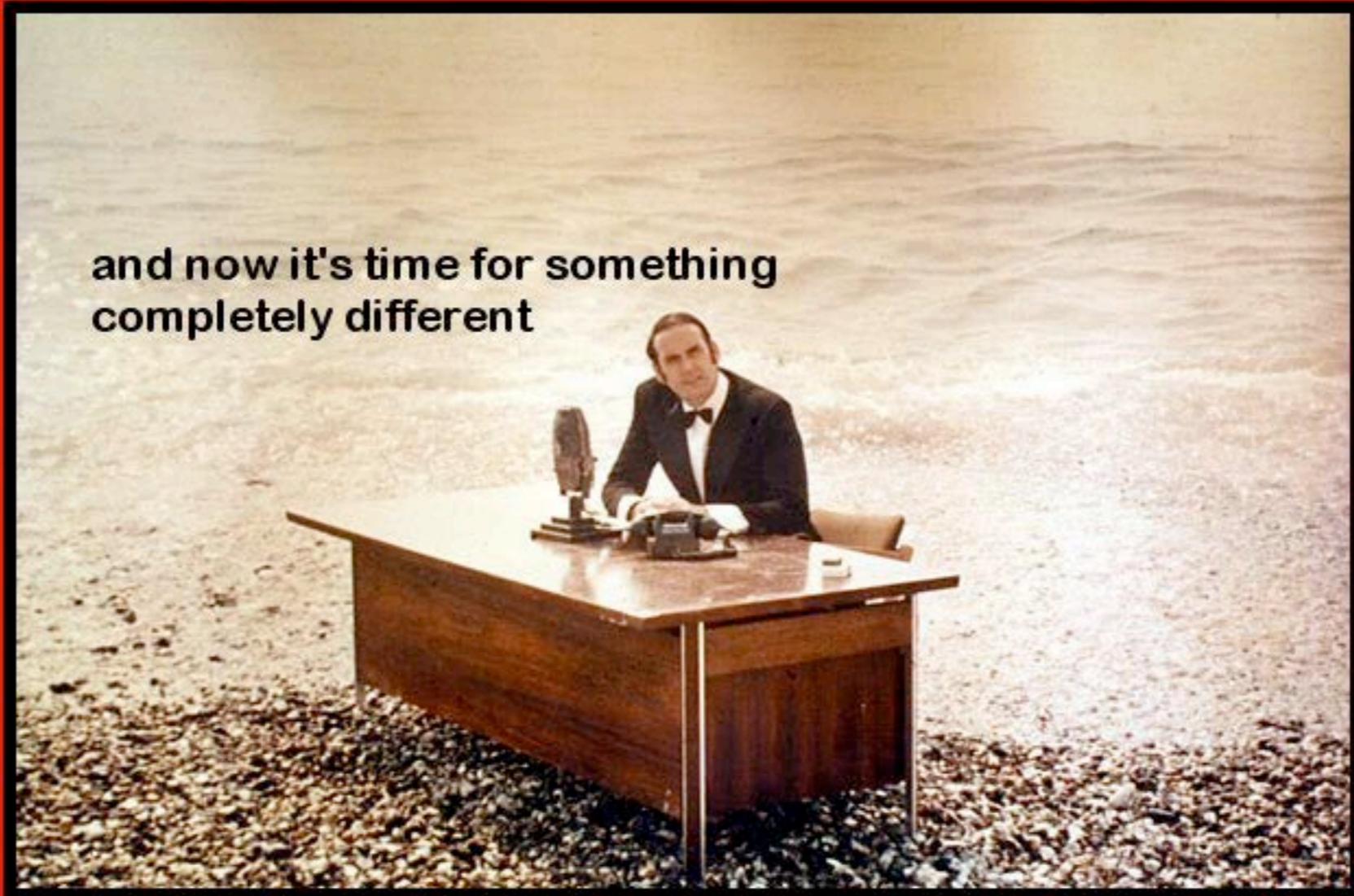


**and now it's time for something
completely different**



Deriving Appearance Scales

Mark D. Fairchild & Rodney L. Heckaman

Rochester Institute of Technology

Color Spaces & Differences

- Space: CIELAB, $L^*a^*b^*$, ΔE^*_{ab}
- Scales: Munsell Hue, Value, Chroma
- Where does the 3D Euclidean geometry come from?

Last Year @ ISCC

Perceptions
The human visual system is a complex system that processes information from the environment. It is not a simple linear process, and the way we perceive color is influenced by many factors, including the lighting conditions and the context in which the color is viewed.

Color Space?
The Munsell Color Space is a 3D model of color appearance. It is defined by three dimensions: hue, value, and chroma. The Munsell Color Space is a 3D model of color appearance. It is defined by three dimensions: hue, value, and chroma.

Appearance Spaces
A unidimensional appearance space is a 1D model of color appearance. It is defined by a single dimension, such as hue or value. The Munsell Color Space is a 3D model of color appearance. It is defined by three dimensions: hue, value, and chroma.

Conclusion
Unidimensional Color Appearance of Objects
- All Lights (CIE2000 & D50)
- All Dimensions of Color Appearance
- Lightness, Chroma, Hue
- Differences Should be 1D

Is there really such a thing as color space?:
Mark D. Fairchild
Rochester Institute of Technology

Foundations of unidimensional appearance spaces
Munsell Color Science Laboratory
Chester F. Carlson Center for Imaging Science
College of Science

Six 1D Appearance Spaces
Hue, Lightness, Saturation, Brightness, Chroma, Chroma, Chroma

Color Wheel
A circular diagram showing the relationship between different colors. The colors are arranged in a circle, with primary colors (red, yellow, blue) and secondary colors (orange, green, purple) labeled. The wheel is divided into segments, each representing a different color.

3D Color Space Diagram
A 3D diagram showing the relationship between different colors. The colors are arranged in a 3D space, with primary colors (red, yellow, blue) and secondary colors (orange, green, purple) labeled. The diagram is a 3D model of color appearance.

