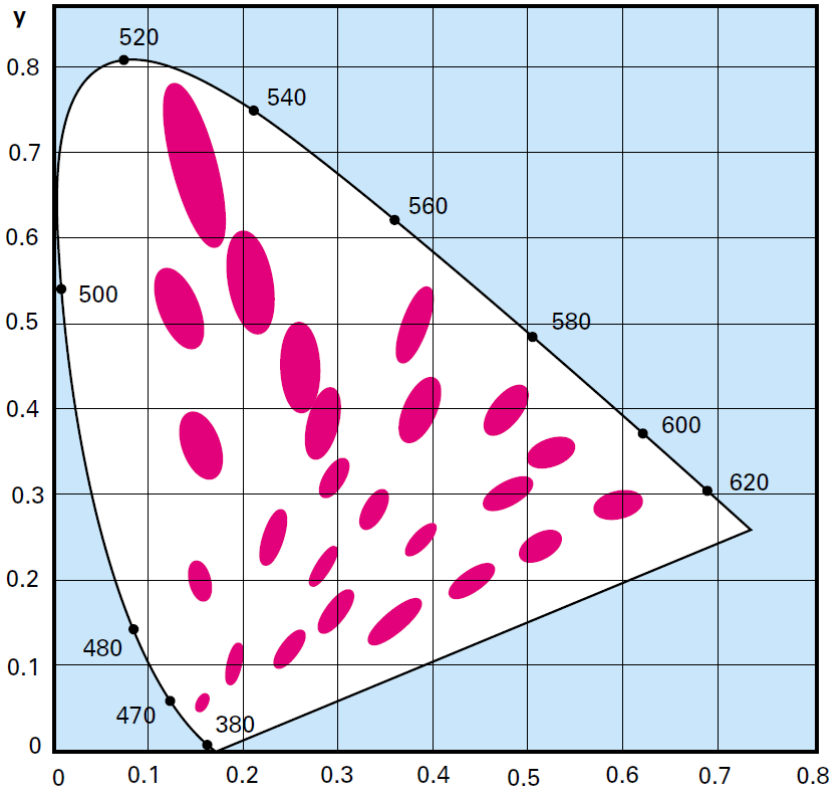
Colorimetry

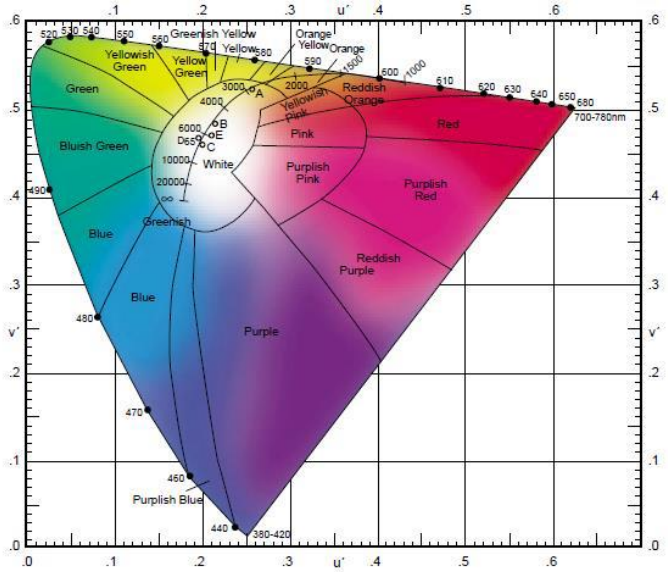
Part 2 of 2

Color space MacAdams ellipses



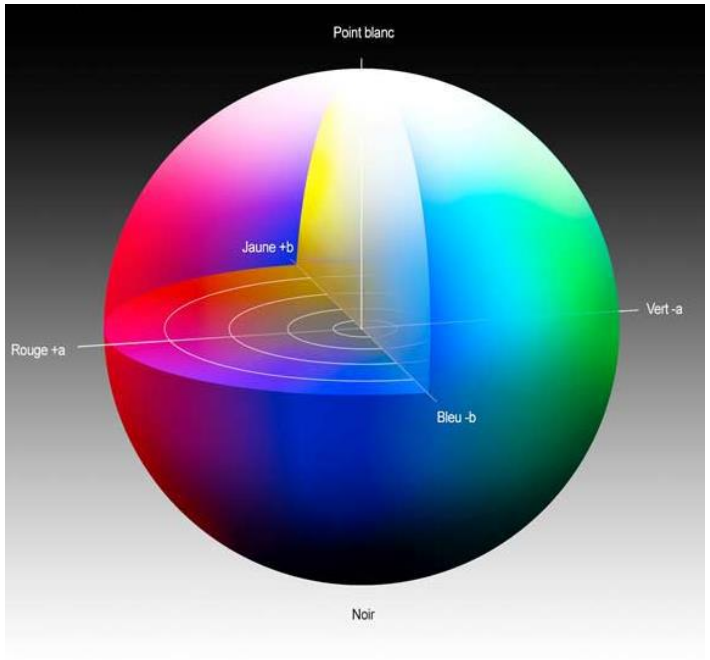
- colors perceived as equidistant by the human eye are located at differing distances in the CIE Chromaticity Diagram

