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Computación Gráfica

Class 4. Fundamentals of Color.

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TRANSFORMATEC

Today

Fundamentals of Color, and some words on color systems

Definition of groups and proposals for the project of the course.

References for the class of today:

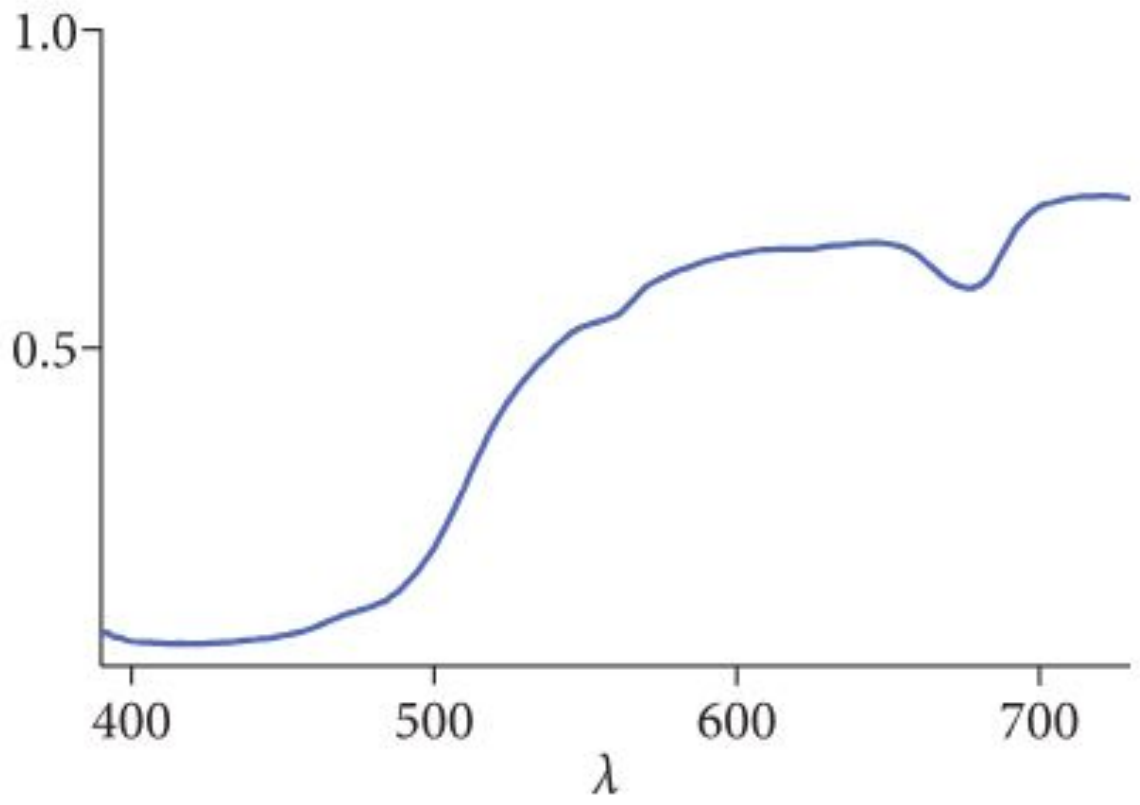
L. Velho, A. C. Frery, and J. Gomes. Image Processing for Computer Graphics and Vision. 2nd edition, 2008. → Chapters 4 and 5.

Color

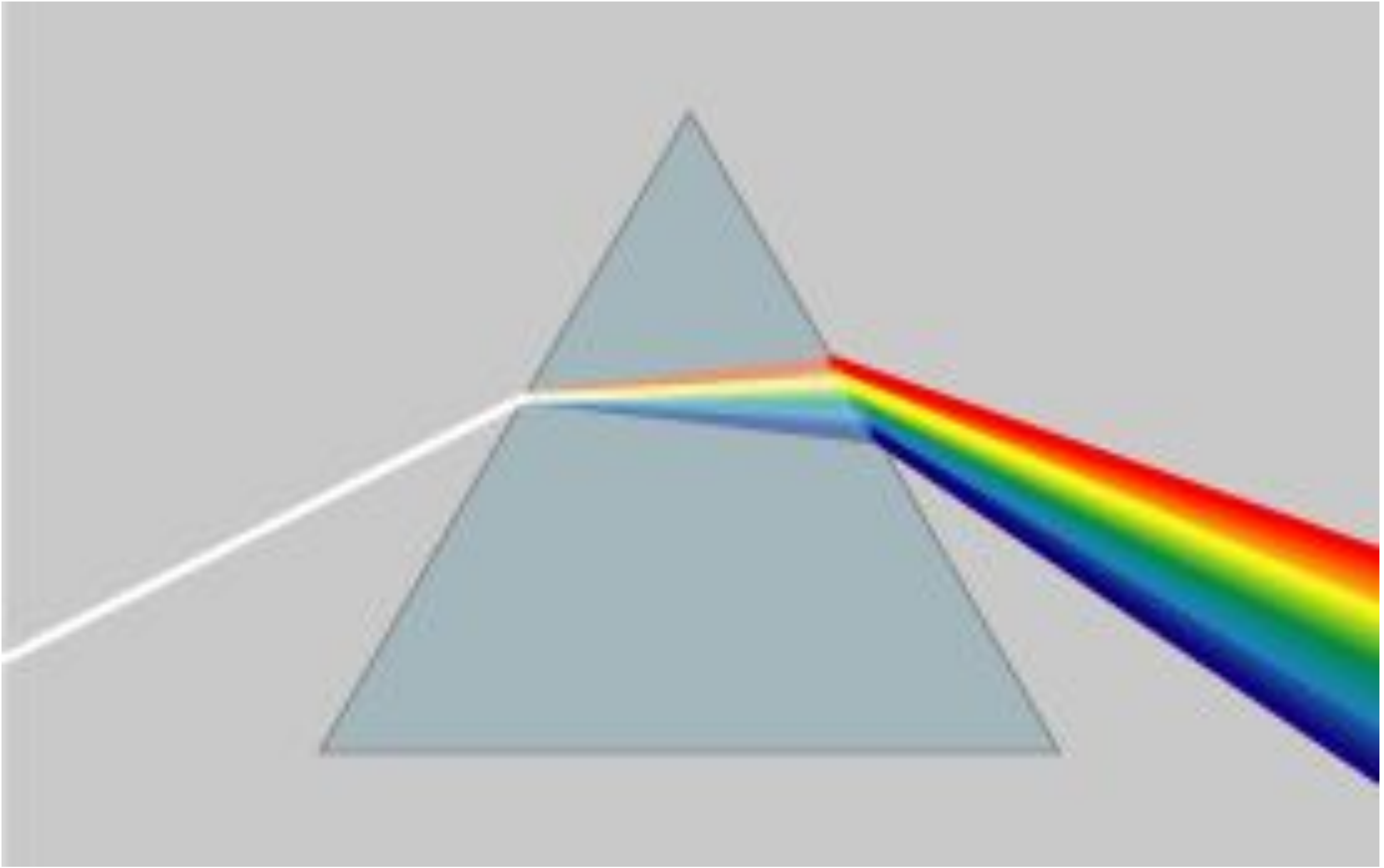
How we represent a color?