Implementation

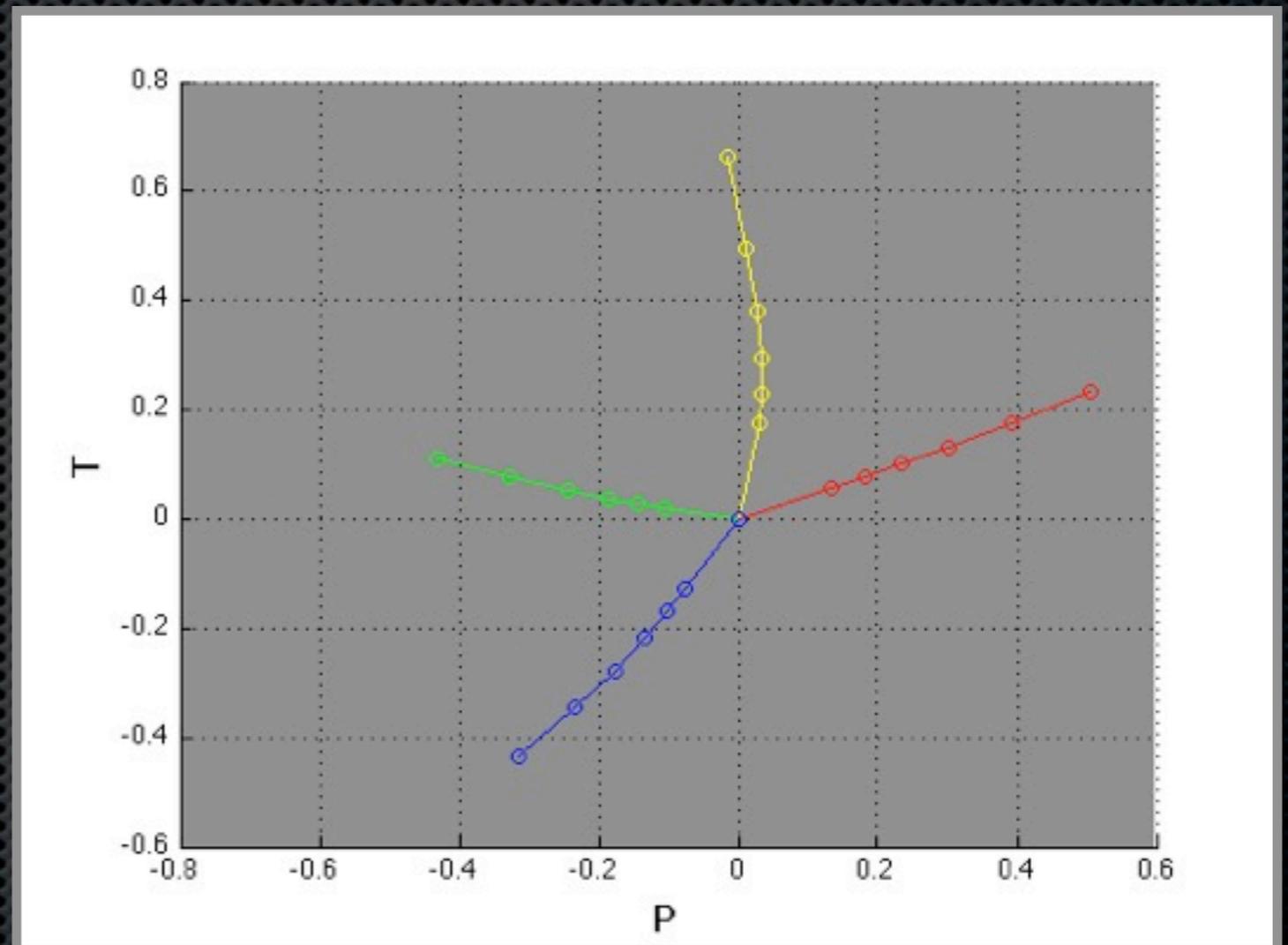
- ✦ Chromatic adaptation
- ✦ Computation: hue, lightness, saturation
- ✦ Derivatives: brightness, colorfulness, chroma

Chromatic Adaptation

- ✦ CAT02 to reference viewing conditions
- ✦ CIE illuminant D65, 315 cd/m²
- ✦ Corresponding colors in XYZ (*any observer*)

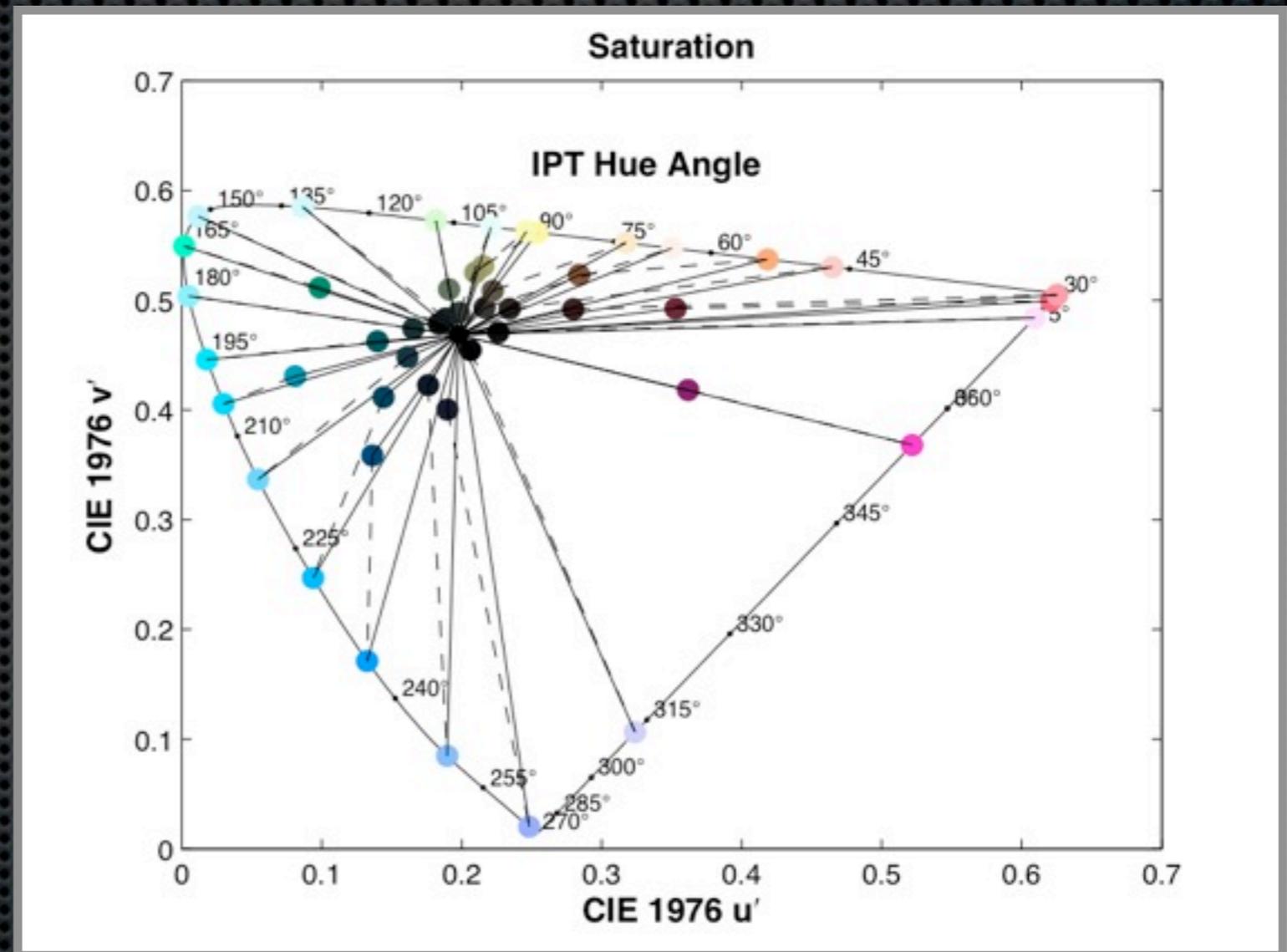
Hue

- ✦ IPT hue angle
- ✦ NCS unique hues
- ✦ 27.4° , 89.8° , 162.2° , 231.3° in IPT
- ✦ Simple computation