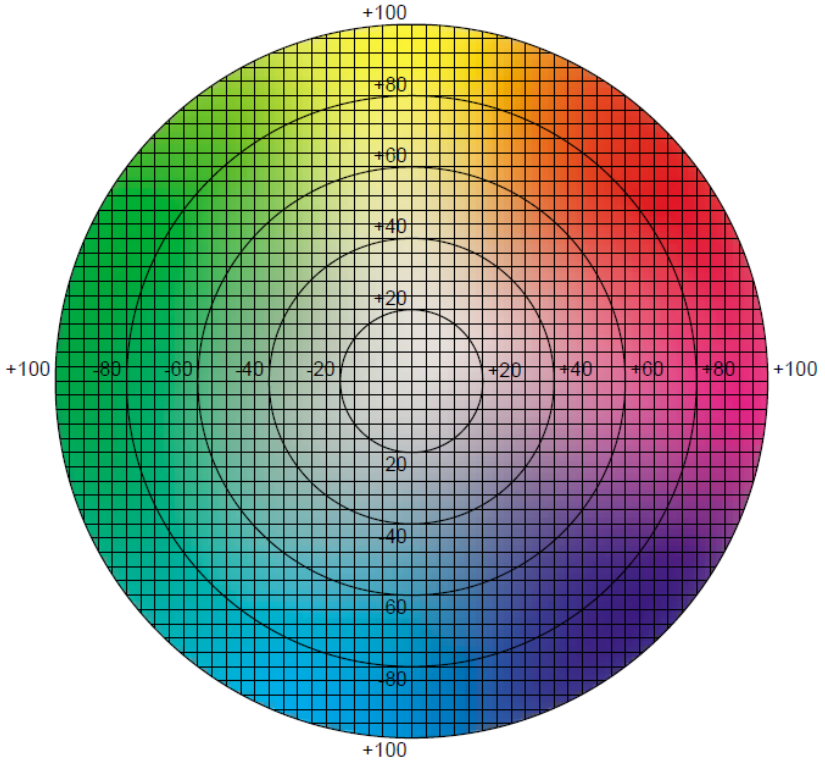
The CIE-L'u'v'

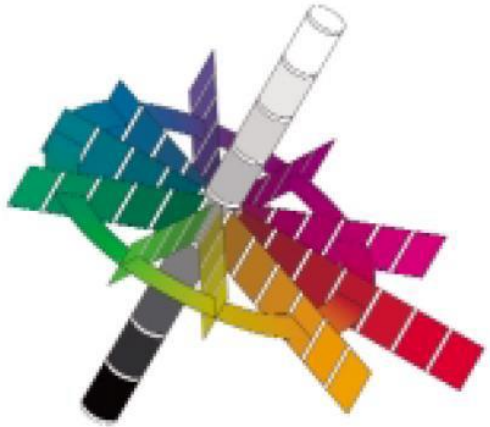


- The CIE-L' u´v´model was created on the basis of the linear displacement of the CIE xymodel.
- •The result is a visually equidistant color space.
- u'=4X(X+15Y+3Z)-1
- v'=9Y(X+15Y+3Z)-1

