大话成像之

数字成像系统 32讲

颜色科学基础

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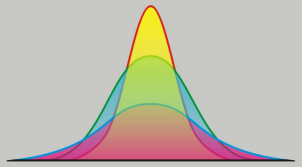
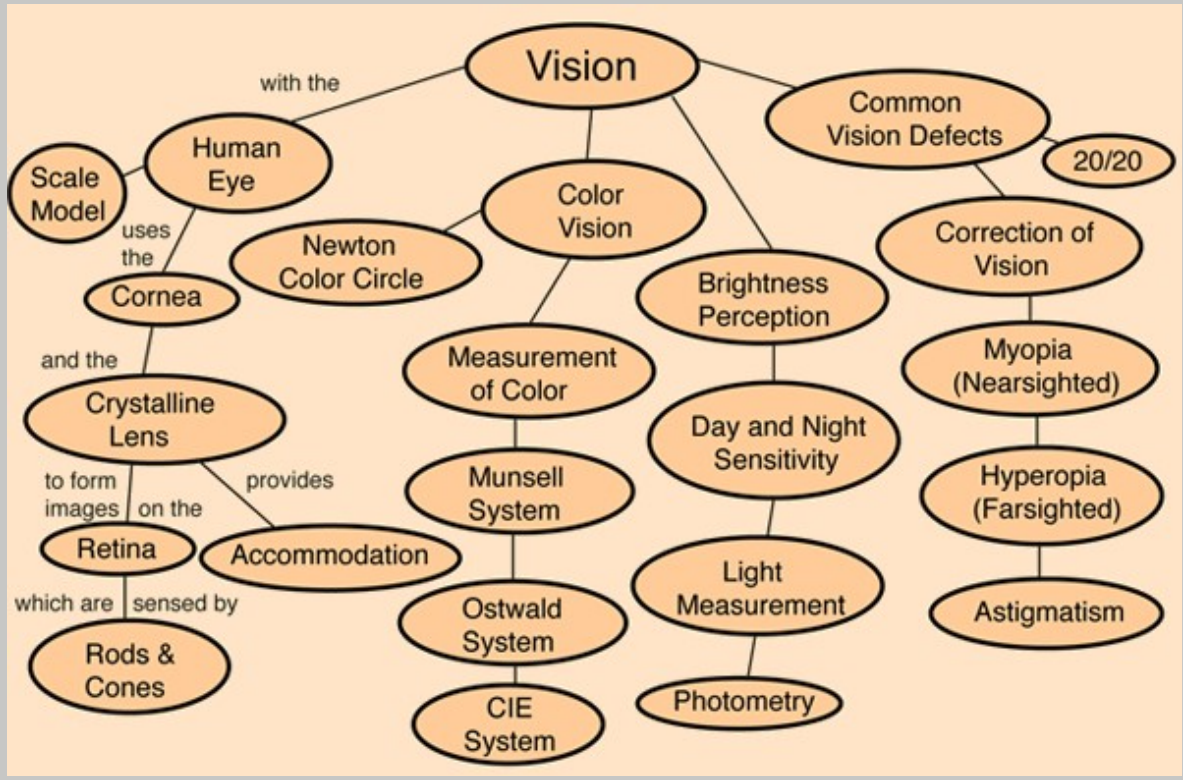
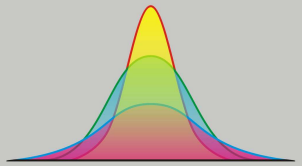


成像工业所涉及的颜色科学基本概念：

（印刷，染色，涂料等工业都涉及到颜色科学）

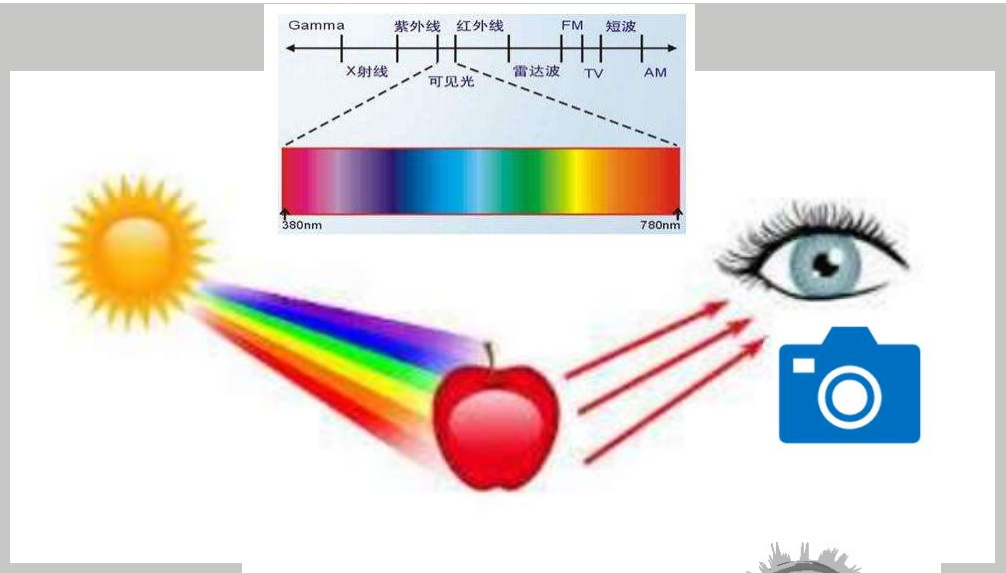
- 颜色科学的基本要素
- 光源
- 色度
- 色差
- 色彩空间
- 色彩与视觉

