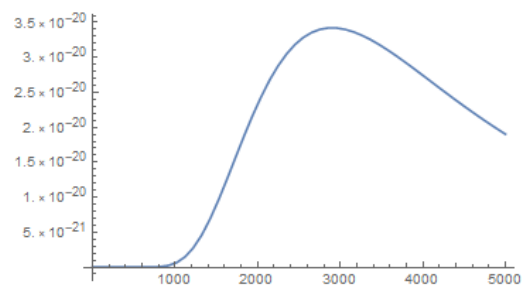


- $X(s) = \sum_i L(s, \lambda_i) \bar{x}(\lambda_i) \Delta\lambda$
- $Y(s) = \sum_i L(s, \lambda_i) \bar{y}(\lambda_i) \Delta\lambda$
- $Z(s) = \sum_i L(s, \lambda_i) \bar{z}(\lambda_i) \Delta\lambda$
- barvni koordinati
- $x = \frac{X}{X+Y+Z}$ in $y = \frac{Y}{X+Y+Z}$

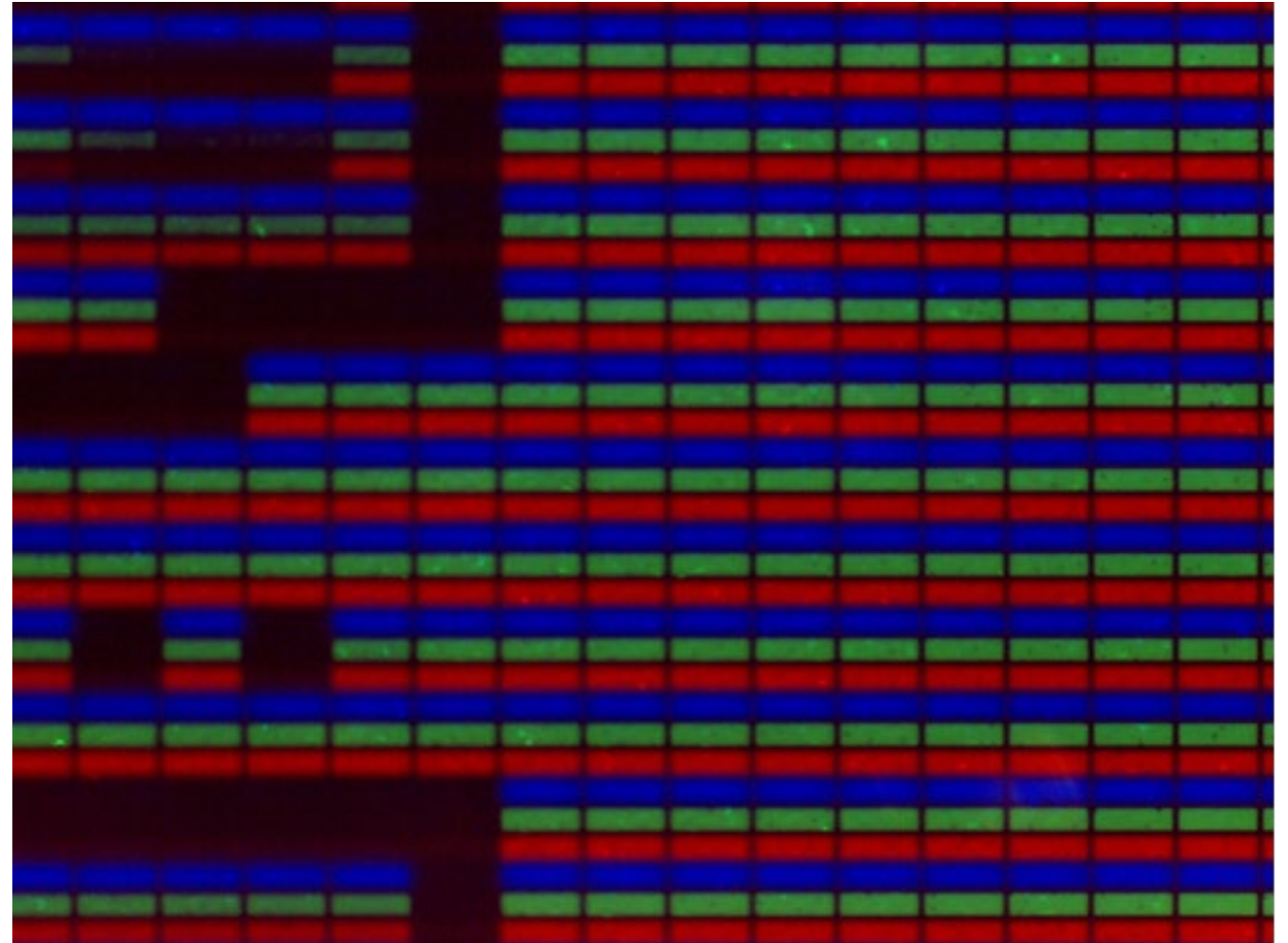
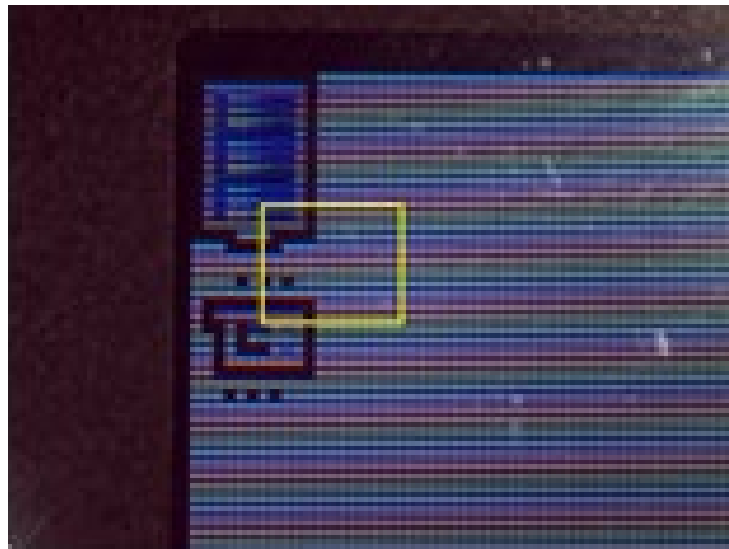




barva segretega črnega telesa



aditivno barvno mešanje



subtraktivno barvno mešanje

OBZORNIK
ZA MATEMATIKO IN FIZIKO

2010
Letnik 57
5