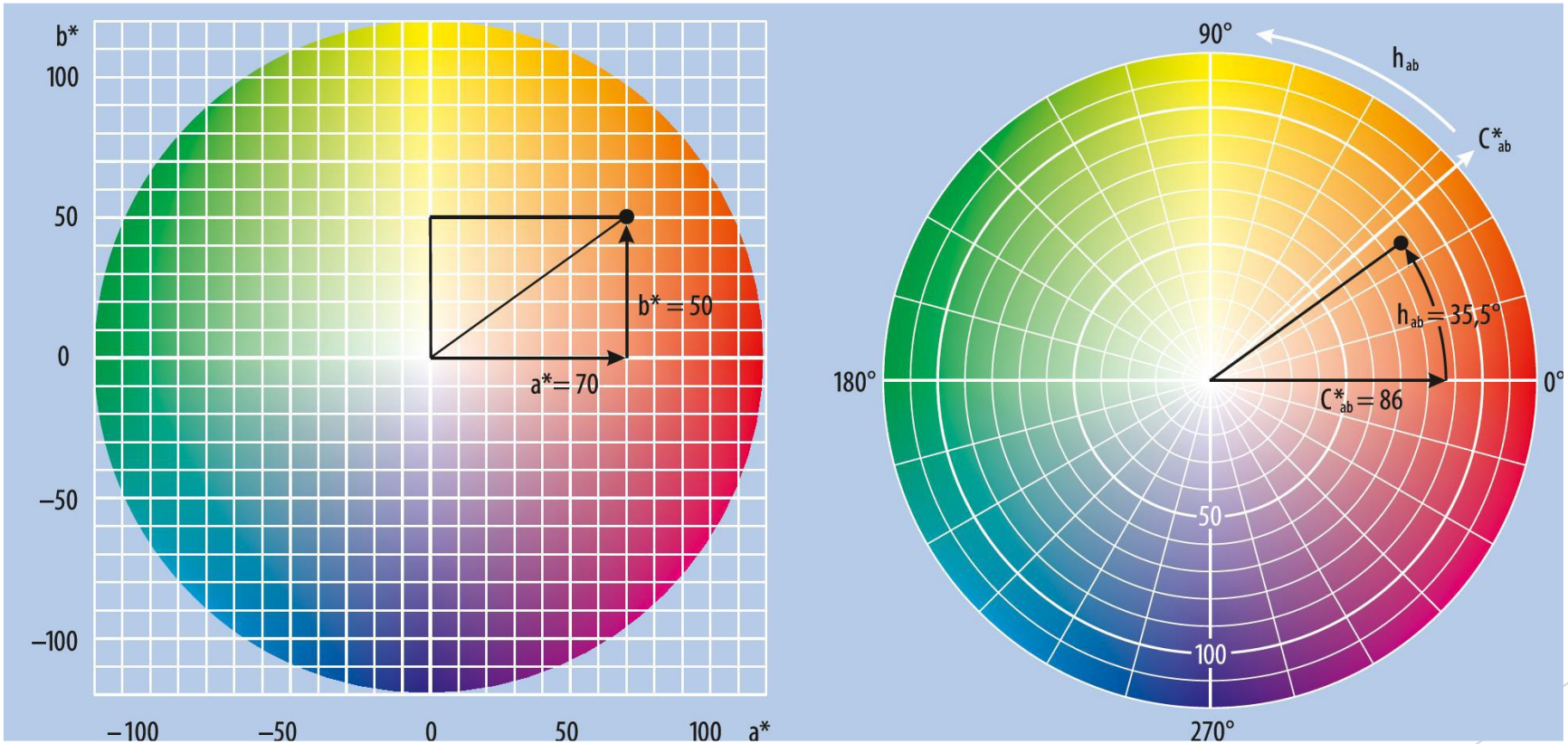
CIE Lab


Point blanc
Jaune +b
Vert -a
Rouge +a
Bleu -b
Noir

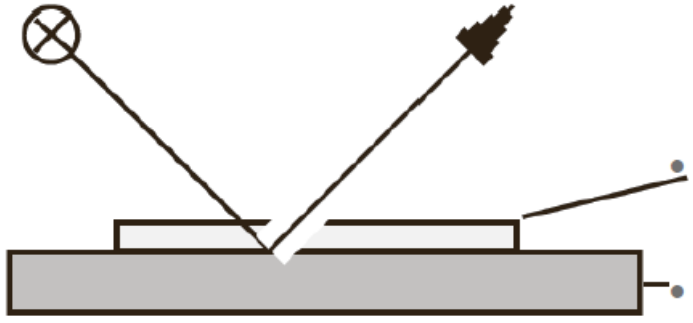

+100
+80
+60
+40
+20
+100
-80
-60
-40
-20
+20
+40
+60
+80
+100
20
40
60
80
+100



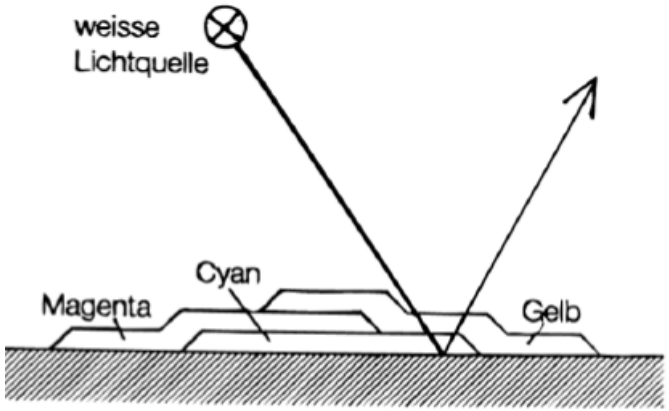
Lab LCh

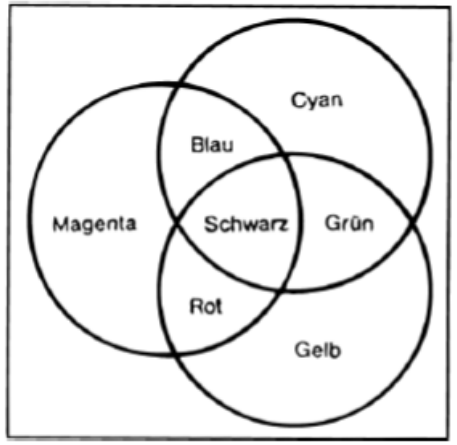

b*
100
50
0
–50
–100
–100
–50
0
50
100
a*
b* = 50
a* = 70
90°
h_ab
C*_ab
180°
0°
270°
h_ab = 35,5°
C*_ab = 86
50
100