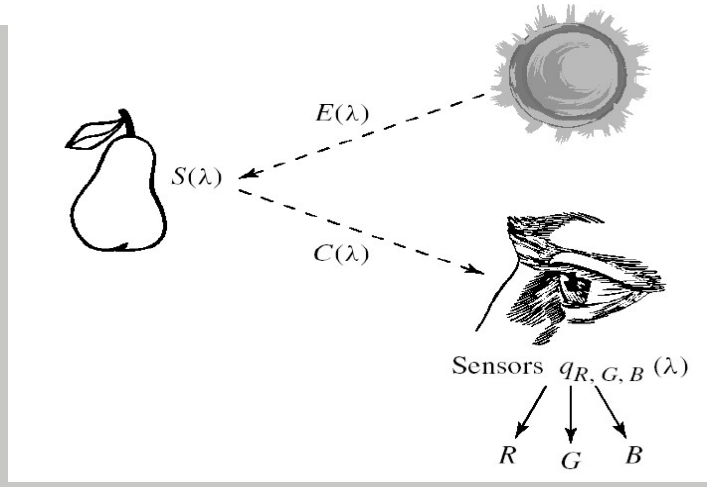


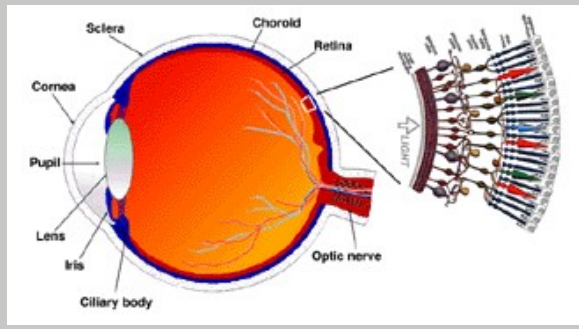


颜色科学的三个基本要素：

- 光源----发出光
- 物体----反射光
- 感受者（相机/人）----接收光







Rod ----luminance
Cones----r,g,b

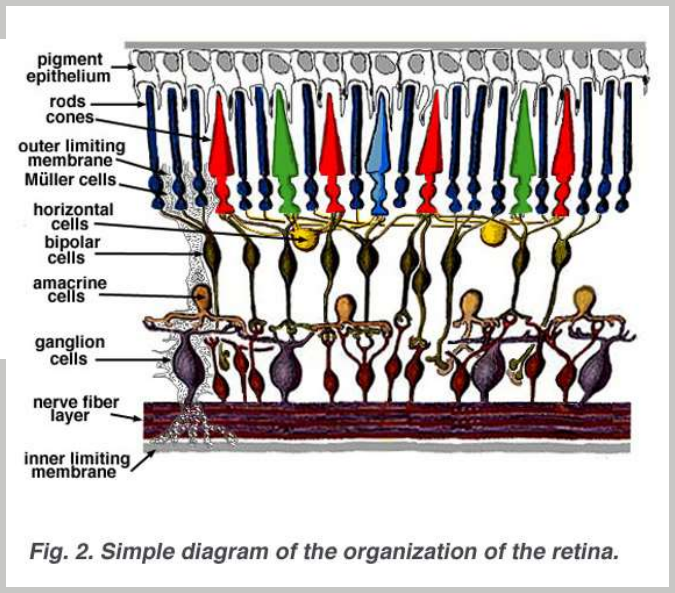
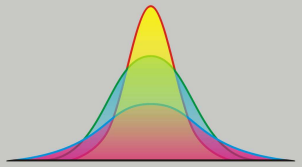


Fig. 2. Simple diagram of the organization of the retina.

