Computer Graphics

Tutorial for Exercise Sheet 02

a) Vector-Based vs Raster-Based

Raster

GIF, JPEG, PNG

Vector

SVG

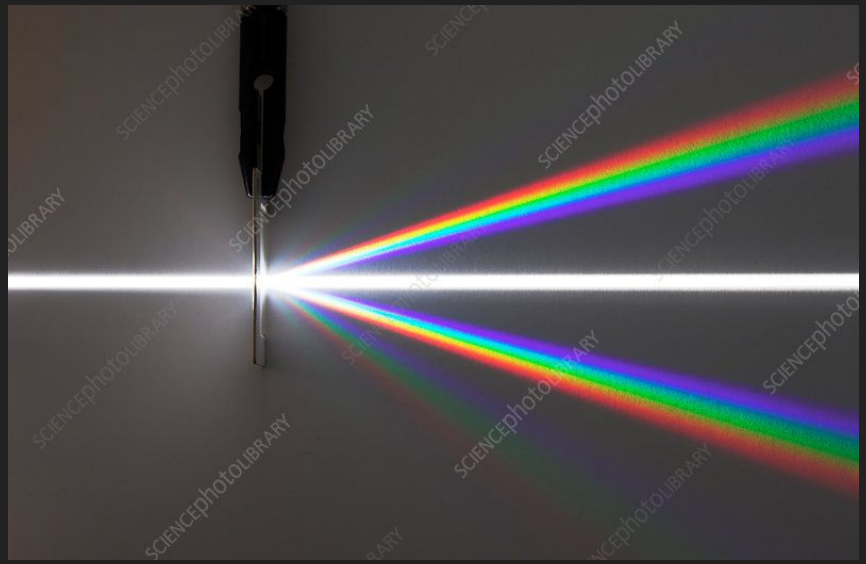
a) Vector-Based vs Raster-Based

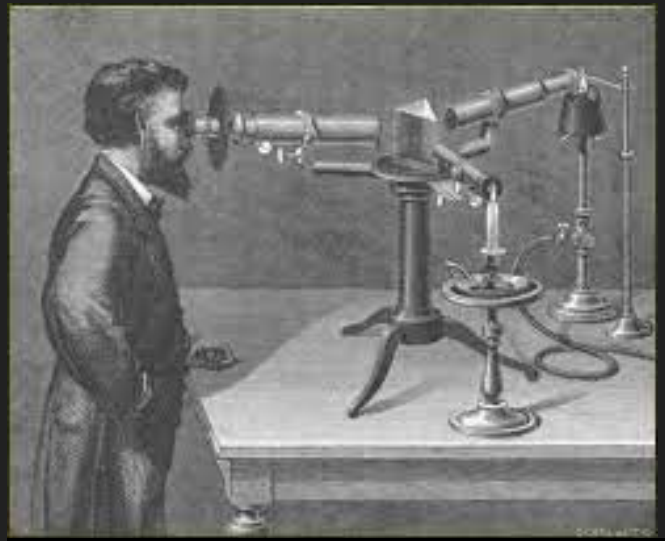
	Advantages	Disadvantages
Vector-Based	- Arbitrary Resolution - Line-Based Images - Schematics	- Computationally intensive - Complex Images are difficult - Vector-Based displays out of use
Raster-Based	- Good vectorization on GPUs - Image buildup independent of scene complexity - Maps to modern pixel-based displays very well	- Pixels are finite - Aliasing - Moiré Effects - Fixed Resolution

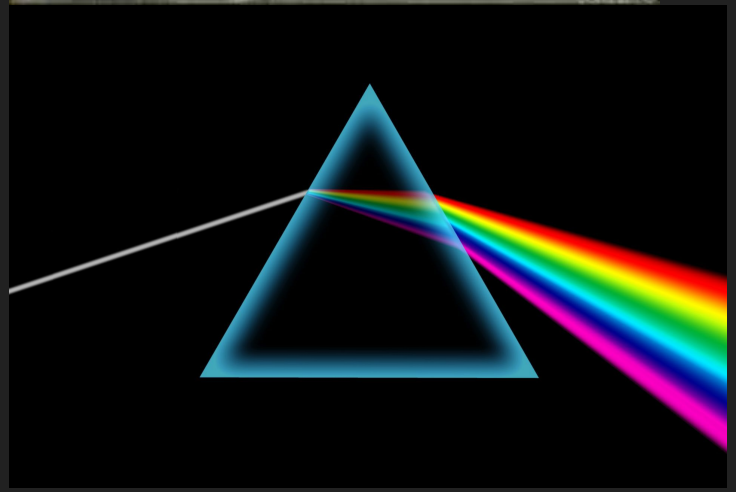
b) Spectral Colors

What is a spectrum?