Ink Transparency

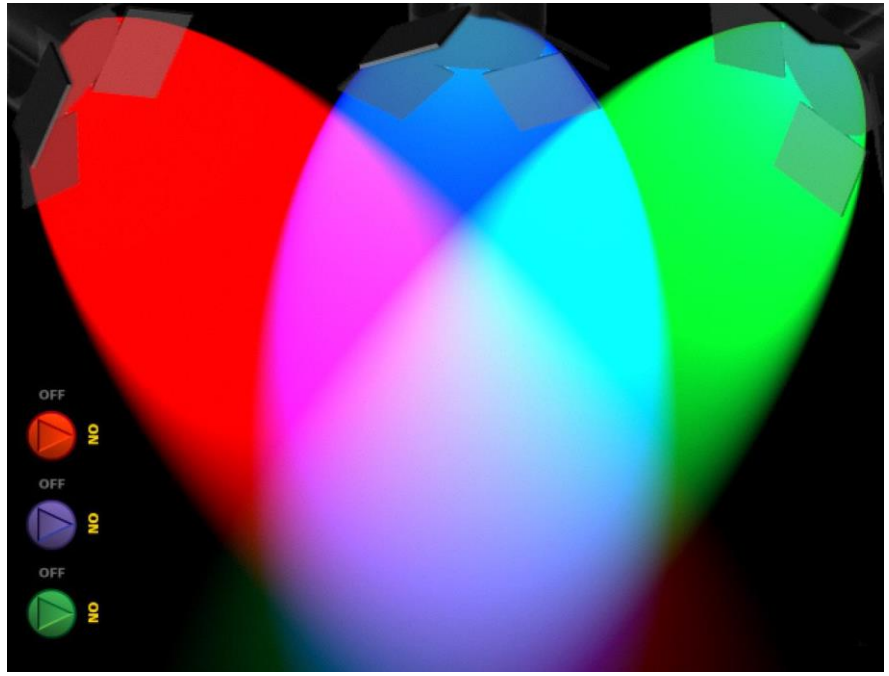


- Printed ink
- White paper

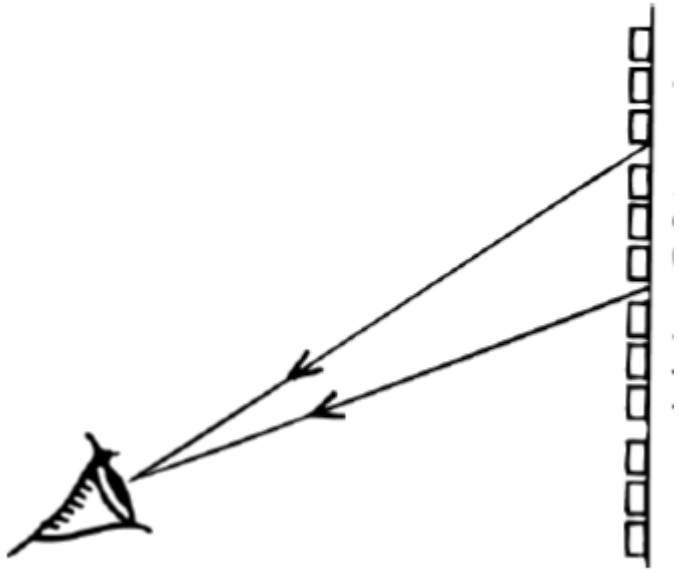




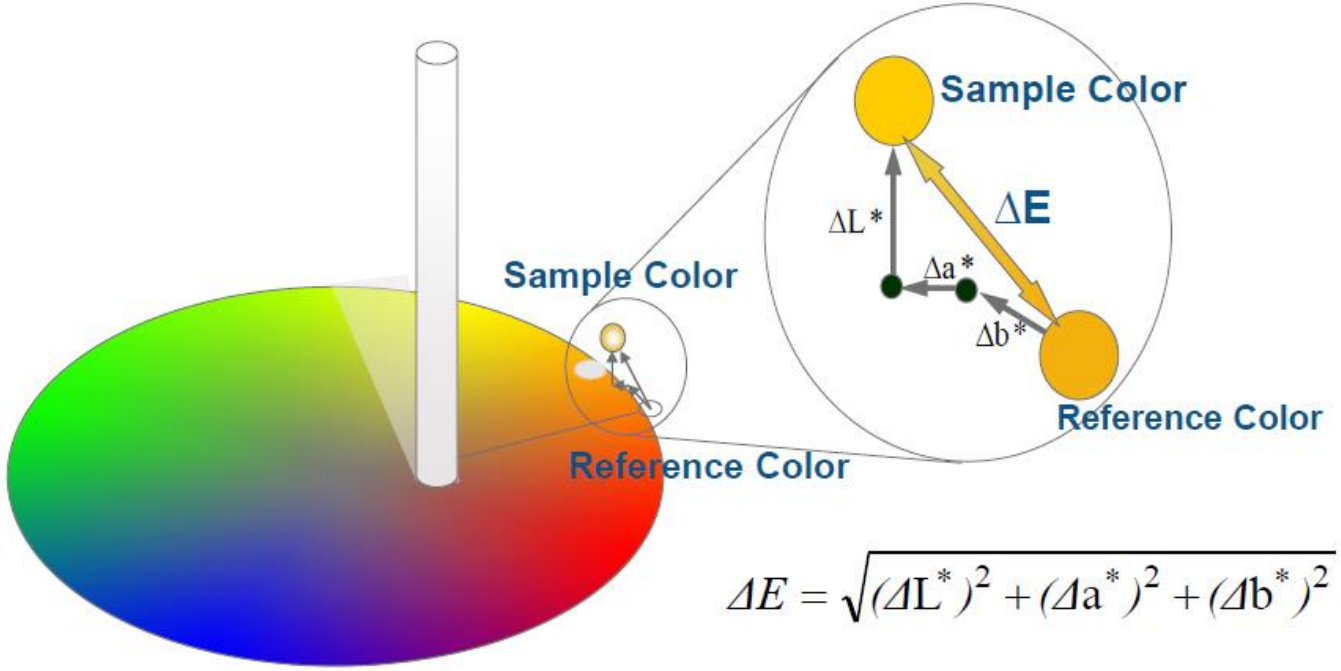
Mix of Colors through Addition



- Red Green and Blue Cones



Color Difference Delta E Lab 1976

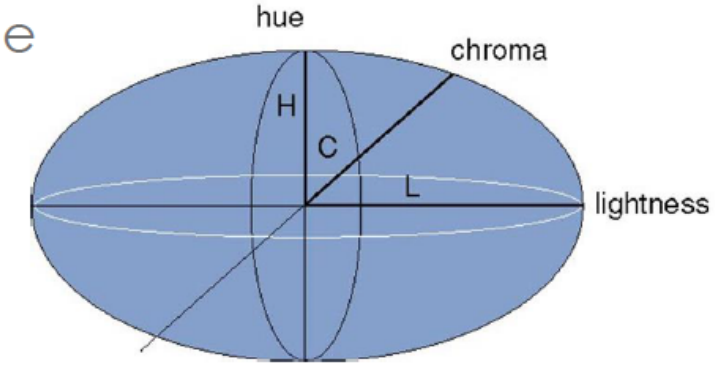


$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

- Named as Delta E (ΔE) and based on a mathematical equation of Pythagoras

Color Difference CMC

- The color difference method of the Color Measurement Committee (the CMC) is a model using two parameters l and c, typically expressed as **CMC (l:c)**. Commonly used values for acceptability are CMC(2:1) and for perceptibility are CMC(1:1).



$$\Delta E_{CMC} = \sqrt{\left(\frac{\Delta L^*}{l \cdot S_L}\right)^2 + \left(\frac{\Delta C^*}{c \cdot S_C}\right)^2 + \left(\frac{\Delta H^*}{H_L}\right)^2}$$

where:
SL = function of L
SC = function of C
SH = function of H and C

l and c = ratio of lightness and chroma

Color Difference CIE 94

$$\Delta E = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_C S_C}\right)^2 + \left(\frac{\Delta H}{K_H S_H}\right)^2}$$

$$\Delta L = L_1 - L_2$$

$$\Delta C = C_1 - C_2$$

$$\Delta H = \sqrt{\Delta a^2 + \Delta b^2 - \Delta C^2}$$

$$C_1 = \sqrt{a_1^2 + b_1^2}$$

$$C_2 = \sqrt{a_2^2 + b_2^2}$$

$$\Delta a = a_1 - a_2$$

$$\Delta b = b_1 - b_2$$

$$S_L = 1$$

$$S_C = 1 + K_1 C_1$$

$$S_H = 1 + K_2 C_1$$

$$K_L = \begin{cases} 1 & \text{default} \\ 2 & \text{textiles} \end{cases}$$

$$K_C = 1 \quad \text{default}$$

$$K_H = 1 \quad \text{default}$$

$$K_1 = \begin{cases} 0.045 & \text{graphic arts} \\ 0.048 & \text{textiles} \end{cases}$$

$$K_2 = \begin{cases} 0.015 & \text{graphic arts} \\ 0.014 & \text{textiles} \end{cases}$$