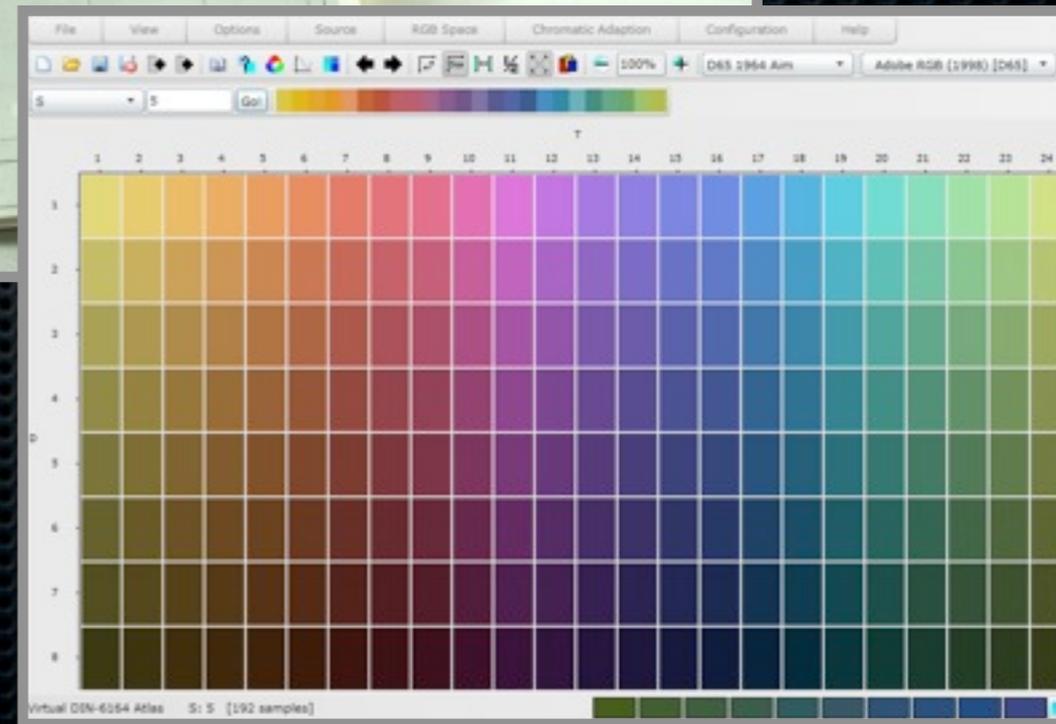
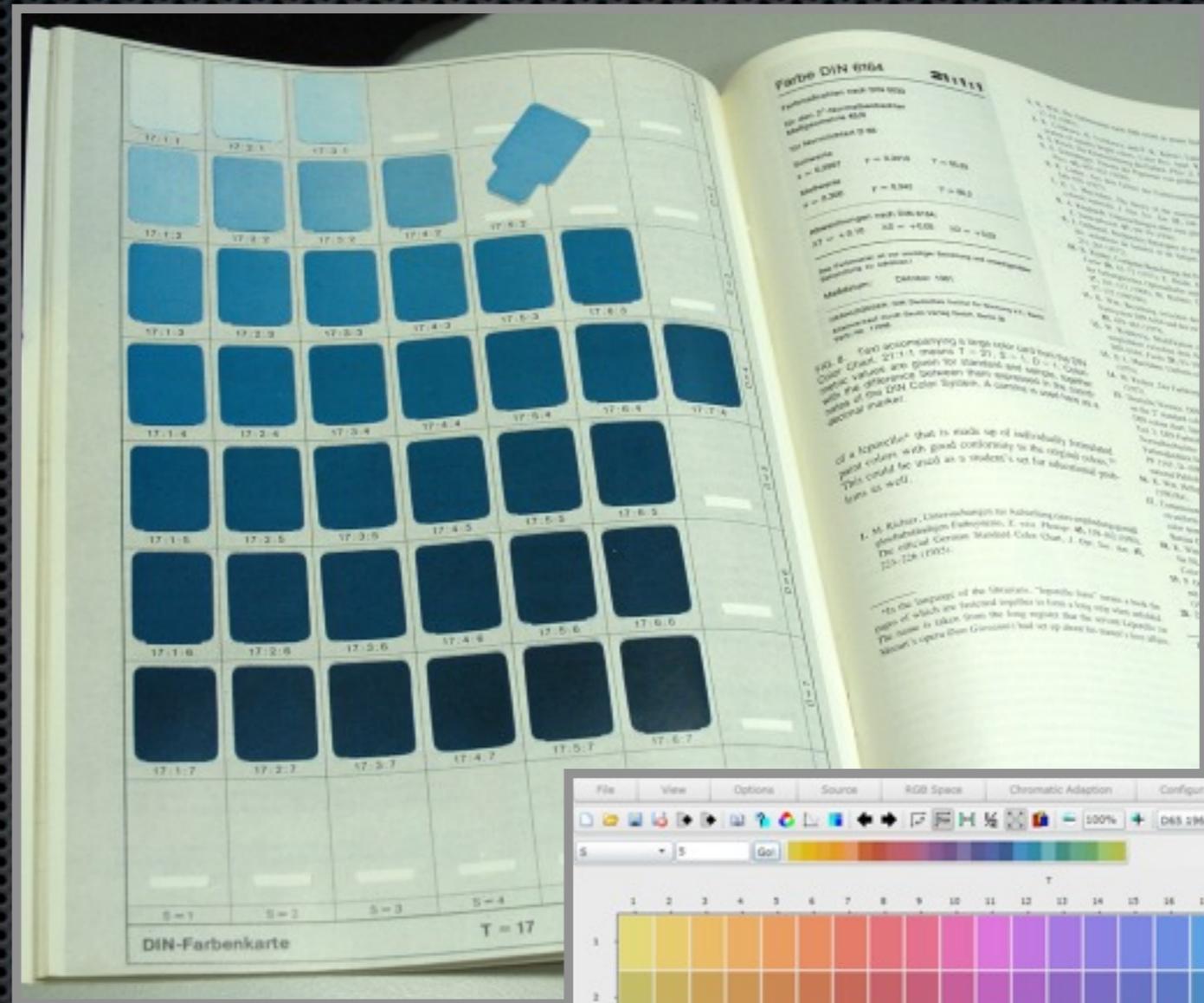
Saturation