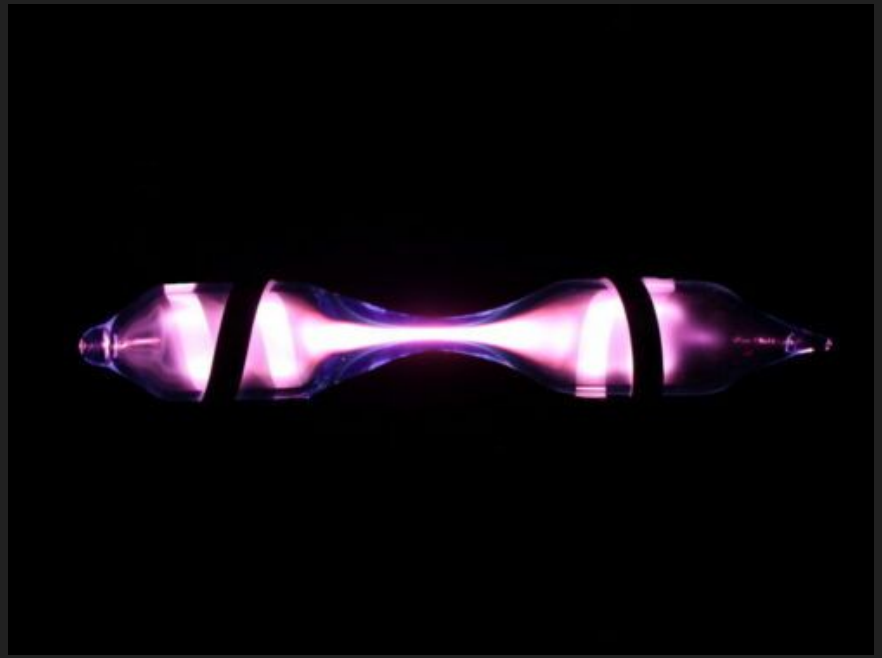
https://www.falstad.com/fourier/

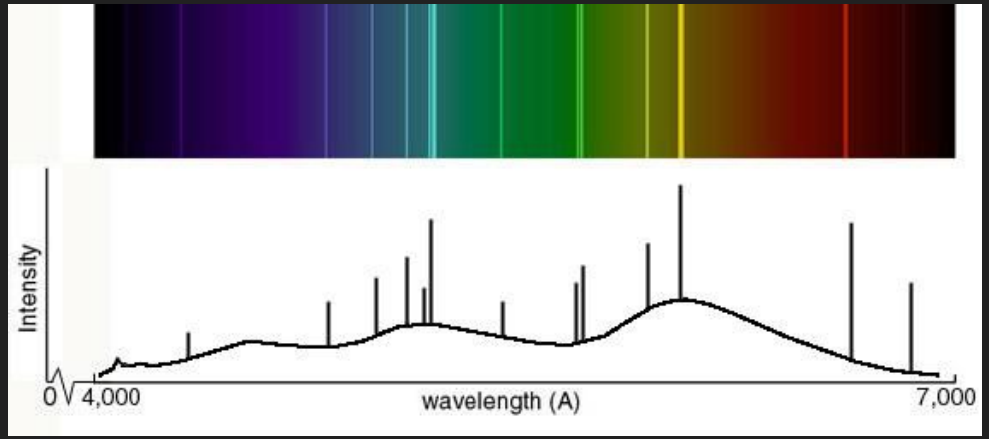






b) Spectral Colors

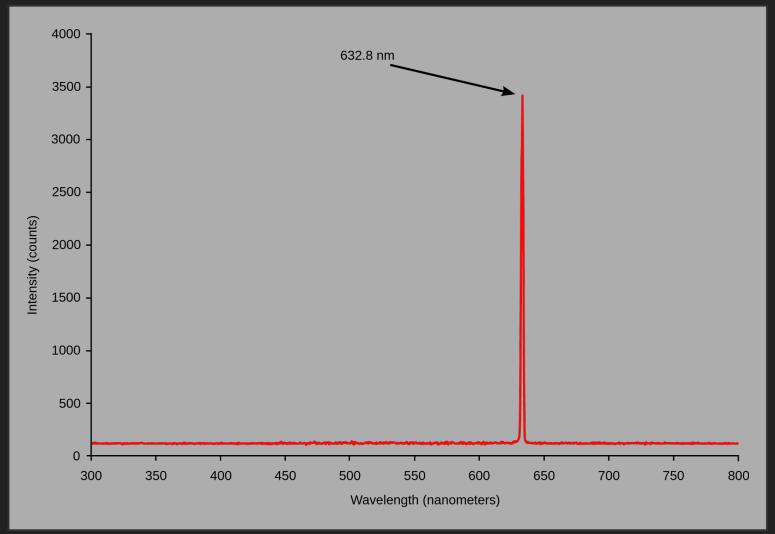


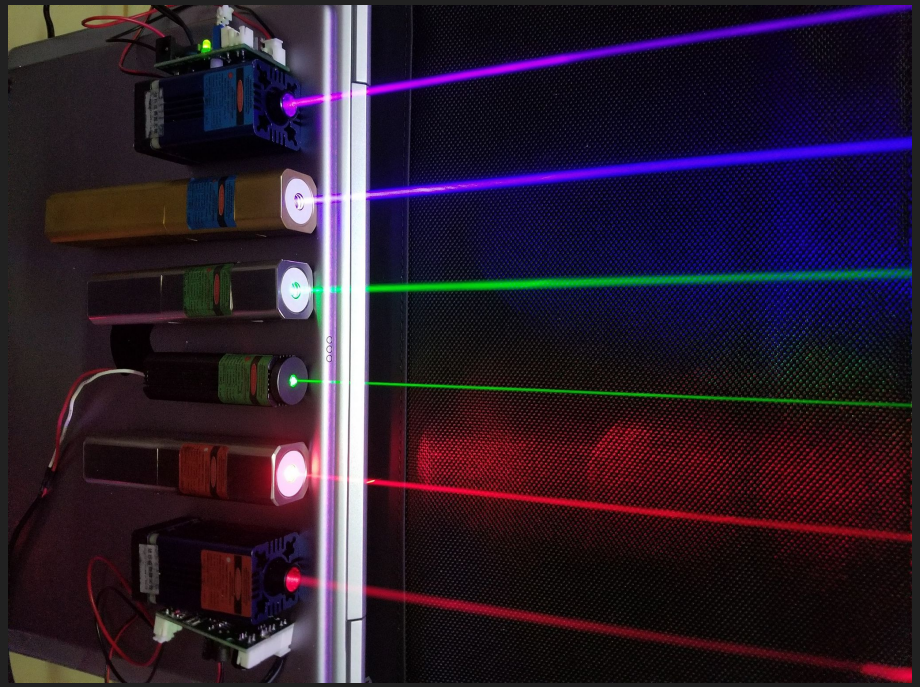


b) Spectral Colors

- A **spectral color** is a color that is evoked by *monochromatic light*
  - Either a single wavelength of light in the visible spectrum, or by a relatively narrow band of wavelengths (e.g. lasers)
- Every wavelength of visible light is perceived as a spectral color
- When viewed as a continuous spectrum, these colors are seen as the familiar rainbow.

b) Spectral Colors



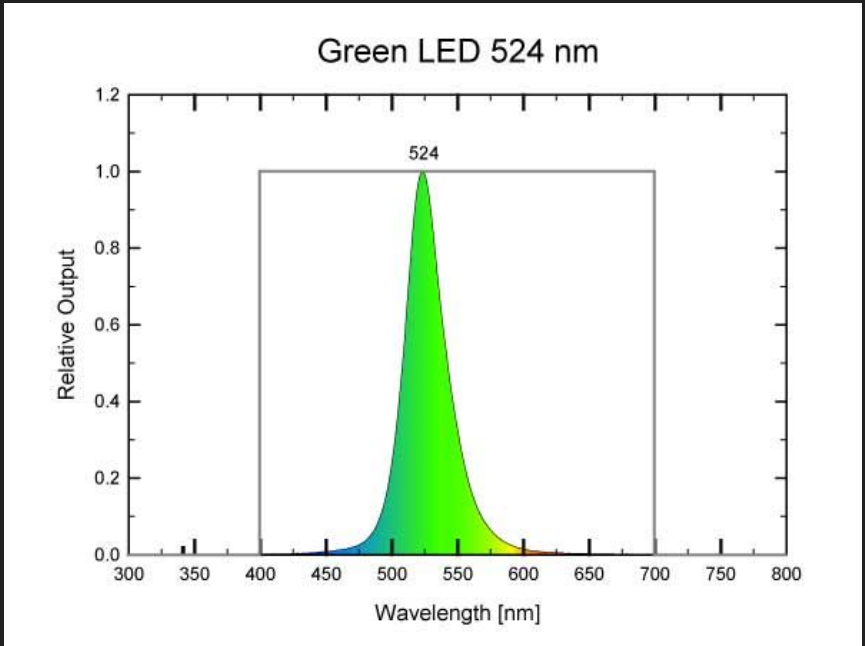


b) Spectral Colors

Question: Is green LED light a spectral color?