$$R = \int E(\lambda)\, S(\lambda)\, q_R(\lambda)\, d\lambda$$

$$G = \int E(\lambda)\, S(\lambda)\, q_G(\lambda)\, d\lambda$$

$$B = \int E(\lambda)\, S(\lambda)\, q_B(\lambda)\, d\lambda$$



Luminance ：描述发射或者反射多少光，单位nit 或者cd/m²
Illuminance：描述落在一个表面多少光，单位lux

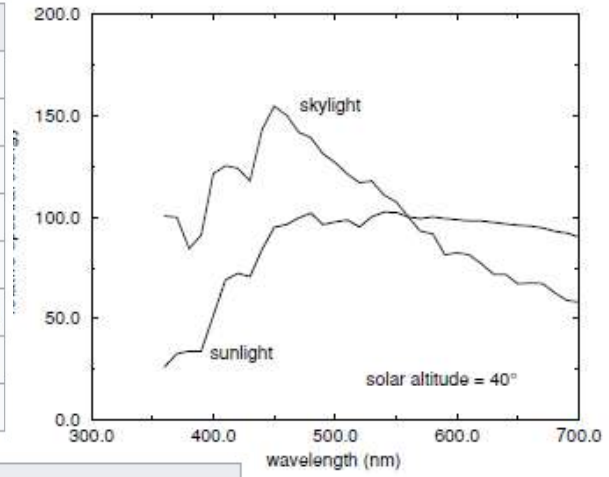
http://sensing.konicaminolta.us/2015/08/luminance-vs-illuminance/

Light 光源：

自然光：

Daylight = Sunlight + skylight

Illuminance	Example
120,000 lux	Brightest sunlight
111,000 lux	Bright sunlight
20,000 lux	Shade illuminated by entire clear blue sky, midday
1,000 - 2,000 lux	Typical overcast day, midday
<200 lux	Extreme of darkest storm clouds, midday
400 lux	Sunrise or sunset on a clear day (ambient illumination).
40 lux	Fully overcast, sunset/sunrise
<1 lux	Extreme of darkest storm clouds, sunset/rise



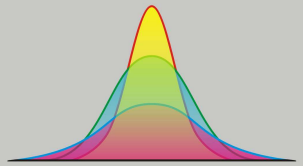
Nightlight = moonlight + starlight

Illuminance	Example
<1 lux	Moonlight[3]
0.25 lux	Full Moon on a clear night[4][5]
0.01 lux	Quarter Moon
0.002 lux	Starlight clear moonless night sky including airglow[4]
0.0002 lux	Starlight clear moonless night sky excluding airglow[4]
0.00014 lux	Venus at brightest[4]
0.0001 lux	Starlight overcast moonless night sky[4]

https://en.wikipedia.org/wiki/Daylight

人造光：

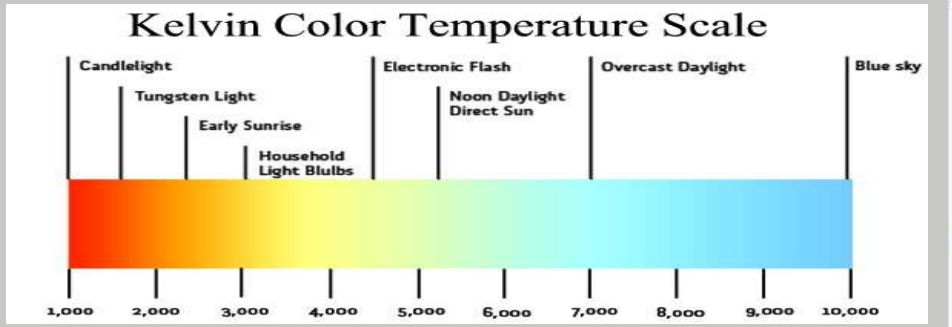
- Incandescent 白炽灯----餐厅
- Tungsten 钨灯----剧场，路灯
- Halogen 卤素灯----卧室
- Fluorescent 荧光灯----办公室，商场
- Mercury 水银灯（EU已禁用）----街道
- metal halide 金属卤化物等 ----球场
- Sodium 钠灯 ----交通要道，工矿场地
- Led 发光二极管----家庭，办公，商场
- Flash (Led, Xenon)----相机闪光灯



