Lecture 3-1 Color Image Processing （chapter 6 ）

Yuyao Zhang PhD

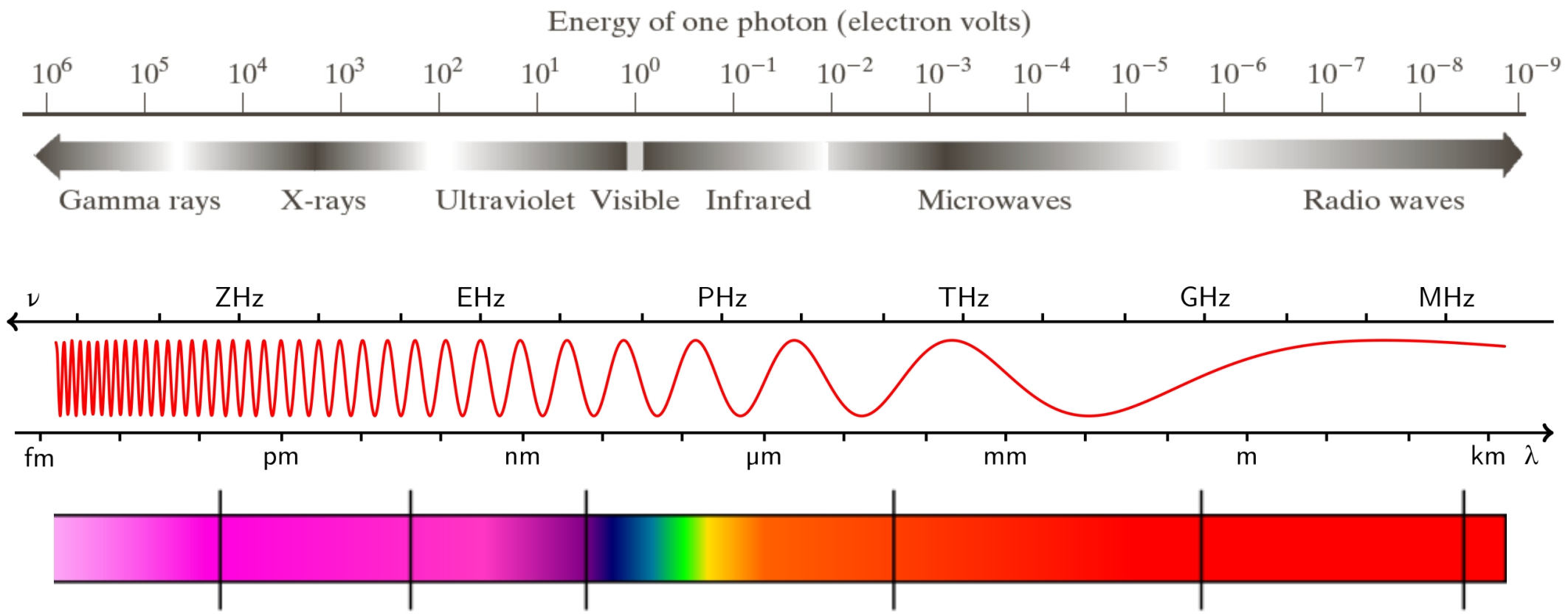
zhangyy8@shanghaitech.edu.cn

SIST Building 2 302-F

Outline

- **Standard color spaces**
  - RGB
  - CMYK
  - HSI
  - Lab
- **Transform between color spaces**
  - RGB to gray scale
  - RGB to
  - HIS
  - RGB to Lab
- **Color balance**

Electromagnetic spectrum



Dispersion of light

Human visual system color Space

- **The LMS color space:** Cones enable color perceptions;
- 3 Types of cones:
- **Long：** sensitive to

"RED" (more yellow to blue) 65%

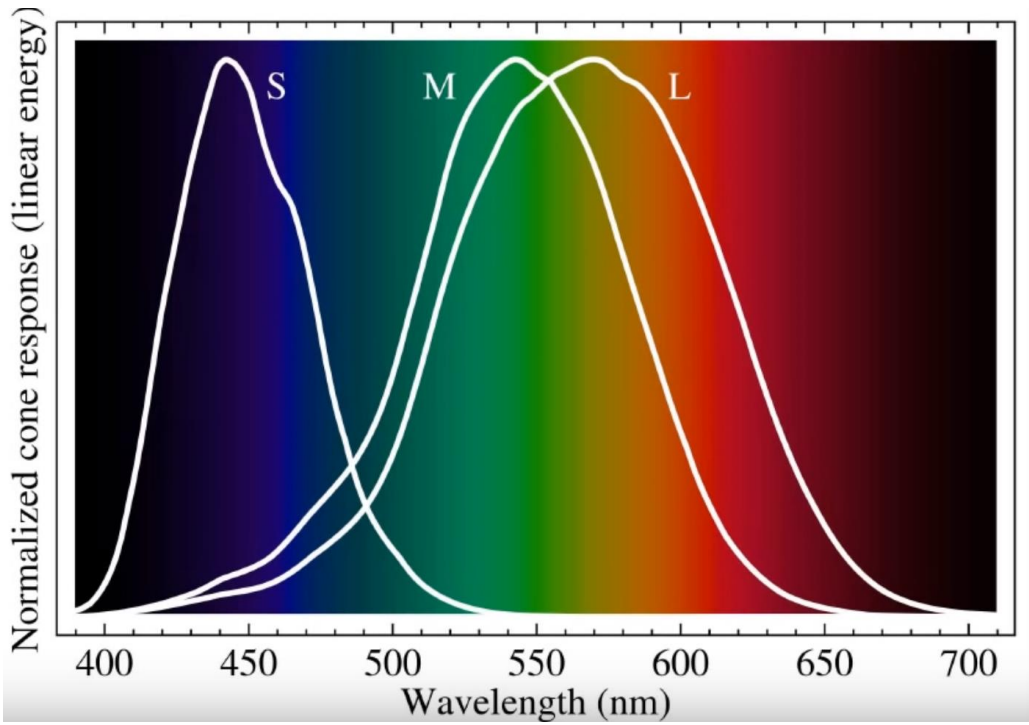
- **Middle：** sensitive to

"GREEN" (more green to blue) 33%

- **Short：** sensitive to

"BLUE" (more blue to purple) 2%

(But most sensitive)