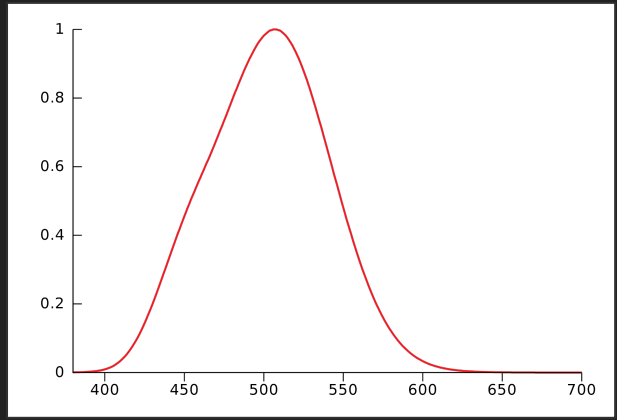
b) Spectral Colors

Question: Is green LED light a spectral color? -> No

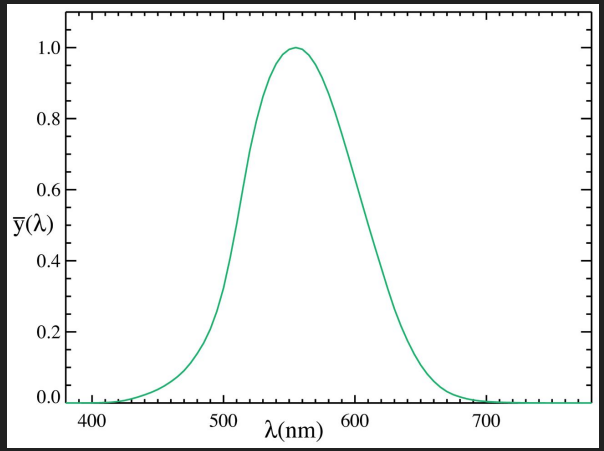


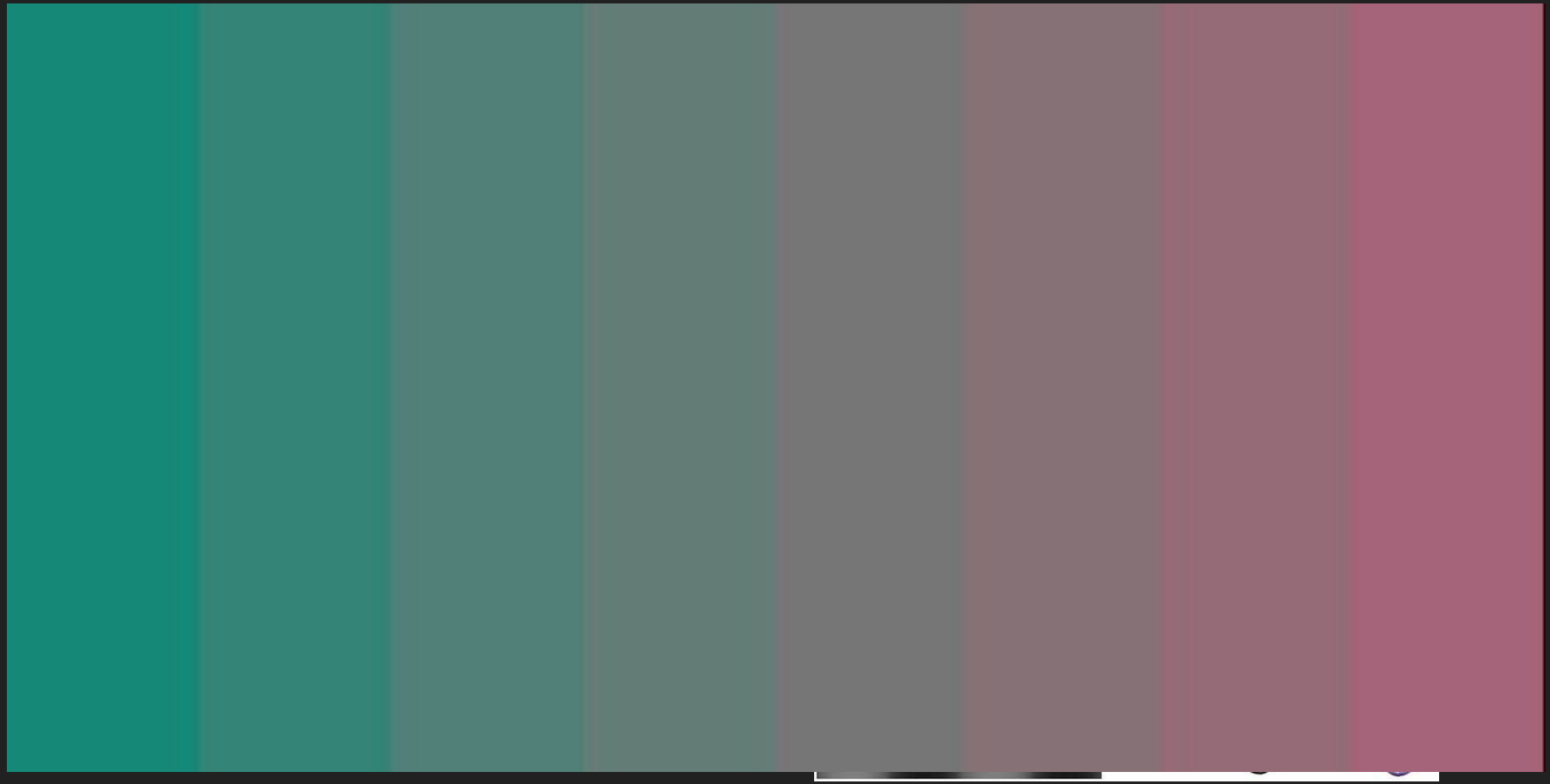
c) Scotopic vs Photopic Vision

- **Scotopic**:
  - Vision under low light (Greek; *skotos*:"darkness", *-opia*: "a condition of sight")
  - Rods are more sensitive at low brightness
  - Luminance of 10^-3 to 10^-8 cd/m^2



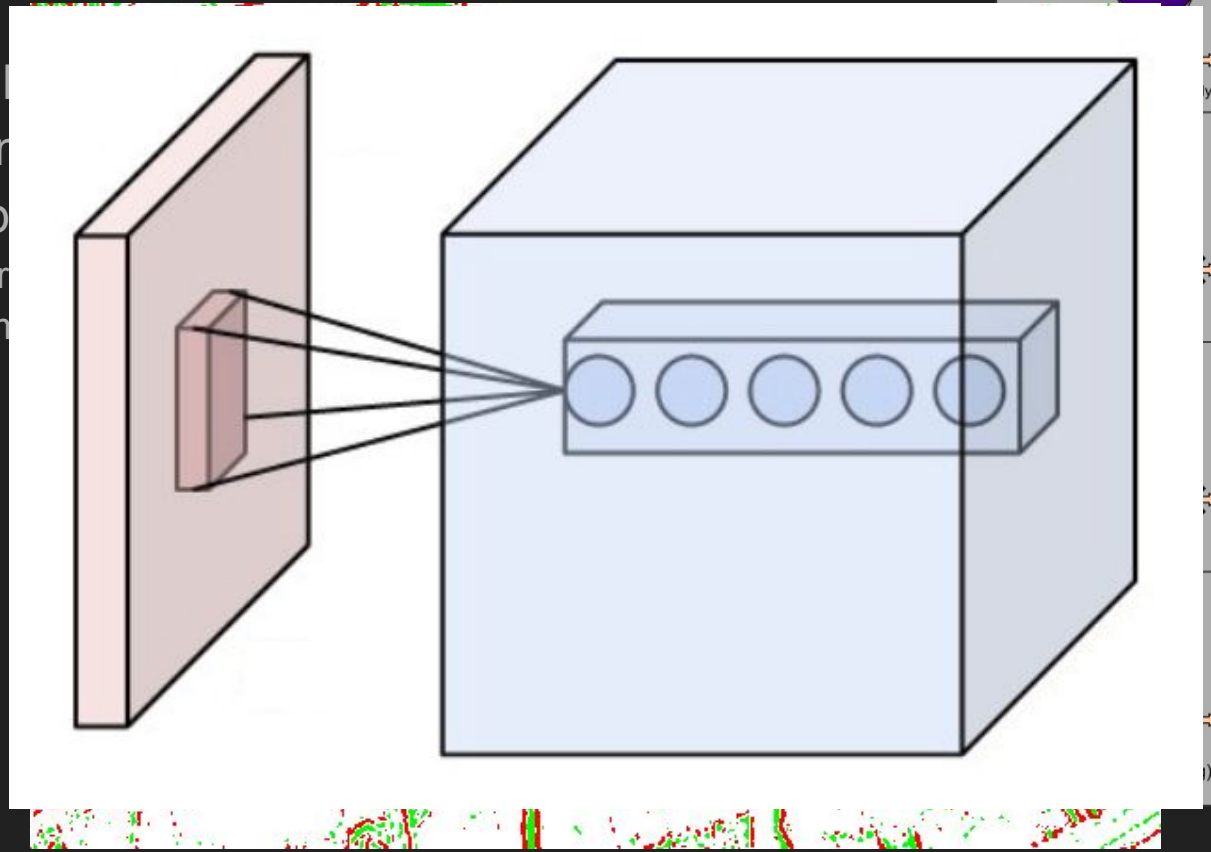
- **Photopic**:
  - Vision under well-lit conditions
  - Color vision
  - Cones are more sensitive to color
  - Luminance of 10 to 10^8 cd/m^2