→ A function that assigns to each wavelength a magnitude.

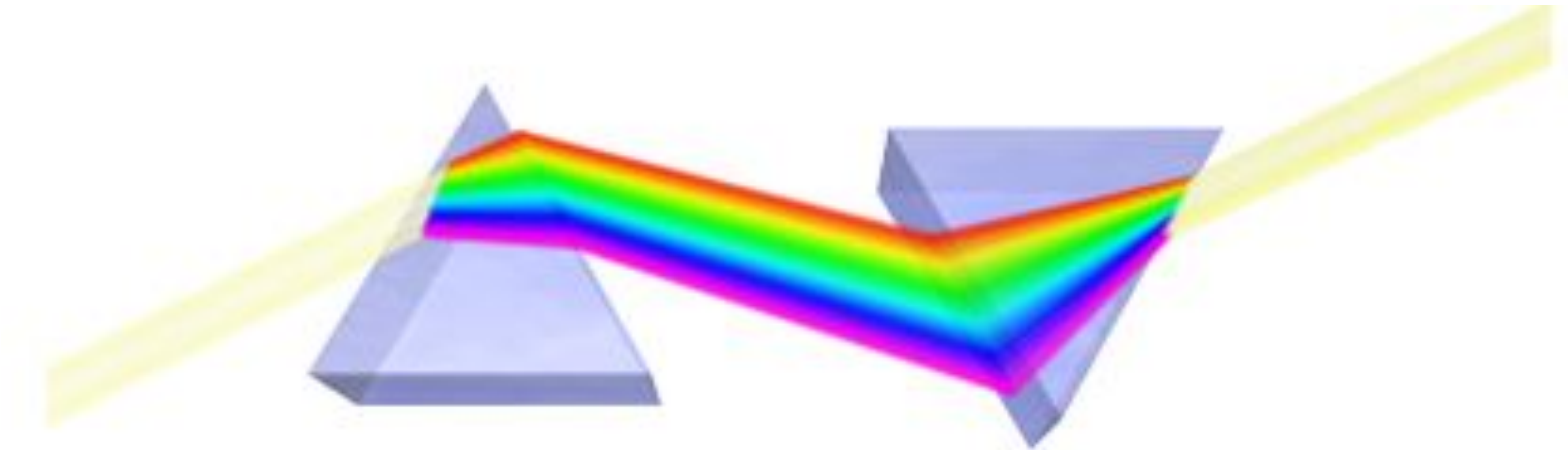
A possible spectral distribution of a color signal:



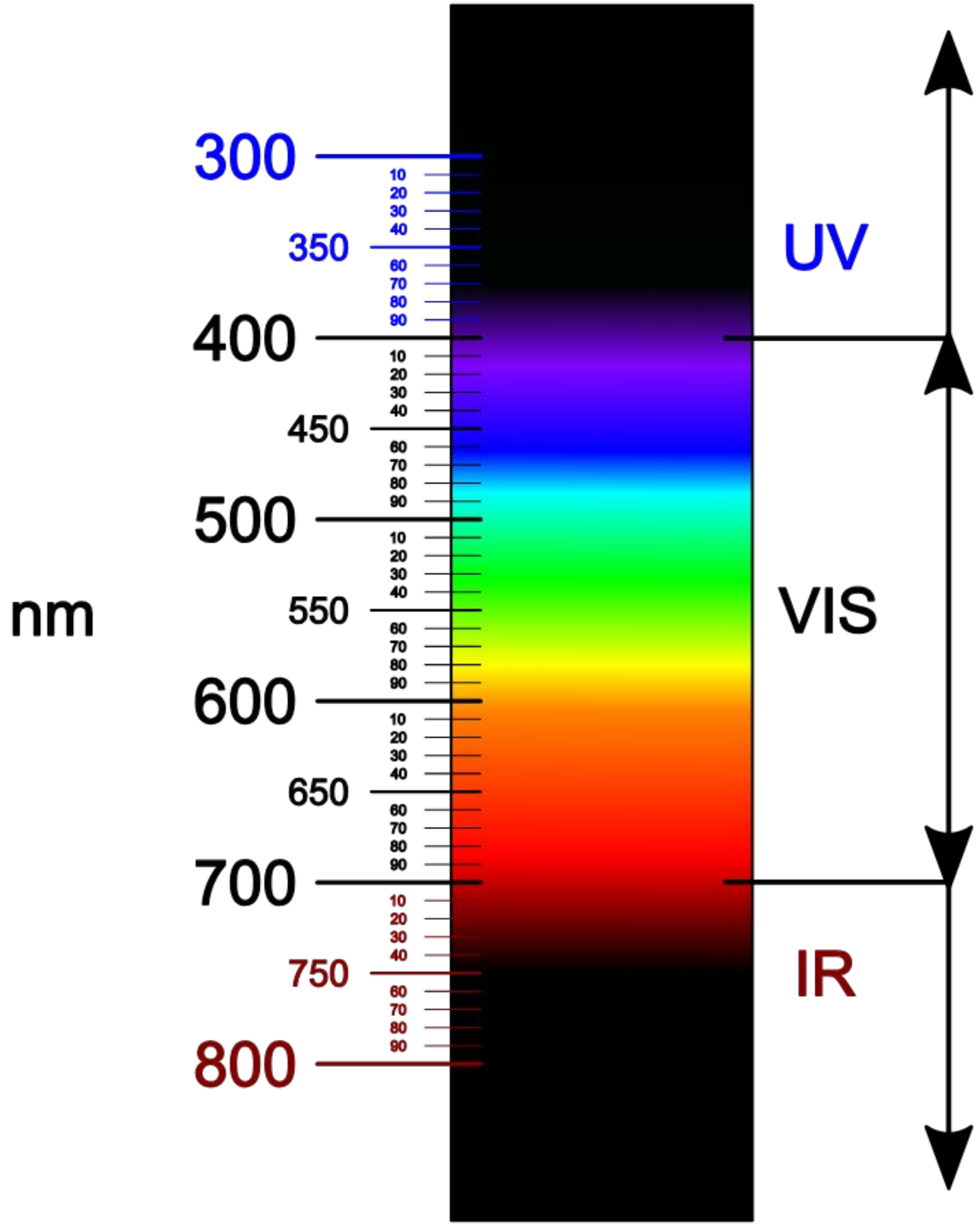
Adding and subtracting colors



Adding and subtracting colors

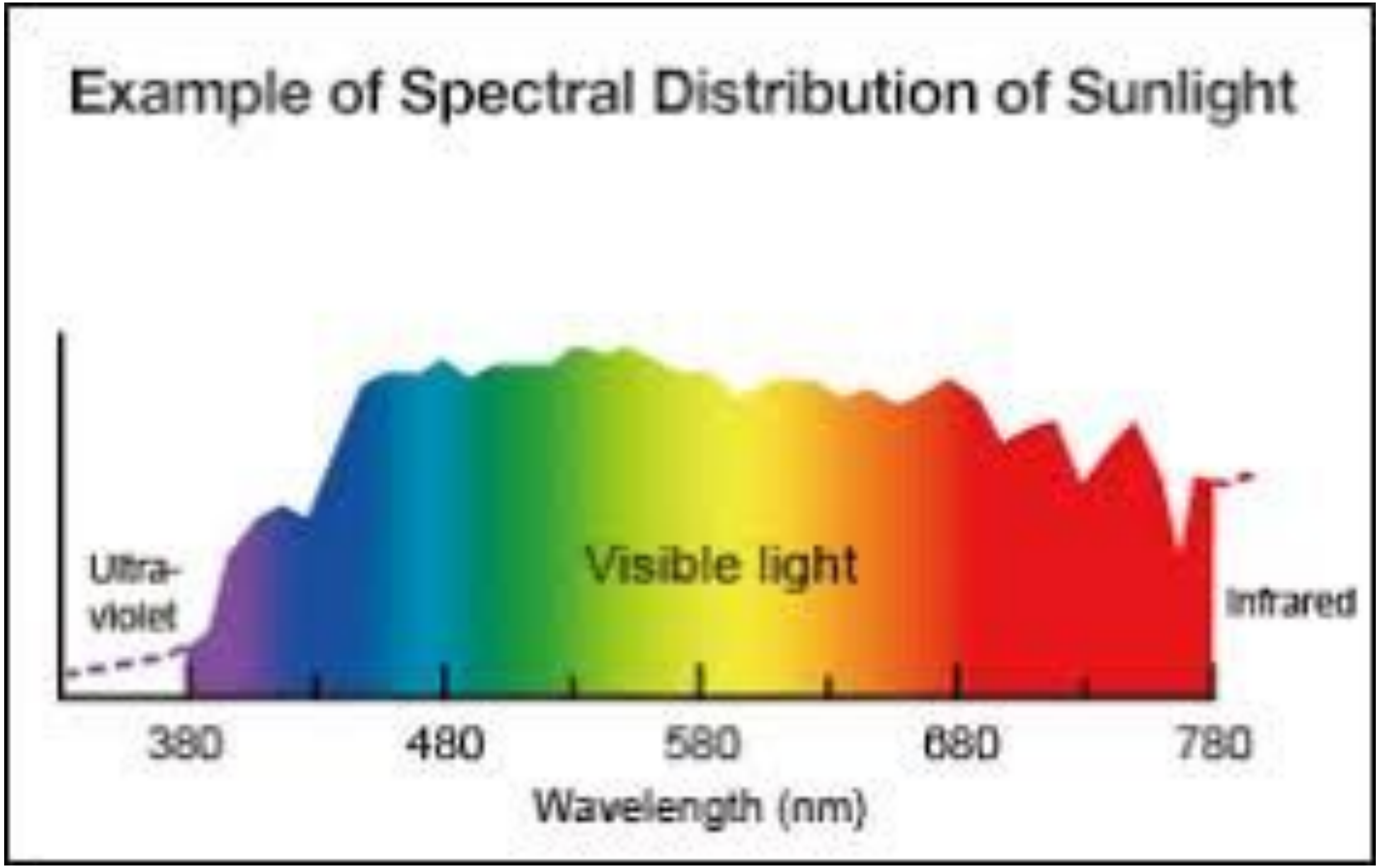


Wavelengths of the different colors



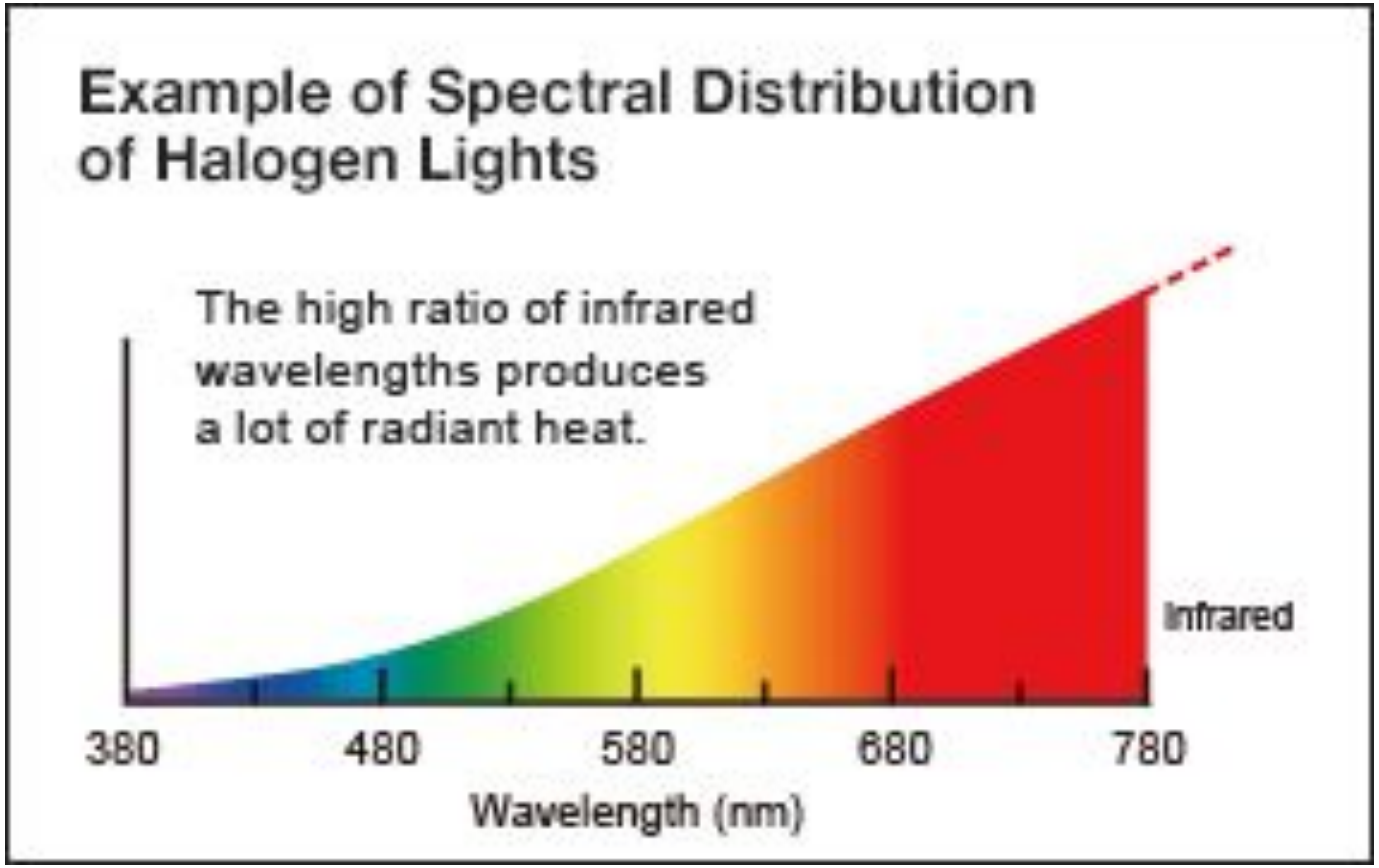
1. **Violet** - shortest wavelength, around 380-450 nanometers with highest frequency. They carry the most energy.
2. **Indigo** - 420 - 440 nm
3. **Blue** - 450 - 495 nm
4. **Green** - 495 - 570 nm
5. **Yellow** - 570 - 590 nm
6. **Orange** - 590 - 620 nm
7. **Red** - longest wavelength, at around 620 - 750 nanometers with lowest frequency