Primary colors

- **CIE RGB Standard (**International Commission on Illumination**)**
  - Blue = 435.8 nm
  - Green = 546.1 nm
  - Red = 700 nm

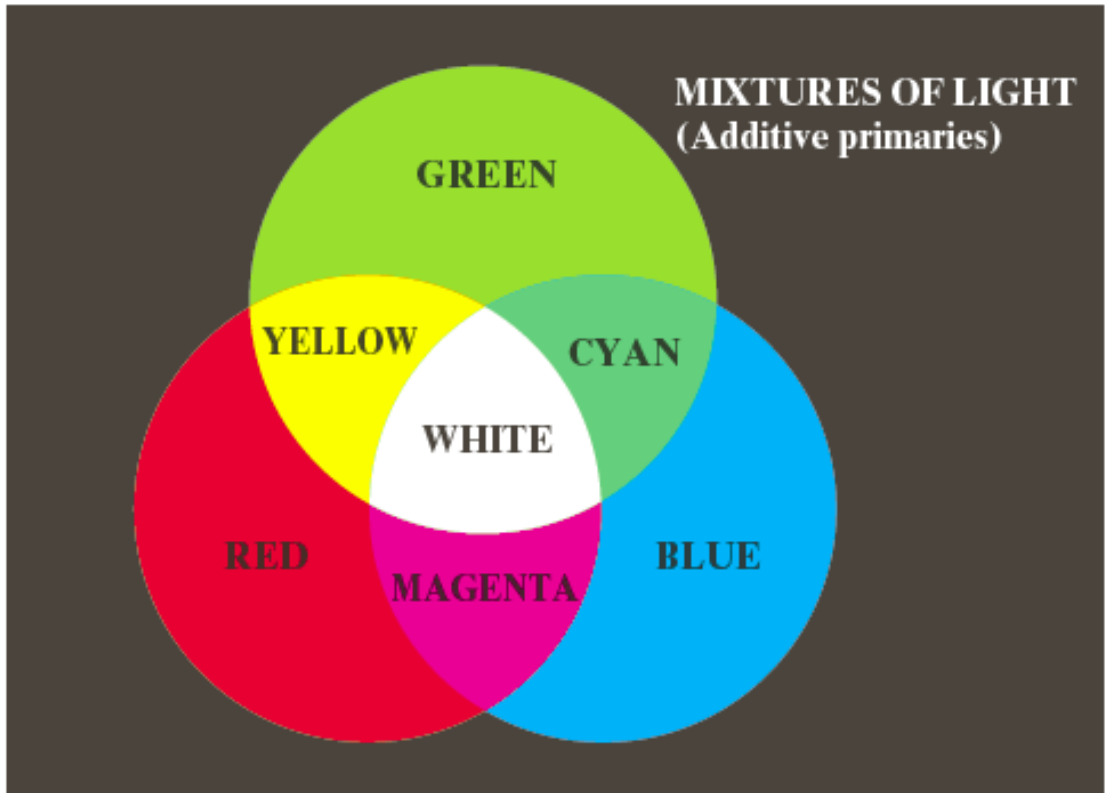
  Commission International d'elairage

- **The white light is** achieved with a mixture of RGB light with:
  - 1.0000 : 4.5907 : 0.0601 of intensity （Luminous intensity）.

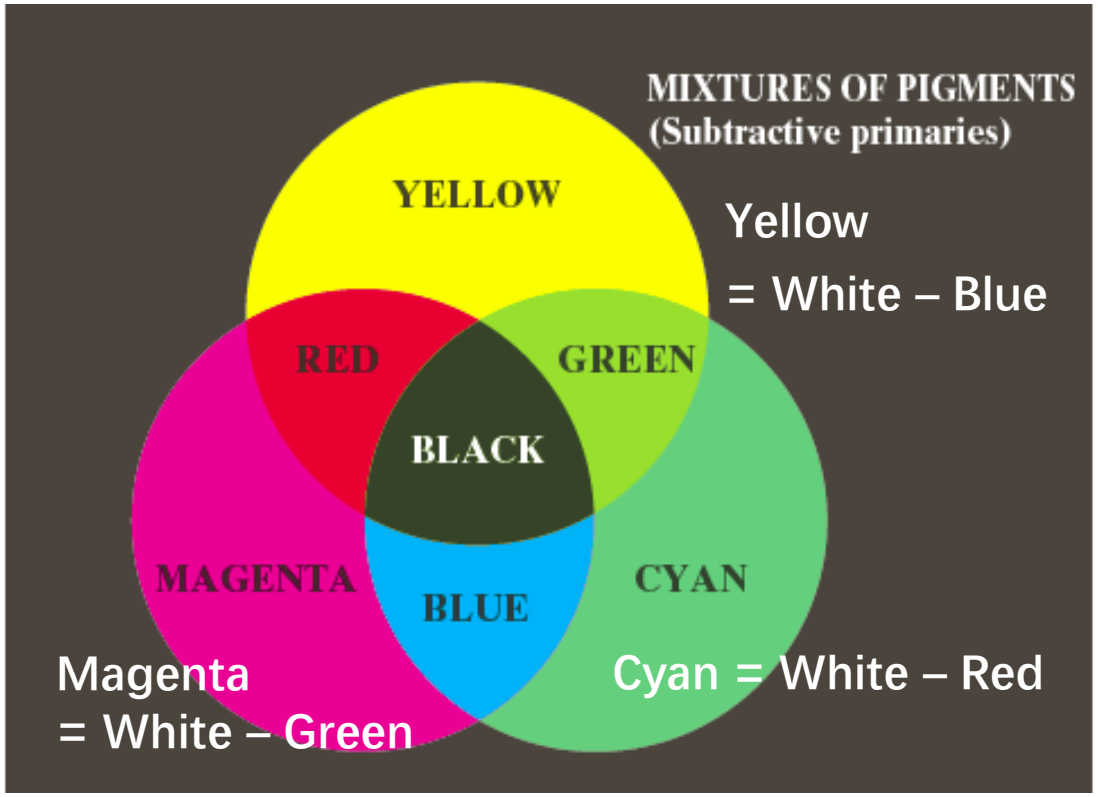
- **CMY and CMYK color**
  - Cyan = White – Red
  - Magenta = White – Green
  - Yellow = White – Blue
  - Black = White – Red - Green - Blue