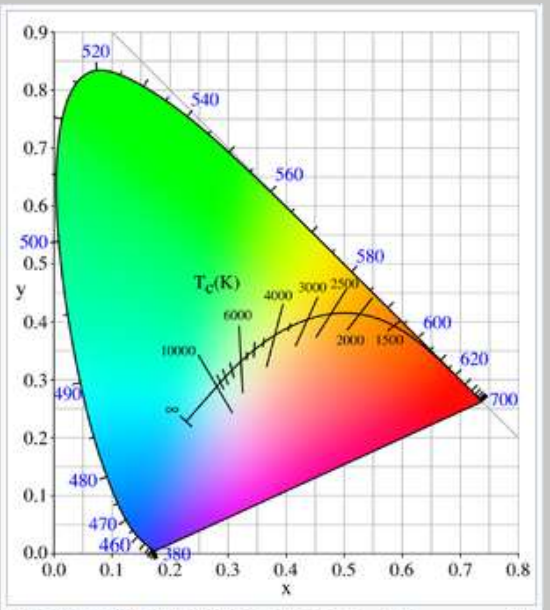
光源的属性：

- 色温 CCT

（与光源不一一对应）



https://en.wikipedia.org/wiki/Color_temperature



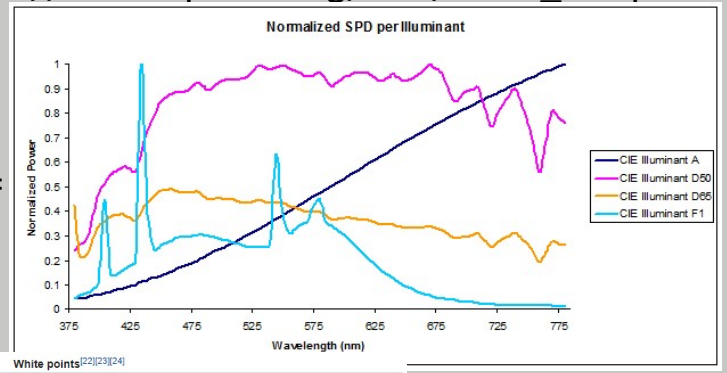
The CIE 1931 *x,y* chromaticity space, also showing the chromaticities of black-body light sources of various temperatures (Planckian locus), and lines of constant correlated color temperature.

- 光谱spectrum 或者SPD

（Spectral Power Distribution）

（与光源一一对应）

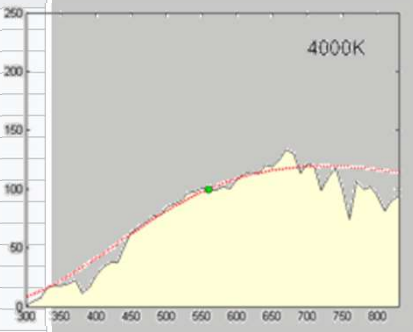
E（λ）=



CIE 标准光源

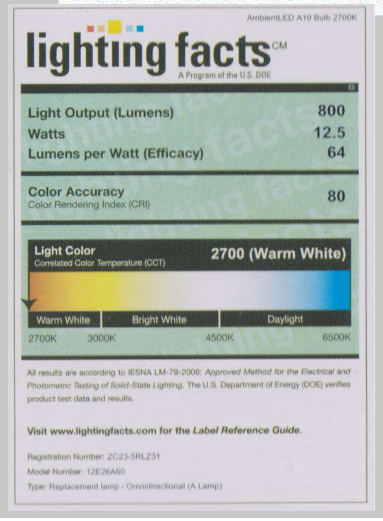
White points[22][23][24]

Name	CIE 1931 2°		CIE 1964 10°		CCT (K)	Hue	Note
	x_2	y_2	x_{10}	y_{10}			
A	0.44757	0.40745	0.45117	0.40594	2856		Incandescent / Tungsten
B	0.34842	0.35161	0.34980	0.35270	4874		{obsolete} Direct sunlight at noon
C	0.31006	0.31616	0.31039	0.31905	6774		{obsolete} Average / North sky Daylight
D50	0.34567	0.35850	0.34773	0.35952	5003		Horizon Light. ICC profile PCS
D55	0.33242	0.34743	0.33411	0.34877	5503		Mid-morning / Mid-afternoon Daylight
D65	0.31271	0.32902	0.31382	0.33100	6504		Noon Daylight: Television, sRGB color space
D75	0.29902	0.31485	0.29968	0.31740	7504		North sky Daylight
E	1/3	1/3	1/3	1/3	5454		Equal energy
F1	0.31310	0.33727	0.31811	0.33559	6430		Daylight Fluorescent
F2	0.37208	0.37529	0.37925	0.36733	4230		Cool White Fluorescent
F3	0.40910	0.39430	0.41761	0.38324	3450		White Fluorescent
F4	0.44018	0.40329	0.44920	0.39074	2940		Warm White Fluorescent
F5	0.31379	0.34531	0.31975	0.34246	6350		Daylight Fluorescent
F6	0.37790	0.38835	0.38660	0.37847	4150		Lite White Fluorescent
F7	0.31292	0.32933	0.31569	0.32960	6500		D65 simulator, Daylight simulator
F8	0.34588	0.35875	0.34902	0.35939	5000		D50 simulator, Sylvania F40 Design 50
F9	0.37417	0.37281	0.37829	0.37045	4150		Cool White Deluxe Fluorescent
F10	0.34609	0.35986	0.35090	0.35444	5000		Philips TL85, Ultralume 50
F11	0.38052	0.37713	0.38541	0.37123	4000		Philips TL84, Ultralume 40
F12	0.43695	0.40441	0.44256	0.39717	3000		Philips TL83, Ultralume 30