- ✦ $u'v'$
- ✦ Excitation purity
- ✦ Constant IPT h



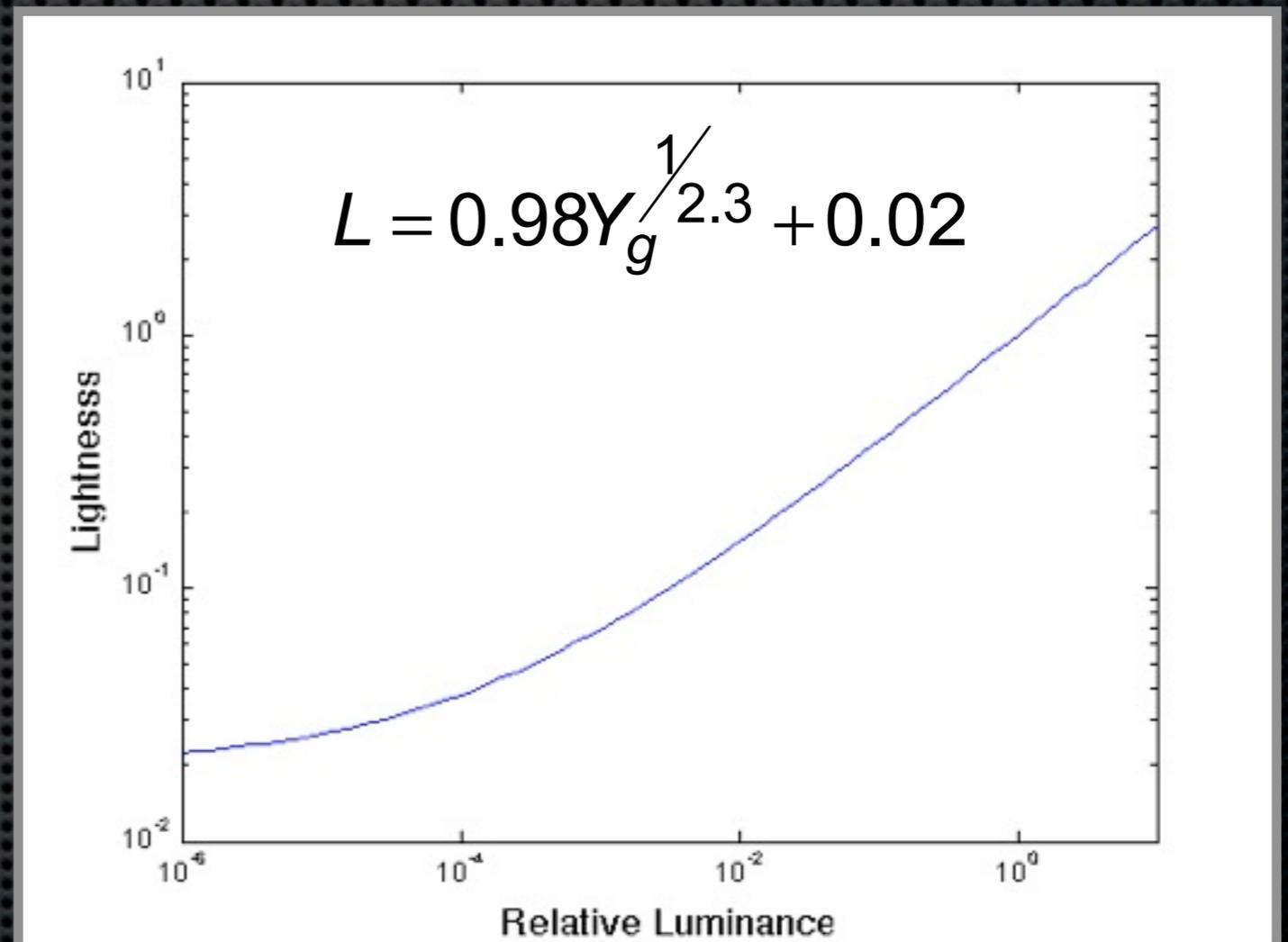
Why saturation?

- ✦ Fundamental perceptually and physically
- ✦ Shadow series
- ✦ e.g. DIN system