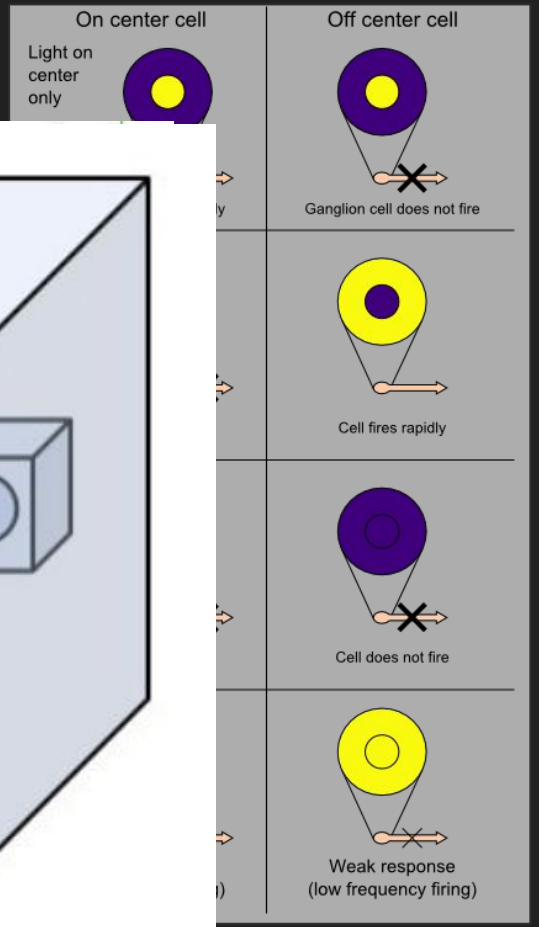




d) Mach-Bands and Receptive Fields

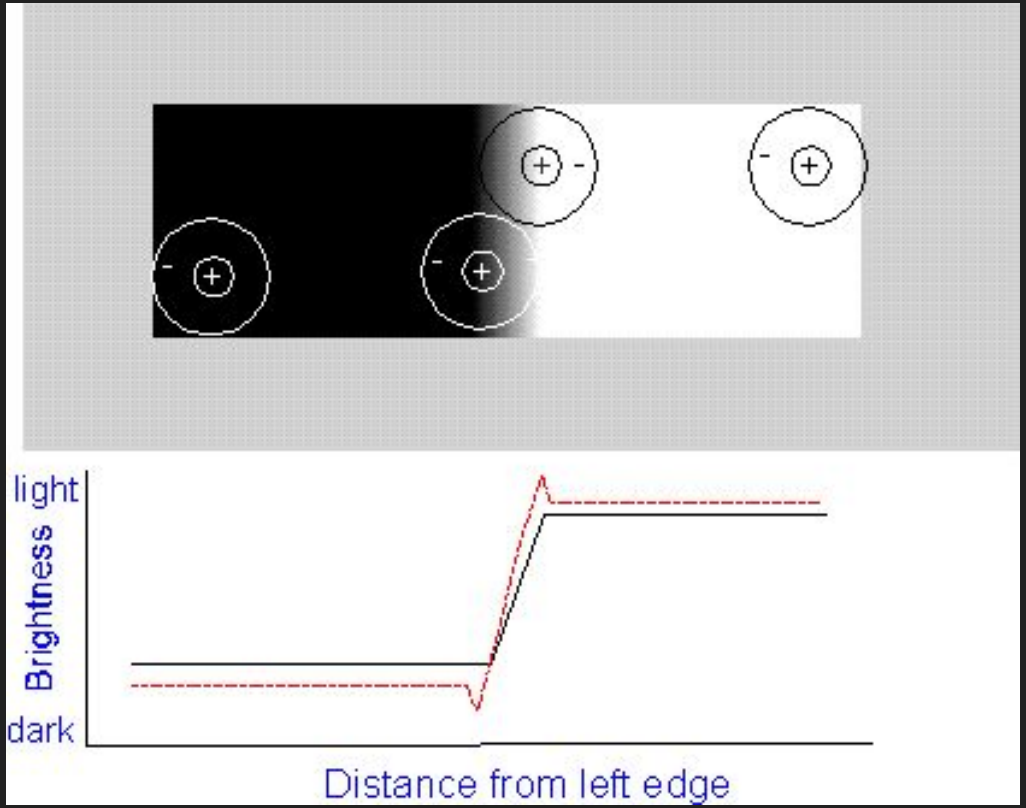
- Mach
  Illusion
- Recep
  - Gr
  - Sm





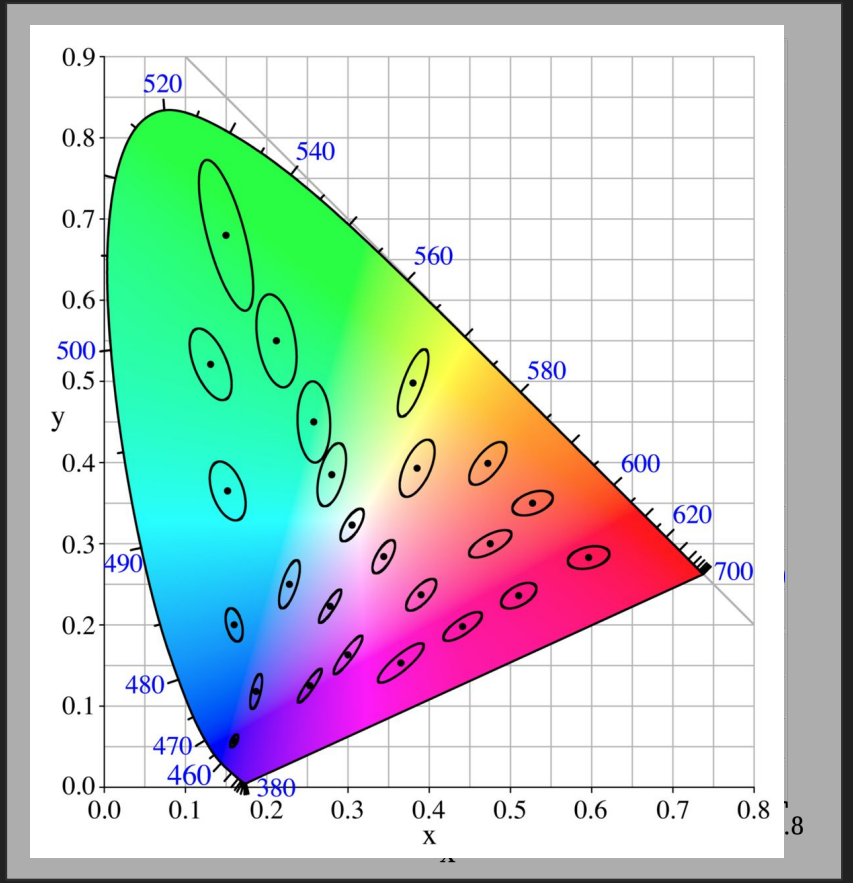
d) Mach-Bands and Receptive Fields

- Mach Bands: Optical Illusion
- Receptive Fields:
  - Groups of cells
  - Smallest in Fovea
- Mach Bands are products of different stimuli of receptive fields
- “Simulation” by convolution filter

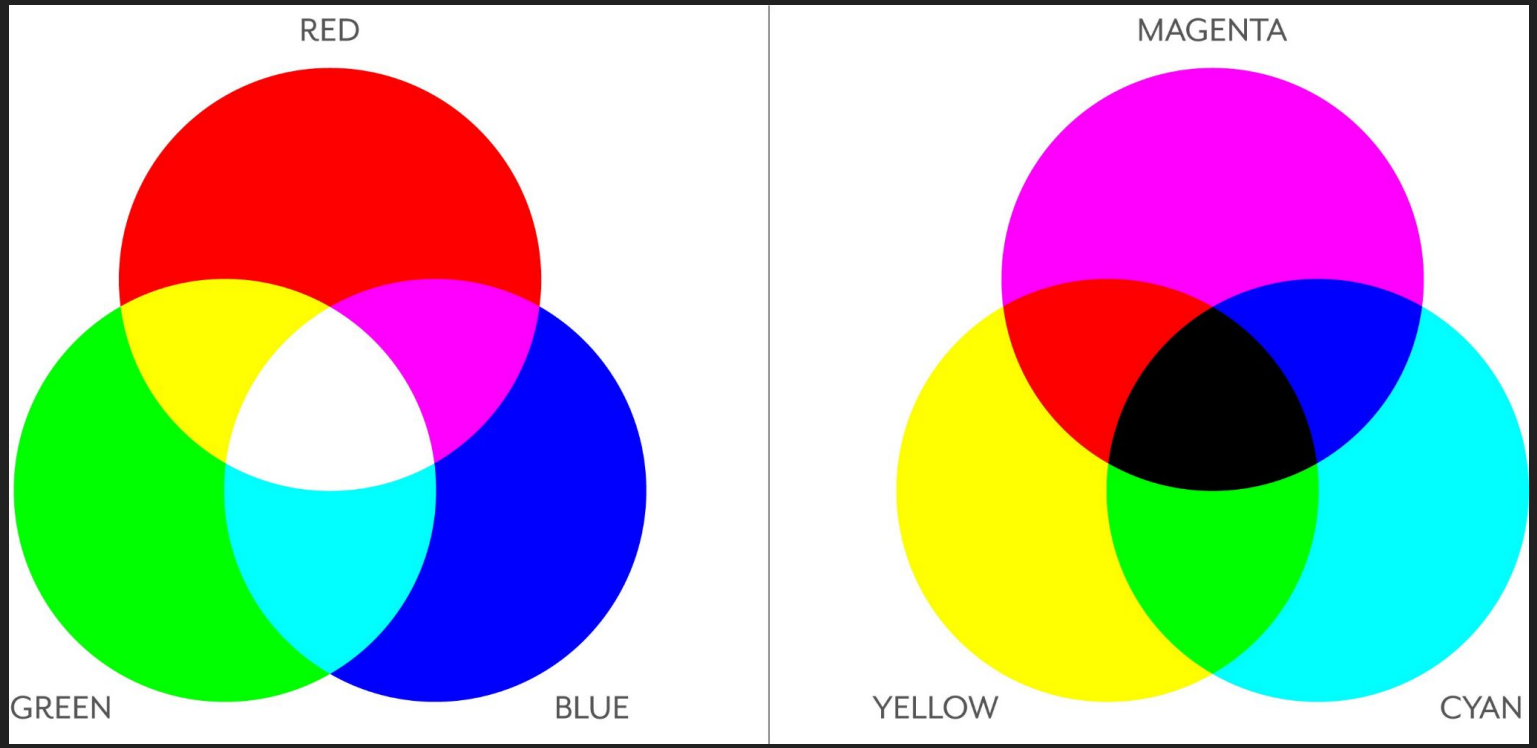


e) Chromaticity Diagram

1. Colors along line can be reproduced by mixing the colors of endpoints
   a. If line goes through “whitepoint” its endpoints colors are complementary
2. Gamut mapping sets “normalized color space” in form of triangle
   a. Reduce/avoid color shifts between devices
   b. Corner points of triangle are primary colors
   c. Outside additional primary colors would be needed
   d. https://www.youtube.com/watch?v=p3erHwzJoSg
3. MacAdam Ellipses describe intuitive hues humans would expect near the marked centers