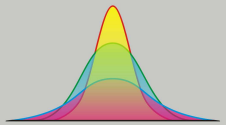


- 白点（white point）

（与光源一一对应）

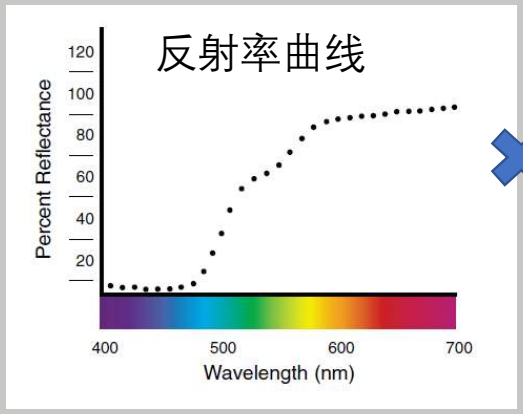


光源的演色性

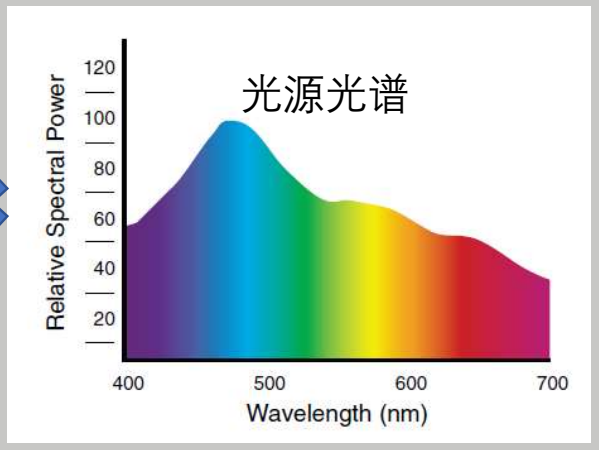


颜色的感知/测量

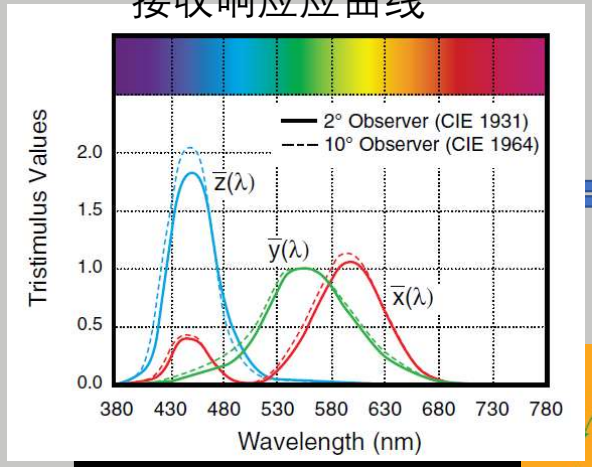
反射率曲线



光源光谱



接收响应应曲线



颜色值

X= 32.01

Y= 12.44

Z= 3.99

$$R = \int E(\lambda)\, S(\lambda)\, q_R(\lambda)\, d\lambda$$

$$G = \int E(\lambda)\, S(\lambda)\, q_G(\lambda)\, d\lambda$$

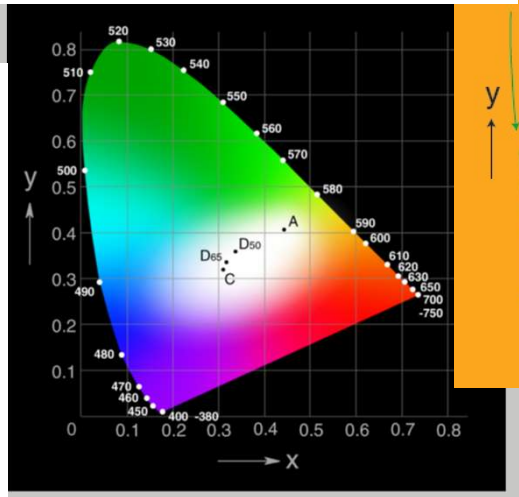
$$B = \int E(\lambda)\, S(\lambda)\, q_B(\lambda)\, d\lambda$$

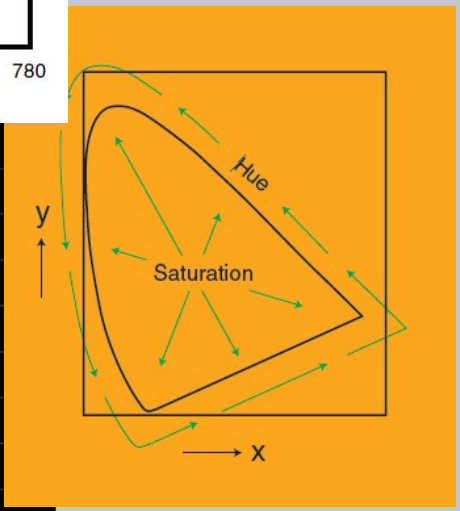
色彩空间 color space：

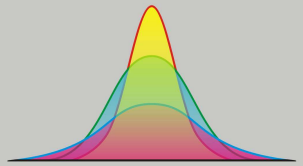
CIE XYZ
CIE RGB
CIE LAB
CIE LCH
sRGB
Rec709
Rec601
YUV…