Secondary colors

RGB color

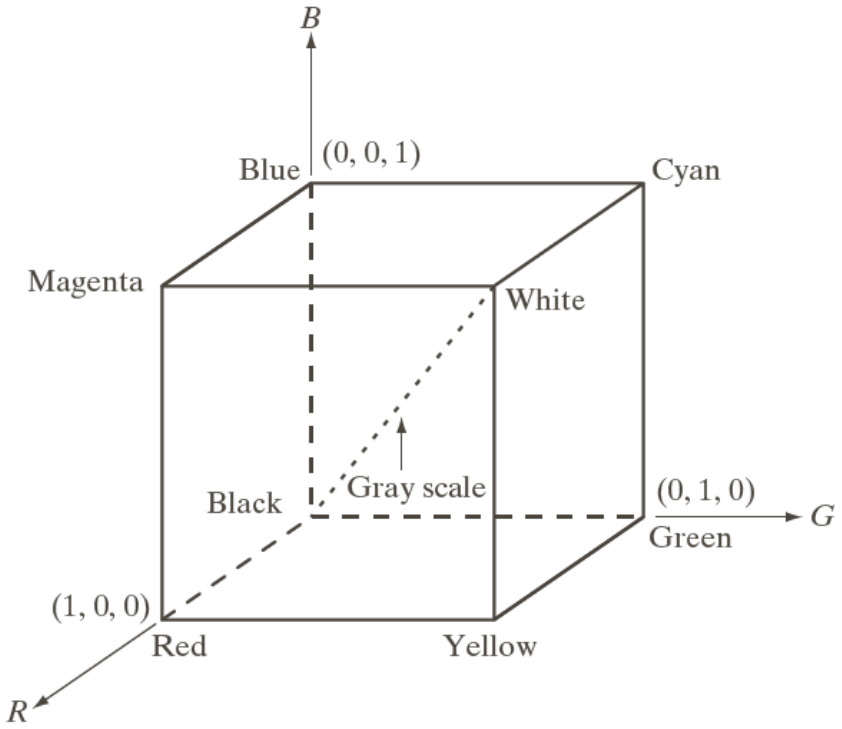


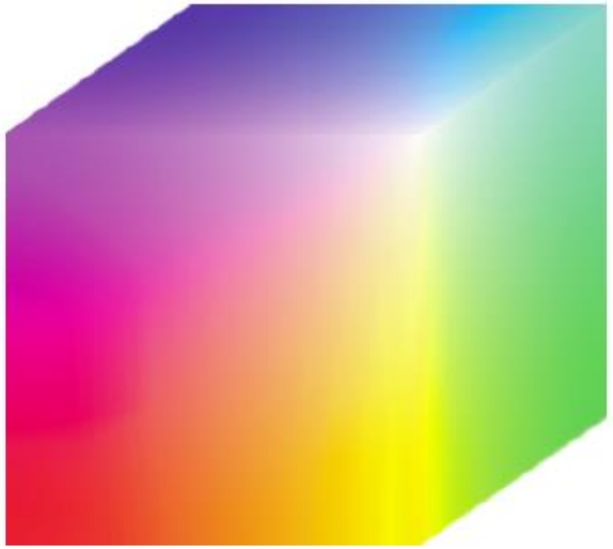
CMY and CMYK color



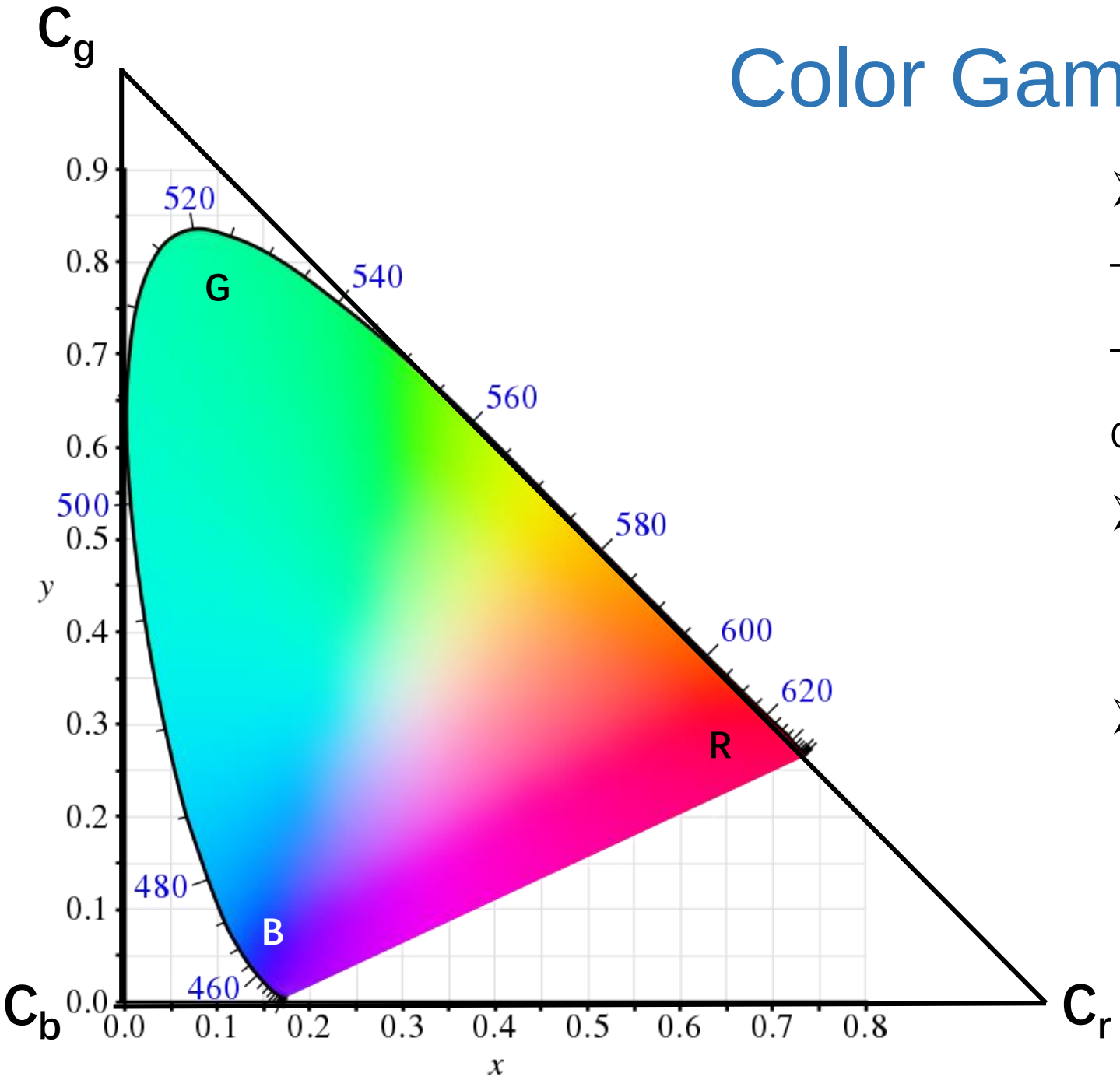