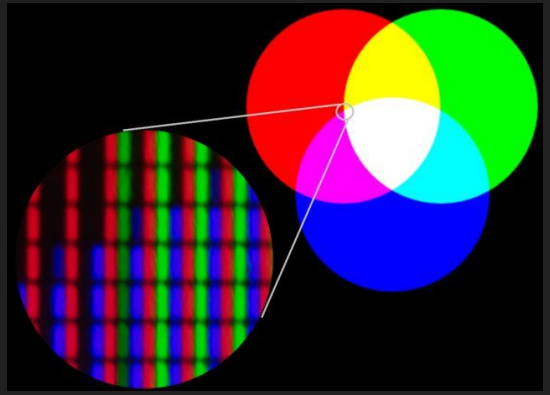


f) Additive vs Subtractive color mixing

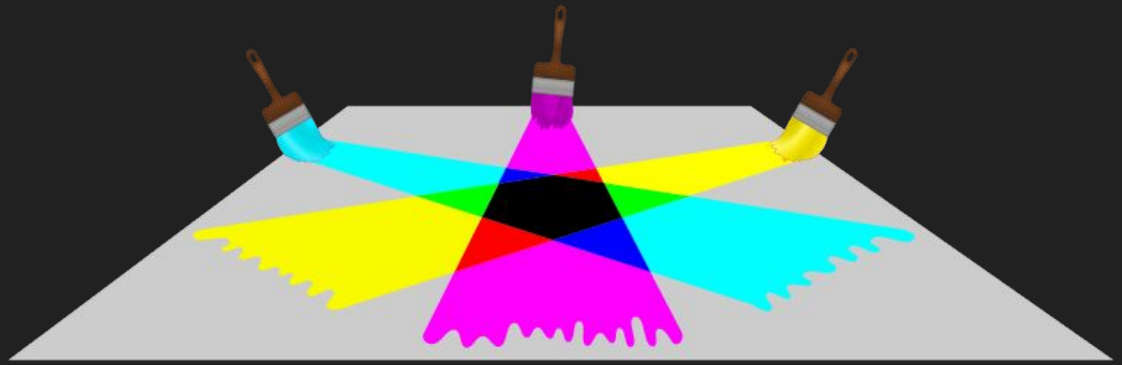


f) Additive vs Subtractive color mixing

- **Additive**:
  - Screens
  - Twitch streamer LED stripes



- **Subtractive**:
  - Art
  - Print Media
  - Chemistry



g) RGB to CMYK

$$R' = \frac{R}{255} \qquad B' = \frac{R}{255} \qquad G' = \frac{G}{255}$$

$$\begin{aligned} C &= (1 - R' - K)/(1 - K) \\ M &= (1 - G' - K)/(1 - K) \\ Y &= (1 - B' - K)/(1 - K) \\ K &= 1 - \max(R', G', B') \end{aligned}$$

RGB = (1, 0, 0) => CMYK = (0, 100, 100, 0) in %

g) RGB to HSV (Hue, Saturation, Value)

$$R' = \frac{R}{255} \qquad B' = \frac{R}{255} \qquad G' = \frac{G}{255}$$

$$C_{max} = \max(R', G', B')$$

$$C_{min} = \min(R', G', B')$$

$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0°, & \Delta = 0 \\ 60°(\frac{G'-B'}{\Delta} \bmod 6), & C_{max} = R' \\ 60°(\frac{B'-R'}{\Delta} + 2), & C_{max} = G' \\ 60°(\frac{R'-G'}{\Delta} + 4), & C_{max} = B' \end{cases}$$

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases}$$

$$V = C_{max}$$

RGB = (1, 0 ,0) => HSV = (0°, 100%, 100%)

g) RGB to HSL (Hue, Saturation, Lightness)

$$R' = \frac{R}{255} \qquad B' = \frac{R}{255} \qquad G' = \frac{G}{255}$$

$$C_{max} = \max(R', G', B')$$

$$C_{min} = \min(R', G', B')$$

$$\Delta = C_{max} - C_{min}$$

$$H = \begin{cases} 0°, & \Delta = 0 \\ 60°(\frac{G'-B'}{\Delta} \bmod 6), & C_{max} = R' \\ 60°(\frac{B'-R'}{\Delta} + 2), & C_{max} = G' \\ 60°(\frac{R'-G'}{\Delta} + 4), & C_{max} = B' \end{cases}$$

$$S = \begin{cases} 0, & C_{max} = 0 \\ \frac{\Delta}{C_{max}}, & C_{max} \neq 0 \end{cases}$$

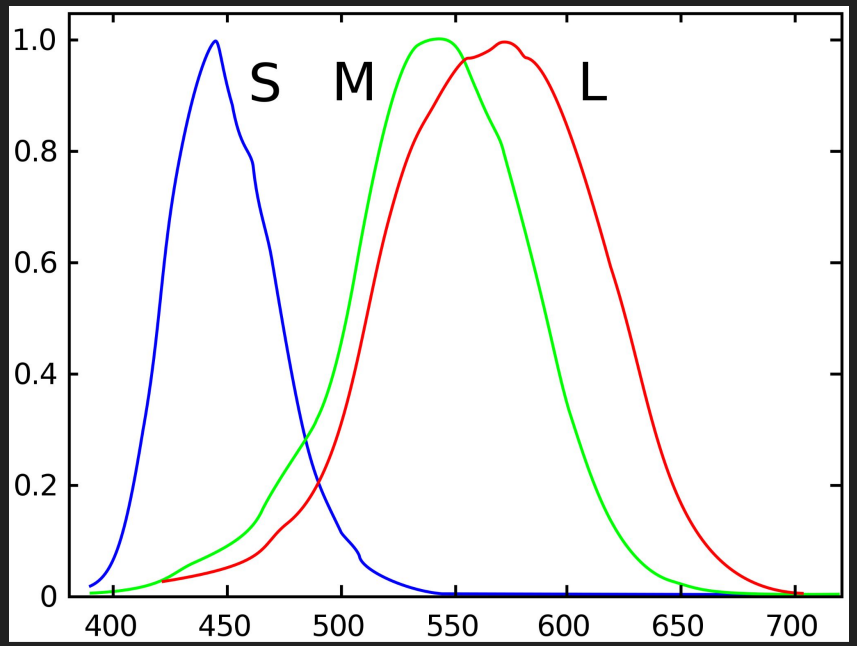
$$L = (C_{max} + C_{min})/2$$

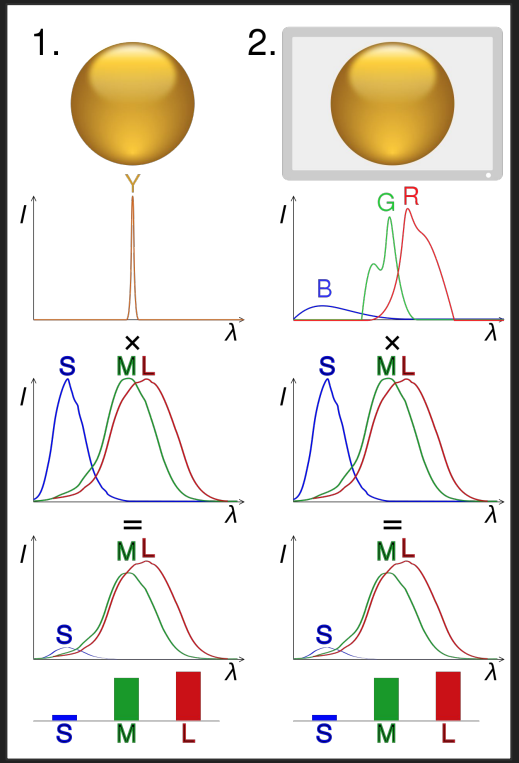
RGB = (1, 0 ,0) => HSL = (0°, 100%, 50%)

h) Black Cartridges for Printer

- Cheaper to use black color for printing instead of mixing three colors
- Black is most used color for printing
- Printers are not good in producing “good” black by using color
  - Three dots on same place instead of one

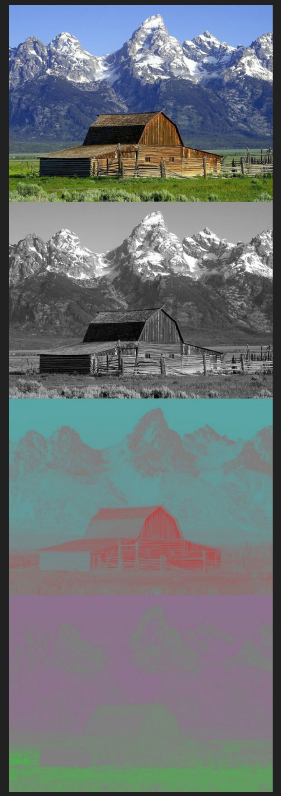
i) Sensitivity curves of trichromatic color vision and YIQ





i) Sensitivity curves of trichromatic color vision and YIQ

- The YIQ system is intended to take advantage of human color-response characteristics
- The eye is more sensitive to changes in the orange-blue (I) range than in the purple-green range (Q)
  - less bandwidth is required for Q than for I
- Used in TV



j) Luminance or Contrast?