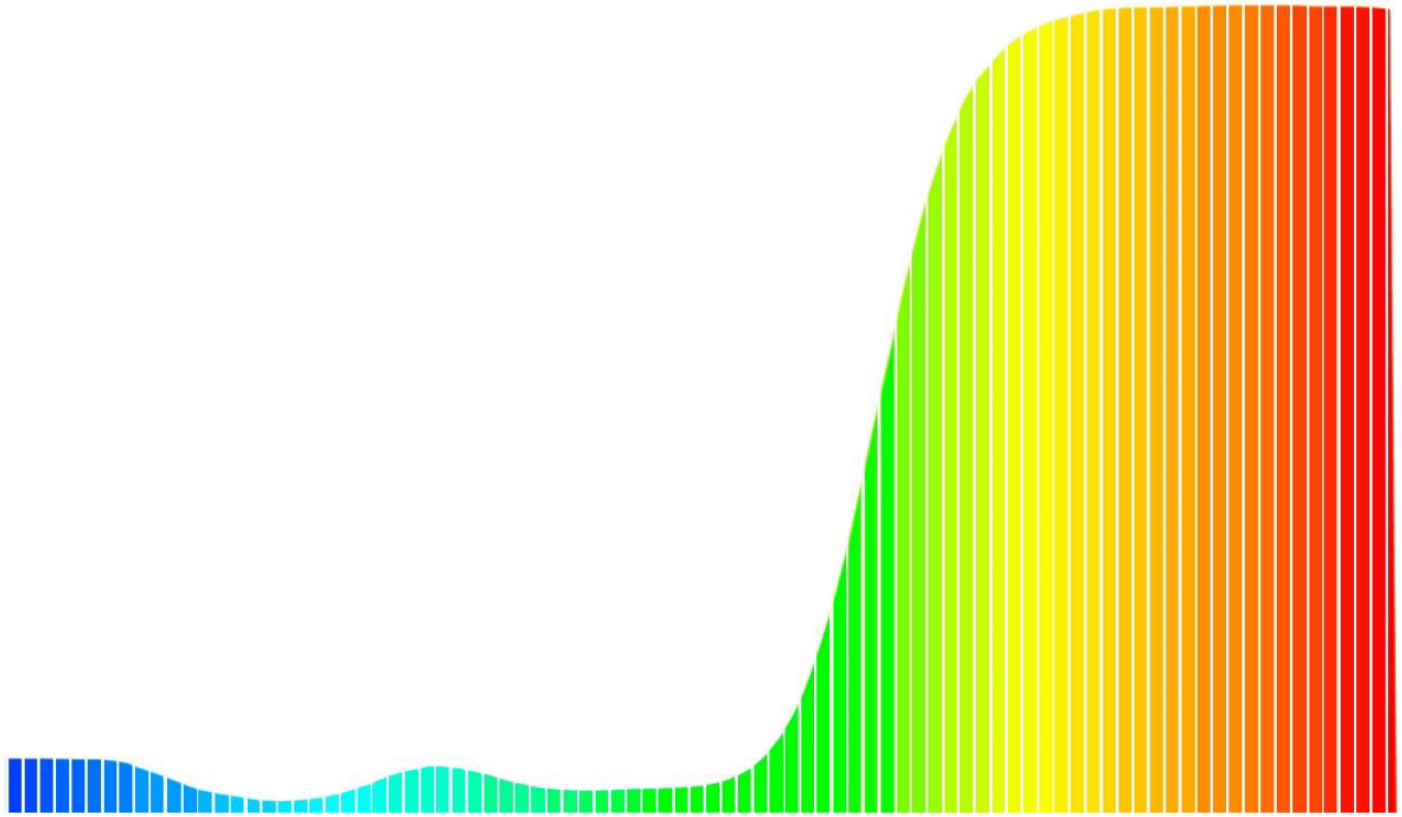
Color difference CIE 2000

$$\Delta E_{2000} = \sqrt{\left(\frac{\Delta L^*}{K_L S_L}\right)^2 + \left(\frac{\Delta C^*}{K_C S_C}\right)^2 + \left(\frac{\Delta H^*}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C^* \Delta H^*}{K_C H}\right)}$$

Rotation term

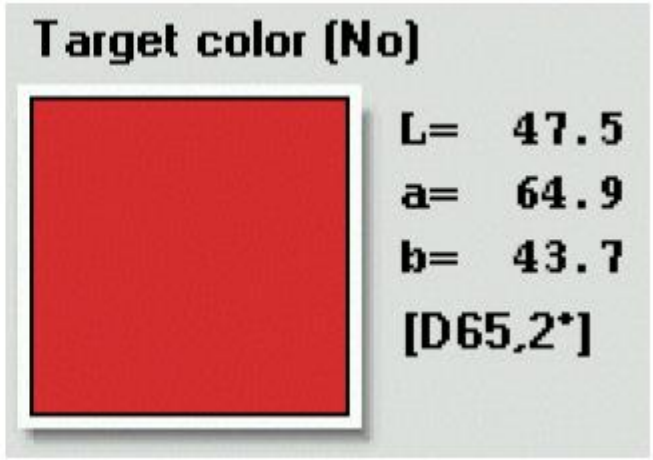
CIE/NPL recommendation for calculation of small color differences, to replace CIE94, CMC, etc.
Introducing a “Rotation Term” correcting of anomalies in the blue area of the color space.