Black = White – Red - Green - Blue

RGB Color Model





Color Gamut



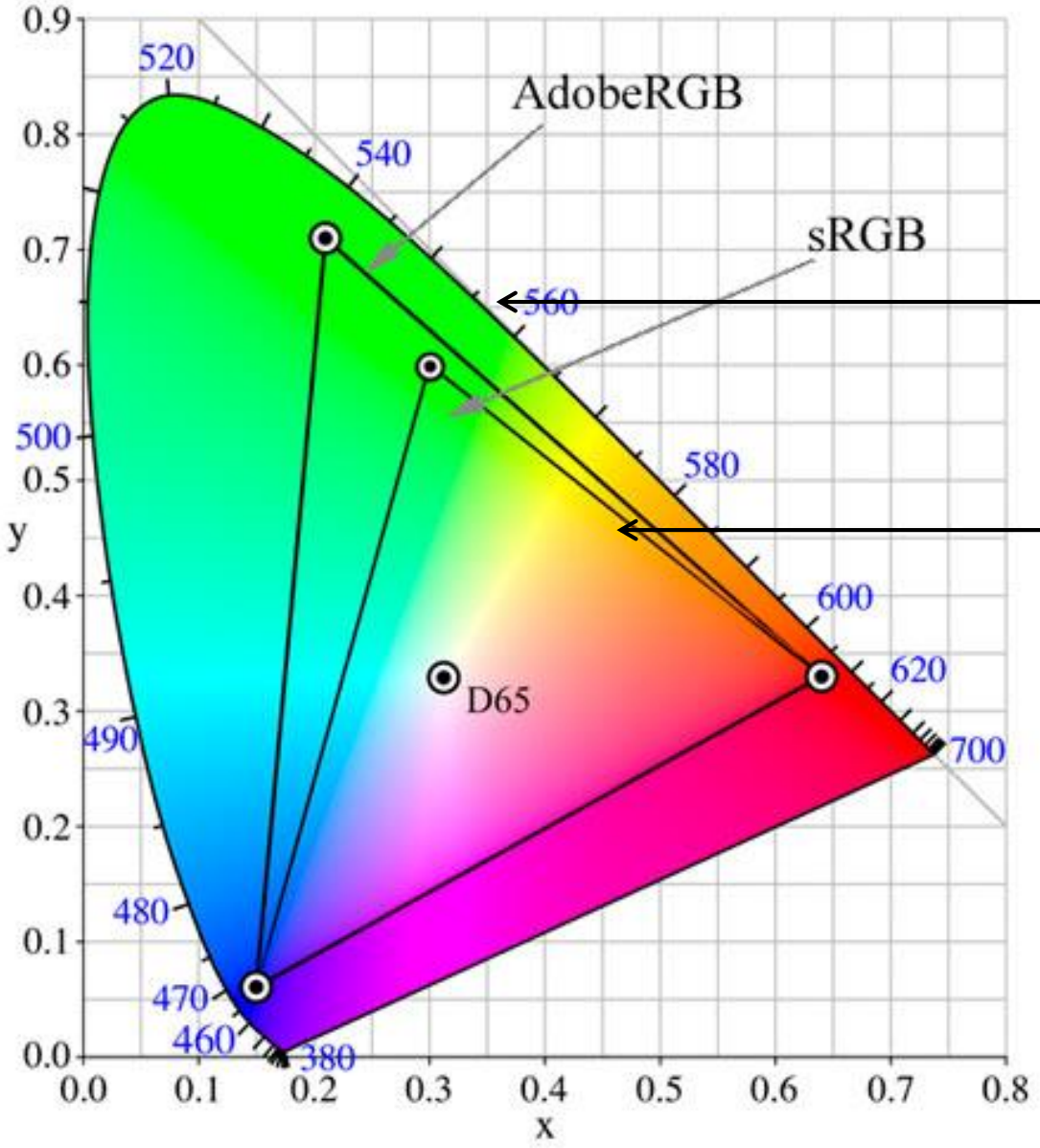
- $x = \frac{R}{R+G+B}$, $y = \frac{G}{R+G+B}$, $z = \frac{B}{R+G+B}$

Then $z = 1 - x - y$.