Some RGB color space parameters

Color space	Gamut	White point	Primaries					
			Red		Green		Blue	
			x_R	y_R	x_G	y_G	x_B	y_B
ISO RGB	Limited	floating	floating					
Extended ISO RGB	Unlimited (signed)	floating	floating					
scRGB	Unlimited (signed)	D65	0.64	0.33	0.30	0.60	0.15	0.06
sRGB, HDTV (ITU-R BT.709)	CRT	D65	0.64	0.33	0.30	0.60	0.15	0.06
Adobe RGB 98	CRT	D65	0.64	0.33	0.21	0.71	0.15	0.06
PAL/SECAM (1970) (EBU Tech. 3213, ITU-R BT.470 System B, G)	CRT	D65	0.64	0.33	0.29	0.60	0.15	0.06
NTSC (1987) (SMPTE RP 145 "SMPTE C", SMPTE 170M)	CRT	D65	0.63	0.34	0.31	0.595	0.155	0.07
Japanese NTSC (1987)	CRT	D93	0.63	0.34	0.31	0.595	0.155	0.07
Apple RGB	CRT	D65	0.625	0.34	0.28	0.595	0.155	0.07
NTSC (1953) (FCC 1953, ITU-R BT.470 System M)	CRT	C	0.67	0.33	0.21	0.71	0.14	0.08
DCI-P3 (2010) (SMPTE EG 432-1, RP 431-2)	Wide	D65	0.680	0.320	0.265	0.690	0.150	0.060
UHDTV (ITU-R BT.2020, BT.2100)	Wide	D65	0.708	0.292	0.170	0.797	0.131	0.046
Adobe Wide Gamut RGB	Wide	D50	0.735	0.265	0.115	0.826	0.157	0.018
ROMM RGB ProPhoto RGB	Wide	D50	0.7347	0.2653	0.1596	0.8404	0.0366	0.0001
CIE (1931) RGB	Wide	E	0.7347	0.2653	0.2738	0.7174	0.1666	0.0089
CIE XYZ (not RGB)	Unlimited	E	1	0	0	1	0	0