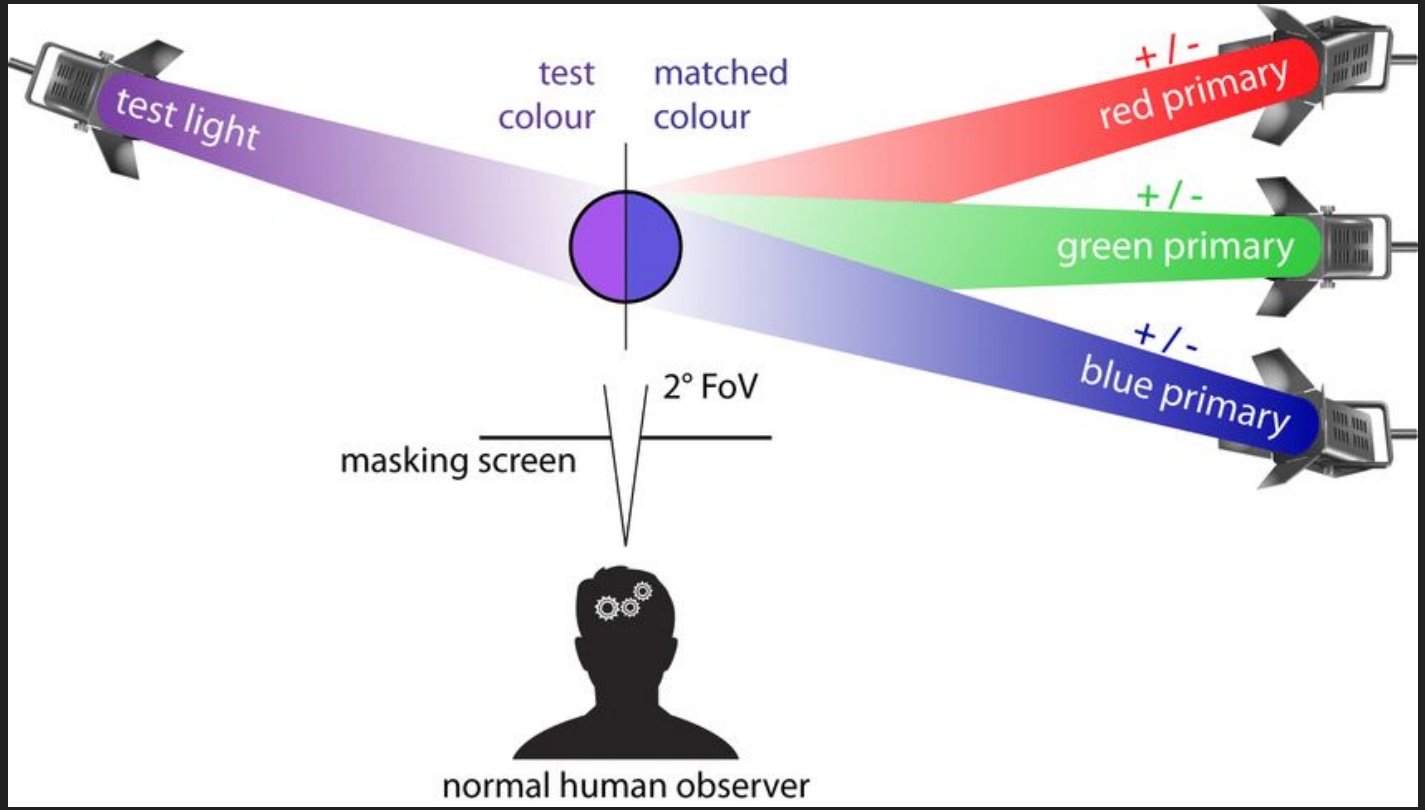
- Direct center of human view (fovea) is more sensitive to contrast
  - Perception not too much influenced by changes in illumination over the day
- Outside fovea is more sensible to difference in brightness

k) Color matching experiments

- Participants of color matching experiment asked to reproduce given color by adjusting intensity of three primary colors red, green and blue
- Stop when the resulting color matches

Surprise: Not all colors can be realized by combining three primaries :o

k) Color matching experiments



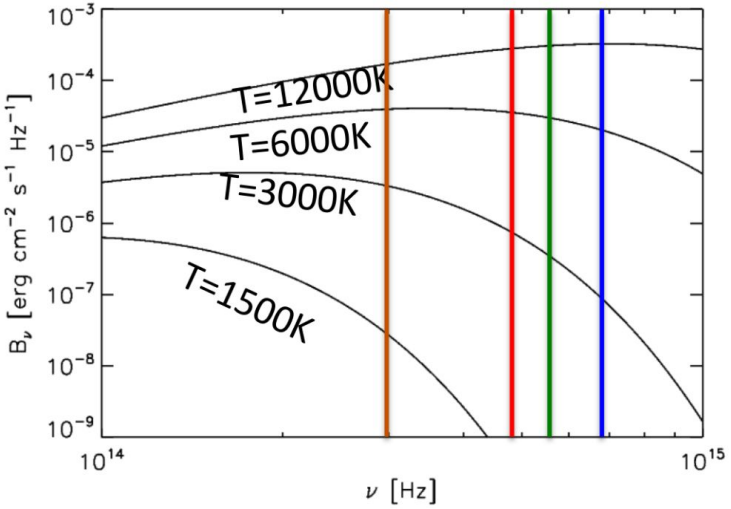
k) Color matching experiments

https://www.tiktok.com/@fritzdoesart/video/7139605661968600366?is_from_webapp=v1&item_id=7139605661968600366