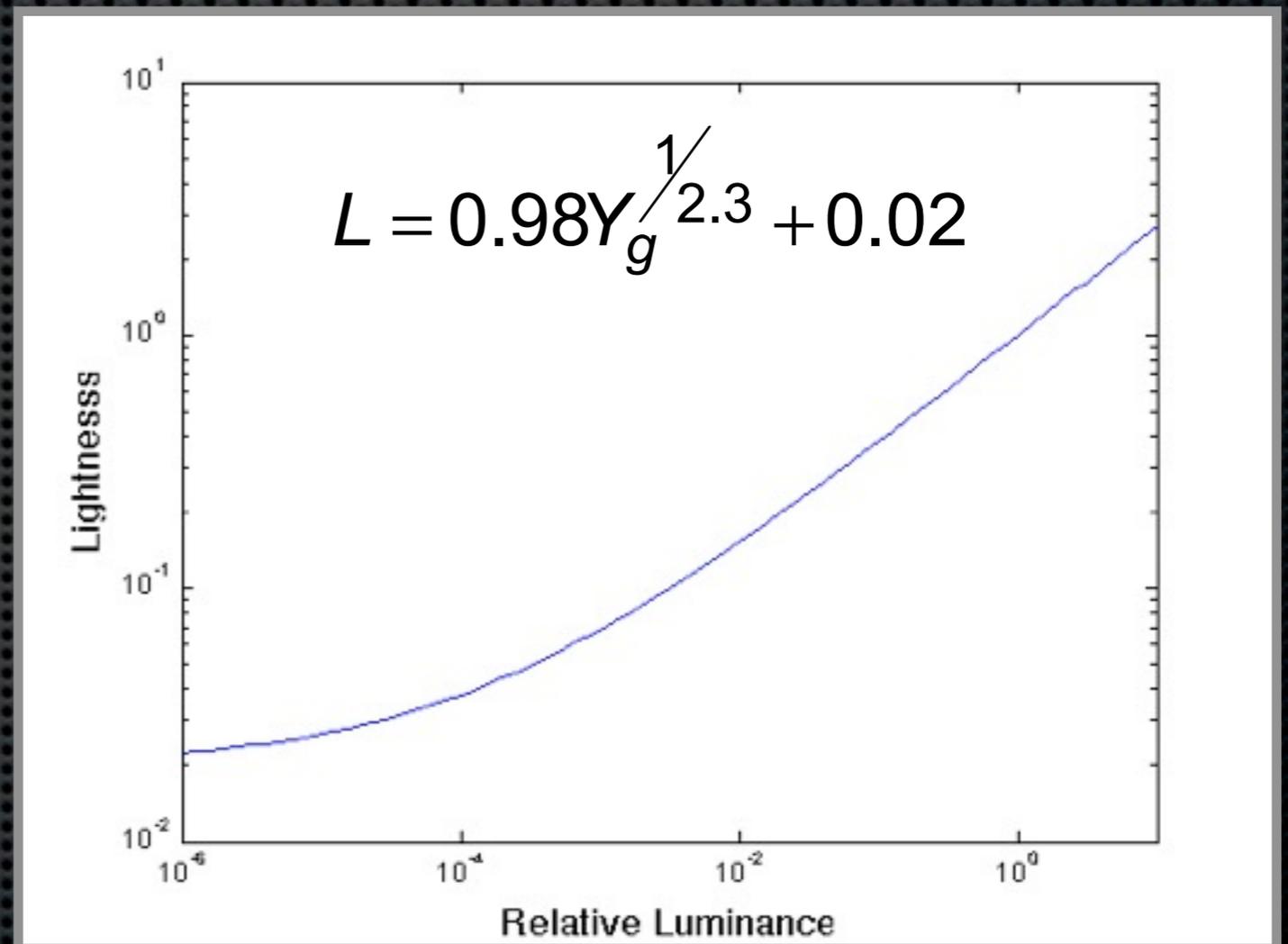
Lightness

- ✦ L^* “like”
- ✦ Power function with offset
- ✦ Supported by recent HDR data



Lightness

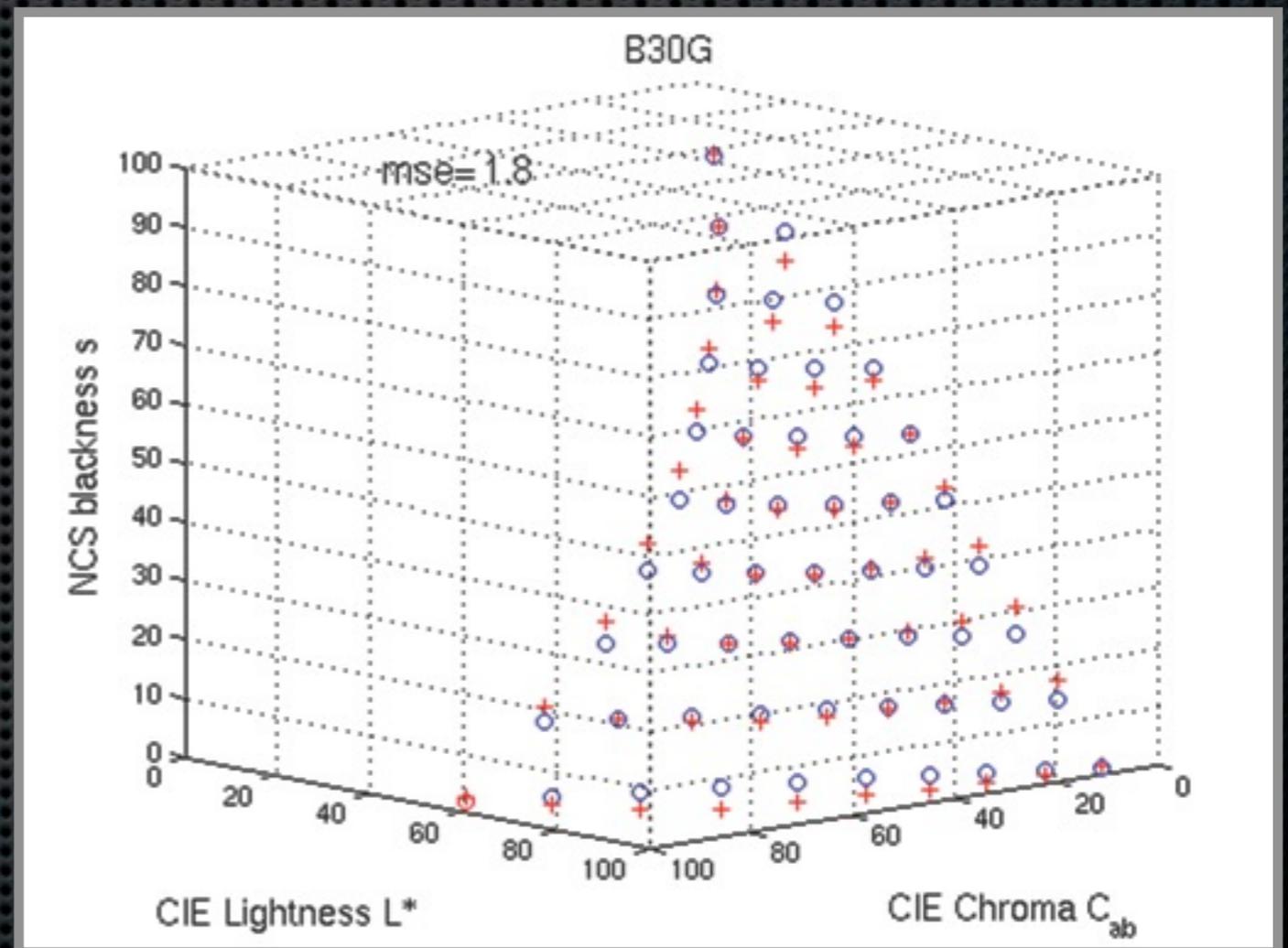
- ✦ L^* “like”
- ✦ Power function with offset
- ✦ Supported by recent HDR data



Relative to luminance at G_0 for h and S

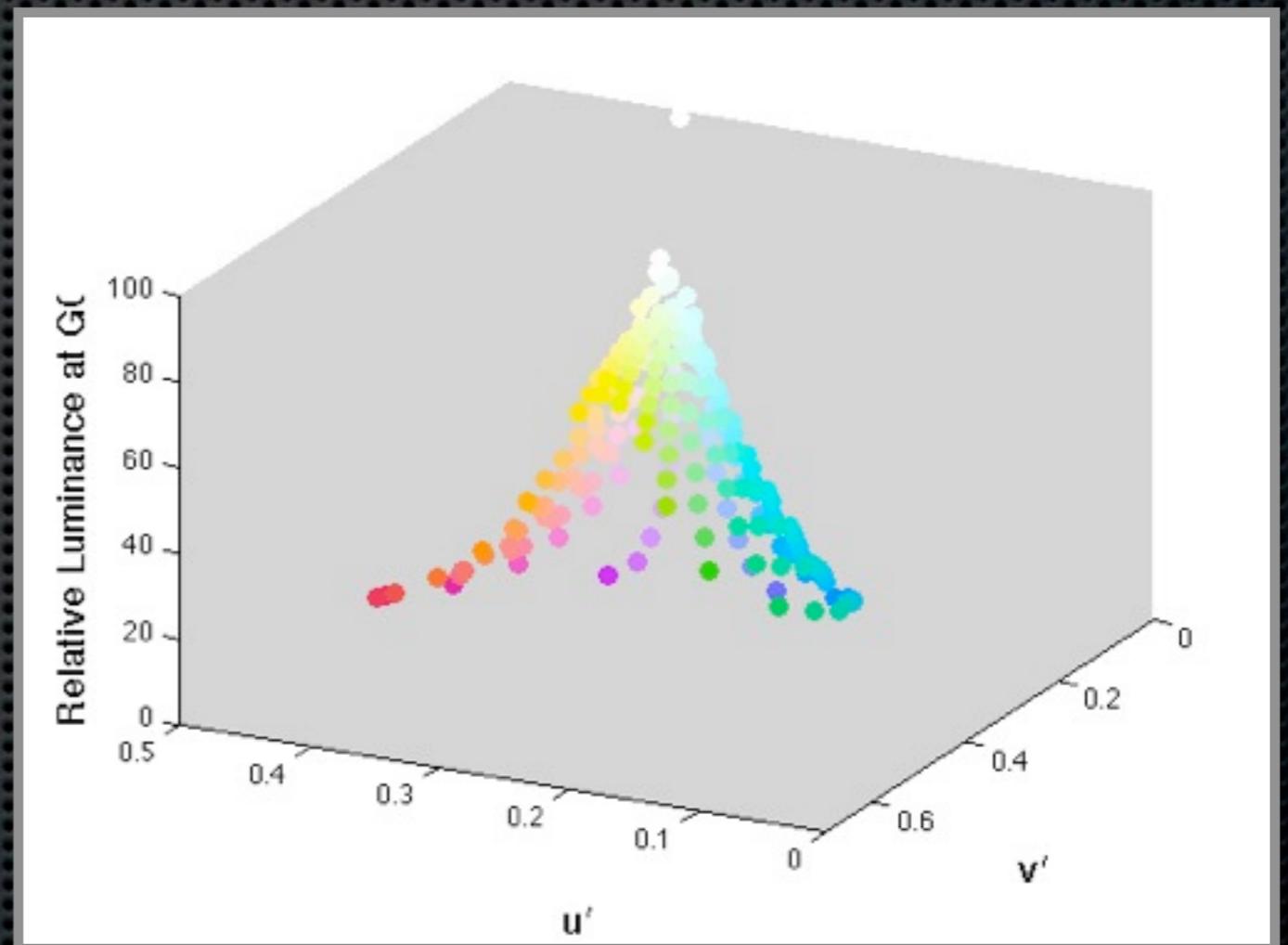
G_0 Computation

- ✦ Locus of zero NCS Blackness
- ✦ Converted into Y at G_0 as a function $u'v'$
- ✦ Based on earlier gamut mapping work



Y of G_0 “Tent”

- ✦ Y of G_0
- ✦ Several h and S
- ✦ Define L reference
- ✦ Automatic Helmholtz-Kohlrausch effect