The color cube is turns to a 2-D color gamut.

- It is seen that all visible chromaticities correspond to non-negative values of *x*, *y*, and *z*.
- An equal mixture of two equally bright colors will not generally lie on the midpoint of that line.

Color Gamut



White：D65 [0.3127,0.3290]
Red：[0.6400, 0.3300]
Green：[0.3000, 0.6000]
Blue: [0.1500, 0.0600]

CIE Chromaticity diagram

Color gamut for monitor

- **sRGB** (**standard Red Green Blue**) is an RGB color space and Microsoft created cooperatively in 1996 to use on monitors, printers, and the Internet.
- The **Adobe RGB (1998) color space** is an RGB color space developed by Adobe System, Inc. in 1998.

CMY Color Model

- **RGB to CMY conversion**

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

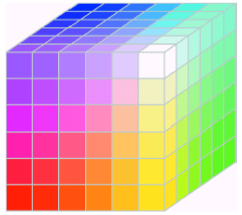
In order to produce true black in printing, a fourth color, black, is added into the CMYK color model

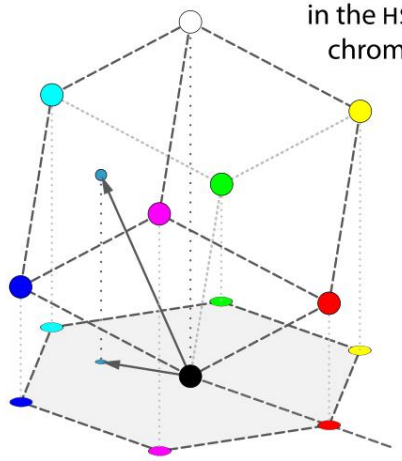
Outline

- **Standard color spaces**
  - RGB
  - CMYK
  - HSI
  - Lab
- **Transform between color spaces**
  - RGB to gray scale
  - RGB to
  - HIS
  - RGB to Lab
- **Color balance**

HSI/HSV Color Model

RGB color cube

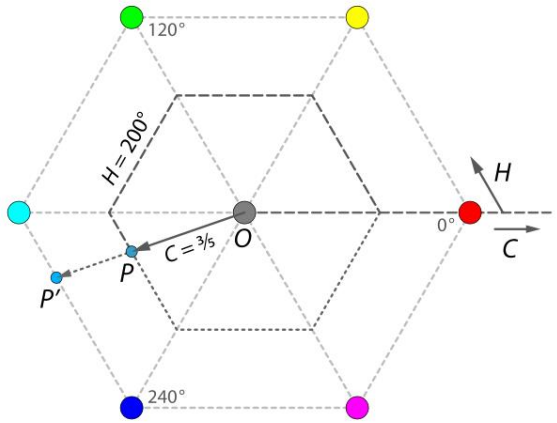




$R = 1/5$
$G = 3/5$
$B = 4/5$

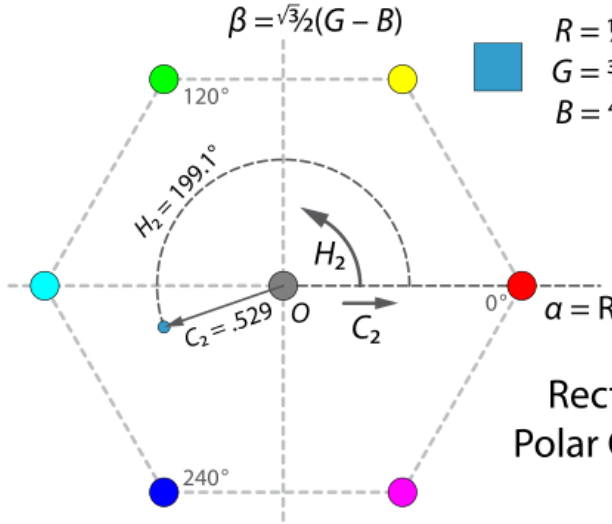
$C = \frac{OP}{OP'} = B - R = 4/5 - 1/5 = 3/5 = .6$