Color Measurement Through Spectral Curves



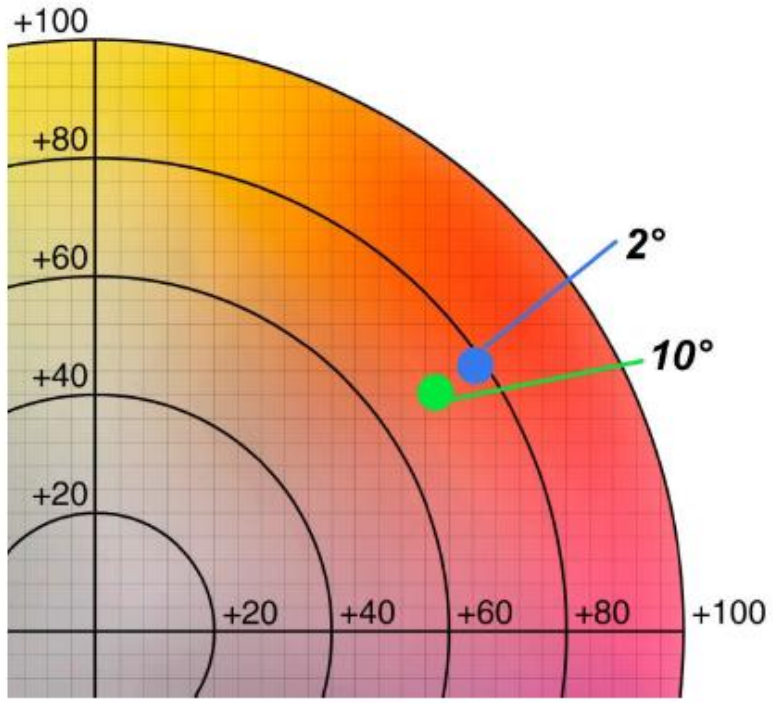
Following a Color Measurement…. What does it mean?

- Spectral data
- L*a*b*-values



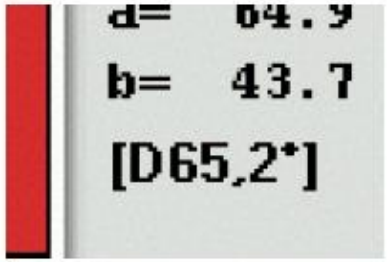
Following a Color Measurement…. What does it mean?

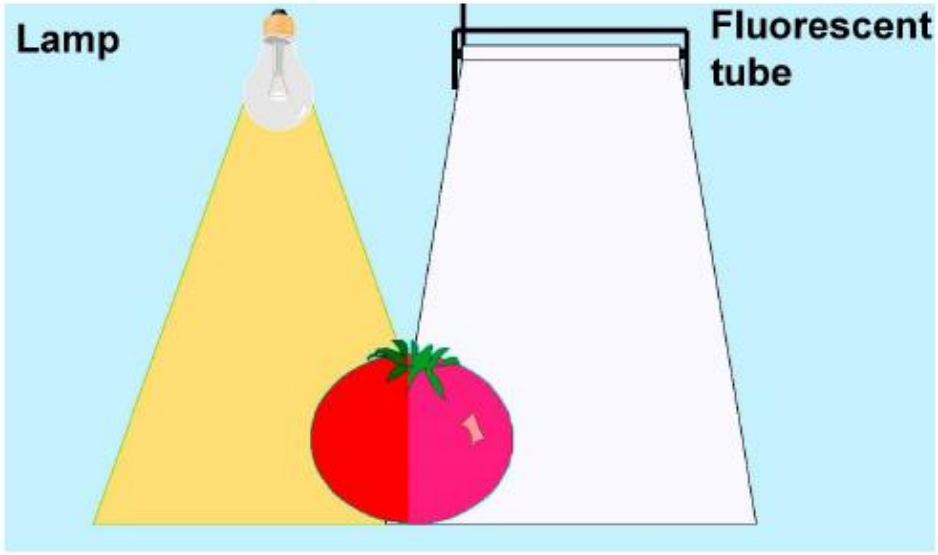
- Spectral data
- L*a*b*-values
- Observer angle



Following a Color Measurement…. What does it mean?

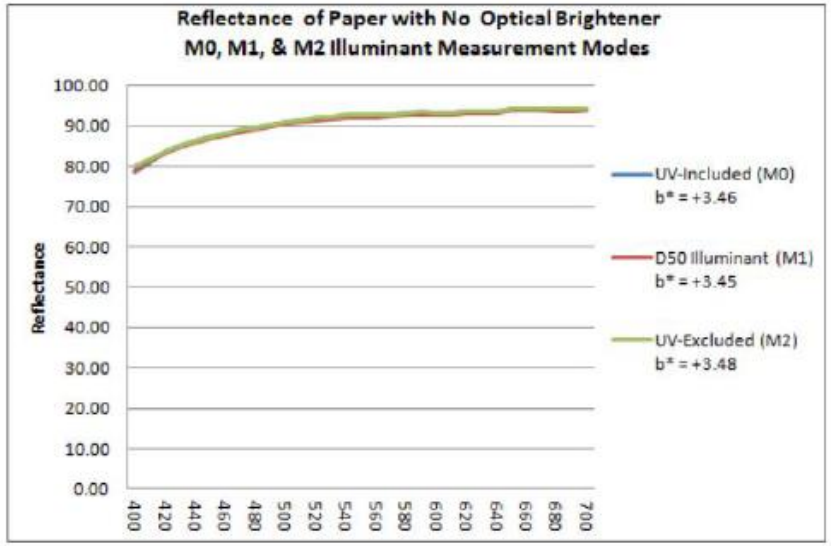
- Spectral data
- L*a*b*-values
- Observer angle
- Illuminance