Evans Terminal Brightness

- ✦ Evans 1948
- ✦ From Marshall and Talbot 1942

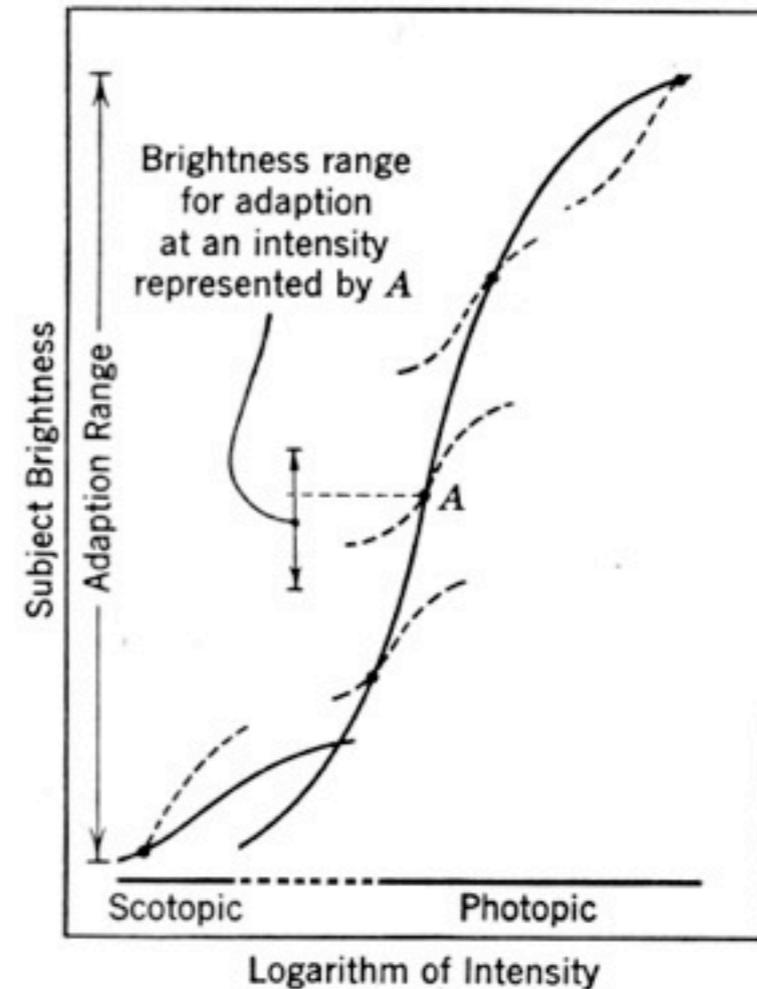


FIG. 7·9 Curve showing brightness range for different levels of adaptation. Above the brightness range for a given level of adaptation added intensity merely tends to cause pain without increasing subjective brightness; below this brightness range, visibility is zero. (W. H. Marshall and S. A. Talbot, *Biological Symposia*, Vol. 7, p. 130, The Jaques Cattell Press.)

Stevens' Terminal Brightness

- ✦ Stevens & Stevens 1963
- ✦ Stevens' Effect
- ✦ Brightness with adaptation
- ✦ Also terminal brightness

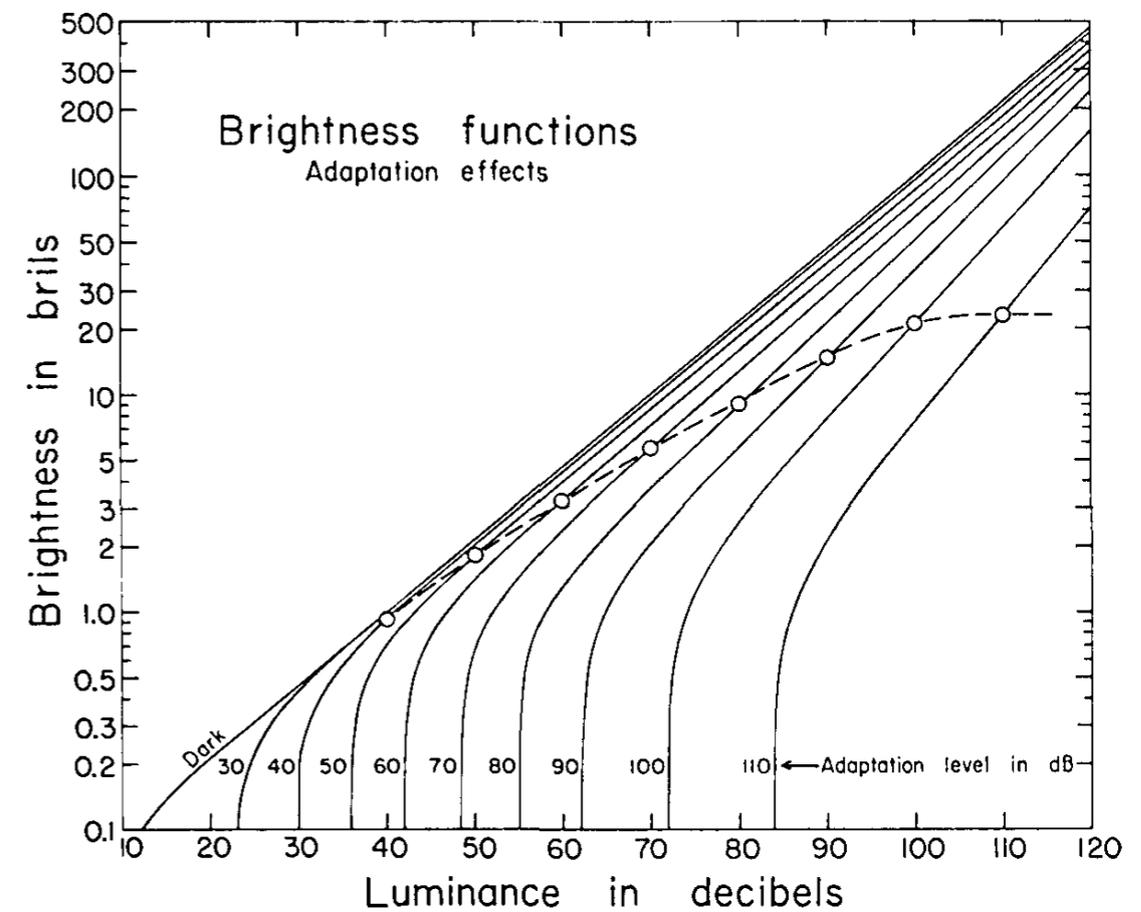
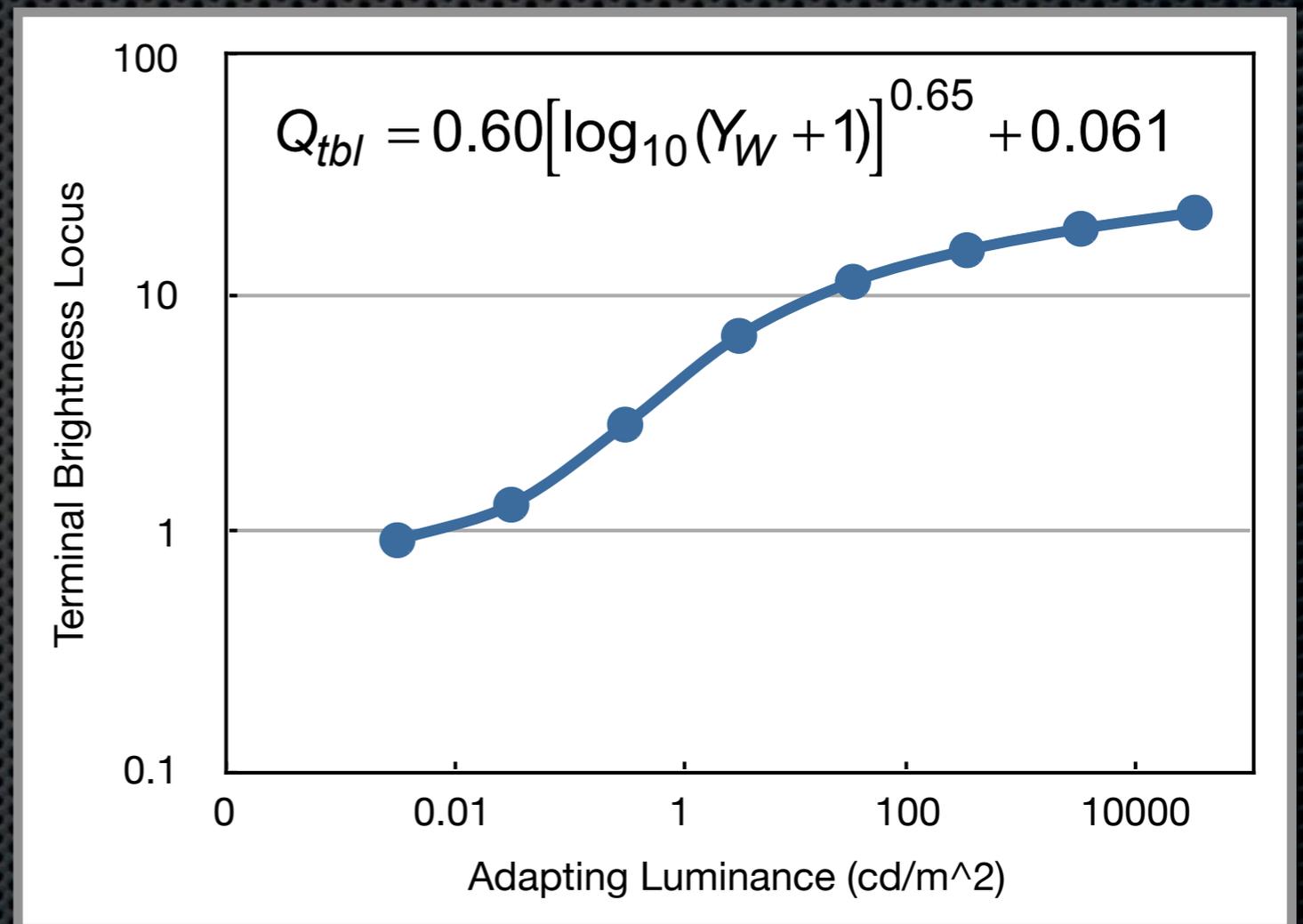