$H = 60° \times \left(4 + \frac{R-G}{C}\right) = 60° \times (4 - 2/3) = 200°$



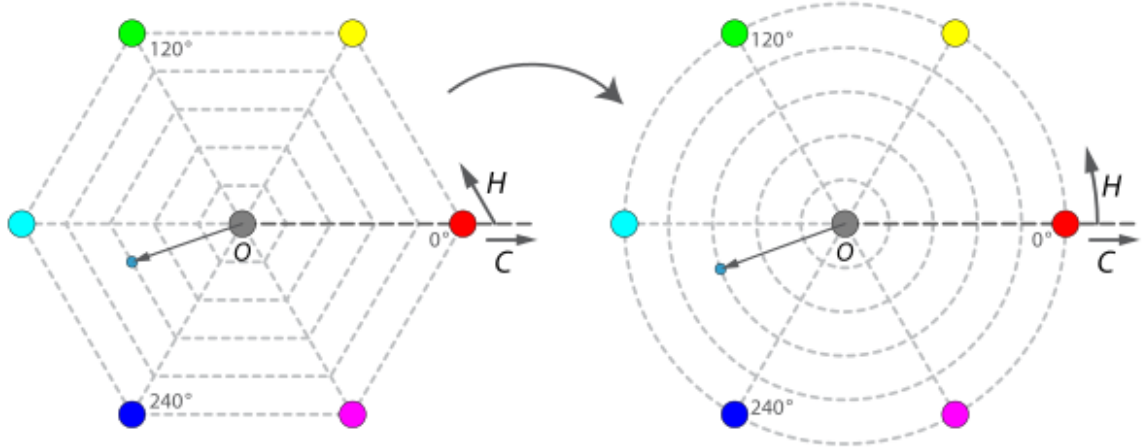
$\beta = \sqrt{3}/2(G - B)$

$R = 1/5$ $\quad \alpha = -1/2$
$G = 3/5$ $\quad \beta = -\sqrt{3}/10$
$B = 4/5$ $\quad = -.173$
$H_2 = 199.1°$
$C_2 = -\sqrt{7}/5$
$= .529$



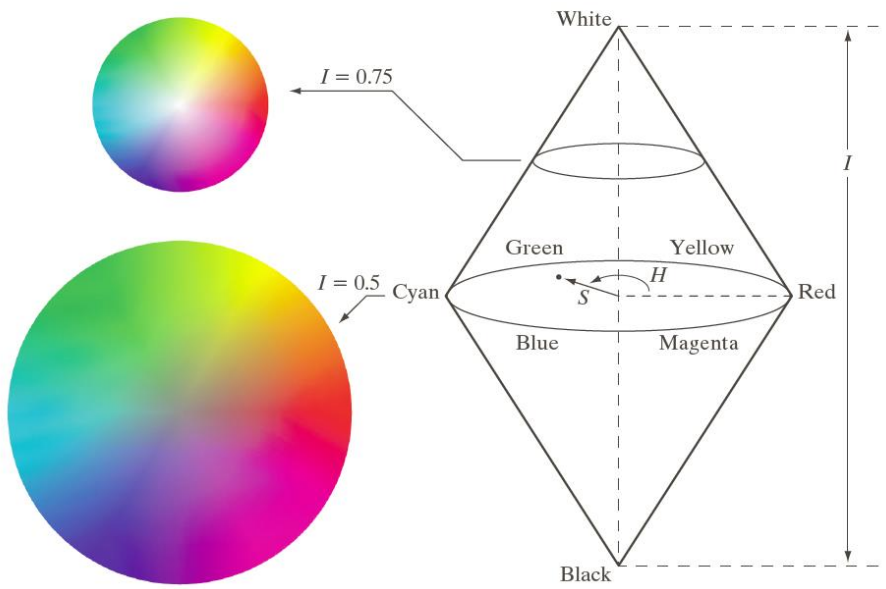
$\alpha = R - 1/2(G + B)$

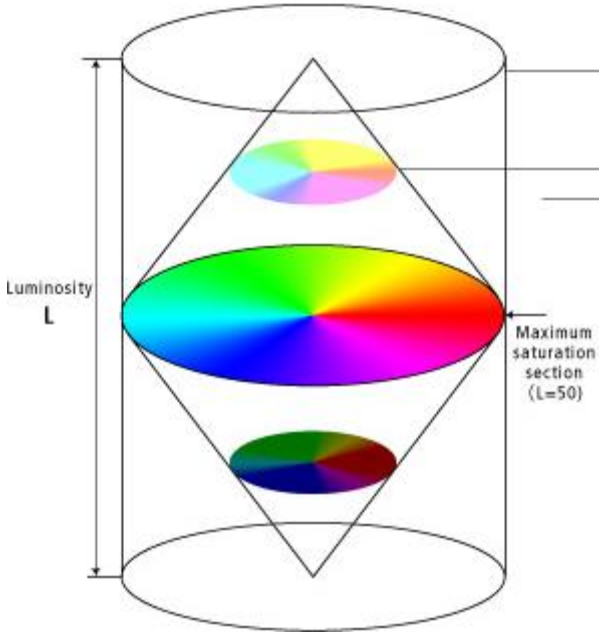
Rectangular and
Polar Chromaticity
Coordinates

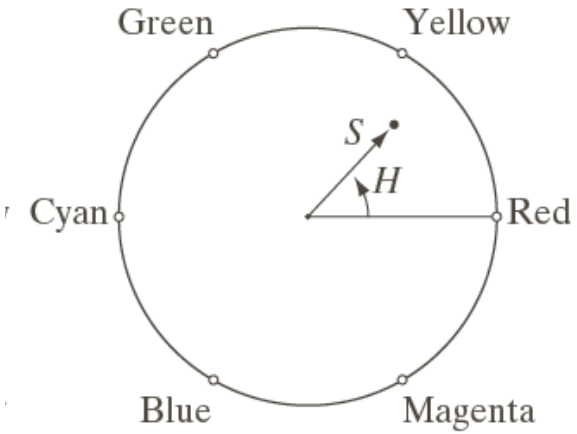


HSI/HSL Color Model

- **HSI Color Model**
  - **Hue:** Dominant color associated with wavelength.
  - **Saturation:** relative purity, the amount of white light mixed with a hue
  - **Intensity/Lightness.** $I = (r + g + b) \,/\, 3$