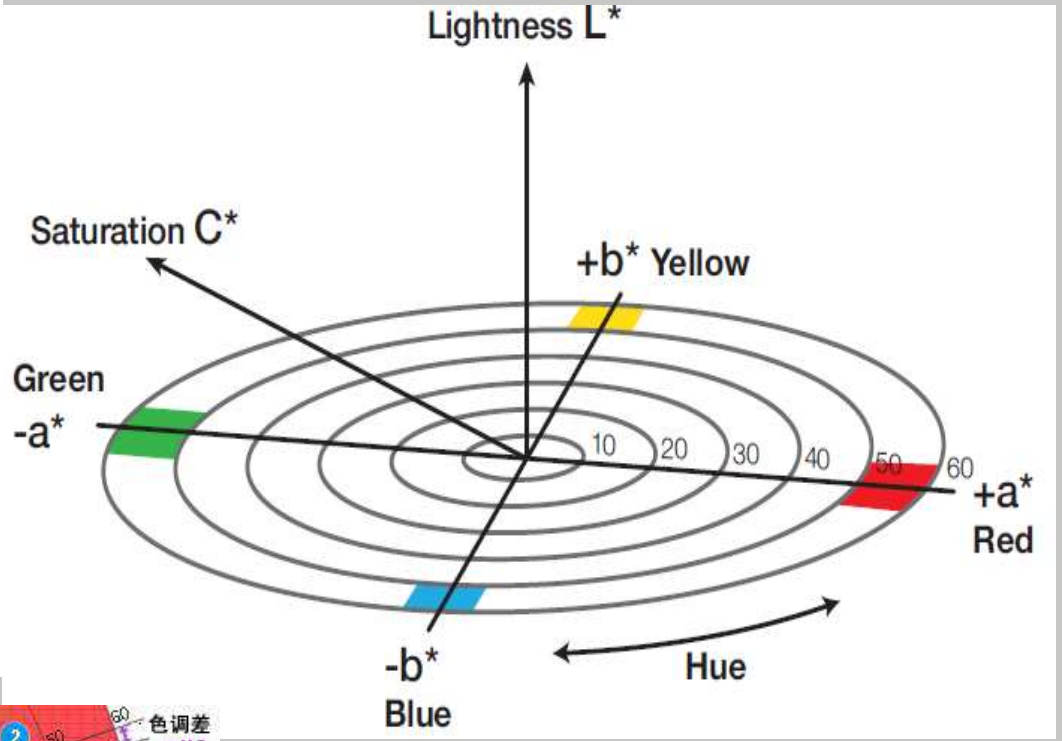


色差：

CIE Color Space Notations

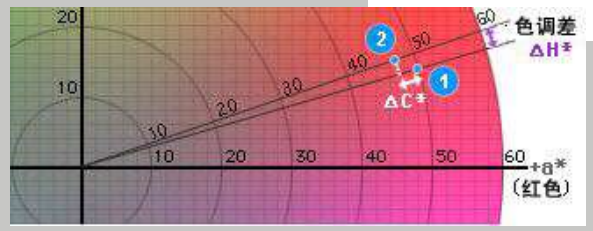
ΔL* -	difference in lightness/darkness value	"+" = lighter "–" = darker
Δa* -	difference on red/green axis	"+" = redder "–" = greener
Δb* -	difference on yellow/blue axis	"+" = yellower "–" = bluer
ΔC* -	difference in chroma	"+" = brighter "–" = duller
ΔH* -	difference in hue	
ΔE* -	total color difference value	
ΔE_{CMC} -	total acceptable color difference value	

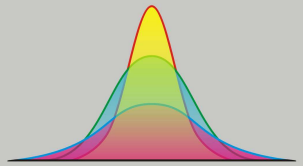
ΔE_H 1942 • ΔE^*_{ab} 1976 • ΔE_{CMC} 1984 • ΔE_{94} 1992 • ΔE_{00} 2000



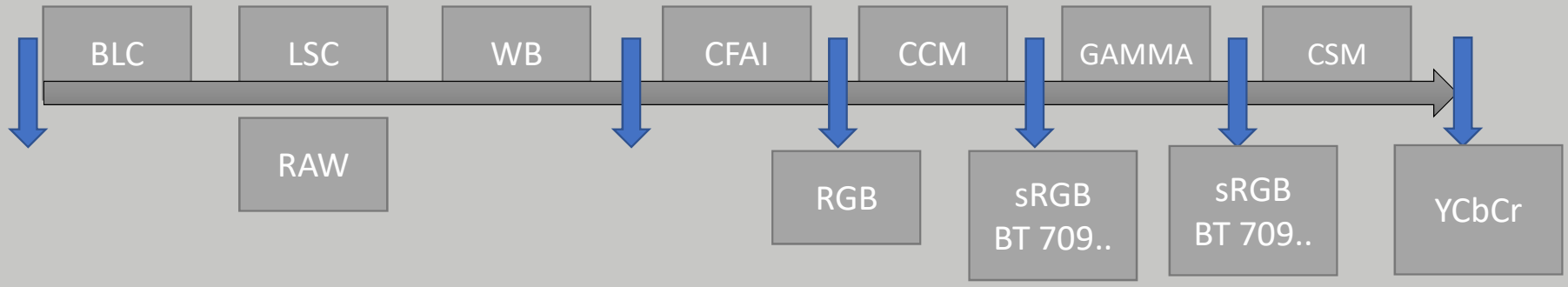
$\Delta E^*ab = [(\Delta L2) + (\Delta a2) + (\Delta b2)]1/2$