I) CIE-1931 XYZ color space

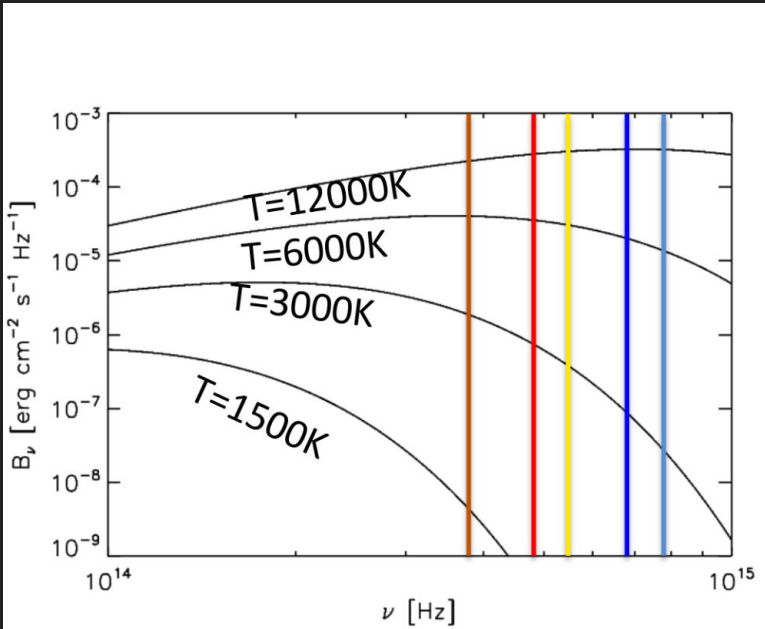
See code

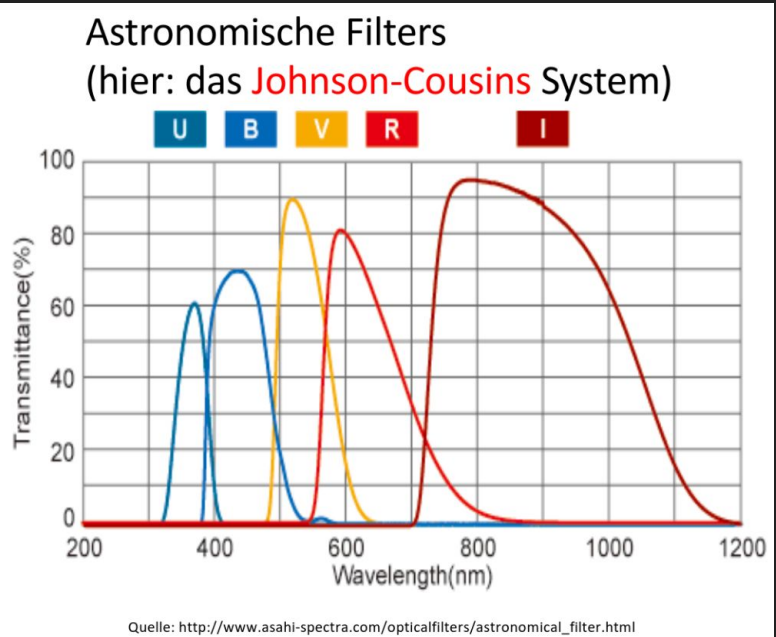
Excurse: Astronomical Filters



Quelle: http://www.opticstar.com/images/astronomy/imagers/MI/G2/G2-RgbFilets-290x218.jpg

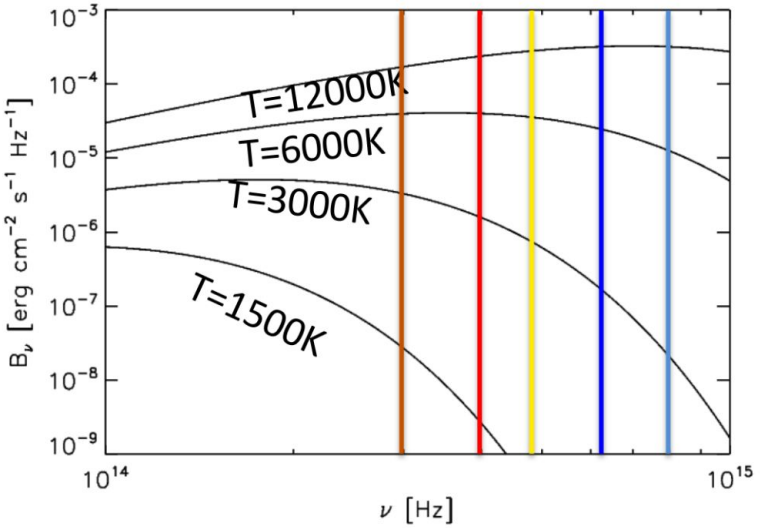
Excurse: Astronomical Filters



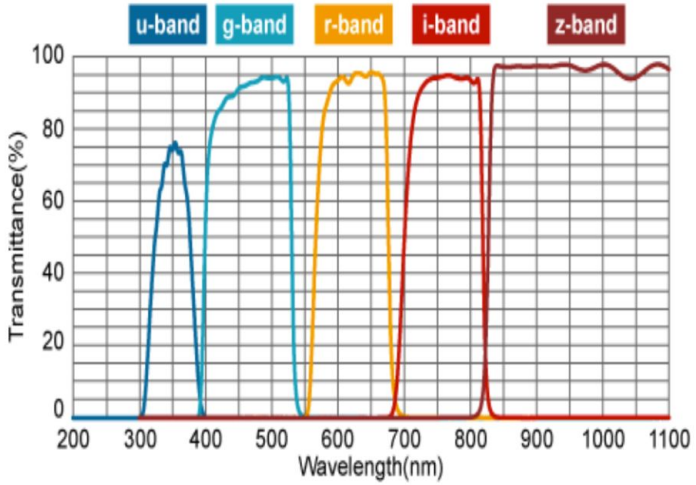


Quelle: http://www.asahi-spectra.com/opticalfilters/astronomical_filter.html

Excurse: Astronomical Filters



Astronomische Filters
(hier: das SDSS System)



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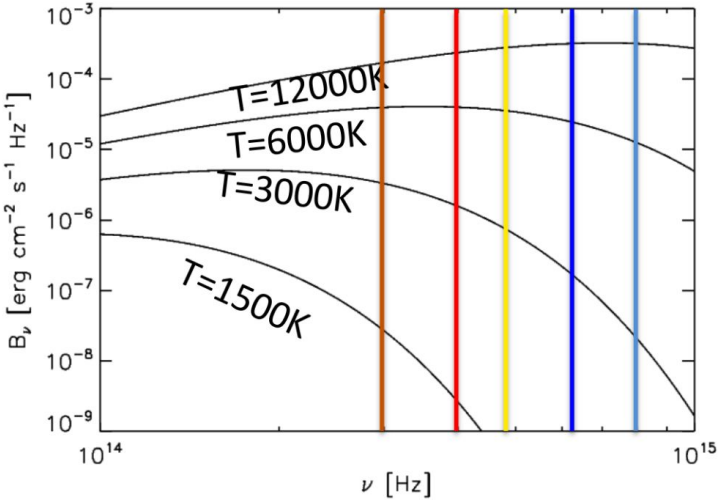
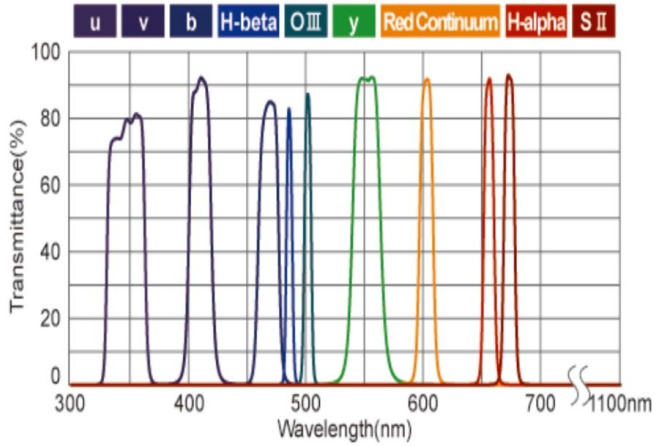
Excurse: Astronomical Filters



Astronomische Filters
(hier: narrow band filters)



Quelle: http://www.asahi-spectra.com/opticalfilters/astronomical_filter.html