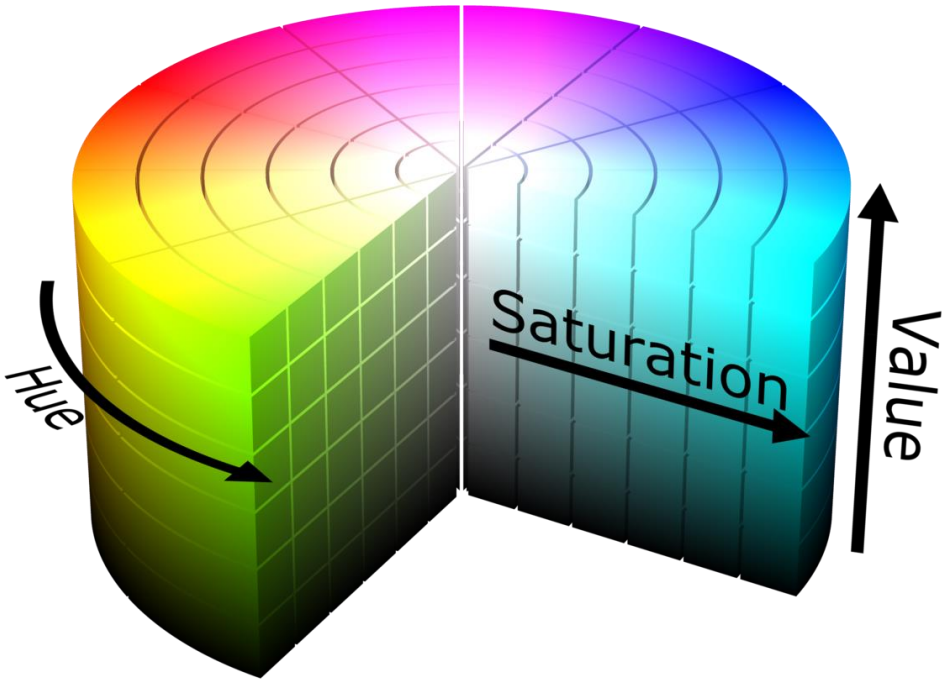




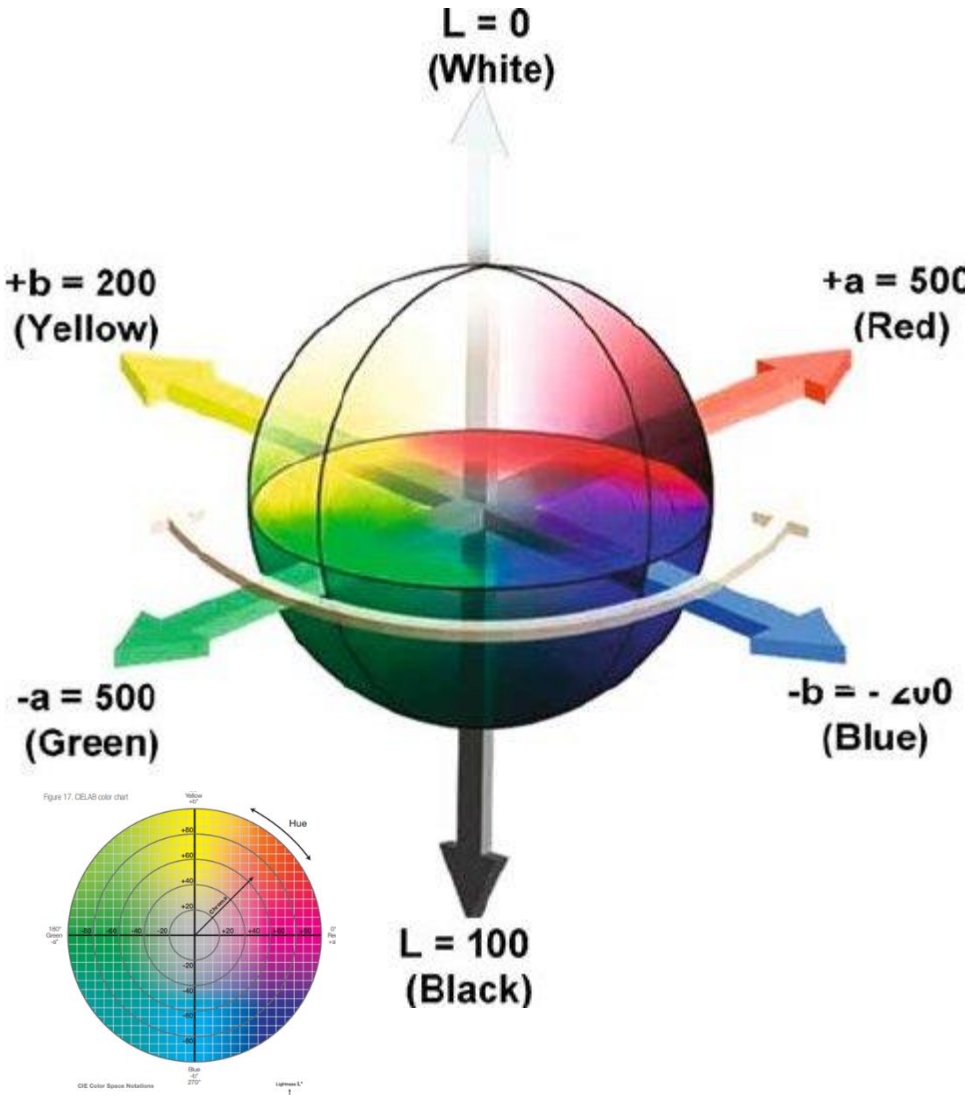


HSV Color Model

- **HSI Color Model**
  - **Hue:** Dominant color associated with wavelength.
  - **Saturation:** relative purity, the amount of white light mixed with a hue
  - **Value.** $v = \max(r, g, b)$;



Lab Color Model



- **L*: Lightness**
- **a*: Red/Green Value**
- **b*: Blue/Yellow Value**
- The a* axis runs from left to right. A color measurement movement in the +a direction depicts a shift toward red.
- Along the b* axis, +b movement represents a shift toward yellow.
- The center L* axis shows L = 0 (black or total absorption) at the bottom.
- At the center of this plane is neutral or gray.