Sunlight

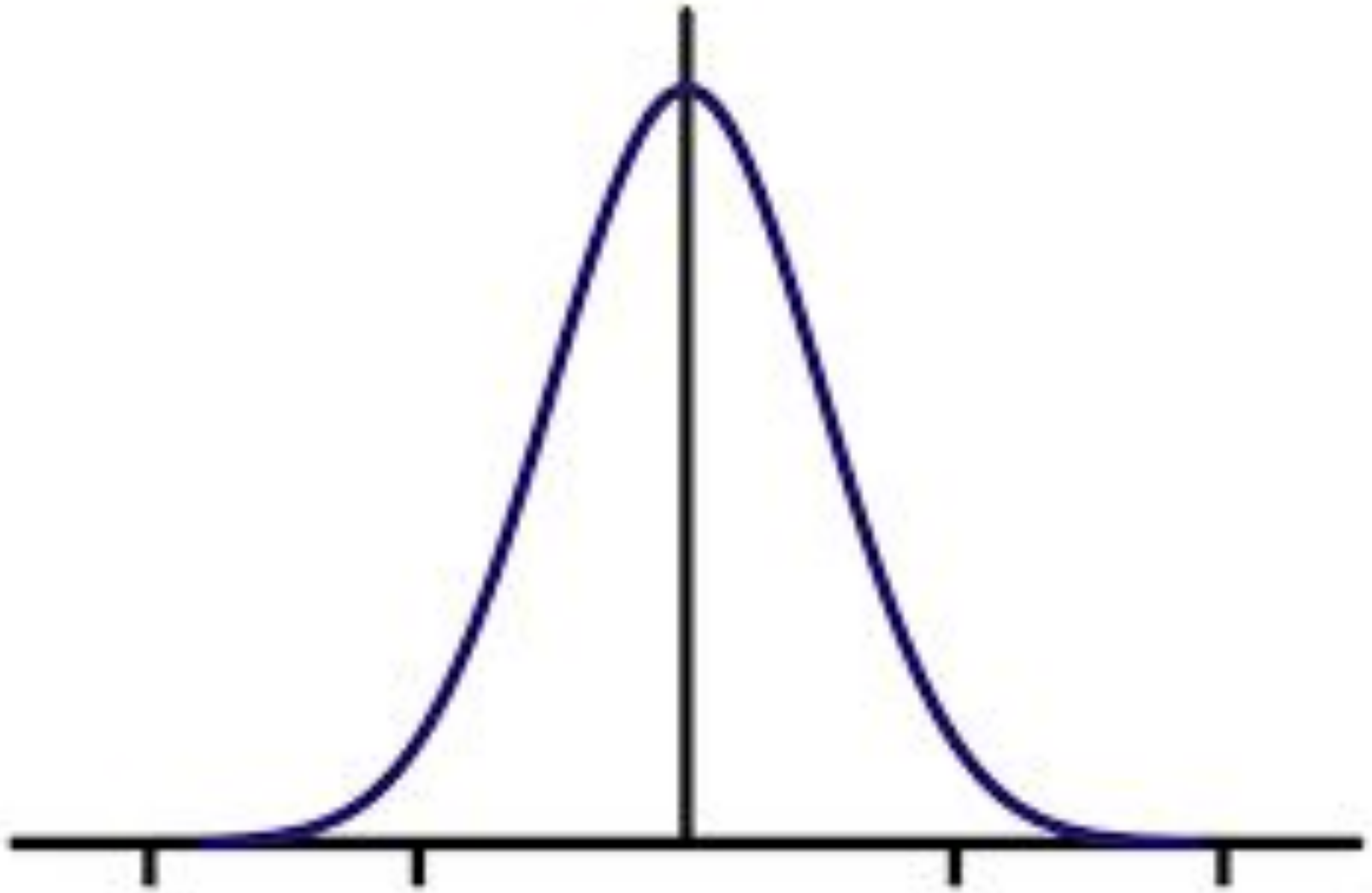


Example of Spectral Distribution of Sunlight
Ultra-
violet
Visible light
Infrared
380
480
580
680
780
Wavelength (nm)