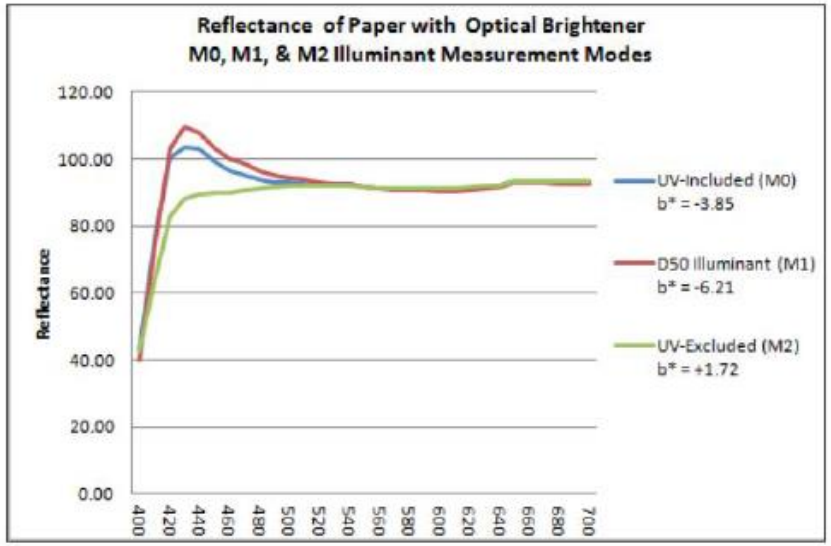




M Factor – Effect of Illumination

Effects of illumination conditions





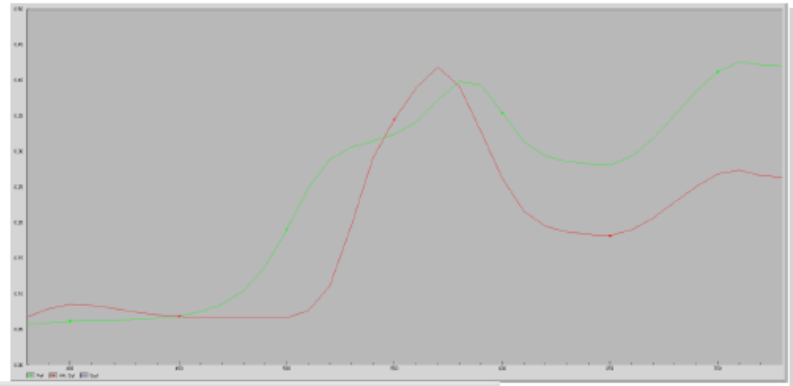
The new M series allows color management of OBA-enhanced substrates

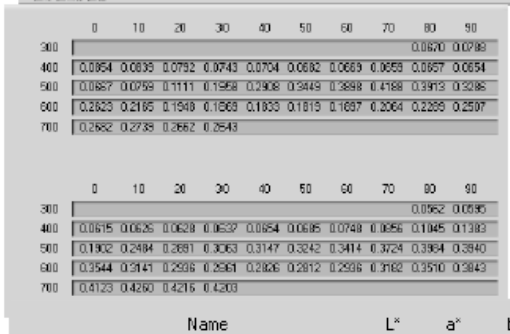
Measurement Illumination **Condition M1 match CIE Illuminant D50**

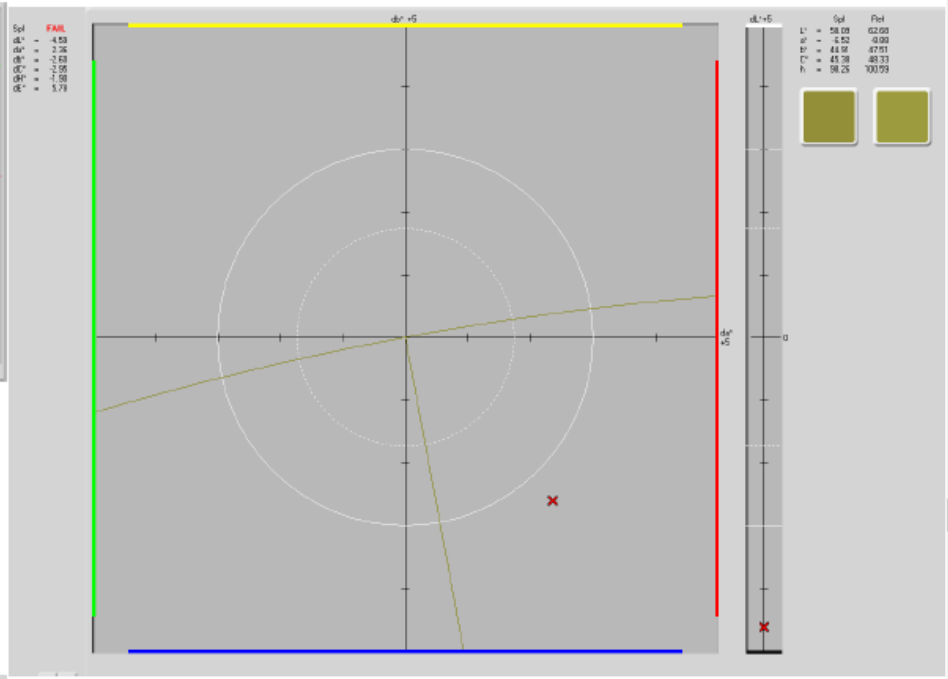
Condition M2 defines what UV exclusion, UV-cut

Condition M0 does not define UV content, Standard Illuminant A

Pass or Fail







		Name	L*	a*	b*	dL*	da*	db*	dE*
		OLIV	62.68	-8.88	47.51				
>	1 FAIL	05.07.2016 23:57	58.09	-6.52	44.91	-4.59	2.36	-2.60	5.78

Example of Pass or Fail Metrics

How is this possible?
Answer: ICC

1993 ICC

Cooperation with Software producer and FOGRA:

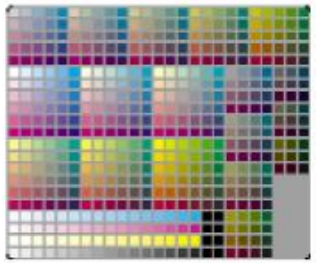
Founder member: Agfa, Adobe, Apple, FOGRA, Kodak, Microsoft, Sun, Silicon Graphics