Outline

- **Standard color spaces**
  - RGB
  - CMYK
  - HSI
  - Lab
- **Transform between color spaces**
  - RGB to gray scale
  - RGB to CMY
  - RGB to HSI/HSV
- **Color balance**

RGB to Gray scale

- **Maximum value:**

$$g_R(x,y) = g_G(x,y) = g_B(x,y) = \max[f_R(x,y), f_G(x,y), f_B(x,y)]$$

- **Average value**

$$g_R(x,y) = g_G(x,y) = g_B(x,y) = [f_R(x,y) + f_G(x,y) + f_B(x,y)]/3$$

- **Weighted value**

$$g_R(x,y) = g_G(x,y) = g_B(x,y) = 0.299 f_R(x,y) + 0.587 f_G(x,y) + 0.114 f_B(x,y)$$




Transform to CMY Color Space

- $\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$

- $\begin{bmatrix} g_R(x,y) \\ g_G(x,y) \\ g_B(x,y) \end{bmatrix} = \begin{bmatrix} 255 - f_R(x,y) \\ 255 - f_G(x,y) \\ 255 - f_B(x,y) \end{bmatrix}$

Transform from RGB to HSI

$$\theta = \arccos\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-G)(G-B)]^{\frac{1}{2}}}\right\}$$

$$H = \begin{cases}\theta, & G \geq B \\ 360-\theta, & G < B\end{cases}$$

$$S = 1 - \frac{3}{R+G+B}[\min(R,G,B)]$$

$$I = \frac{R+G+B}{3} \qquad V = \max(R,G,B);$$

$$S = 0 \rightarrow H = 0\ , \quad I = 0 \rightarrow S = 0,\ H = 0$$

Transform from HSI to RGB

- $0° \leq H < 120°$

$$B = I(1 - S), \qquad R = I\left[1 + \frac{Scos(H)}{\cos(60° - H)}\right], \qquad G = 3I - (R + B)$$

- $120° \leq H < 240°$

$$R = I(1 - S), \qquad G = I\left[1 + \frac{Scos(H - 120°)}{\cos(180° - H)}\right], \qquad B = 3I - (R + G)$$

- $240° \leq H < 360°$

$$G = I(1 - S), \qquad B = I\left[1 + \frac{Scos(H - 240°)}{\cos(300° - H)}\right], \qquad R = 3I - (G + B)$$

Color Balance

➢ White balance:

$$I(x,y) = 0.299f_R(x,y) + 0.587f_G(x,y) + 0.114f_B(x,y)$$

$$k_R = \frac{\bar{I}}{\bar{f}_R} \quad k_G = \frac{\bar{I}}{\bar{f}_G} \quad k_B = \frac{\bar{I}}{\bar{f}_B}$$

$$\begin{bmatrix} g_R(x,y) \\ g_G(x,y) \\ g_B(x,y) \end{bmatrix} = \begin{bmatrix} k_R & & \\ & k_G & \\ & & k_B \end{bmatrix} \begin{bmatrix} f_R(x,y) \\ f_G(x,y) \\ f_B(x,y) \end{bmatrix}$$

➢ Maximum value balance

$$S_{RGB} = \min[R_{max}, G_{max}, B_{max}]$$

$$k_R = \frac{S_{RGB}}{T_R} \quad k_G = \frac{S_{RGB}}{T_G} \quad k_B = \frac{S_{RGB}}{T_B}$$

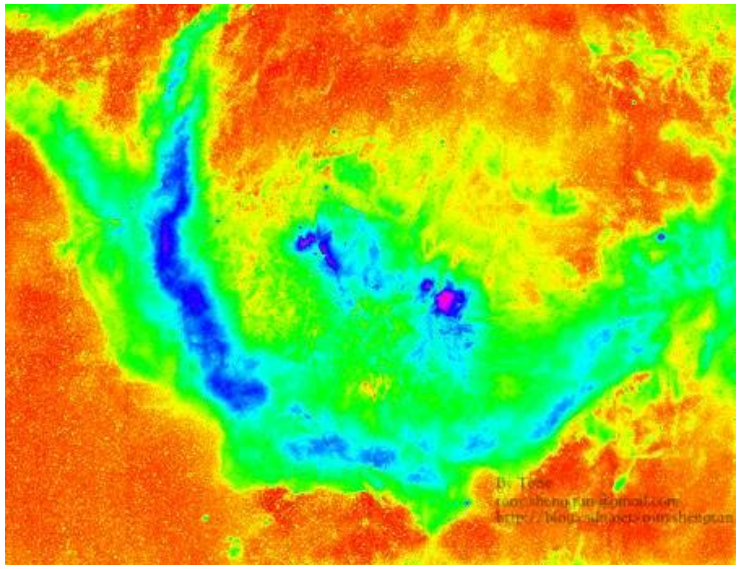
$$\begin{bmatrix} g_R(x,y) \\ g_G(x,y) \\ g_B(x,y) \end{bmatrix} = \begin{bmatrix} k_R & & \\ & k_G & \\ & & k_B \end{bmatrix} \begin{bmatrix} f_R(x,y) \\ f_G(x,y) \\ f_B(x,y) \end{bmatrix}$$

1.Find the smallest max value S_{RGB} in each color channel.

2.Calculate the number of intensities Nr, Ng, Nb that larger than S_{RGB} in each color channel. Then fin the largest number Nmax = max[Nr,Ng,Nb].

3.Sort the intensities in each channel and find the the $Nmax_{th}$ intensity value [Tr, Tg, Tb] in each color channel.

Pseudo color enhancement



Take home message

- 1. The color that you perceived depends on the cone cells in your eye.
- 2. There are variety of different color space defined by CIE. Each color space has its unique advantage.
- 3. When the intensity in each color channel is unbalance, the color looks weird. Try to practice color space transform by implementing a color balance correction method.