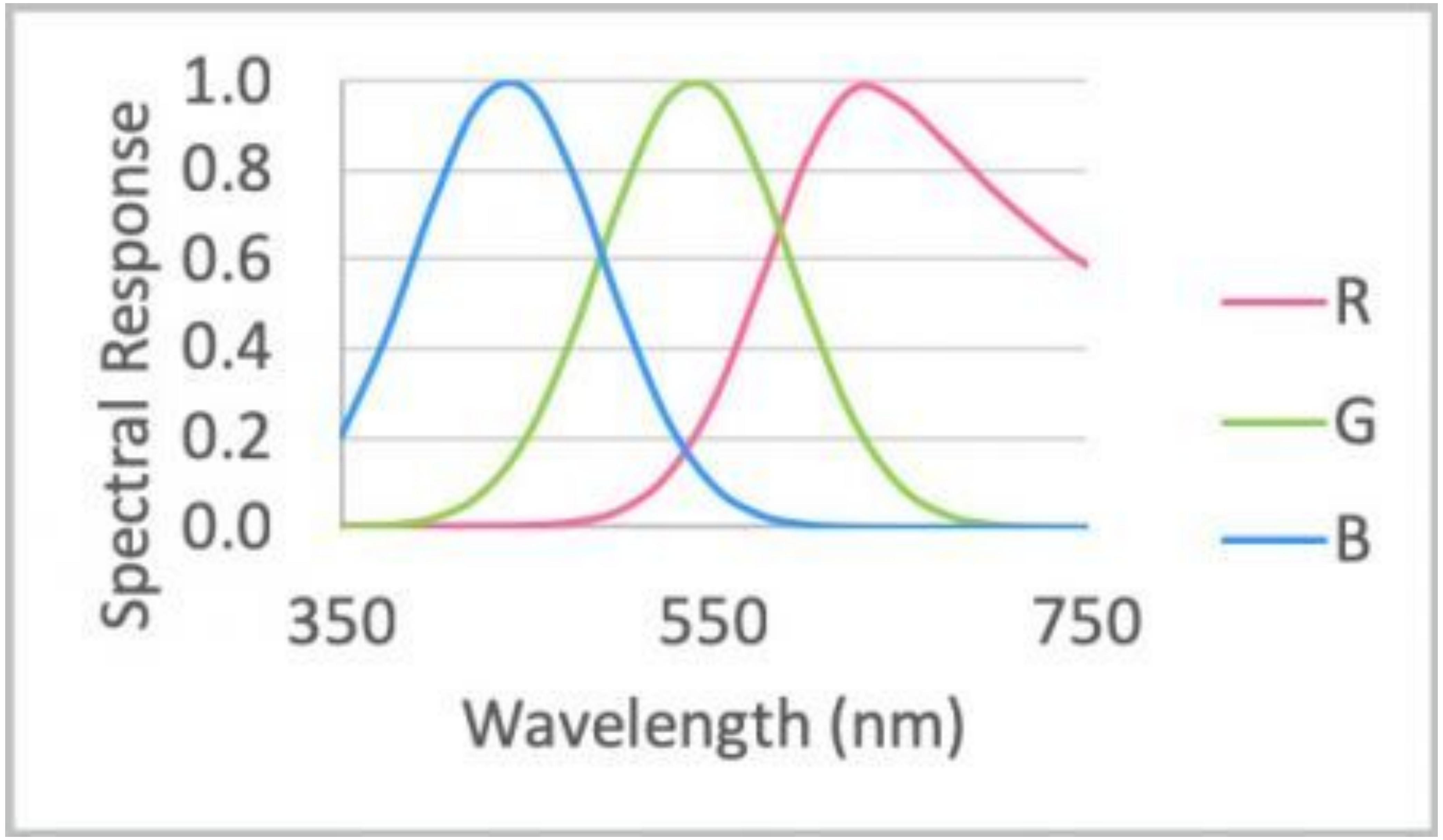
Halogen lights



On the usual spectral response of a sensor



Spectral response of the human eye



CIE-RGB

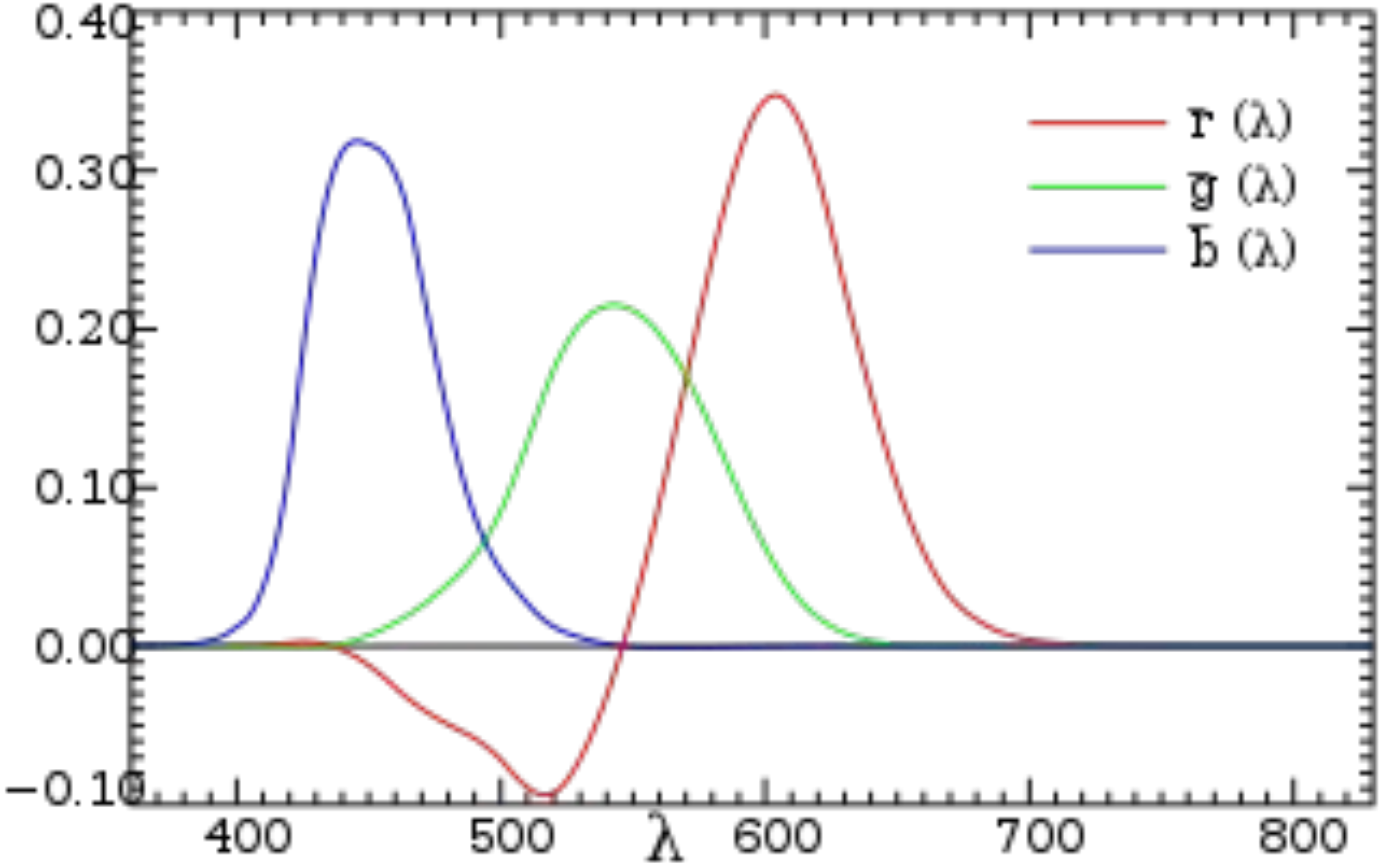
- We can accurately model human's eye as a 3-dimensional receptor (R, G, B)
- → The International Commission on Illumination (**CIE,** for **Commission Internationale de l'Éclairage**) adopted such a representation. The basis chosen for the representation is:

$$P_1(\lambda) = \delta(\lambda - \lambda_1) \text{for } \lambda_1 = 700nm(\text{red}).$$
$$P_2(\lambda) = \delta(\lambda - \lambda_1) \text{for } \lambda_2 = 546nm(\text{green}).$$
$$P_3(\lambda) = \delta(\lambda - \lambda_1) \text{for } \lambda_3 = 435.8nm(\text{blue}).$$