FIG. 7. Brightness functions for various levels of adaptation. The dashed line shows the terminal brightness locus—the level of sensation reached when the eye comes into full equilibrium with the luminance it is viewing.

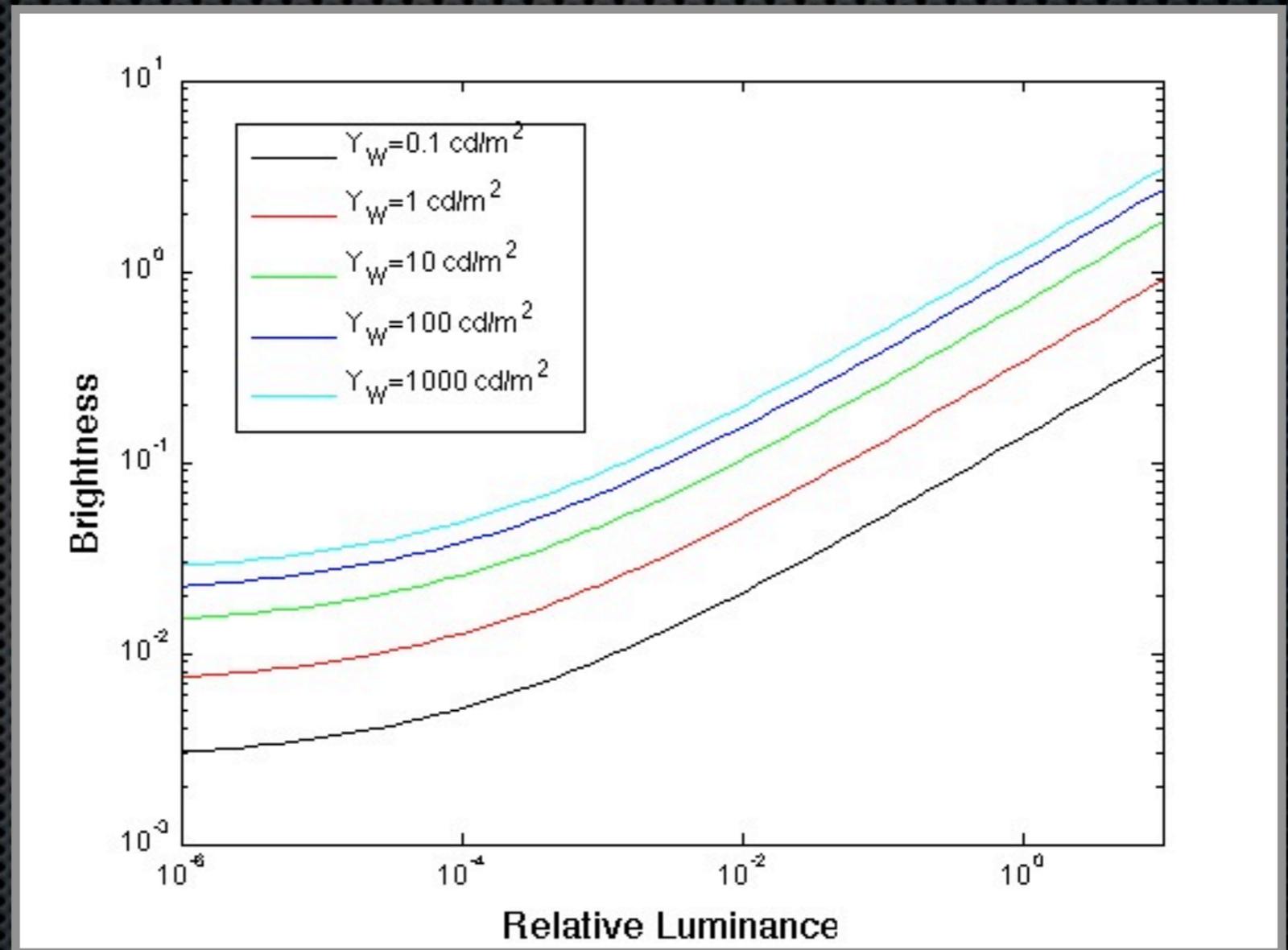
Terminal Brightness Locus

- ✦ Fitted to Stevens' data
- ✦ Defines maximum brightness for each adaptation level