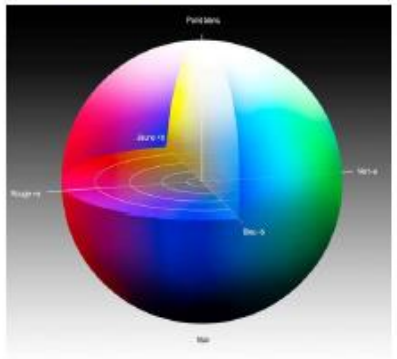
Today more than 50 members
FOGRA, Technical secretary

Goal: Standardization - ICC

ICC Purpose

Goal: characteristics of color





output
CMYK values

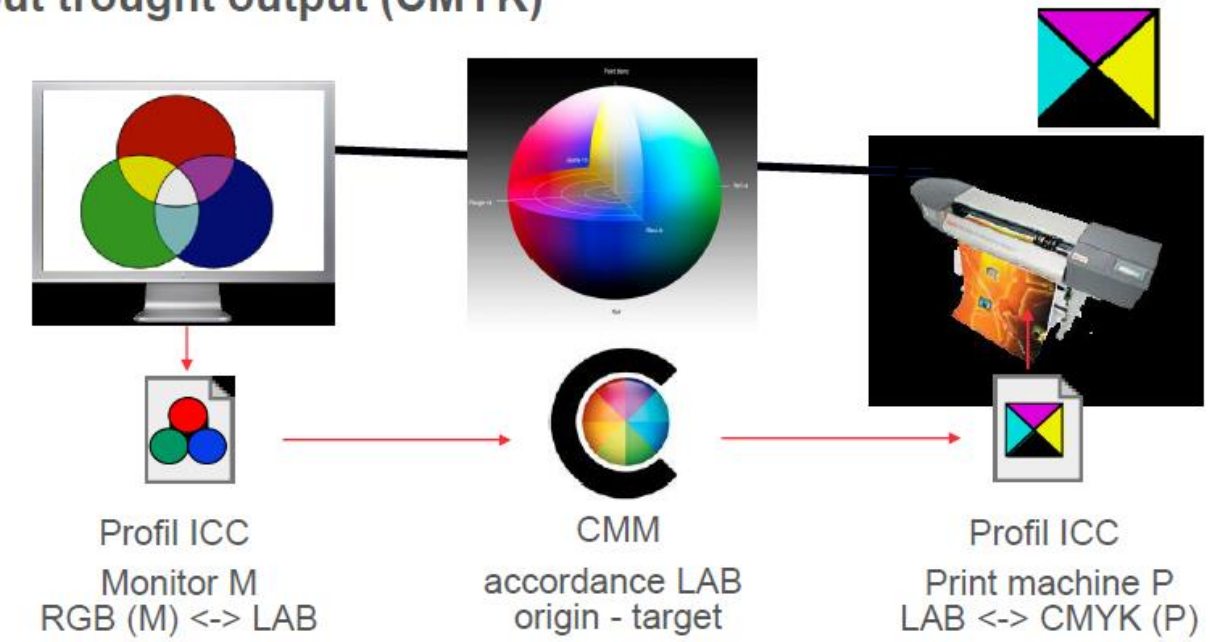
measure
color with
color-measuring device
(Spektrophotometer)

comparing of
CMYK-values
Color values=
Profil ICC

Profil = relation values cmyk <-> color CIELab

ICC Founding Goals

ColorManagement: adapt hardware values (RGB) from Input trought output (CMYK)



Profil ICC
Monitor M
RGB (M) <-> LAB

CMM
accordance LAB
origin - target

Profil ICC
Print machine P
LAB <-> CMYK (P)

Colorspacetransformation from RGB to CMYK with the aid of CIELab Colorspace

Measuring the Data

- CMYKOG profiling target, A3 (X-Rite EyeOne iSis)
- LGOROWLENGTH "30"
- CREATED"2016-07-06T23:11:08+02:00"
- ORIGINATOR "ColorGATE"
- DESCRIPTOR "CMYKOG profiling target, A3 (X-Rite EyeOne iSis)"
- KEYWORD "INFO"
- INFO "CMYKOG Profilierungstarget für X-Rite EyeOne iSis, gedruckt auf einer A3 Seite mit 1920 Farbfeldern."
- INSTRUMENTATION "EyeOne iSis"
- KEYWORD "ILLUMINATION_NAME"
- ILLUMINATION_NAME "D50"
- KEYWORD "OBSERVER_ANGLE"
- OBSERVER_ANGLE "2"
- KEYWORD "MEASURE_CONDITION"
- MEASURE_CONDITION "M0"
- NUMBER_OF_FIELDS "44"
- NUMBER_OF_SETS "1920"
- BEGIN_DATA_FORMAT
- SAMPLE_ID SAMPLE_NAME 6CLR_1 6CLR_2 6CLR_3 6CLR_4 6CLR_5 6CLR_6 SPECTRAL_NM_380 SPECTRAL_NM_390 SPECTRAL_NM_400
  SPECTRAL_NM_410 SPECTRAL_NM_420 SPECTRAL_NM_430 SPECTRAL_NM_440 SPECTRAL_NM_450 SPECTRAL_NM_460 SPECTRAL_NM_470 SPECTRAL_NM_480 SPECTRAL_NM_490 SPECTRAL_NM_500
  SPECTRAL_NM_510 SPECTRAL_NM_520 SPECTRAL_NM_530 SPECTRAL_NM_540 SPECTRAL_NM_550 SPECTRAL_NM_560 SPECTRAL_NM_570 SPECTRAL_NM_580 SPECTRAL_NM_590 SPECTRAL_NM_600
  SPECTRAL_NM_610 SPECTRAL_NM_620 SPECTRAL_NM_630 SPECTRAL_NM_640 SPECTRAL_NM_650 SPECTRAL_NM_660 SPECTRAL_NM_670 SPECTRAL_NM_680 SPECTRAL_NM_690 SPECTRAL_NM_700
  SPECTRAL_NM_710 SPECTRAL_NM_720 SPECTRAL_NM_730
- END_DATA_FORMAT
- BEGIN_DATA
- 1 A1 100 0 0 0 0 0 0 0.08396

Understanding the Data and Workflow