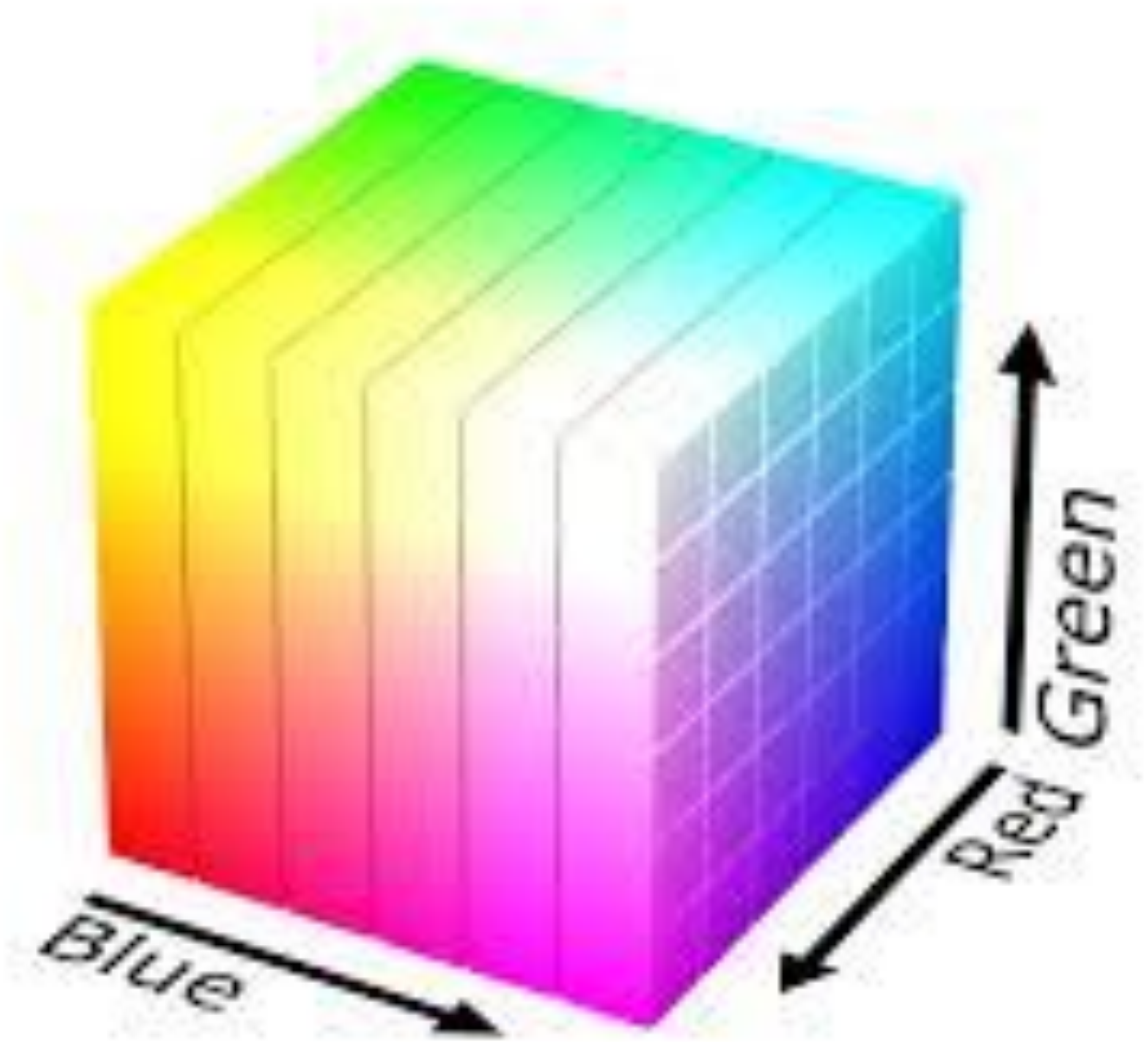
δ is the impulse function (Dirac delta).

- The reference white adopted by CIE has, by definition, uniform-energy spectral distribution.

CIE-RGB



The cube RGB



Luminance and Chrominance

- Young-Helmholtz → The eye has three sensors (R, G, B)
- Hering → R, G, B does not completely explain the perception of chrominance and luminance.
    - Hering: 3 channels
        - black / white (luminance)
        - red/gren
        - blue/yellow
- Hering's model explained experiments that Young-Helmholtz could not cope.
- The fundamental ideas of Young-Helmholtz were confirmed in the mid 1960's, with the discovery of three types of photosensible structures in the eye.

Luminance and Chrominance

- R, G, B are computed
- Sent to the brain:
  - R + G
  - R - G
  - B - (R + G)
- The B component has very little influence on wether a color is perceived as dark or light, so we can roughly say that R + G is the channel that contributes the most to the luminance.
- The other two channels encode color information (chrominance)

Color systems

- CIE-XYZ
- CYM
- YUV
- YIQ
- HSV
- HSL
- Munsell
- Pantone
- maybe others…

Change between different color systems

- Sometimes it is just a change of basis
- Sometimes it takes a deeper understanding of the underlying models, and involves nonlinear transformations.