$\Delta C^* = ((a2^*-a1^*)^2 + (b2^*-b1^*)^2)1/2$

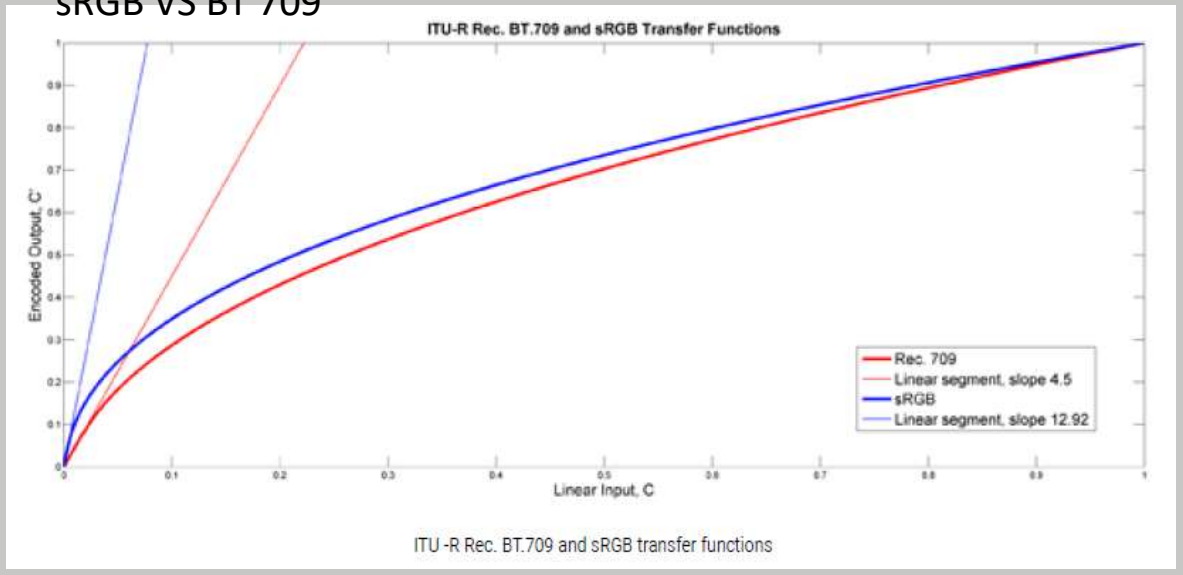




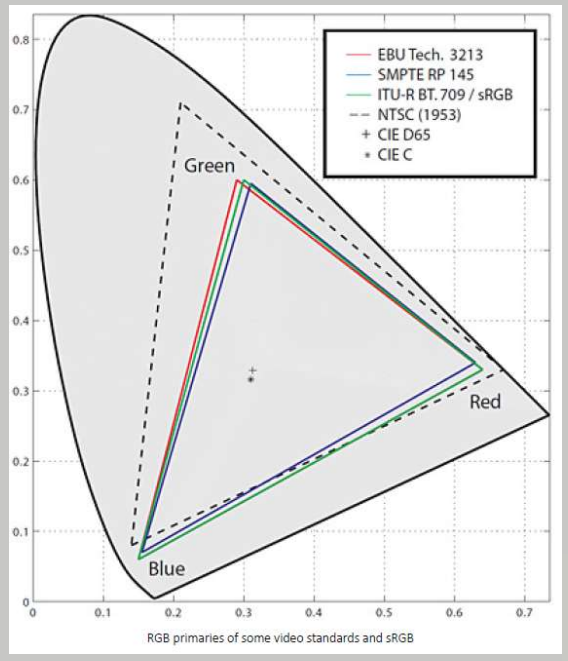
Color reproduction in camera pipeline



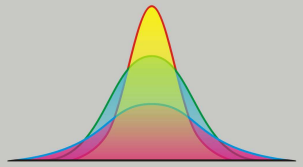
sRGB VS BT 709



ITU -R Rec. BT.709 and sRGB transfer functions

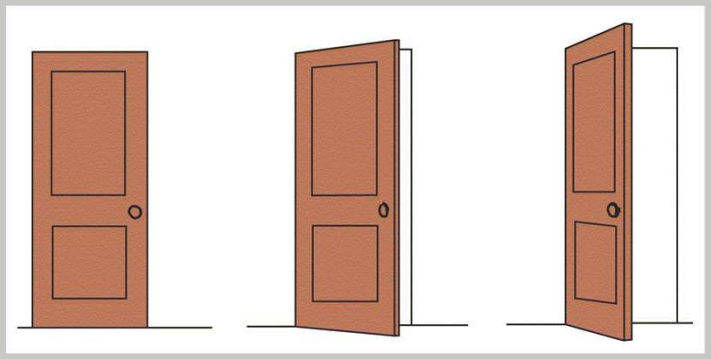


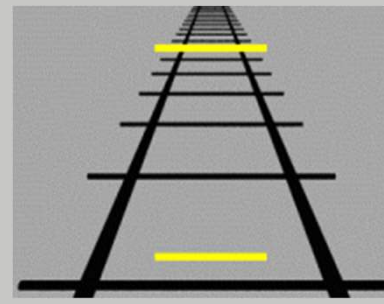
RGB primaries of some video standards and sRGB



色彩与视觉

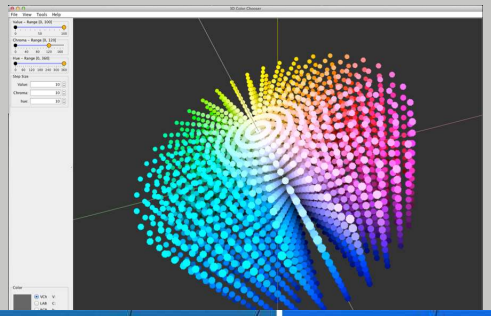
Color Constancy

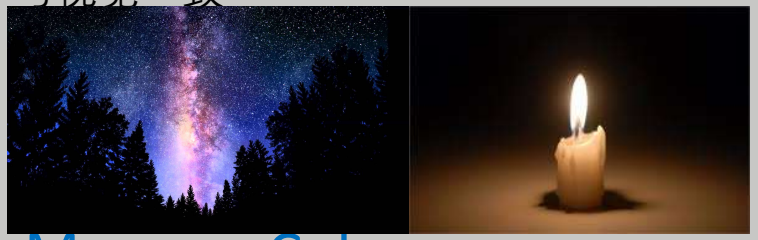




Color Appearance model

理想的色貌模型就是把所有颜色都映射到与视觉一致



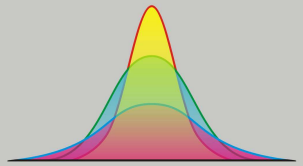


Memory Color

肤色是粉橙色的
草地和夏天的树都是绿色的
蓝天是蓝色的
血液是红色的
香蕉是黄色的...

THANKS

本课程由 Maver Jiang提供



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内容目录