Brightness

✦ $Q = Q_{tbl}L$



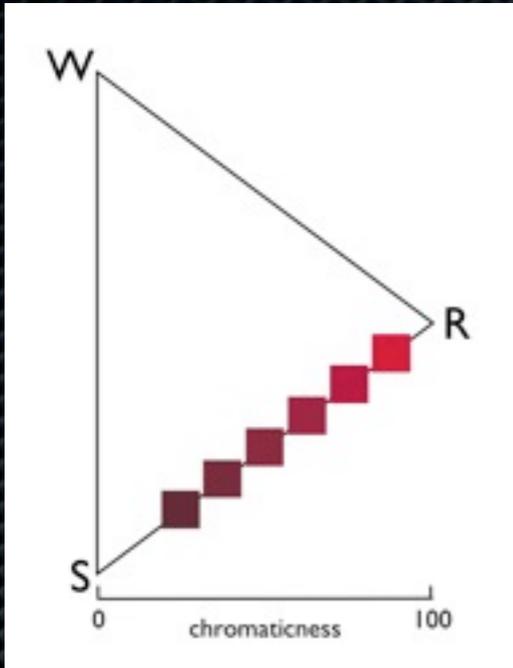
Colorfulness & Chroma

- ✦ $C = LS$
- ✦ $M = QS$

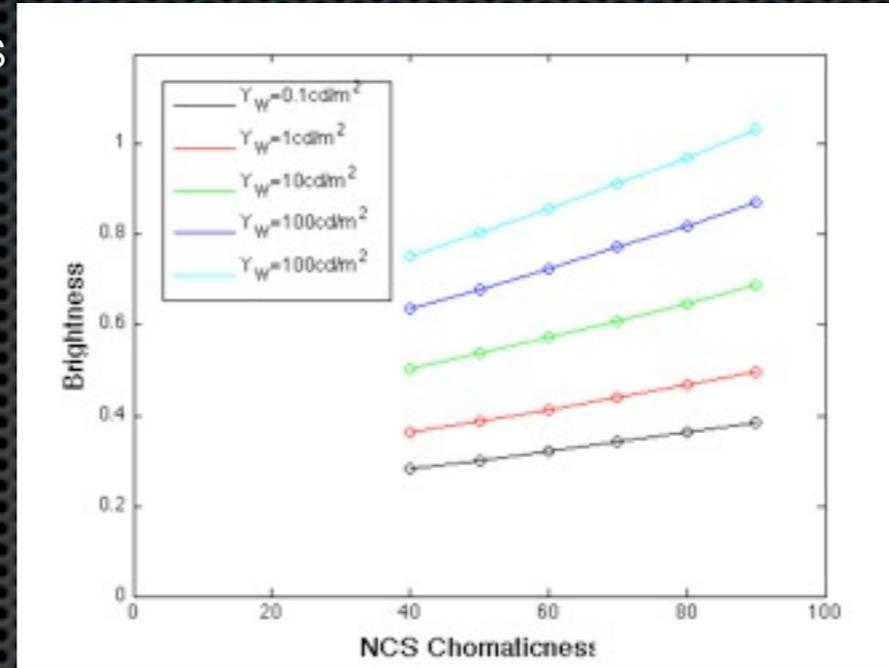


Examples

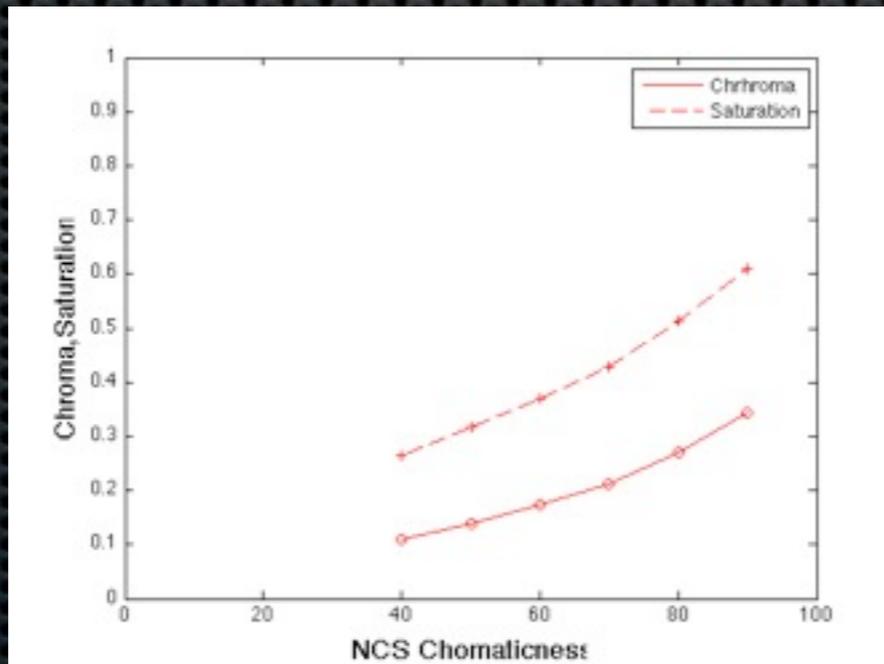
Some
NCS
Samples



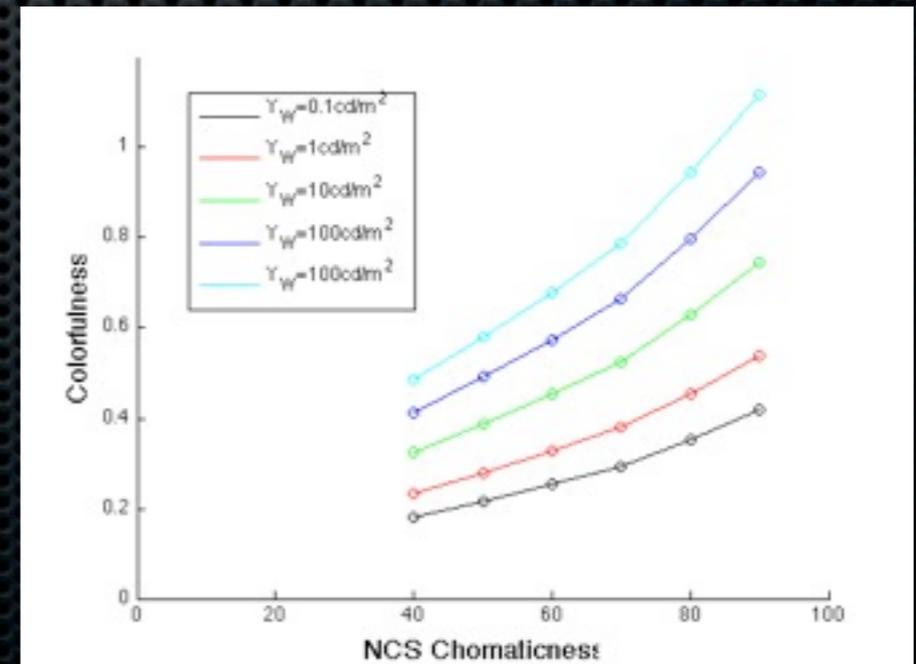
Brightness



Chroma
Saturation



Colorfulness



Color Differences

- ✦ $\Delta h = h_2 - h_1$
- ✦ $\Delta L = L_2 - L_1$
- ✦ $\Delta S = S_2 - S_1$
- ✦ *etc.*

Color Differences

- ✦ $\Delta h = h_2 - h_1$
- ✦ $\Delta L = L_2 - L_1$
- ✦ $\Delta S = S_2 - S_1$
- ✦ *etc.*

ΔE

Color Differences

- ✦ $\Delta h = h_2 - h_1$
- ✦ $\Delta L = L_2 - L_1$
- ✦ $\Delta S = S_2 - S_1$
- ✦ *etc.*



Conclusions

- ✦ Scales ... not spaces
- ✦ Lightness, saturation, hue ...
- ✦ ... Brightness, colorfulness, chroma
- ✦ Differences on scales only

Thank You

Questions ...