Example 1: RGB / CYM

$C = B + G$

$M = R + B$

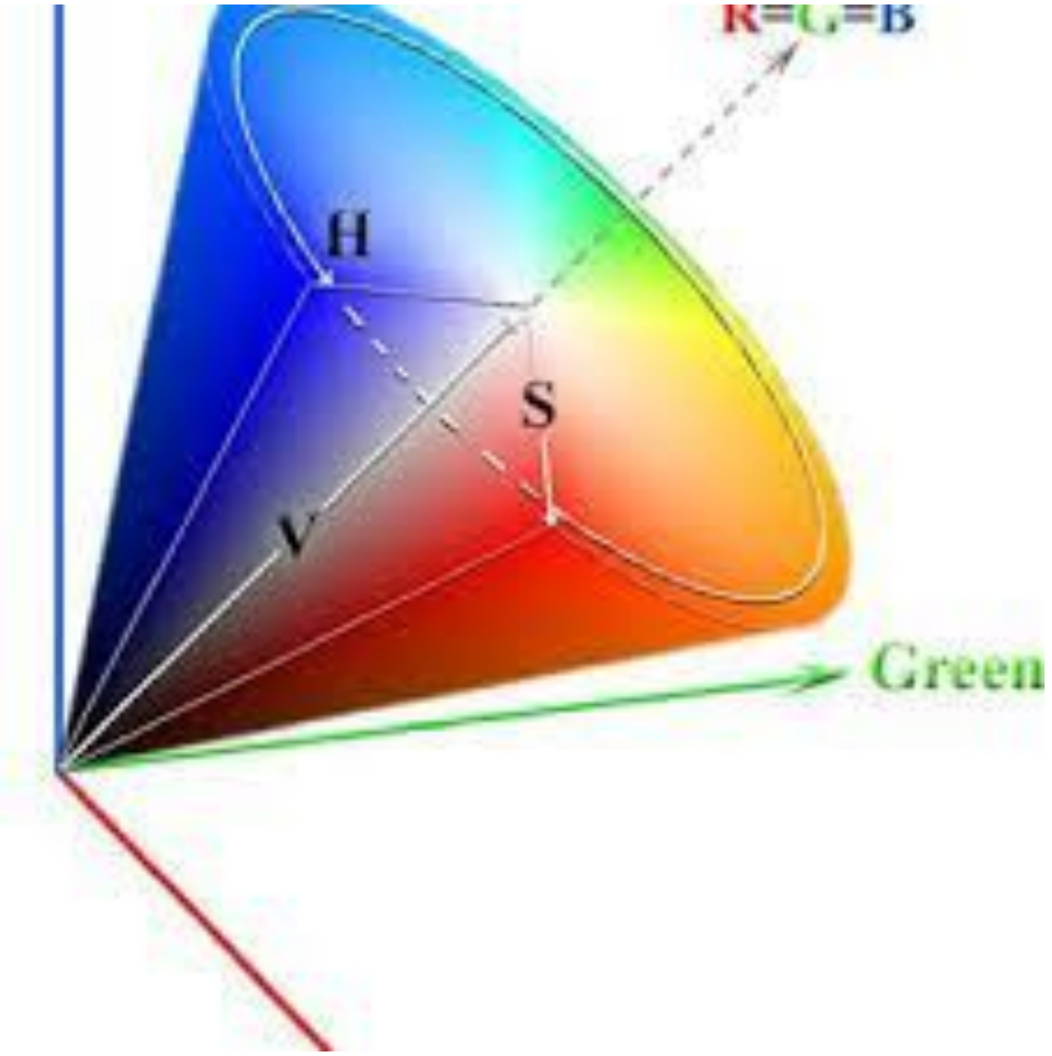
$Y = R + G$

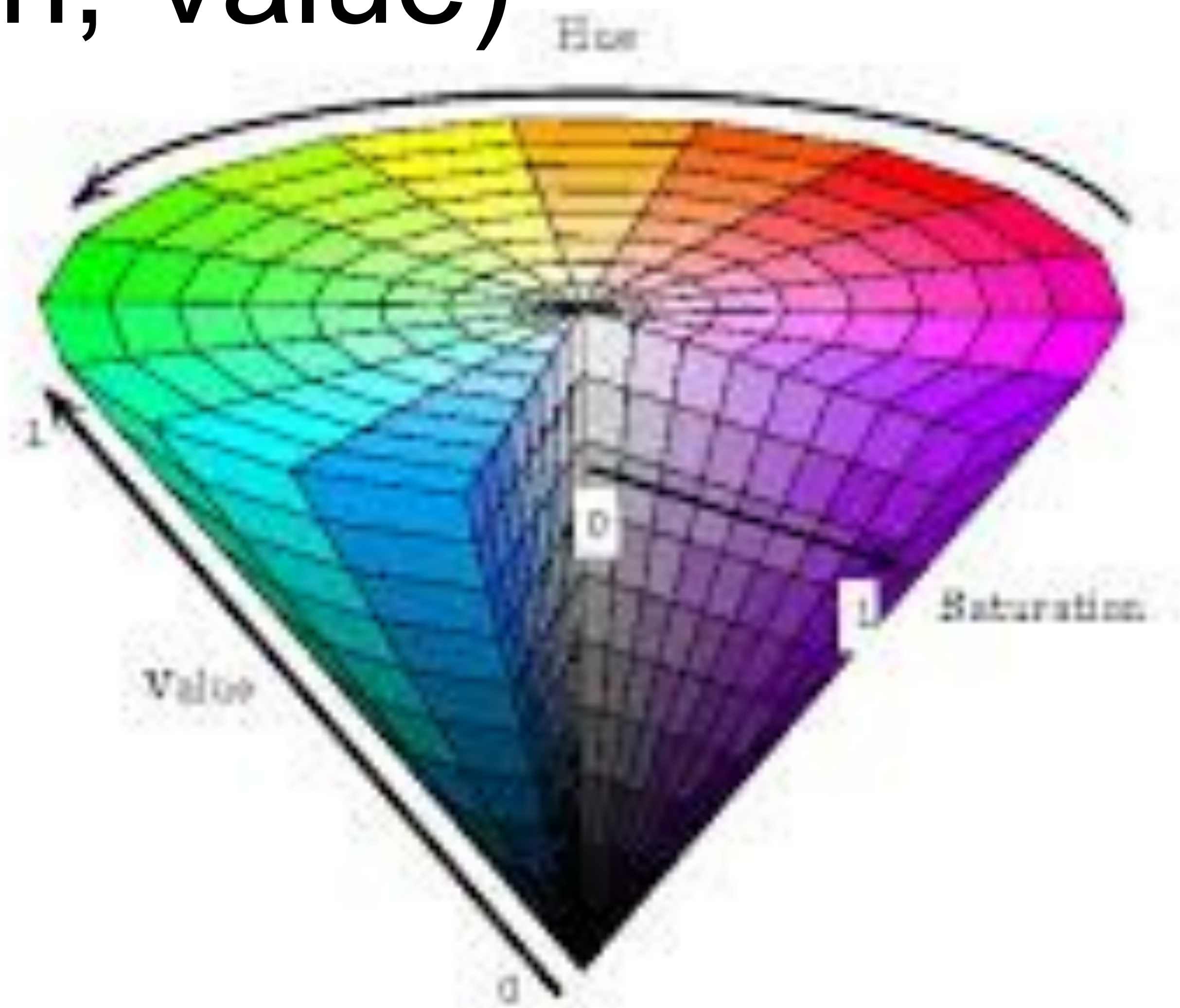
Discussion: how we convert from/to RGB to/from CYM?

Example 2: RGB / HSV (Hue, Saturation, Value)

- C = (C_R, C_G, C_B)
- V(C) = max{C_R, C_G, C_B}

Discussion: how to convert from/to RGB to/from HSV?





Projects for the course: Discussion on the groups and on the ideas for the projects.

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Thank you

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